CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Distributed Solar on the Grid: Key Opportunities and Challenges

—Transcript of a webinar offered by the Clean Energy Solutions Center on 17 November 2016—
For more information, see the clean energy policy trainings offered by the Solutions Center.

Webinar Panelists

Owen Zinaman	National Renewable Energy Laboratory
Michael Coddington	National Renewable Energy Laboratory
Jeffrey Haeni	United States Agency for International Development

This Transcript

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Sean

Hello, everyone. I'm Sean Esterly with the National Renewable Energy Laboratory and welcome to today's webinar, which is being hosted by the Clean Energy Solutions Center in partnership with USAID and the National Renewable Energy Laboratory. And, today's webinar is focused on the unique set of opportunities and challenges posed by distributed grid-connected photovoltaic systems. And one important note of mention before we begin our presentations 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 practices resources reviewed and selected by technical experts.

And just want to go over some of the webinar features for you. You do have two options for audio. You may either listen through your computer or over the telephone. To listen through your computer, please just go to the audio pane and select the mic and speakers option. That will help eliminate any feedback and echo. And if you're dialing in by phone, select the telephone option instead, and it will give you the number and audio PIN that you can use to dial in. If anyone is having technical difficulties with the webinar, you may contact the GoToWebinar's helpdesk at the number at 888-259-3826. You can also send in a question to us, and we can try to help you out remotely if possible.

And we do encourage our attendees to ask questions at any point during the webinar. To ask a question, you simply type it into that question pane. And it will be submitted to us, and we'll save those for the Q&A session at the end.

If you're having difficulty viewing the material through the webinar portal, we will be posting PDF copies of the presentations at cleanenergysolutions.org/training. And also, we'll be posting a full audio recording of the webinar to that page within a couple days of the broadcast. And in addition, we are now adding all recordings to the Solutions Center YouTube channel, where we have a great library, now, of video resources, as well as video interviews with thought leaders on clean energy policy topics.

So we have a great agenda set for you today. It's centered around the presentations from our guest panelists, Owen Zinaman, Michael Coddington, and Jeffrey Haeni. These panelists have been kind enough to join us to discuss distributed grid-connected photovoltaic systems as part of the Greening the Grid toolkit, which is a USAID and NREL collaboration designed to support countries and integrate in renewable energy into the power system.

And just before they start, I just want to give a short, informative overview of the Clean Energy Solutions Center Initiative and their resources and services provided. And then following their presentations, we'll have the Q&A session, moderated by Jeff, where the panelists will address questions submitted by audience. And then we'll have some quick closing remarks and a brief survey for today's attendees.

And so just want to give an overview of the Solutions Center, and this slide provides a bit of background in terms of how the Solutions Center came to be formed. And the Solutions Center is 1 of 13 initiatives of the Clean Energy Ministerial that was launched in April of 2011, is primarily led by Australia, the United States, Sweden, and other CEM partners. Some outcomes of this unique initiative include support of developing countries and emerging economies through enhancement of resources on policies relating to energy access, no-cost expert policy assistance, and peer-to-peer learning and training tools, such as the webinar you're now attending.

And there's four primary goals for the Solutions Center. First goal is to serve as a clearinghouse of Clean Energy Policy resources. Second is to share policy best practices, data, and analysis tools specific to clean energy policies and programs. A third is to deliver dynamic services that enable expert assistance, learning, and peer-to-peer sharing of experiences. And then, lastly, the center strives to foster dialogue on emerging policy issues in innovation from around the globe. And the primary audience for the Solutions Center is typically made up of energy policymakers and analysts from governments and technical organizations in all countries. But then, we also strive to engage with the private sector, NGOs, and, also, civil society.

One of the marquee features that the Solutions Center provides is its no-cost expert policy assistance known as Ask an Expert. The Ask an Expert program has established a broad team of over 60 experts, now, from around the globe who are available to provide remote policy advice and analysis to all countries at no cost. So for example, in the area of renewable energy policy, we're very pleased to have Paul Komor from the Renewable & Sustainable Energy Institute serving as one of our experts.

So if you have a need for policy assistance and renewable energy policy or any other clean energy sector, we do encourage you to use this valuable service. And again, it's provided to you completely free of charge. So if you have a question for our experts, please submit it through our simple online form at cleanenergysolutions.org/expert. And we also do invite and encourage you to spread the word about this service to those in your networks and organizations.

So now, I'd like to go ahead and introduce our speakers for today's webinar. And first up will be Jeffrey Haeni who is an energy division chief for the USAID in Washington, where he provides support to USAID missions worldwide on the design, implementation, and evaluation of clean energy projects. And after Mr. Haeni, we will be hearing from Owen Zinaman who is from NREL and who is a power sector analyst and serves as a technical lead for the USAID distributed generation technical assistance program among other roles.

And our final speaker today is Michael Coddington who is a principal electrical engineer at NREL and is focused on the interconnection and integration of distributed energy resources up to the utility distribution grid. And so with those brief introductions, I'd now like to go ahead and welcome Jeff to the webinar.

Jeffrey

Thank you so much, Sean, and let me add my welcome to the latest edition of the Greening the Grid webinar series, where we periodically explore some of the key issues to integrating renewable energy into the grid. As Sean said, my name is Jeff Haeni, and I work at USAID's Office of Energy and Infrastructure. I'm going to start off the series today with a high-level overview of some of the _____ distributed PV market segments.

I'll then turn it over to Owen Zinaman at NREL to over some of the economic and business model aspects of distributed PV and then turn it over to Michael Coddington at NREL who will review some of the key technical challenges and solutions. I'll then come back online and happy to entertain any of your questions, which you are free to type in throughout the course of the webinar.

So if we look quickly at some of the projected capacity additions, we can see that distributed PV is going to comprise a significant share of new-generation capacity moving forward to the tune of about 50 gigawatts projected capacity additions per year out through 2040. And while historically a lot of this capacity has been concentrated in Europe, Australia, US, Japan, China, and other developing countries, you can see from this chart here that a lot of new emerging market players are beginning to add significant capacity. And some of the key emerging market drivers include, of course, the improving economics of rooftop PV, particularly in countries that have high end-use tariffs, and the dropping cost of solar makes the economics very appealing to end users.

There's also the positive side, the rooftop PVs, a way to rapidly deploy much-needed capacity and several of these capacity constrained emerging markets. It's an opportunity to tap new sources of investment capital, predominantly domestic capital that might have a higher risk appetite than international investment. And of course, other benefits that we all know of rooftop PV in terms of reduced air emissions and allowing consumers to take part in the traditional markets that have been dominated by utilities and other players.

But why it does offer so many significant benefits, it also presents some challenges, and distributed generation is really challenging, globally, how we plan, operate, and regulate the power system. And this can be particularly noticeable in emerging markets that may be defined by weak or underdeveloped regulatory regimes, limited cost recovery mechanisms for utilities and very fragile utility business models; on the technical side, outdated grid codes, poor distribution infrastructure. So some of these challenges, which we are currently debating in the developed world may in fact be magnified in the emerging markets.

So whether you're in a country that's just starting to add a few panels of rooftop PV or one that is rapidly scaling up, there are a number of issues that should be considered, and that is the focus of the webinar today. So let me turn it over to Owen, who will get us started on some of the economics and business model sides. And then, he'll turn it over to Michael. So Owen, the floor is yours.

Owen Thank you, Jeff. Let's go to the next slide. So at a high level, why is distributed generation challenging from an economic perspective? First, it's important to understand that in our sort of in our standard utility business model, utilities make money, either by selling kilowatt-hours or by building new infrastructure and receiving a regulated rate of return on that capital expenditure.

Now, if you examine the case of the utility customer choosing to install some rooftop solar, the customer is using less electricity, perhaps even selling energy back to the utility, and investing their own capital. So without a doubt, there are certainly some challenges to be addressed with respect to ensuring the revenue sufficiency of utilities in the face of growing distributed solar programs. And one of the landmark issues there, and many settings, being that fixed utility costs are no longer being recovered through volumetric energy charges. And we'll talk more about this soon.

On top of this, if you think just conceptually about what types of customers might want to invest in distributed PV, just purely from an economic standpoint, it's those who pay the highest rates for electricity. Now, as it happens, high-income, high-credit residential customers and, often, industrial customers, very commonly pay higher rates relative to the cost they incur to the system. And that's typically done in order to subsidize low-income customers and/or rural or agricultural customers. It's a very common regulatory policy for electricity systems. It's been around for a while, particularly in developing countries.

So anyway, if these sort of subsidizing customers for whom DG is quite attractive to invest in begin to fall off the grid, this means that more of the cost for the system will inevitably fall on a smaller portion of the population.

And that potentially leads to some equity issues unless, of course, there is some sort of holistically designed intervention, which we'll start skimming the surface of later on in this webinar. Next slide.

So if we're going to talk about utility revenue sufficiency and distributed PV, just and how that might be challenged under some circumstances, then we need to first quickly establish some vocabulary. So first, I want to define "utility cost." These are expenses incurred by the power utility to serve their customers for any number of the individual functions that the utility performs, and then, in the next slide, I'll show you an example of what some of those functions are.

But for now, we want to categorize these costs into two simple bins. In reality, it's slightly more complicated than this. But in general, let's say that utility costs are either fixed or variable. If a cost is fixed, it isn't going to change if a customer decides to use more or less electricity. If the cost is variable, it might be reduced if a customer decides to use less electricity or vice versa.

Next, we have "utility charges." Utility charges are the elements of an overall electricity bill that the utilities and regulators use to facilitate the recovery of those utility costs. And they're similarly binned into two categories. Variable charges are on just about every electricity bill in the world, and they're structured in a currency—dollar, peso, what have you, per-kilowatt-hour structure. This is a volumetric rate. The more electricity you use, the more you pay. It's extremely common.

Now, on the other hand, some power bills have fixed charges. These charges are ones that customers get hit with regardless of how much electricity they use. So let's head to the next slide.

So here, on the left, we have an example illustrative breakdown of a utilities cost to serve a residential customer, and it's broken down as a percentage of overall cost. On the bottom, we have our traditionally fixed cost associated with maintaining the network, the administration, certain special programs, regulated profit, et cetera. And then, on top, we have the traditionally variable costs, those associated with generation and fuel.

Now, again, I want to point out that not all generation-related costs are variable, and not all network-related costs are fixed. This is just an illustrated example. Now, on the right, we have a typical electricity bill for a residential customer—again, for this particular example, this illustrated system. The bill is about $45.00 involving maybe a $7.00 fixed charge and perhaps $38.00 of variable charges.

Now, you're probably observing that some—not all—but some portion of the utility's fixed costs are being collected through a variable energy charge. Again, this is very common practice in electricity tariff design around the world, oftentimes, in the name of simplicity for the consumer and also to discourage overuse, which may happen if customers pay a lower variable rate for energy. All right, so let's head to the next slide.

So now, let's imagine that this customer that otherwise would've had a $45.00 bill for the month of October had installed PV at the beginning of that month. And over the course of that month, the generation of that system netted out with their electricity consumption to a nice, flat zero net consumption. So now, in this scenario, all of the utility's variable cost related to generation and fuel purchases would go away. So there would be a notable cost savings to the utility in that respect.

However, a good deal of the fixed cost that the utility incurred that month for that customer are not being recovered. And in this scenario, when enough DPV is installed in this utility service territory, it's possible that some revenue sufficiency issues may be encountered. Next slide.

So now that you understand, hopefully, this concept of lost fixed cost recovery, let's think about all this at a slightly higher level and walk through this figure to understand the implications of what this might look like, starting with the black circle on top. So we begin with a scenario where a customer installs a solar PV system. This allows them to eliminate their variable energy charges from their utility bill, and that can, in certain circumstances, lead to unrecovered fixed utility cost.

However, as a regulated utility, it's almost certainly going to be made whole in this situation, which will require raising rates on non-DPV customers. Now, what happens when you have higher rates? Well, the investment signal for customers to go off the grid becomes stronger, and then, more customers will potentially drop off. And round and round this cycle may go.

So now, of course, all this completely depends on how retail rates are designed and also how the compensation scheme for the rooftop solar generation is designed. So even though this seems like a gloomy and challenging situation, it can, without a doubt, be avoided, and we'll talk more about this later. But before we do that, I want to complicate things a bit.

So we all know that retail electricity rates are different for different types of customers, whether you're a low-income customer or a business or an aluminum smelter. So because of this, it turns out that the types of customers that install DPV matters quite a bit from the standpoint of the utility and their revenue sufficiency, and that can influence this little cycle here quite a bit. So to the next slide.

So again, I think we need a little bit more background on retail electricity rate design fundamentals and to kinda dig into these DPV issues. So this time, I want to try and explain how retail rates are commonly subsidized. This happens in most countries in the world but is of particular relevance in developing country contacts, where there's a lot economic development objectives that are sort of caked into the regulators thinking on things as a set rate.

So the two concepts I want to explain here are direct rate subsidies and rate cross subsidies, and let's start with the latter. So here, we see an illustrative example of retail electricity rates for four different customer types. From left to right, we have agricultural customers, residential customers, commercial customers, and industrial customers. All of these customers pay a different tariff, some below and some above the actual cost of electricity or really of the cost that it takes to serve them.

So in this example, we see a very common practice where industrial and commercial customers are paying higher than cost-reflected rates. And the additional revenue that they provide ends up subsidizing residential and agricultural customers. So now, again, this is a simplified example, and in practice, we see cross subsidization of cross-rate classes happen in many different directions.

But in this example, as in real life, the customers with the strongest economic signal to invest in distributed PV are usually the subsidizing rate classes who are paying the highest rates. And when these customers drop off the grid, not only does fixed cost potentially go unrecovered, but on top of that, this cross subsidy is lost, which further places burden on customers that don't have distributed PV systems. All right, let's head to the next slide.

So also, just to provide an alternative perspective, in many countries, cross subsidies are not employed at all. And instead, the central government, particularly in developing countries, will come in and subsidize electricity rates directly for customer classes of their choosing. So in this example, we see the central government directly subsidizing agricultural and residential customers, while commercial and industrial customers are paying a cost-reflected rate.

In this particular rate, from the standpoint of a central government, it's actually quite attractive to get these agricultural and residential customers on PV because it can reduce the burden on the national budget. And however, because those customers pay so little for electricity as it is, an investment for them in PV doesn't seem to attract it from a financial standpoint. And oftentimes, we've seen government programs that try and sweeten the deal a little bit for those types of subsidized customers. All right. So let's head to the next slide.

Now, just to give you a real-life example, in this slide, we have pictured the average retail rates for electricity across customer classes in Mexico in 2015. So now, in Mexico, they employ a scheme that primarily relies on central government subsidies for certain customer classes but also across subsidy between high-income residential customers and more lower-use residential customers.

So to quickly go over the graph, we see commercial and service-sector use just paying cost-reflective rates on the left, industrial, residential, and agricultural customers paying increasingly subsidized rates as we move to the right. And then, on the far right, we also see a breakout of residential rates between the low-use residential customers and the high-use residential customers, with the high-use residential customers paying an above-cost-of-service rate, which supplements the National Treasury's subsidies in providing that additional cross subsidy.

So now, Mexico's—they're currently in the fairly early stages of the DPV market. And based on this graph, you will likely not be surprised to know that the customer types in the highest rates for electricity are also the ones in most commonly investing distributed PV.

Now, for the high-use customers, in particular, those paying 3.41 pesos per kilowatt-hour, over on the far right, there is certainly some concern about these wealthy, credit-worthy subsidizing customers dropping off the grid, which could put further strain on the National Treasury of Mexico. And at the same time, it's been acknowledged, and it's actually currently being studied by the government Mexico, that there very well could be a huge opportunity to deploy DG for the subsidized customers and accrue major benefits, both to those customers and into the national treasury in terms of reducing the subsidy payments that they have to make.

So now, I just wanted to share this as a real-life example of how retail rates' structures and subsidy structures are quite important and how they can sort of be very influential on how policymakers and regulators approach distributed PV, utility cost recovery issues, et cetera. So let's move to the next slide.

As well, now that we kinda covered this cross-subsidy thing a little bit, I just want to come back to the cycle we went through earlier, and I suppose I haven't yet said that explicitly. But it's important to note that this cycle can become exacerbated quite a bit if cross-subsidizing customers are leaving the grid. And certainly, equity issues may arise if lower-income customers are stuck with the bill for the utility's fixed cost, even though the higher-income customers who can traditionally afford DPV are still utilizing the gird in the evening, overnight, the morning, et cetera.

However, again, this is not all doom and gloom. To this point, I provided a short review of some of the potential issues. But I need to empathize that there truly are a vast range of solutions available in terms of retail-rate design, customer-compensation design, and business models and financing—you name it—to address all of these issues. And to be fair, DPV provides a huge amount of potential benefits, which we'll touch on shortly. Next slide.

So in later-stage policy dialogues around DPV, there's often the sentiment that, well, you know, if we can establish "fair compensation" for rooftop solar customers, a compensation which kinda elegantly balances many different valid perspectives on the cost and benefits of distributed PV, many of these issues that I've talked about with you may go away. Before I jump into talking about those costs and benefits, I did want to quickly elucidate some of the key stakeholder perspectives on the DPV scene with respect to establishing fair and equitable customer compensation.

So first, on the utility side, fair compensation to the utility would likely mean that the DPV customer is paying her or his fair share for use of the grid and that the utility is being compensated for any equipment that might be installed or maintained to enable that DPV customer to use the grids, both for consuming and exporting electricity. Next, on the developer side, DPV developers are very quick to stress the value of DPV to the grid with respect to the energy it provides that reduce transmission and distribution losses, the capacity value, the potential for these systems to provide localized grid stability services, potential environmental benefits. The list goes on. And from their perspective, compensation to their customer should include a very holistic consideration of these benefits.

So for non-DPV customers, oftentimes, they're getting informed through public relations campaigns run by their utility. They need to be concerned about subsidizing DG adopters, which, depending on the regulatory paradigm, the retail rates, the compensation scheme, could be a valid issue to be considered.

And then, finally, from a societal perspective, perhaps through a broader policymaker lens, the potential role for these systems to provide jobs and economic development, emissions, and water-use reductions, perhaps in the case of subsidized retail rates, the potential to reduce stress on the national government budget, these are the types of values that, from more of a societal perspective might be considered. And the reality is all of these perspectives are quite valid. We head to the next slide.

Okay. So now, in practice, for those of us who work in this DPV policy and regulation field, we find that where most of these perspectives tend to coalesce around is in the balance of the value between the DPV customer who installs the system and the value that the DPV system provides to the broader utility system. To quickly run through these costs and benefits, which, by the way, is by no means a comprehensive list. Let's start on the left.

From the standpoint of the consumer, this is relatively simple and intuitive. The DPV customer enjoys the benefit of having a reduced electricity bill. And an additional benefit in some less electrified settings, additional electricity during times of power shortages. These benefits accrue ultimately at the expense of the system itself to the consumer. And in general, let's note that this tends to be fairly simple and easy to quantify and calculate.

On the right, we have the value to the utility. We note that the utility avoids having to generate power, perhaps saving on the fuel cost of their marginal, most expensive generator, reduce TND line losses, and perhaps, they can defer, even fully avoid, needing to make certain capital expenditures. And that frees up funding for other more pressing needs.

Now, on the other hand, a grid-connected program costs money to administrate. That's a cost that the utility incurs. And depending on how retail rates are designed, they may experience lost fix-cost recovery issues that we discussed earlier. If they're a distribution-only utility that generally buys power wholesale and then turns it around and sells it at a markup, then that's a very common structure around the world. There may be a lost margin on sales. And I think, actually, in the interest of time, let's just keep going.

So in terms of calculating the right side of our balance figure, the value to the utility, we see that in practice, many utilities and regulators are starting to study this question in a lot of detail. And each one takes not only a different perspective on which costs and benefits should be included, but also, they're employing a range of different methodologies to evaluate each of those cost and benefit streams.

The figure on the right here illustrates a 2013 review of various utility distributed PV valuation studies, and we see that there's a huge range, you know, way of error of ours of what value-distributed PV brings to the grid. One important thing to note is that two very smart analysts with great data could approach the exact same utility system and run the numbers and come out with very different results, my point being that there's no single global best practice for how DPV should be valued from that utility and system perspective.

We here at NREL have certainly tried to do our part to map out some of the different methods that might be employed. But again, there's a lot of individual customizations that need to be done for each study based on the available data and really like the exact question that the analysts want an answer to.

So stepping back for a second, before we launch into the solutions base for these distributed PV issues, it's important to take the perspective of the regulator. They tend to be at the center of many of these dialogues on how to fairly and equitably compensate DPV while preserving revenue sufficiency. So here are some of the goals to scan over. I think in the interest of time, I want to just move forward into discussing some of the compensation mechanisms.

So this is kind of the fun stuff, in my opinion. These are some of the available policy and regulatory approaches to promote distributed PV while mitigating some of the issues we've discussed. They ultimately fall into three bins, which we can jump right into. So let's start from the top with net metering.

Net metering, which is the most prevalent compensation mechanism in the US, allows for one meter to spin forward or backward based on the customer's net consumption. The grid is used as an energy bank, where, purely from a financial standpoint, credits from kilowatt-hours exported during the day can be used to pay for kilowatt-hours used overnight or any other time the sun isn't shining. At the end of the billing cycle, the customer may have an excess of kilowatt-hour credits, which can be applied to subsequent month's bills.

All of this implies that the crediting value for exported generation is equal to the full retail rate for electricity. And at the end of a set period of time, usually between 12 and 24 months, if any kilowatt-hour credits remain banked, they are deemed net excess generation, and they either expire for zero value, or they're paid out in cash at a predetermined rate, usually somewhere between the utility's avoided energy cost and the full retail rate. Now, because of a net scheme, the implication is that—the implication in the title is that the PV system is wired such that the customer has the opportunity to consume the _____ energy before it's sent out to the grid. And that's very different from our next scheme, which is a feed-in tariff.

So for a feed-in tariff, the customer continues to consumer electricity as normal, paying the standard applicable rate for electricity. The PV system is not really wired behind the meter at all in this case, rather the power generated from the PV system is sent directly out to the grid, measured separately and credited separately. This is a proper buy-all-sell-all scheme, where the sell rate is customized and usually fixed for the lifetime _____ _____.

So now, a quick note on feed-in tariffs. As I have these discussions in various countries around the world, when the prospect of a feed-in tariff comes up, I found that many of our country partners react quite strongly to the prospect of a feed-in tariff by saying, "Oh, no, we cannot do a feed-in tariff. It's way too expensive. Just look at Germany and look at Spain."

And my response is always the same, which is to take a step back and point out that a feed-in tariff is a way of metering exported electricity and billing reports. That's it. It's not a requirement of a feed-in tariff that the sell rate for the generation be high. Many feed-in tariffs we're observing around the world are well below the retail rate for electricity. Again, a feed-in tariff is a metering and a billing arrangement. There's no implication, tacit or otherwise, that it's expensive. Let's move on to the next one.

So finally, one emerging solution in many jurisdictions that perhaps used to have net metering is a shift to this concept called "net billing," and many would refer to this, also, as a net feed-in tariff. Here, the customer has two meters. The system is wired to give the customer the opportunity to consumer their own electricity, first, before that power gets pushed out to the grid.

The first meter is a net consumption meter. It spins forward if at any given point in time the customer is taking power from the grid in excess of what they're generating. And then, that meter is billed at the retail rate for electricity since it's measuring what the customer is taking from the grid.

The second meter is a net export meter. This one spins forward. If at any given point in time, the customer is sending out power to the grid in excess of what they're consuming, that second meter is credited to the customer at a separate predetermined rate, similar to a feed-in tariff. Okay. And then, in the interest of time, let's move forward.

So I just want to quickly point out that when people are thinking about retail rate design for customers and maybe revisiting it for rooftop ports, because it's distributed PV, there's two approaches. You can either change retail rates for all customers, or you can change retail rates just for solar customers, and I think, in practice, we found that creating specialized solar customer rate classes ends up allowing much more surgical solutions and also much more politically expedient solutions so that you're not changing rates for millions of people. You're only changing it for the folks that have installed distributed PV.

And then, let's just move forward another slide or more. So just wrapping up here, this slide has a lot on it, but I want to, first, quickly point out that there are a range of ownership models for distributed solar. Obviously, we have the fairly standard model, where the customer purchases and installs the system, but an increasingly common approach around the world, which I believe dominates 80 percent of the market in the US, is 3rd-party leasing. Under that setup, solar installers or other investors associated with that solar installer will put up the capital for a customer system. And then, the customer will effectively sign a long-term lease for their electricity, which perhaps costs 70 to 80 percent of their normal electricity bill.

Again, this has been a very successful model to close the financing gap for many residential and commercial customers. There's also community solar in this respect, which, just because in the interest of time, I think we're going to have to skip. In terms of financing, I'll mention that access to capital is a huge deal for distributed PV and distributed PV customers and that there are many innovative public and private approaches to achieve this.

And then, finally, I'll say in terms of carving out an increased role for the utility, we're beginning to see certain models where the utility builds, owns, and operates its own distributed PV systems. As I've alluded to in the previous slide, no one knows a distribution system better than the utility that owns it. And these utilities are very well positioned to identify sites that have a large amount of value to the grid.

So this is now being done under rooftop rental arrangements, where the utility, again, builds, owns, operates the DPV system, but then makes a monthly payment to a customer for using their roof. This is particularly an attractive prospect maybe to provide some income and free electricity to low-income customers. We've already seen the model work quite well in several places in India, most notably Gujarat.

Anyway, I've just run over time here. So I'm going to have to wrap up and pass it over to Mike Coddington to talk about technical issues.

Michael All right. Well, thanks, Owen, and my thanks to Jeff Haeni for pulling this together. I'm going to kinda take a different direction and talk more about the technical challenges and codes and standards, some of the topics that are very important to the utilities that are working to integrate PV with their customers onto their system.

I think the utilities are not really allowed to say no to interconnecting in most places. They just have to find a way to make it happen, and that's where the mitigation strategies come into play. And I'll just cover some of those briefly this morning, not too much of a deep dive, but I want to wrap up with some of the thinking for electric utilities and their distribution, planning, and engineering, and how they're looking at kind of building their systems in the future to accommodate larger amounts of distributed generation. And distributed generation primarily around the world has been photovoltaic systems almost entirely. So go to the next slide, if you would.

I think some of the foundational components of making a successful PV system have to do with having the right technology and solutions to integrate to the grid, and that's one of the ways that the utilities will leverage those technologies, like inverters, to play well with the grid. And we'll talk a little bit more about that in a couple of slides. Really critical to the foundation of any utility or any country's approach is to have good and solid interconnection rules and codes and standards in place. I mean they're really foundational.

I had a conversation with Jeff about a year and a half ago. We were very visiting an island country, and the utilities there had mentioned that they just saw PV systems popping up, and nobody was talking with the utility. They weren't sure if these systems were really suitable to tie into their grid.

They knew they were having an impact, and they were concerned about it, but this utility, this country, just didn't have a really good interconnection rule and codes and standards process in place. So that's very important to develop those, and it can take a lot of work, but many countries could adopt what has already been going on and developed around the world. And finally, I'll just mention that utilities and their planning strategies are—many utilities, especially those that are dealing with larger and larger amounts of distributed generation, are kinda looking at a different way to plan their system to make sure that the system operates reliably and safely in the presence of large amounts of DG.

So if you go to the next slide, these are four of the, I guess, the major utility concerns that I hear about, not only in North America but in many other countries. We work with, of course, US utilities but quite a bit of work with the IEA countries. And so many of these topics come up, and it really doesn't matter where you're at because utilities operate in kinda the same manner no matter where you are. Ever utility's different, and yet they operate very similarly.

And so these concerns are very common. The top concern is voltage regulation. If you don't keep your voltage within the right kind of boundaries, you can damage equipment and utility system devices, as well. And I'll talk a little bit more about that in just a couple of slides.

But reverse power flow is a concern. Again, having power that's flowing from a neighborhood or a very large PV system and going back to into the utility system can create a number of different challenges. And that may include creating higher voltage or having problems with the fuses and the circuit breakers to protect that system, which is the third bullet her, really, the protection system coordination. Large amounts of distributed generation can have a negative impact on that.

And finally, unintentional islanding is a concern that comes up, really, universally, and that's the notion of having photovoltaic systems or other distributed generation running on. When the utility system drops off for an outage, there's concern that these PV systems would continue to operate and cause other problems, perhaps damage the system. So if you go to the next slide, this just illustrates—and again, you don't see any numbers here, but I just want to show that risk factors for photovoltaic systems can come in a number of different flavors.

But in this case, you can see that as you get farther and farther away from the utility substation—and that's on the lower axis—you have a higher risk of problems occurring, and I think that's just universally true. And on the left or the y-axis, you'll see the size of the PV systems or the group of systems, the larger they are, the higher the risk of problems for the utility. And I think suffice it to say that if you have one or two small rooftop systems, utilities, wherever they are, probably aren't going to experience any major disruptions. But as you start to get higher and higher levels of penetration of PV, potential problems and the risk factors grow.

So if we go to the next slide, you'll see that this is kind of a voltage range limit. And in North America, we try to adhere to this, and this is based on kind of the nominal voltage. In the US at a receptacle outlet, it's 120 volts. That's a 120-volt scale, and we try to stay within plus-or-minus five percent, and I've asked utility engineers—that's my background believe coming to the lab—but I've asked utility engineers around the world about this issue. And I think that it's pretty universal. Utilities strive to keep their voltage within limits. Plus-or-minus five percent, it may be a little broader than that, but if voltage gets out of range by too far, we know that equipment can be damaged, and the utilities don't want to see that.

So the next slide is an illustration showing a large PV system, or perhaps that might be, say, a large neighborhood with PV on ever rooftop. But if you're in a situation where you're exporting significant amount of power back to the utility, again, a number of different problems may arise that need to be mitigated. And in this case, you can see that kinda the red-dashed line show that the voltage can potentially be higher than the utility wants to serve their customers, which could cause damage to the equipment.

So the next slide is kind of an illustration showing how the fuses and the circuit breakers on a circuit could be impacted by large amounts of photovoltaic or distributed generation. And while I won't get into the details, but electrical engineers tend to enjoy so much. But I think it's pretty straightforward that if you have a significant amount of power flowing from a photovoltaic system and then power coming from the utility substation, you can create a situation where the fuses can basically be miscoordinated. And you may end up causing a larger outage to more people if there is a problem because of this additional current coming from a PV system.

So these are issues, this protection system coordination. As long as the utility knows what's coming and can study the application, they can address this, but they have to coordinate with their customers.

Now, the next slide talks a bit more about this whole unintentional island issue. And while I won't really dig into this too deeply, I think the notion is or the concern is, again, that if the utility power goes away and there's a potential for this photovoltaic system, a large PV system or perhaps a whole neighborhood that could continue to run on and create a situation where maybe the voltage gets out of range, or there would be safety concerns. It's highly unlikely. This is just not an issue that has been documented anywhere around the world to really any extent. But it is a major utility concern, and it can be very costly to try to address this particular issue. So I wanted to raise it as being one of the major utility concerns.

Now, the next slide shows kind of standards and codes and where they might apply, again, no matter where you're at in the world, what country. In North America, I've listed some of the standards that we apply. But as you see, there's kinda three different areas. There's the utility side over on the left side, and really, all utilities have some kind of a manual of, say, practices and how to operate their systems, and they try to adhere to voltage standards. In the US, we use that ANSI c84.1 standard.

The point of common coupling, which you see is the meter there, is where kind of the interconnection rules typically apply. And again, in the US, in North America, we typically use this IEEE standards—1547. And on the right side, you'll see kind of the building, the commercial, the residential, the industrial buildings, and in the US and many countries, there's pretty strong electrical code requirements for safety. And again, in our electrical code, in North America, we have a whole section on photovoltaic systems, and that's important to make sure things are built safely and to keep the reliability at a high level.

So if we go to the next slide, this shows the kinda the classic interconnection process that we'd like to see, really, in any country that's starting to see distributed generation roll out. This process is really straightforward. You've got your application, and this is where a developer or a customer notifies the utility that they intend to install a PV system. Utility, then, would apply kind of a fast-track screen and just some basic technical questions to determine if that system can be interconnected quickly. If you could hit the button again.

This is kinda the preferred path, where the fast-track screens are approved, and the PV system gets a green light, and the systems allowed to be installed. If it's a larger system, or if there's more complexities to the application, there may need to be kind of different review screens applied, kind of impact studies where utility engineers will use computer models to model the proposed system. And if the computer model determines there may be problems, that's the point where the utility would model some kind of mitigation strategy to see if they can make whatever potential problem go away. And if the mitigation strategy is not too costly, then it can actually be built once the system is approved.

So if you go to the next slide, this is a list of some of the mitigation strategies that are used throughout the world. I think one of the most promising and that we here so much about, even just over the last couple of years, has to do with smart inverters. We've got very robust advanced technology in these inverters that can solve a lot of problems, and we're seeing a deployment of those in many countries. And we're seeing a big push for those throughout the United States.

Other mitigation strategies, as I mentioned, is really making changes to the fuses and the protection settings, perhaps putting in voltage regulation devices or modifying the controls. These are not very expensive mitigation strategies. We show upgrading the conductor as a potential solution, and that can be something fairly _____. When a utility requires that the lines get rebuilt, that can definitely put the brakes on a system being proposed.

So and that, along with the next one, this whole direct transfer trip, which is required by some utilities that we're familiar with, that can also be a very expensive mitigation strategy. And that whole—the point of this direct transfer trip is for the utility to send the signal to the PV system to drop offline in the event of some kind of a problem.

Then, we've got battery solutions listed, as well as other smart grid devices, which I won't dig in too deeply at this point. But there are other solutions, some of which are, again, inexpensive, and others, which can be very expensive. And we certainly encourage utilities and policymakers to choose the solutions that are the most inexpensive, I guess.

And I'll go back to this smart inverter or advanced inverter technology. Pretty much all of the inverters being sold worldwide today have got some of these smart inverter functions built in. So we know those are available and fairly inexpensive, and it's just a matter of which functions to turn on and which ones to use to make the grid play better with the PV system.

Next slide just talks a bit about utilities and how they plan their system. And while I won't get into these major components here, the utility engineers tend to watch the loads over the years and plan and forecast for when they need to put in system upgrades. Certainly, there are countries that just don't have enough electrical systems serving all of their country inhabitants, but that's an issue that certainly is being addressed, I know, and by many utilities.

But again, in many countries, most customers that want electricity have electricity, and the utility does watch kind of the load growth if there is growth and has a budget around serving the new loads and the new needs. Reliability is certainly a top issue here, and the utilities and the electricity consumers certainly want to keep the lights on and their equipment running.

But the last bullet here is kind of more germane to what we've been talking about—distributed generation, and that is that the utilities are beginning to plan their system to support distributed generation, especially photovoltaic systems. And they're starting to get a better handle on what the hosting capacity is for photovoltaic systems and other distributed energy resources. So part of the challenge is that utilities, they know that they can accommodate a certain level of PV systems on their feeders, but they may want to increase the levels of that. And again, that's the notion around grid-hosting capacity.

And finally, my last slide, just want to mention that there's a lifecycle around photovoltaic systems like there is with any systems that tie to the grid. And certainly, the grid itself has a limited lifespan, and so in the case of PV, it's pretty straightforward that somebody makes a decision and purchases a PV system. It's designed, and then, the whole interconnection and permitting process is completed with the utility through the local jurisdiction, maybe the inspector if there is one.

And then, the system's commissioned if it's approved to be interconnected. The system is commissioned, tested to make sure it operates properly, and then, over the course of a number of years, the system operates normally. And then, ultimately, after a number of years, a system is retired, and basically, the cycle starts over again, where a PV system may be updated and something else installed.

But just keep in mind utilities typically design their systems where equipment is expected to be operating for at least 30 years, and PV systems aren't quite that long today. So that whole lifecycle may be closer to 15 or 20 years. All right, with that, I think I'll turn the presentation back over to Jeff.

Jeffrey All right, well, thank you so much, Owen and Michael, for those outstanding presentations. And thanks to Michael for—or thanks to Owen for this next slide, which attempts to summarize many of the key topics discussed today and is associated with distributed PV. Now, certainly taken together, this slide can be a bit daunting, but that's certainly not the impression we want to leave you with today, that rooftop PV is simple too complicated to warrant the benefits.

In fact, there's probably, as Michael mentioned, a pretty good probability that whatever country you may be in today, there are probably customers adding rooftop PV, and it is quite possible that the utility has no idea where these are. There might be no interconnection standards being followed. So certainly, as a first step, I think it's very important to regularize interconnection process and catalog the systems on the grid even if your country is just starting to go down this road.

Now, when it comes to some of the issues that Owen discussed, such as rate design, business model issues, some of the more complicated technical issues, as Michael noted, these typically scale in magnitude and impact with penetration levels. So there's likely some time to devise appropriate solutions and to refine these as you're market evolves. But there, I guess one word of caution is that we have seen certainly countries where, when the economics and the incentives are very positive, rooftop PV can scale extremely quickly. So it's never too early to start thinking about some of these topics.

I think the bottom line is that things do not have to be perfect from day one to launch a rooftop PV program. Many countries around the world will launch a pilot rooftop PV program with periodic reviews and revisions to program objectives, tariff scheme, size limits, et cetera, and this is emerging as a global best practice.

So now that we have piqued your interest, skipping ahead a slide, where can you go for more information? Well, Owen and his colleagues have done a terrific job of pulling together many of the leading publications and studies on these whole host of issues associated with rooftop PV, and these are available at the website listed on this slide. Highly recommend visiting this site for additional information on all these topics and more that we have discussed today.

And finally, I wanted to note that USAID, next slide, has launched a program with NREL to help our emerging market partners to address many of the challenges and opportunities that we have reviewed today. We have some existing work, as Michael mentioned, in Jamaica, Southeast Asia, Brazil, and welcome inquiries. You can send an e-mail to myself, or Owen would be happy to discuss the program with you in more detail.

So with that, I think we can leave the contact information up as we start to address some of the questions that have been submitted online. Maybe we could start with a question for Owen. "Owen, what are some of the emerging best practices that you've seen regulatory commissions start to adopt to help utilities cover these fixed costs that you discussed under a net metering protocol?"

Owen

That's a great question. So generally, it's going to be under "retail rate design approaches." There's a range of strategies within retail rate design that can help here. So in some limited circumstances, there can be merit under net metering to raising the fixed charge, and that's either with or without lowering the variable charge to—you know, in line with that.

But otherwise, we've seen regulators and utilities changing tariffs to employ demand charges as a component of utility bills. So that's charging based on the magnitude of the customer's peak grid—distribution grid usage. We've seen time-of-use rates, where both the buy and the sell rates for electricity change to be a little bit more reflective of the time dependency of utility costs that get incurred between days or months or seasons.

One particular approach for net metering that I think is quite clever is instituting a minimum bill. So a minimum bill is a tariff component that it doesn't change the rate components of the standard bill, but instead, it specifies a minimum amount that a customer will owe in each billing cycle. So if they happen to get to that minimum bill through buying kilowatt hours, if they're net consuming that month, so be it. But if they don't, then they're still hit with that minimum bill to ensure that utility recovers its fixed cost.

And then, I'll just wrap up by saying that minimum bills, they tend to result in substantially lower electricity bills for solar customers relative to increasing fixed charges to the exact same magnitude. But both minimum bills and fixed charges can help maintain utility cost recovery. So minimum bills tend to be a pretty good approach, and we're seeing a transition towards those in many contexts around the world.

Jeffrey

Great. Thanks so much, Owen. And Michael, maybe one for you. "As you correctly noted, unintentional islanding continues to be a concern of utilities and linesman around the world. I was wondering if you could talk in a bit more detail, _____ modern inverters with the features like they have today, how much of an issue is this, particularly in countries where the installers may have a variety of different approaches, some of which may be best practice and others not? And in addition, is there any additional training or best practices that utility line workers need to follow in countries that have rooftop PV or the standard safety procedures that we have followed for years sufficient to address rooftop PV safety concerns?"

Michael Well, thanks. That's a great question, Jeff, and I'd be happy to kinda dig into this a little bit more. First off, I want to say that most photovoltaic systems are meant to be grid tied. I mean and that's what we're seeing worldwide because the cost is so much lower than a standalone system. So early PV systems from 20—30 years ago were almost all kind of battery system, where it was not tied to the grid. You would charge a local bank of batteries, and then you would use that power whenever you needed. Very limited power capability.

But today, what we're seeing are these grid-tie systems that really require the grid to be operational for them to be operational. And so when there is some kind of emergency or an outage from the utility, the downside of these grid-tie systems is that they go offline. And again, you need the utility power to be present in order to get the PV up and running again during the daylight hours, of course.

One of the issues that's so important for countries to have a good set of standards around their PV inverter and Underwriter Laboratories—UL—has a number of standards throughout the world. Again, certainly in North America, but they've been kind of adopting inverter standards in other countries. But as long as an inverter or a set of inverters kind of meets the requirements of the local countries' interconnection kind of guidelines, there should really be no problem.

We've demonstrated in the lab and in practical experience that inverters don't tend to create unintentional islands when the utility goes down. And so to address your—so the probability—and again, we've tested this in the lab—but the probability of an island forming is incredibly low. But even in the case of an island forming, the generation of the photovoltaic would have to match the load pretty exactly, and that's extremely unlikely because people turn loads on and off all the time.

As far as the line people that work on the lines—and again, I spent a lot of my years, prior to the lab, out working in the field with some of these line people, and I know kinda how things work for them. And I would just say this, that utility line people, when there is an outage—and that's kind of this, when we're talking about an unintentional island scenario, that's when there's a problem with the utility grid. And so they've got trouble men or linemen that are out trying to solve the problem.

And when they do so, they treat everything as if it's energized. They don't have time to make sure that everything's disconnected and that they kind of ground all the lines together, which is the requirement if they were to be able to kinda take off their rubber gloves and their protective devices. So line people around the people know that they just need to work—they need to pretend as if the line is energized or assume the line is energized and work so that they continue to be saved, and they solve the problem. There should never be any kind of additional risk from photovoltaic systems and line safety.

Jeffrey Terrific. Thanks, Michael. Going back to Owen, I think I correctly understand this question. The question, Owen, is, "For countries that might have increasing block tariffs, how do you calculate under a net-billing scheme? Is it simply a net value of the energy consumption levels at the beginning and the end of the month? Or do you need some sort of a more advanced formula to calculate appropriate rates?"

Owen Yeah. Great question. Okay, so again, just if we're talking about inclining block tariffs and how we set the consumption tiers and the prices associated with those tiers, generally—and this is on the retail rate side for consumption—generally, there's no set formula or method here. Inclining block rates are generally driven by social policy and knowledge of the various consumers. So how much energy different consumers use and then how much the government of that country or the regulator in that country wants to see those different customer types pay, if anything at all, really from more of a social policy/economic development standpoint.

But I guess I'll say, for distributed PV, there are undoubtedly some very interesting interactions between inclining block rates for consumption, particularly if they're quite steep and these net metering and net billing schemes. We've seen situations where designing a PV system that's quite, quite small, just large enough to move a customer from, say, the highest tier where they're paying the highest price, down into the mid-tier where they're paying a medium price. Those systems could have a payback period of between one and two years under certain circumstances.

So I think, in those situations, if that's deemed undesirable, which maybe it is if you want higher-income customers or higher-use customers really paying into the system at that higher rate, that can be mitigated quite effectively, again, through retail rate design. Particularly, I would say that would be a good case for creating a specialized solar rate class and just getting these customers on the exact rate that you want them on to ensure that you're getting the cost recovery very surgically and precisely from them that you need.

But yeah, I guess there is no really set way of doing it. It's a very context-specific undertaking, a lot of politics involved in retail rate design, as well, in practice. But I would say to whoever asked the question—just 'cause I can't see the screen—please feel free to send me an e-mail, and we can certainly brainstorm for your area or your utility jurisdiction if that's of interest.

Jeffrey All right, thanks so much, Owen. Michael, a question for you regarding the appropriate geographic scale for short-circuit current coordination. And the question is, "Should this be done on a state-by-state basis, utility-by-utility basis, consumer-by-consumer? What are some of the best practices that you've seen as it pertains to short-circuit current coordination?"

Michael Well, that tends to dip in heavily into the electrical engineering side of things, but I'll try to answer in a way that talks to all the non-electrical engineers. Each location on the utility system is different. Every utility substation and circuit is different, but what I would say it that it's kind of a utility-by-utility type issue. Any particular utility has kind of a list of their standards, their standard approaches for fuse sizes and their settings on their equipment, and it's all kinda pre-designed to coordinate with one another.

And they have ways of kinda modifying those coordination issues on their lines, but it's definitely a utility-by-utility type question. And again, when you've got, say, large amounts of photovoltaic or distributed generation going into a utility service territory, that can definitely stir things up a bit and create additional challenges. I would say that this whole concept of kind of coordination on the various fuses and circuit breakers, it's a bit of an art, as well as a science.

And so there are not really solutions at the ready when you decide to add a photovoltaic system. The utilities really do need to take a look at that, often employing a modeling system to model that distribution line. And then, they can determine if there's going to be any particular problems. And again, it's very much utility-by-utility, and it's one of the biggest issues that have come up, at least in North America and parts of Europe is just making sure these systems coordinate.

So utilities are pretty good at this. It's not a major issue, but sometimes, they need to study it to determine if minor modifications need to be made. And I'll just end with saying this is typically not an expensive solution. It's just a matter of applying good engineering rigor to an application. That's why it's so important to coordinate with the utility and the PV developer. So thanks, Jeff.

Jeffrey Great. Owen, one of the key concerns we often hear in emerging markets is that rooftop PV—early adopters tend to be the more wealthy, possibly the commercial or industrial customers. And without a lot of thought to redesigning the retail rates, they, therefore, tend to get a lot of the benefits at the expense of some of the poor customers. What are some of the emerging best practices you've seen globally to help some of the lower-income customers take advantage of some of the benefits that rooftop PV can offer?

Owen Great question. So I'll quickly say that, first and foremost, retail rate design can help to mitigate some of the potential negative impacts in terms of the cross-subsidy issues or the fixed-cost recovery issues. But I think the question's really important, and it's sort of how do you get these lower-income customers not only to have the negative effects—impacts that may occur mitigated, but how do you get them into the game? How do you make them, these customers that are—they're low income; they're likely low credit. They certainly don't have money lying around to go out and buy a PV system. How do you get them into the game on all of this?

So certainly, one approach that I mentioned is the idea of a rooftop rental program. So the utility will go out. They obviously know, in many cases, where their low-income consumers are. And if possible, those customers, if they have roofs, the customer can—or the utility can go out, place PV systems on their roof that they finance themselves. They collect that out of the rate base and get a regulated rate of return on it just as if they were procuring new capacity on the utility side. And then, they pay sort of a fee to rent that roof just as if they would be paying a fee to rent land for a utility-scale PV system. And then, so that's sort of one element.

The other thing that we find is that a lot of the sort of lower-income customers, they're living in urban or peri-urban environments. They may not have roof space. So the question is, "What do you do about that?" So community solar, also known as "shared solar approaches," can certainly be very effective here, where, so again, in the case of a low-income customer that doesn't necessarily have income to purchase a system, the utility could go out and perhaps partner with a developer, perhaps not, depending on the business model.

Would go out and build a larger system and then, more from a financial construct standpoint, would chop that much larger system up into a whole bunch of small systems and then assign them to the low-income customer and perhaps collect some payment for the system. But overall, it would be sort of a lower bill for the customer, and the financing here certainly can get complicated. But it absolutely can work, and particularly, it can work if there's sort of central government backing. If the government has developmental objectives, this is certainly one great way to invest money in doing that, so yeah.

But generally, I think it's a little bit of retail rate design, and it's a lot of sort of innovative financing and utility business model approaches. And it's really, again, very context specific in terms of what's going to work, technically, financially, and politically.

Jeffrey Super. Thanks, Owen. Michael, if you're in a developing country that was just starting to realize that people were starting add rooftop PV and you needed to quickly come up with some decent interconnection standards, what resource would you point people towards in terms of a good starting point to understand some of the emerging global best practices on interconnection standards?

Michael Well, that's a great question and one that I've thought about certainly over the last few years. And while I don't know that I've got specific documents I could point to, I'd have to kinda coordinate with Owen a bit because I know we do have many documents out there. But I would say this, that if I were working with these developing countries, I think what I'd highlight is the need for kind of an interconnection process that would work with the utilities so that utilities can be notified when these systems are going in.

And again, you'd certainly hope that the utility would want to coordinate and help facilitate that interconnection. Sometimes, that can be a problem of its own. Especially in nascent markets, utilities may not want to see kinda what they may deem as competitive sources of energy. But as long as you can get the utility to develop a process—and again, I think we've got so much information on this that it wouldn't take too much to look at some model interconnection approaches. It all kind of depends on what some of the technical requirements are, depending on the contrary, whether that's 50 hertz or 60 hertz. It depends on kind of the voltage that is served to the customers, but those are actually kind of minor issues.

And when it comes to codes and standards, that's also a very critical issue. I mean codes and standards need to go hand-in-hand with kinda the utility interconnection procedures, and those need to be matched up with whatever the country's prevailing frequency and voltages are. And again, those are pretty straightforward, but again, the codes and standards need to match those parameters for the country. And so much work's been done worldwide that I think it would be relatively—and I don't want to say easy, but it wouldn't take too much effort to come up with codes and standards and procedures that could be duplicated.

Again, we're talking about maybe smaller countries or smaller utilities. They just don't want to reinvent the wheel. It's far better to look at what's been done and to avoid the pitfalls that other countries or other utilities may have made and, again, kind of stand on the shoulders of giants. So I think we've got material. I wish I could just point at a report that tells you how to kick start an interconnection process and codes and standards, but I think that's something we'd like to work with USAID and Europe, kind of the member countries, in developing further and kind of help point them in the right direction to make those choices. So great question. Thanks.

Jeffrey Okay. Quick question for Sean. Are we looking to go right up to 11:30, or did you say you wanted a bit of time at the end to make some additional comments?

Sean We only need about three minutes at the end for a quick attendee survey.

Jeffrey So we will continue with questions for a bit. Michael, back to you. "Could you tell us about any technological innovations that are on the horizon that you might be particularly excited about as it pertains to rooftop PV? This could either be in terms of advanced inverters, battery storage. What are some of the emerging technologies that you're seeing start to come on the market that have a chance to perhaps redefine or improve the way that rooftop PV is deployed?"

Michael Yeah. That's a great question. Thanks. I did mention kind of smart inverters and advanced inverters earlier in my presentation, and I think that's one of the most promising areas for a number of reasons. Some of the smart inverters, again, if they match the local utility specifications, have the capability to, for instance, charge battery systems and be able to, perhaps, use the energy that's generated when the sun is shining and use that when the grid really needs the power.

So there's greater capability to tie into energy storage systems, which I think you mentioned that, and that is such promising technology. In the last few years, I think it's been acknowledged that battery systems could solve a lot of the potential problems that solar PV bring to the grid, but there's a cost, a pretty significant cost to the various battery system technologies. Batteries are expensive, and it's difficult to add batteries and keep the finances palatable for the developer.

But as the battery system prices continue to drop and we have these systems like the power wall that's been announced by Tesla, those do offer a lot of, I think, promising new technology advances. And especially if you think you've got a storage system in your home, perhaps your small business, you could also use that if there is a power outage and when there's a storm or some kind of event to keep a few lights on, to perhaps keep a refrigerator going, and maybe charge your cell phone.

I think that's one of the big concerns we heard in the US when kinda that superstorm Sandy rolled through the Northeast and knocked out millions of customers' power, and some of that power stayed off for many days. That kind of event happens worldwide, not the same type of event. But disasters happen, and people need electricity. And so I think that some of these storage systems could be very beneficial in helping people kind of limp along until the utility gets the power restored.

One other thing I'd mention is that over the last handful of years, we've seen a significant move toward these micro inverters, where you've got a PV panel or a module on a rooftop or maybe ground mount. And each one of these modules have a micro inverter, a small inverter that changes the DC power to AC, compatible with the grid. And what's nice about those systems, if one of them fails for whatever reason, the other parts of the system continue operating giving a higher reliability.

And you can also integrate new additions to a PV system at any time without having to redesign the entire system using micro inverters. And there's a number of other benefits that I think these smart micro inverters are bringing, and that's the technology to keep your eye on. And again, for remote areas where it's difficult to maybe transport in equipment, micro inverters are smaller and easier to transport and move around, so that could certainly be a benefit for specific regions. Thanks.

Jeffrey

Terrific. Okay. Let me just end with one last question for both Owen and Michael, and it could be a very long question, but you can keep your responses short. We now have the advantage of having several countries or regions that actually have quite high penetrations of rooftop PV. I was wondering if you could pick one, maybe Kauai or Italy—you name it—that does have very high penetration levels, and walk us through how they're coping. What does it mean from the technical performance of the grid?

What challenges are they finding? Are they being able to manage it? And on the economics, as well, is the utility still functioning operational? What sort of tools, perhaps, has the regulator put in place to allow the utility to maintain a viable business model?

Michael This is Mike, and I'll take a shot at that. I think one of the best examples that I like to use is Germany, and that they're certainly leading the world in the total amount of photovoltaic system deployed. And I think they're somewhere between 40 and 50 gigawatts, and I think my understanding is that they generate, on some days, more power as a nation with solar than they consume. And so they export power to the rest of the kind of the ENTSO-E grid in Europe that actually goes down into kinda North Africa and up into the former Soviet Union, so it's a very large grid in Europe.

But back to Germany, I think that they have a goal, a countrywide goal of rolling out PV systems, and it was kind of a situation of, "Damn the torpedoes. Full speed ahead. We'll figure out the problems when we get there and try to solve them." And they indeed have seen problems in Germany, and one of the biggest problems is that they generate so much PV power during certain times that they can actually see the frequency in the grid rise higher than the 50 hertz that they try to operate within.

The inverters in Germany were programmed to all drop off if the frequency got above 50.2 hertz. And that became a major problem and one that they they've had to go back and spend hundreds of millions of Euros trying to reprogram and solve this problem because if you're generating more power than you consume, your grid frequency will start to rise. And when that happens, again, all of these inverters were programmed to drop off at 50.2 hertz.

And if you end up losing, say, 40 gigawatts of photovoltaic system pretty simultaneously, then you would see the frequency crash downward or start to drop dramatically causing kind of another problem, where they'd start to take out wind systems that drop off at low frequency. And so Germany has had to, again, spend a significant amount of effort and actually send people out to reprogram inverters at a very high cost, and that's a lesson that I think we're all watching and trying to make sure that we don't repeat that.

I would also mention, and this is kind of—gets into the tariff and rate issue that Owen has been talking about, but in Germany, they've got a great system or had a great system, where they offer—or they have offered very generous feed-in tariffs to kind of get the photovoltaic market stimulated. And they made the process very easy, where all you had to do was fill out one application, and that went to the utility. That went to the financier. That went to everybody in the country that needed to know you had photovoltaic system being installed, and it was very easy.

And basically, if there were mitigation strategies that needed to be deployed, the utility picked up the cost and socialized it. And so the result of that is that their process was very fast, and their cost of interconnection was cheap—low—at least on the surface. But it's had a dramatic impact on rates, and they've seen their residential rates approximately double from I think 2003 to 2012, and that's documented. We've got that documented in reports, so if anyone wants information on that, I'd be happy to follow up.

But just the point is that seeing residential utility rates double or even go up 20 or 30 percent is very unpalatable, certainly in the United States. But I think in many places, customers would perhaps—they certainly would not be pleased, and they might even reach panic. And what devices are they going to shut off if their rates go up that much? So we don't want to see a kind of a repeat of that. Germany has done a lot of things well, but they've also taught us a lot of lessons on, perhaps, what countries shouldn't do in the race to deploy PV.

Owen And this is Owen. Just to add a little bit more perspective here, the idea that establishing a feed-in tariff—I sort of said this earlier—is going to lead top doubling of rates or 20—30 percent increase in rates, that's just not the world we're in today. Germany employed a fairly generous feed-in tariff at a time when they were trying to really build a market and get manufacturing costs down and get installation costs—soft costs down. So that's important to note.

Also, because Germany employed a proper buy-all-sell-all feed-in tariff, they haven't really had fixed-cost recovery issues in that I've kinda reviewed in the same way that you would in a net metering or a net-billing scheme. So now, you know, at the same time, that doesn't mean that there aren't revenue issues. They have a huge amount of rooftop PV on their grid that perhaps was not envisioned 20 or 30 years ago when many of their larger conventional generators were invested in.

So some of the plants are fully amortized. They're through their economic lifetime. Some are not, but there is significant discussion in Germany, mostly a political discussion at this point, about how to address the revenue sufficiency of some of these individual plants that they no longer need but are sort of 60-year assets and what exactly to do about that. And who's going to pay? And how much are they going to get paid? And again, I guess this is really more of a political discussion at this point than it is anything about practical or regulatory or doing too much math. So anyway, with that, we're right up on our time.

Jeffrey Terrific. Well, thank you so much, Mike and Owen. What a tremendous wealth of knowledge. And Sean, why don't you take it from here.

Sean Great. Thank you, everybody, and thanks for the great discussion and response to the questions. I just want to ask our attendees to hang on for another minute or two. We just have a quick survey for you. I'll launch right into it.

First question is, "The webinar content provided me with useful information and insight." Great. And the next one is, "The webinar's presenters were effective." And the third question is, "Overall, the webinar met my expectations."

And then, just two more yes-or-no questions for you. The first being, "Do you anticipate using the information presented in this webinar directly in your work and/or organization?" And then, finally, "Do you anticipate applying the information presented to develop or revise policies or programs in your country of focus?"

Great. Thank you very much for your responses. I do appreciate that. And again, just want to thank all the panelists for their excellent presentations and the great Q&A that we followed up with there. And also, I want to thank the attendees for participating in today's webinar. We very much appreciate you taking the time to do so.

I do invite everyone to check the Solutions Center website to download PDF versions of the slides. Those are now posted there, so you can access those right away. And just a reminder, we'll be posting a full recording of the webinar to that page, as well, and we are also uploading those recordings to the Solutions Center YouTube channel. Please allow about a day or two for the recording to be posted.

And finally, we also invite you to inform your colleagues and those in your networks about these Solutions Center resources and services, especially the no-cost Ask an Expert technical assistance. So with that, hope everyone has a great rest of your day and we hope to see you again at future Clean Energy Solutions Center events, and this concludes our webinar.