Greening the Grid: Utility-Scale Battery Storage

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Webinar Panelists

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This Transcript

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Stephanie

Hello, everyone. I'm Stephanie Hernandez and welcome to today's webinar, which is hosted by the Clean Energy Solutions Center in partnership with the United States Agency for International Development and the National Renewable Energy Laboratory. Today's webinar is focused on Greening the Grid: Utility-Scale Battery Storage.

Before we begin I'll go over some of the webinar's features. For audio you have two options; you may either listen through your computer or over the telephone. If you choose to listen through the computer please select the mic and speakers option in the Audio pane. If you want to dial in by phone please select the telephone option and a box on the right side will display the phone number and audio PIN you should use to dial in.

If you would like to ask a question, and we encourage that you do, we ask that you use the Questions pane, where you can type that in. An audio recording and the presentations will be posted to the Solutions Center training page within a few days of the broadcast. And the recording will also be available on the Solutions Center YouTube channel, where you can find other informative webinars as well as video interviews with thought leaders on clean energy policy topics.

One more note to mention before we begin 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 is part of the Greening the Grid platform, a USAID and NREL collaboration designed to support countries integrating renewable energy into the power system. Before we jump into the presentation I'll provide a quick overview of the Solutions Center. And following the presentation we will have a question and answer session where the speaker will address questions submitted by the audience. And at the end of the webinar you will automatically be prompted to fill out a brief survey, so we thank you in advance for taking a moment to respond.

This webinar is provided by the Clean Energy Solutions Center, which 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, share lessons learned and best practices, and to encourage the transition to a global clean energy economy. Twenty-four countries and the European Commission are members, contributing 90-percent of clean energy investment and responsible for 75-percent of global greenhouse gas emissions.

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 support in crafting and implementing policies related to energy access, no-cost expert policy assistance and peer-to-peer learning and training tools, such as this webinar. The Clean Energy Solutions Center is cosponsored by the governments of Australia, Sweden, and the United States.

The Solutions Center provides several clean energy policy programs and services, including a team of over 60 global experts that can provide remote and in-person technical assistance to governments and government-supported institutions, no-cost virtual webinar training on a variety of clean energy topics, partnership-building with development agencies and regional and global organizations to deliver support, an online library containing over 2,500 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 strive to engage with the private sector, NGOs, and civil society.

The Solutions Center is an international initiative that works with more than 35 international partners across its suite of different programs. Several of the partners are listed above, including research organizations like IRENA and the IEA, programs like SEforALL, and regionally-focused entities such as ECOWAS Center for Renewable Energy and Energy Efficiency.

A marquee feature of the Solutions Center is the no-cost expert policy assistance known as Ask an Expert. The Ask an Expert service matches policymakers with one of more than 60 global experts selected as leaders on specific clean energy, finance, and policy topics. For example, we are very pleased to have Louis Seck, the former Senegal Minister for Renewable Energy serving as one of our experts. And if you have a need for assistance in renewable energy or any other energy sector, we encourage you to use this valuable service. Again, assistance is provided free of charge. If you have a question for our experts please submit it through our simple online form cleanenergysolutions.org/expert. We also invite you to spread word about this service to those in your networks and organizations.

Today's webinar will be co-moderated by Jennifer Leisch, who is the Climate Change Mitigation Specialist at USAID, where she supports the US Enhancing Capacity for Low Emission Development Strategies program. Jennifer manages the USAID Greening the Grid partnership, and she directs agency work to account for greenhouse gas emission reductions as well as results of USAID clean energy programs.

And our panelist today is Paul Denholm, a leading researcher in integration of renewable energy at the National Renewable Energy Laboratory. He has pioneered a variety of research methods for understanding the technical, economic, and environmental benefits and impacts of the large-scale deployment of renewable energy generation.

And with those introductions I would like to welcome Paul to the webinar.

Paul

Thank you. So today we're going to be talking about battery storage. And I know there's been a lot of activity and interest about battery storage, so I'm excited to get a chance to talk about this technology. Our focus today will be really talking about a variety of questions that people ask about batteries, including what types, how much is needed, where might it be needed, and when will battery storage become cost-effective for their specific application.

And the first thing I need to say, of course, is that we don't have a general rule; there's no kind of one-size-fits-all answer that I can give you. It's really application-specific, but I'll kind of walk through a lot of the analysis that we've seen done both here at NREL and around the world to try and understand the answer to a lot of these questions.

So before we go in I might as well give you some of the answers upfront of things that we do know and things that I think I understand about energy storage. One of the big questions that we always get, of course, is do you need energy storage to integrate renewables. And maybe that's not the best question, but quite frankly what we've found to date is that need isn't really something that is appropriate for storage yet. We don't necessarily need energy storage, but it's becoming more cost-effective, and when we talk about cost-effective applications, that's when we start thinking about the duration of energy storage, where it's cited, and its ability to provide multiple services.

What we do know is that for short duration ancillary services we're already seeing cost-effective deployments of energy storage, both in the United States and around the world. And as we increase renewable penetration the value of storage increases and we'll see more deployments of things like storage for providing capacity. So those are some of the key takeaways and let's get into some of the details now.

So what we always need to talk about when we start talking about storage is why, what are the motivations of talking about energy storage, what's different. We have not really had much battery storage on the grid in the last hundred years or so of evolving power systems, but something is happening now, so we're finally seeing significant cost reduction of energy storage. Over the last five or so years we've seen dramatic reductions in the cost of both the energy part of the storage, which is the batteries themselves, as well as continued deployment or development of the balance of systems, the power-related component. And in combination of that declining cost we're seeing increased real deployments as well as increased projections. So people really think that we're going to start to see accelerated growth of energy storage in different parts of the world and for different applications. So that's really exciting and that's why we're seeing so much hype, so let's kind of dig into why we think some of that hype might actually be true.

When we talk about a storage system we need to be really careful about defining terms. So unlike a conventional generator, there is this energy component. So we have the normal power component, just like a normal generator. So when we talk about normal generators we talk about in terms of the megawatts of power capacity. And we can do that the same way with batteries, but we also have to talk about the stored energy or the amount of kilowatt-hours or megawatt-hours of stored energy and the combination of the power component and energy component leads to the hours of duration. So for instance, a one-megawatt battery with four megawatt-hours of capacity means it's a four-hour battery. So those terms are really important.

The other thing, of course, is understand the fact that when we're talking about batteries it has the DC component, so you need to be really careful about if you're taking a measurement or quantifying a battery are you talking about the DC side of things or the AC side of things? And when you talk about the roundtrip efficiency, which is one of the important figures of merit for better performance, make sure you're talking about the AC-to-AC roundtrip efficiency. Battery manufacturers often love to talk about their DC efficiency, but it's really the AC roundtrip efficiency that's the critical measure. So be careful about all of the different metrics and performance metrics for energy storage; many of these can be a little bit different than for conventional power plants.

So again, one of the questions that we get early on is do we need battery storage to integrate renewables. When we talk about the integration renewables probably the most important concept to explore and talk about is the concept of net load or net demand, and that's the amount of demand that's left over after we subtract out the contribution from in this case variable renewables or wind and solar. So on this graph we show the variable renewables, we show the normal load, so the normal demand for electricity, and then that residual load or net load. So terms vary, but it's that net load that we need to meet with a balance of system. So the remaining thermal plants, the hydro plants, maybe energy storage, that's what we need to meet. It's not the demand or supply of individual renewable resources; it's that net demand, that leftover quantity of energy.

One of the key things that we talk about when we look at integrating renewables is the variability of the resource as a whole. When you look at the variability of an individual solar plant or an individual wind farm it can be pretty dramatic; especially for solar, you can have clouds passing over a solar plant, especially a small solar plant, and you can have rapid changes in output. And sometimes I know that those changes can look pretty dramatic and a little scary if you're a system operator. Here on the upper right-hand corner we have the output of individual solar plants, and you can see massive ramp rates over really short periods of time. And if we had to design a power system around this individual power plant that would be a real big problem. But we look at the aggregation and the combination of multiple solar plants, that net supply of energy from that large amount of solar can be relatively smooth. The same thing that happens for wind at the lower right-hand corner, which is essentially a combination of wind turbines that has a smooth output.

So we don't balance these individual resources, just like the same way we don't balance individual loads. When you think about the demand for electricity in your house or in an individual building, the rapid change in electricity demand can be large, but when we aggregate multiple homes, multiple businesses together, it's that net demand that we need to meet. So we don't really think that we need to balance these individual resources, so we don't provide backup to these individual resources, it's really the system we look at. So to date we haven't really seen the need to balance these individual resources and that's why we don't think that energy storage is necessarily needed. And it really comes down to part of this concept of the flexibility supply curve. And that's the integrated set of resources that we can use to help integrate renewable energy, and that includes the way that we operate our markets, the way that we control our individual power plants, the way that we balance energy using transmission with neighboring resources. All of these items together are how we integrate renewables.

It used to be that we used to think about batteries being as probably the last thing you'd do, probably the most expensive resource. But that's changing and that's one of the reasons why there is so much interest in batteries, because that declining cost is meaning not only are batteries an improved resource for integrating renewables, but an improved resource for providing the grid various services altogether. So that's one of the reasons why we're so excited about batteries as being a lower-cost part of this flexibility supply curve.

But then it comes down to, okay, what type of battery storage do we need? How much duration and how might this change under high renewable energy systems? So the first thing we needed to do is of course talk about the different applications that energy storage can provide. Energy storage, there's a lot of these different types of charts available and they all kind of show all these different applications, ranging from energy and capacity to ancillary services to transmission services. And one of the key elements is understanding which of these services different types of batteries can provide.

So they can provide a bunch of different services, and a lot of these services are based on time scales. And what we mean by time scales is things like how fast does the battery need to respond. So in this chart the how fast does the battery need to respond is the left side of the bar, and on the right side of the bar it's how long do we need the storage resources, so how many minutes or hours does the storage resource need to provide the service.

Another part of when we look at energy storage is this concept of value-stacking, and this is really a key element that a lot of energy storage people talk about; it's the fact that we need to combine multiple services. Because arbitrage alone, the kind of classic buy low-sell high or store off-peak energy and discharge on-peak energy, I can tell you that we've probably done—and I don't mean we at NREL, but we in the kind of collective storage community have done dozens or hundreds of analysis and pretty much everyone says the same thing, arbitrage alone isn't going to pay for battery storage; it's not going to pay for just about any storage technology we know about. It really comes down to combining multiple services. So for instance, if you've got a battery that's providing capacity services it can also provide energy arbitrage and maybe transmission congestion relief as well. So identifying these multiple services is going to be a key part of figuring out whether or not storage makes sense for your particular location or application.

Another really important thing about analyzing storage is understanding whether or not you can actually get paid or gain the value from the services provided. So here in the United States, for instance, you might get energy arbitrage and capacity compensated through an independent system operator or regional transmission organization market, an ISO/RTO market. But the value of transmission deferral would come from a cost-of-service transmission company and it be challenging to get revenue from both of those sources. So in this example we've got some colored dots that indicate what the status of markets for energy storage are in the United States. There's other resources that simply don't exist in terms of there's no markets for a _____ in the United States. So you have to be really careful; while these charts are really nice in terms of showing the different services that energy storage can provide, you have to be really careful to make sure that you can actually get paid for them.

One other thing is people often talk about renewable-specific applications for energy storage. So for instance, this concept of renewable firming or renewable time-shifting, meaning if the wind is blowing at a time where you don't need the energy maybe you can time-shift the supply that renewable energy via storage, or address renewable ramping. Again, we don't necessarily need storage to address these issues, and these renewable applications are really kind of just specific subsets of the larger category. So renewable time-shifting is nothing more than a special case of energy arbitrage, where addressing renewable ramping is just a special case of the larger ramping reserve services that energy storage can provide.

So renewable integration really is captured by, for the most part, existing services. And never forget that renewables will always be competing against alternative sources in that flexibility supply curve. So if it's more cost-effective to do something else to provide these services you always have to keep that in mind.

We're going to talk today about two potentially cost-effective storage applications, two general categories, the first being operating reserves, or fast operating reserves, which include regulating reserves and fast frequency response and peaking capacity, or the ability of energy storage to replace conventional capacity used for meeting peak demand. So we'll start with talking about operating reserves and the potential economic application of battery storage for operating reserves.

Here in the United States we're seeing significant deployment of energy storage for provision of operating reserves, and specifically for frequency regulation. And the key element to those are the fact that it's got relatively short duration, you don't need a whole lot of energy, and the high utilization; the fact that these reserves are needed almost constantly. And you can see in the chart that the majority of the single application storage deployed is for this frequency regulation.

So when we talk about operating reserves, operating reserves from battery storage is no different than from any other resource. And the key element is in terms of the types of reserves it can provide, the key elements of providing reserves are these three questions: How much? Or how much can you increase the output from a plant? How fast? How quickly do you need to respond? And how long or how long do you need to continue responding to reserve event?

Batteries have one really unique advantage, which is—or a couple unique advantages, which is really fast response time, faster than pretty much any conventional generator, thermal generators, or hydro generators; they can respond almost instantly. They're not limited by minimum stable levels. So unlike a thermal generator that needs to operate over maybe 50-percent of its range, batteries can operate over its entire range. But there of course the limitation of batteries only have so much stored energy. So if you're looking at a long duration reserve event, so maybe a replacement reserve or non-_____ reserve, short duration batteries may not be the best application.

So the main focus is on regulating reserves. Now this has a lot of different names depending on what part of the world you're in. This could be frequency regulation, regulating reserves, or secondary frequency response. But this is the short duration response to random events. So this is either random fluctuations to normal demand or that picking up a little bit in response to contingency events. And so it's a relatively short duration service. And one question is why batteries for regulating reserves? Here's a more detailed chart of some of the different reserves that we have with kind of the US names, and we focus on regulating reserves primarily because it's one of the fastest responding services, which means it's also the most costly. So if you look at the prices for reserves in the US, regulating reserves are almost always the most expensive of these services. So that's good for batteries and they can take advantage of those high costs.

And regulating reserves are typically only needed to provide service for 15 to 30 minutes, which means you don't need a four-hour battery; you can maybe just build a 30-minute battery, which is relatively low-cost compared to longer duration applications. And that's why we've seen the early application storage, at least in the United States, being focused on regulating reserves. And again, I already showed the fact that they can operate over this large range, and batteries can do some unique things. For instance, they can provide full up over twice the capacity of the battery if they're charging, or they can provide a lot of downward reserves when discharging. So again, you need to consider the full flexibility range of batteries when looking at the economics of batteries compared to other alternatives.

One question we get a lot related to the "Do you need batteries?" is what's going to happen as we introduce more renewables on the system, and won't that increase the market potential for energy storage providing reserves? In general we'd say yes, but not as much as you might think. In fact, in Texas, for instance, when they started looking at how much reserves were needed when they started building a lot of wind, they actually started decreasing the amount of regulating reserves needed or procured. Now that has nothing to do with the actual requirement; what they realized was they were over-procuring wind. But again, it's probably not going to triple or increase by a factor of ten the amount of reserves we need. So we need to be a little bit careful about being too optimistic about tremendous increases in market opportunities for regulating reserves.

Now one other class of service that we want to talk about is fast frequency response. So we talked about regulating reserves, but even faster is the provision of inertia response and primary frequency response. Now in the United States these are uncompensated services, but we are starting to see creation in new markets. Texas is going first, but other parts of the US are also looking at this potential market opportunity. Fast frequency response from things like energy storage could replace some of the services we get currently from synchronous generation.

This is an example of some tests run at NREL and it's basically demonstrating the ability of energy storage to provide frequency responsive services. So batteries can act very quickly, and as we add—as we introduce markets for these services we can potentially gain additional value and additional services from battery storage providing inertia response and fast frequency response.

Again, I mentioned this a little bit, but we have to be really careful about banking many, many gigawatts of deployment on energy storage. There's a limited market potential for these service. So in the United States, for instance, the total market for the entire RTO/ISO markets in the US is about 2.6-gigawatts. We've already got about 700-megawatts of new battery storage, so we're already beginning to start saturating the markets for regulating reserves in the US. We also see increased competition from demand response and other sources, so we have to be a little bit careful about the ultimate potential for these sources. Again, there may be increases from wind and solar, the need for regulating reserves, but a lot of folks are kind of moving past operating reserves, at least here in the US, as the primary market, and asking what's the next big thing.

Well, something we think might be the next big thing is battery storage for provision if peaking capacity. And that's a recent focus on the US markets and we're seeing also interest in this from growing economies, because we have increased peak demand due to new air conditioning demand, impacts of climate change, or just simply load growth. In the US the big focus is just simply the fact that we've got a lot of generators that are getting old and potentially retiring. The graph on the right-hand side of the screen shows when we installed peaking capacity in the United States, and you can see a big amount of capacity that was installed in the 1960s-1970s, so we've got a lot of peaking capacity that is now 40-plus years old, and that's about the average age at which a lot of these power plants get retired.

So our estimate is that over the next 20 years we would expect to see about 150 gigawatts of peaking capacity in the United States retiring. And so the big question is can storage potentially replace some of this peaking capacity. And we're seeing increased interest by utilities around the US in potentially replacing peaking capacity. We're seeing people slowing down their thoughts of acquiring new peaking capacity maybe thinking about acquiring storage instead.

So one of the challenges of analysis or understanding whether or not batteries are suitable for replacing peaking capacity is comparing a battery to a conventional generator, such as a combustion turbine. And there's kind of two elements of this comparison. The first is the capacity credit or the capacity value. So these terms are sometimes used interchangeably; other times people talk about capacity credit as being kind of the megawatts that you can expect to replace, whereas capacity value might be the actual monetary value. But regardless, these terms reflect the ability of storage to replace an alternative resource. And what we really need to do is we need to look at the ability of storage of various durations to meet that peak demand.

If you're in a region that has strong summer demand and short, narrow peaks storage may be very well suited for this application. The left-hand curve shows the peak demand day from a historical load pattern in the state of Florida in the United States. And it has relatively narrow peaks, so you can imagine four-hour storage being able to provide some of that peak demand. Now you can see that four-hour storage is not going to be able to replace the entire peak; at some point you simply run out of energy because the width of the peak increases as you increase penetration of storage. Alternatively, regions like New York, which is also summer-peaking, but it has longer durations of peaks, it may have less of an ability to use four-hour storage. You may need six or even eight-hour storage to provide a big amount of peaking capacity.

So analyzing the ability of storage in each specific location to see if whether or not it can provide that peaking capacity, that is a key part of doing the analysis to compare peaking storage with peaking thermal capacity.

The second part of analyzing or comparing these resources is looking at how these plants will be operated. So if you take a 100-megawatt storage plant and a 100-megawatt combustion turbine, they may provide the same level of capacity with sufficient amount of energy, but they may be operated quite a bit differently. They may have different capacity factors. So they're both going to have low capacity factors. Almost by definition peaking capacity typically means plants that are operating with less than a 20-percent capacity factor. But batteries might still have a higher capacity factor relative to a combustion turbine. They may have also different operational profiles.

So when we simulate the operation of batteries in a production cost model like PLEXOS or GridView or PROMOD or one of the other commercially available software packages, we often see that batteries are used to avoid thermal plant starts or avoid ramping events. Especially if you have a big unforecasted load or wind event you may need to quickly start up a higher-cost quick start combustion turbine, storage may be uniquely suited to avoid that start. And so those frequent, quick kind of blasts of energy from storage are quite different than how you would operate a combustion turbine. So capturing all of those events and making sure they're properly monetized is a key part of this analysis.

And so one of the key elements or one of the key things to consider is don't just compare the simple levelized cost of energy or levelized cost of storage. That may be a poor comparison metric. You really have to do a more complete life cycle cost analysis considering both the capacity and operational benefits.

So what we're seeing is when we do the analysis how cheap does storage have to be? At what point do we have a case where storage is cheap enough to replace combustion turbines? And we at NREL and people around the world have done these estimates, and when we look at locations in the US we find that cost of storage in the range of $200.00 to $300.00 per kilowatt-hour of stored energy would provide four-hour storage, a cost-competitive alternative to combustion turbines. One estimate of where we'll be in 2020 is about $217.00 per kilowatt-hour. People have told me that's really conservative; people have told me we're there now. But the point is if we're not there now most projections indicate that within the next few years we will have an increasing number of locations at which storage is a cost-competitive alternative to peaking capacity. And that's really exciting, because as most of you know, changes in the electric power system typically don't happen that quickly, so to have this kind of revolutionary new technology being a cost-effective alternative to a classic traditional technology, that's a real change in the way the electro-power system may evolve.

Now one thing we have to keep in mind is just like that we have a limited potential market for storage providing regulating reserves, we also have a potentially limited market for energy storage based on that kind of geometry slide I showed earlier; there's only just a limited amount of the peaking demand you can actually meet. When we look at the US, for instance, we're looking at a few tens of gigawatts of total peaking capacity. This is some examples of analysis we've done looking at this potential in three different states in the US: California, Texas, and Florida. In total throughout the US this is still tens of gigawatts, which is still considerably larger than regulating reserves or operating reserves. But one question is what happens when you add renewables? Will this change the potential market for energy storage?

This is a picture of one day where we have load and some solar generation and some wind generation and when you look at what happens to the net load, it gets narrower. The amount of width of the peak demand actually gets narrower, and that has interesting implications for the capacity of storage that could potentially provide an alternative to conventional combustion turbines. So this is an example of what happens when we add photovoltaic energy to our system. As we add PV it narrows the peak, increasing the amount of storage that can provide peaking capacity. So while the capacity credit of PV decreases, the ability of storage to meet peak demand increases. So that's a really nice synergy between the two technologies.

So when we look at the amount of storage that can provide peaking capacity in a place like California, it increases as we add more photovoltaics. This graph basically shows the amount of four-hour storage that could essentially replace conventional peaking capacity. At no PV it's something around 3,000-megawatts. As we add a little bit of PV, PV actually acts to flatten the load and actually decreases the amount of storage, but once we keep adding storage or keep adding solar to the grid in California, it increases that amount of storage that could meet peak demand. So again, like in the previous graph, we see a nice synergy between these technologies. And just in the next few years we'll probably see a doubling or tripling of the amount of storage that could meet peak demand in places like California.

So another outstanding question that we have is it looks like storage is becoming cost-effective for several applications, but then the question of where should storage be deployed on the grid. There's a few different potential locations that need to be analyzed. One potential opportunity is putting storage at the load site, near major load centers. Another is putting storage near remote renewables, and a third is to actually couple storage with other generation technologies. So for instance, combining storage, both physically coupling the technologies and citing them at the same location.

Within load centers this allows storage to replace peaking capacity in congested regions. One of the really nice things about this is, especially in places in the United States it's becoming more difficult to cite thermal generation in congested regions; people just don't like having power plants emitting criteria pollutions, NOx, Ox, carbon dioxide in the middle of cities. So we can move those combustion turbines out of cities and replace them with energy storage.

This also defers investment in your distribution assets and reduces T&D [transmission and distribution] losses. Storage will store energy typically in off-peak periods when transmission systems are more lightly-loaded, so you have lower what we call I2R losses or resistive losses in transmission and distribution lines. And then they'll produce energy during times where those lines are more congested and avoid some of those losses. The other nice thing about this application is it's scalable. So conventional power plants come in kind of discrete sizes, typically large sizes. Storage is more scalable; you can install 10 megawatts or 15 megawatts, depending on what you need.

Another potential application of energy storage is to co-locate storage with remote renewable resources. Here in the United States the best wind resources are not where people live. So this graph shows the resources of wind, and the best resources are in the dark blue, and major load centers are the red dots. You can basically see that people live on the coasts and our best wind resources are largely in the middle of the country. So here in the United States we're looking at long distance transmission lines to deliver that wind energy to these populated regions. The challenge, of course, is that wind typically has capacity factors in the 30, 40, maybe 50-percent, which means if you build transmission for that resource the transmission will be relatively lightly loaded.

This curve is a generation duration curve of a wind resource. This is 1,000-megawatts of wind in Texas and it shows how much, what fraction of that wind is blowing for how many hours of the year. And you can see that that aggregated wind plant is only generating at full capacity during a relatively few hours of the year. Most of the hours of the year it's producing at some fraction of that rated output. The top ten-percent—so if we built 1,000 megawatts of new transmission capacity the top 200 megawatts, that top 200 megawatts of transmission capacity—the capacity factor of that part of the transmission is only about 10-percent. We're just not using that transmission very much. Maybe it would be better instead to downsize the transmission or oversize the wind relative to that transmission, store the wind when it exceeds the transmission capacity, and discharge that wind later.

So the gray line shows the use of storing wind. In this case it's about 150 megawatts of storage added to that 1,000 megawatts of wind, storing that wind and shifting it to a later time. And that's what we're showing here, is we're moving that transmission or oversizing the wind relative to the transmission for a later time. This will increase the cost-effectiveness of transmission. Now when we consider this type of configuration we always have to compare the application of storage at this location to other locations. So we have to compare this to load-sided storage, but this might be one application of energy storage that helps integrate more wind energy alongside of providing peaking capacity and other services.

The third application or third location is integrated with renewable generation. Where we're seeing this most of all is integrating solar PV or solar photovoltaics with energy storage. And there are different ways we can integrate these technologies. The early deployment of storage with solar has been where the storage is basically co-located but not really integrated. So this is called AC-coupling, or putting the inverter and the battery on the AC side of the PV inverter. So again, it's kind of a standalone application maybe sharing some common engineering and siting, share a common point of connection to the grid, but they're not truly integrated.

A potentially more cost-effective way of deploying this is if we can actually couple the storage on the DC side of the inverter. The advantage of this is we can take advantage of some of the power electronics and some of the components while still remaining the independents of the storage system. And by that I mean if we include a bidirectional inverter we can still charge energy from either the photovoltaics or the grid, which gives us maximum flexibility, it allows us to maximize the value of the systems while reducing the costs by sharing components.

We have to be really careful about how we cite this. This is still kind of an emerging application, but there's a lot of interest in this application, especially because you can share these components. When you look at the power electronics and components of a photovoltaic inverter they're very similar to a lot of the components in a battery inverter and charge controller. So hopefully we can share some of the components and reduce the overall cost of this particular application.

Now when we consider where to site energy storage with renewable energy it always depends on what types of applications we're providing. So if we do something like PV with integrated storage closer to load, that can increase its value of energy and capacity services. If we site energy storage closer to remote wind, that can increase its transmission value. So as always, the actual application, the value of application and choosing which application depends on doing the careful analysis of which application we're looking at, as well as the sizing of the various storage components.

So overall when we look at standalone renewable integration applications I still think we're not quite there where we can say, "Oh, we will just use storage to integrate renewables." We really need to look at the full set of services that the two primary services that appear to be the most cost-effective right now are ancillary services including regulating reserves with short duration storage and longer duration storage, several hours, providing peak and capacity. And I'd say we are approaching an actual tipping point where storage provides a cost-effective alternative to conventional peaking capacity. Again, whenever considering peaking capacity you always need to look at its ability to also provide energy arbitrage or other services.

And so there's kind of no one-size-fits-all rule for energy storage. We still need to do careful analysis of storage to make sure that we're siting it in the proper location and applying the appropriate benefits and making sure that rules are in place where we can capture all the value they can provide.

So that's my talk and I'm happy to take questions. You can submit questions to the GoToWebinar and happy to take questions. We've got plenty of time to discuss additional questions. And if you've got additional questions that you want to ask at a later time you can find my e-mail address. I'm always happy to exchange e-mails about energy storage. So with that I'll hand it back over to our moderator.

Stephanie Great. Thank you so much, Paul. We have Jennifer Leisch on the line and she will be going through the questions that are submitted. Just it's right in the Questions pane there on the right-hand side of your screen.

Jennifer Great. Thank you so much, Paul. I think that was really interesting to hear about some of the different use cases for batteries and how to approach these questions of the what kind, the when, and the how much. We have a few questions coming in and I'd like to encourage folks to use the Question pane if you have anything that you would like to hear more from about from Paul.

So an initial question for you, Paul, is you talked about replacing peaking capacity and that these batteries are to the point in systems with adequate capacity that they're cost-competitive with peakers. And so I'm wondering if you can talk a little bit about the experience in the US right now, where we have seen several utilities starting to think about batteries instead of peaking capacity and what they've been doing and how they're progressing in that direction?

Paul Sure. So traditionally utilities in the US when they look at peaking capacity have really looked at conventional natural gas-fired combustion turbines. And again, until a few years ago that was really the default choice. In places like California, where they had a storage mandate it really forced utilities to take a deeper look at energy storage, develop new analytic tools to analyze storage, and that really was an important part of this. Traditional integrated resource planning tools have not done a super-great job of being able to analyze storage. That's changing. Tools that are available now, production cost models and other tools can do a much better job of comparing storage to conventional capacity.

So what we're seeing is in places like Arizona and California either the vertically-integrated utilities or utilities in market regions are looking at their growing capacity needs or they're looking at an older plant retiring and they are at the point where they're looking at the life cycle costs of natural gas-powered plants, comparing those to storage plants and seeing that storage plants are getting really, really close to being at life cycle cost parity. When you look at things like potential for stranded assets and price volatility in natural gas markets, that's also pushing these utilities to be a little bit more conservative and saying, "Gosh, maybe we should just hold off and continue looking at energy storage as an alternative."

So again, that's pretty exciting because we really are seeing the costs coming down and utilities in a number of places in the US saying it really is looking like storage, if not now, in the next couple of years is going to be at or below cost parity for conventional thermogeneration.

Jennifer So, Paul, in systems that don't have adequate capacity—so in other words a lot of the countries, unlike the US, who still have a lot of demand growth or growing demand, what is the highest value for storage right now in the near-term? And what use cases should they be considering maybe in the longer term as they're evaluating storage?

Paul I think that storage—the values of storage that should be looked at for both places that are both system adequate and not are really the same. I think those two primary applications that I talked about, both provision of operating reserves and provision of peaking capacities both can provide high-value services. So starting with short duration storage to address things like contingency reserves or regulating reserves, that is perfectly adequate in systems that are both highly reliable and see outages, but also peaking capacity.

Now again, it really depends on the load patterns. I mean if you're in a part of the world that maybe has really flat load, kind of cost of demand on a day-to-day basis, I don't know such a place, but if that place does exist maybe storage really isn't the right place. But if you've got strong peaking capacity or peaking demand and you do have kind of spare capacity during the off-peak periods that could be used to charge the storage, that could be a high-value application as well. So it really does depend on that particular case.

Now if you're in a case where you never have spare capacity, if you truly don't have off-peak generation available then storage probably isn't going to provide peaking capacity; then it might just be an operating reserve provision. An operating reserve plant doesn't really shift a whole lot of energy; it's just kind of changing it up a little bit.

So again, if you're in a place that truly doesn't have any spare capacity during any kind of 24 or 48-hour cycle then it's hard for me to see how peaking capacity would be a good application. But again, if you've got some excess capacity during off-peak periods then I'd say peaking capacity should be something that should be looked at carefully.

Jennifer

Great. You had mentioned, you know, looking at and modeling storage for that peak capacity, and I'm curious how does demand response or other things that haven't typically been considered in the IRP, the traditional IRP process compare to utilizing storage for those purposes?

Paul

So demand response is always kind of tricky because it depends on creating tariffs and creating the right marketing opportunities. Demand response can kind of both be complementary to energy storage as well as potentially competitive. So here in the United States, for instance, there's only so much regulating reserves, and most system operators don't care where it comes from, if it can reliably be provided from demand response that's great. Places like ERCOT, the Texas grid, gets 50-percent of its spinning reserves basically from demand response. So that's a proven application.

So again, it really depends on local market structures and how much of that resource is available. We've definitely seen places where they can be complementary, you can kind of shift load into the later evening and maybe use storage there, so it really is kind of a local dependency. And again, I think a lot of it, though, is the kind of market and regulatory framework for how demand response versus storage can be introduced.

One of the nice things about storage is if you are in a kind of vertically-integrated location storage is pretty easy. A central actor can acquire storage, they can dispatch it, you don't have to worry about sending signals to demand response; it's one device instead of getting response from hundreds or thousands or tens of thousands of individual loads. So that ability to integrate storage a little bit easier, doesn't require quite the communication protocols and some of the cybersecurity issues; all those things need to be considered.

Jennifer We have a few questions about transmission deferral come in. Can you talk a little bit more about how storage can really help with looking at or determining if you would rather build new transmission versus defer building new transmission?

Paul Sure. So transmission builds always come down to the load factor of the transmission lines. So if you've got—depending on your load factor, you know that your transmission line is never going to be fully utilized. So here in the US load factors of 50-60-percent means that you've got a lot of base load demand on your transmission system, but there are still going to be times where the transmission system is underutilized and the need for new transmission, it's basically driven by peak demand. So you may have a transmission line that is underutilized 80-percent of the time, but it's those 100 or 200 hours of the year that's going to need the requirement for other new transmission, new substation, new transformers. And so it's essentially the same thing as generation; it comes down to transmission has kind of a base load utilization, but also peak demand. And if you're at or approaching the thermal limits on your transmission system for 100 hours of the year you really need to look at whether or not storage can provide a cost-effective alternative.

One of the beauties of storage, again, is that modular nature. You've got a 1,000-megawatt transmission capacity, you need an extra 100 megawatts, you know, it's hard to build and just add on an extra 100 megawatts of transmission capacity or add 100 watts of transformer capacity. Adding storage at the end of a congested transmission line, you can ship energy during off-peak periods when the transmission line isn't overloaded, and then when the transmission line is near its capacity and that load peaks you can discharge energy from storage.

We've seen a number of locations here in the US where storage has been utilized, used to relieve congestion. Typically not in really big lines. You know, utilities are kind of dipping their toe in the water and just getting used to this, so these are typically on long radio feeders, some of your lower voltage circuits where storage can be used. But I think as storage becomes cheaper we're probably going to start seeing storage being applied to on larger transmission systems and defer instead of a megawatt or two, tens or even hundreds of megawatts of capacity.

Jennifer That's great. For storage that is co-located with PV, which is a little bit of what we're talking about, are there any rules of thumb that you would use for sizing storage in these type of applications?

Paul Not yet. It's pretty immature. What we do know is that the relative power capacity of the storage is typically going to be a lot less. I mean I wouldn't want to use rules of thumb or say anything like that, but definitely we're seeing for the optimum mix it's not going to be one-to-one. So if you've got 100 megawatts of PV it's not going to be 100 megawatts of batteries; it's probably going to be 20 or 30 megawatts of batteries to take advantage of the inverter. You can't overload the power components of the system by installing a lot of storage.

Now that said, one of the things that we're exploring is whether or not DC-coupled storage will allow us to fundamentally change the configuration of PV systems. So right now in the United States, and it's probably similar around the world, we're finding that when you build a solar system you typically oversize the PV component by about 30-percent, meaning if you build a 100-megawatt inverter you're probably going to build maybe 130 or 140 megawatts of PV capacity. That minimizes the cost of the system because you rarely have full output from the PV system. What we're wondering is whether or not integrating DC-coupled storage will allow a greater amount of PV on the systems.

So I think the message is not necessarily basically saying what a rule of thumb is, what I'm saying is storage is really changing a lot of how we think about the system. So in this particular example it's making us rethink how we configure PV systems. I think overall it's going to make us rethink how we build the system. Again, are we going to have transmission plus storage, PV plus storage, wind plus storage? I think it's going to make us rethink how we designed the architecture of the overall grid. That can be a little intimidating; it means that I'll have full employment, but, you know, I think we really do have to think about how we configure all of the elements of the power system under a regime of low-cost storage.

Jennifer That is a little bit overwhelming to think about, but I think there is a lot of opportunity in systems that, as we talked about, have an increasing amount of demand, they haven't been fully actualized or built out yet, and so there's an opportunity to start thinking about these questions early on. And that leads me to ask you if I am a system operator or a planner thinking about not only the value of storage, but other new technologies in my system, and I wanted to ask a lot of questions about storage and begin thinking down that path, what would my ideal approach be? Is there specific tools or software or questions that I might want to start out by asking?

Paul Sure. And that is really important. I think the tools are improving. I don't think the tools are where we need to have them yet, and that's unfortunate. I think we'll get there, but when you look at the classic sequence of integrated resource planning or grid planning in general, when you look at the classic part going from capacity expansion, where you're kind of figuring out which generators or transmission lines to build through production simulations and power plant simulations, resource adequacy simulations, I think that sequence of tools that have been used for decades, I think that set of tools can be and can utilize effectively storage as well. So it's just another set of options. It's just another technology. Hopefully we'll get to the point soon where storage is appropriately represented. I think now it's still kind of semi-manual.

I think now it's going to be if you're thinking about a new generator your tool might not have storage built into it. There are some tweaks done. We at NREL and folks around the world have had to make some modifications to the standard software packages. One example is concentrating solar power with thermal energy storage. We've done work improving the treatment of that in models. I know I've got papers from folks in really a number of countries that have made changes to kind of these standard software packages.

So it's a little bit difficult right now, but I'd say if you're patient and really look at the capabilities of your tool and think about how you can modify them to include storage it's not only fine if you're an engineer, but also potentially rewarding, and ultimately I think we will see more cases where storage does work in terms of the economics.

Jennifer So long-term modeling aside, are there any early actions that you might recommend a system planner or a utility to consider, whether it's pilots or some other policy or something to try out in the near-term?

Paul Well, I'm certainly not a policy expert, so I'm not going to talk about that. I do know that one of the most important things is just giving all new technologies, whether it's storage or demand response or really anything, a level playing field. That's one thing that came out of a lot of the US policies, is the recognition that some of the storage mandates, and that's—I'm not really giving judgment on whether the mandates themselves were worth doing, but one of the things that we saw coming out of those mandates were it was forcing you at least to look at these technologies. When utilities weren't forced to build these technologies they basically weren't even considering them.

And we have pretty strong anecdotal evidence that the lack of inclusion, of storage in the software packages, and the lack of utility interest in storage was really not giving storage an equal chance. It was only when they were forced to look at storage because they were told to, that's when the modeling techniques improved, when they were realizing the full value of these. That's when FERC stepped in recognized the fact that market rules need to change to better value energy storage. So going back to when we change rules for storage providing frequency regulation and making sure it was appropriately compensated to something called FERC 841, which is basically telling the system operators in the US that you really need to make sure that you're appropriately compensating. No special compensation; we're not asking for storage—folks aren't necessarily asking for anything special; they just want to be treated equally and fairly.

So I think that's really the key thing, is making sure that you give all these technologies appropriate valuation so you can truly determine whether or not they make sense. I'm not saying that storage is going to make sense. I mean if you do the analysis it may turn out that they just don't work in your application, but they might, and so giving them that chance, that's the key element.

Jennifer I think the lesson that I am taking away from this, and hopefully others are as well, is that the answer to the question is always "It depends." Everything is very—

Paul Unfortunately that is true.

Jennifer Yes. Everything is very system-specific and so it requires doing the analysis to really understand the applications that are applicable and economic for your specific situation and system.

Paul Yes.

Jennifer I think that we are coming up at the end of the hour and I wanted to pass the line back to Stephanie. So everyone who is on the line, please don't go yet; we do have a survey for you and we'd really appreciate you filling that out. And before I do that, Paul, is there anything else that you'd like to add?

Paul I can't think of anything. Just thank you.

Jennifer Great. Well thank you. And, Stephanie, I'll turn it over to you.

Stephanie Great. Thank you. I'll continue the same here. Thank you so much to Paul and Jennifer for joining us for a Solutions Center webinar and thank you to the audience for participating; we really appreciate you taking time to watch this presentation and we invite you to inform your colleagues and those in your networks about the Solutions Center resources and services, including the no-cost policy support through Ask an Expert.

The website will have the slides from today as well as a recording of the presentation. Please allow about a week for that to be posted. And another reminder to please fill out the survey that will pop up on your screen once the webinar concludes. And with that, please enjoy the rest of your day, wherever you're listening from, and we hope to see you again on future Clean Energy Solutions Center events. This concludes our webinar.