FEMALE: So now we're going to begin talking about the Storage Innovations 2030, which Deputy Secretary Turk mentioned. So please join me in welcoming Ben Shrager, General Engineer with the Office of Electricity at DOE, Patrick Balducci, Manager of the Power Systems and Market Research Group in the Center for Energy, Environmental and Economic Systems Analysis at Argonne National Laboratory, and Thomas Mosier, PhD, Group Lead of the Energy Systems within the Power and Energy Systems at Idaho National Laboratory. Ben, I'm going to turn it over to you.

BEN SHRAGER: All right, great. Thanks so much, Meridith. And huge thanks to the ICF team and the Argonne team and everyone who's made this event possible over the last two days. Still a little weird, in my opinion, coming back to such a large in-person event, and it's been going really, really smoothly, and there's been tons of work behind the scenes, so thank you so much.

So as Deputy Secretary Turk mentioned, we are going to be talking about Storage Innovations 2030 and taking a lot of the kinds of conversations that we've been having over the last two days and taking that forward over the next several months and year into developing a cohesive strategy around energy storage. So we can go on to the next slide. As the Deputy Secretary mentioned, we are looking at 30-plus different storage technologies, and we have funded or enabled, in some way, technologies on this whole list. If you click ahead one more time, you could see just how many different technologies, different kinds of research projects, we have looked at over the last several years, even, in recent history, and as we look ahead at the landscape for 2030, we want to try to understand, how can we better target our future investments and our future projects?

So one more click over – the need here is a specific, actionable roadmap to develop, scale and deploy these most promising technologies to meet this 2030 long-duration storage cycle that the Deputy Secretary talked about. On how we get from today to 2030 – that's really the key question that we're trying to answer, have been answering in these conversations and will continue to address over the coming months. Next slide. And one more. This comes from not just what we've heard from industry and internal to DOE but also congressional and administrative priorities. So we're seeing this need for an energy storage strategy come out in the legislation that's been passed, as well as all of the conversation that we've been having. So the justification is here from all sides. We've heard it loud and clear, and now we're ready to address how we can come up with this strategy. Next slide.

So when we look at strategizing and accelerating the future of energy storage, we're thinking about it in three main sort of parallel paths. Click ahead one more. The first thing that we're looking at – this has been a theme for this whole summit – is around developing industry consortia and enhancing collaboration. So where are the places – what are the ways that we can foster more relationships and more collaborations among all these different industries for these many different competing storage technologies? Next slide.

The second area of interest for storage innovations is on quantifying the benefits of different RD&D activities. So when we look at not just 30-plus storage technologies but dozens and dozens more possible R&D investments and R&D areas that we could prioritize in the next one, five and 10 years for many different technologies – so how we quantify those benefits is a critical question that we're going to hear a lot more about in a few moments from Patrick and Thomas. And one more click.

And the final area is on enabling emerging technologies. So while the first two areas focus on mid- to later-stage technologies for the most part, we're also interested in the next innovative out-there ideas and, what are the emerging technologies that could help us meet our goals in 10, 20, 30 years and beyond? And if you click one more, you can see how we've named each of these and how we've organized them in to these buckets. So we are looking at three separate initiatives under the Storage Innovations 2030 umbrella flight paths framework and the prize, and we'll talk about each one more in turn.

And if you click two more times, we'll get into the framework part of this. Over to Thomas Mosier.

PATRICK BALDUCCI: Thank you, Ben. And thank you to everyone in the audience for putting up with me for the last two days and to all of you who have been so helpful for helping me get through the conference. You've been exceptional people, and I really appreciate it. So we've been working on this for roughly the past year, Thomas and I have, with the guidance of Ben and others at DOE, and we wanted to give you sort of an overview of the framework that we developed, a framework that was originally developed by Ben and Hill Balliet at DOE, and then Tom – Thomas and I built on it.

And some preliminary results from two evaluations with lead batteries and Lithium-ion batteries in my next slide, please. So yeah, so we're going to give you an overview of the eight-step framework and some of the detail of how we're actually performing these assessments. I'll give you the lead–acid results, and then I'm going to turn it over to Thomas to discuss the Lithium-ion results and also a synthesis of these results and the lessons learned, and then he's also going to be talking about the next steps, because this framework really aligned well with a requirement for a report to Congress that will be due in the coming years, and so we'll be expanding beyond just these two battery systems into several others as well, and he'll highlight those. Next slide, please.

So what we've done is, we've created an eight-step framework that we'll actually present on the next slide that begins with effectively creating the status quo trajectory for battery storage technologies in terms of really two different parameters: One is levelized cost of storage, so what's the cost to effectively store and then provide the energy back to the grid, and the target there that was in the Energy Storage Grand Challenge roadmap was five cents per kilowatt-hour. It's quite a lofty goal, and so there are projections. The primary one that we've relied on is that prepared by Pacific Northwest National Laboratory under the Energy Storage Grand Challenge for the technology cost and performance projections out to 2030. Then we identify a number of potential innovation categories that could reduce the costs, and then we evaluate investments in each of these categories in terms of the budget requirements and then the impacts to either capital requirements, [inaudible] costs, cycling, roundtrip efficiency and the like.

The other thing that we're doing is, we're evaluating each of the technologies against the suitability requirements that are outlined in the Energy Storage Grand Challenge framework for each of the use cases that were defined in that document. The connection there is actually presented in the backup slides. And together we've put these innovations together into categories of investment, run it through a Monte Carlo simulation model, and what we get from that are effectively bundles of investments, and so you can see in this slide here that some will be required to achieve a higher return on investment, but others may be required to achieve large-scale reductions in the cost. So for example, with lead batteries, manufacturing may not necessarily be the highest-return-on-investment innovation category and is more expensive than most other categories, yet it's absolutely required to meet the goals of the Energy Storage Grand Challenge. Others, of course, yield less results, and so we're less confident than the absolute values that we generate but much more confident in terms of directionality and then of course the targeting of high-impact R&D investment categories. Next slide, please.

So there are those different packages of investments. We can go ahead and move to the next slide. So here is our eight-step framework, which I've already outlined. Effectively we'll run through that in a very high level and give you some preliminary results, but we identified the individual innovation opportunities, assessed portfolios of innovations and then of course report out on the results. Next slide, please. So here were some of the innovation categories that were identified for Lithium-ion batteries and lead batteries. Effectively we have Tier 1 and Tier 2 investment categories or innovation categories.

Tier 1 is common to all technology, so it's the beginning of the sourcing of the raw materials to the end-of-life considerations and everything in between, and from there we then identified – and these are quite specific to each technology – not only the innovation categories but the findings with respect to the impacts of investing in these innovation categories and the costs associated with them too. So for lead–acid batteries, it includes everything from domestic production of lead to recycling of the raw materials to advanced manufacturing to redesign of standard current collectors, alloying of lead sources and advanced novel electrolytes and other materials. Next slide, please.

Great. So lead–acid battery results – I can tell you that, thanks to the industry participation from several within the lead battery industry, some of whom are here today – Matt Rayford [phonetic] and John Haus [phonetic] and several others – thank you so much – we were able to identify 24 separate groups or companies to interview, and we went through a two-step process. The first process was to actually interview them and get an idea of what these innovation categories entailed, and of course they've already been investing in industry consortia and also investing with the assistance of Dr. Emery Zuch's [phonetic] program, the DOE Office of Energy Storage, and so they had some thoughts on this matter, and we began with that process. And then we created two forms to measure the impacts of investment in each of these innovation categories and then also the potential suitability for each of them. Next slide, please.

And so for the 14 categories that we defined, we could effectively package them together, and of course we did this in an automated manner using a Monte Carlo simulation analysis, and you could find that with the top 10 percent of the categories bundled together, the top 10 results, the packages, we could potentially achieve two to seven cents per kilowatt-hour, a levelized cost of storage. Of course, this is a very ambitious goal, but this is something that many within the industry – and to a certain extent it was actually validated with some of the results that were coming out of the industry consortia evaluations and the results of the DOE investments as well to solidify and verify the veracity of some of these inputs that we received. But the top 10 percent were effectively achieving the goals of the ESGC. Next slide, please.

So what you see from this slide is, effectively we got there primarily through significant improvements in cycling. Now that seems to be incredibly ambitious there, but keep in mind two things: First of all, the base or the status quo was a very low level of 700 cycles per battery system with an 80 percent depth of discharge, and that's a metric from the 2020 Energy Storage Grand Challenge Cost and Performance Report. In the 2022 storage report, it's actually doubled. So it's already doubled from where it was just in 2020, based on the technology that they evaluated. So really, you can cut these in half effectively to a 500 percent improvement rather than 1,000 percent. But still, once again, with the very best outcomes and the most ambitious improvements, those are where the improvements are occurring and how the gains are being made. Next slide please.

Great. So what you see here is that, first and foremost, as I mentioned previously, although advanced manufacturing is more expensive than most of the innovation categories and really relies on participation from industry and loans and grants to industry working hand in hand with National Laboratories – but mostly it's an industry-driven investment category – manufacturing was first and foremost the highest-rated in terms of its integration into those top-performing packages or portfolios. There were several high-ROI lab-based and fundamental research categories, like redesign of standard current collectors and novel electrolytes and novel materials and some others. And then, finally, what we also found is that demonstration projects and scaling and managing of the battery systems are already yielding extremely high returns for some of the companies and organizations that are pursuing these paths and are absolutely necessary to get to the next level, so taking all of these lessons and then applying them in the field.

And so what you can see here is that the top 10 percent, 75 percent of which is below $175 million total – not $175 million annually – and the investment requirements would I believe be over roughly the next five to eight years to achieve these investment – or these gains associated with the investments. And so you can see it's basically for the top 10 percent, the investment requirement, the time duration to make this investment, and then of course the enormity of the Monte Carlo simulation, with tens of thousands of runs that we performed – once again, this is really the top 10 percent, but you can see how the distribution runs for all of the packages in one of the previous slides. Next slide.

Great. So that's basically the overview of our framework and our lead battery results, and I'd like to turn it over to Thomas Mosier to take us the rest of the way. Thank you, Thomas.

THOMAS MOSIER: Great. Thank you, Patrick, and thank you, Ben. Okay, next slide. So essentially, for the Lithium-ion results, I'm going to show you the analogous figures that Patrick did for lead–acid and then do a synthesis across the two at the end.

So again, to reemphasize, these are different portfolios of innovations that DOE could invest in beyond what industry is already doing today to drive down LCOS, and for Lithium-ion, you probably don't recall, because you only saw the figure once, but for lead–acid, the skew of the distribution is actually more favorable for drastic LCOS reductions. For Lithium-ion, the skew is opposite. So we need to be very intentional with Lithium-ion relative to lead–acid about achieving those deepest LCOS reductions. But for that top 10 percent performing portfolios, we still do get very close to that five-cent-per-kilowatt-hour- target. Next slide.

And again, contrasting this with what we saw with lead–acid, where improvement in cycles was by far the leading factor, for Lithium-ion, we have reductions in [inaudible] costs, as well as increases in cycles, but we have contributions from all of the major factors impacting LCOS. So a little bit more in all of the above strategy for LCOS reductions. Next slide. But when we break that down into the particular innovations that are really present and driving those top 10 percent of portfolios, we see that controls to improve cycle life is number one, and the kind of anecdote or the narrative around this is that there have been a lot of really impressive gains and chemistries in the initial stages of deployment of Lithium-ion, and there's a lot of potential for us to learn from the operations of those deployed systems and incorporate the learning to further enhance cycles. But aside from that, although it's not evident, because they're not demarcated within these innovations, we also see significant contributions from other deployment-focused activities, as well as advancing materials. Next slide.

And this is also a very robust ecosystem of investment on the private sector side, and so when we look at the cost of these innovations, that also requires a larger price tag from these top-performing portfolios, and so 75 percent of these top 10 percent performing portfolios have a total cost of under $1.2 billion, and some of the richness of this dataset that we don't have time to get into today but that we'll be further publishing and looking into is, even within this $1.2 billion and under, there is quite a range there, right? So many of these portfolios achieve all or most of the LCOS reductions and cost significantly less than that, and so that points to targeted innovations that we can invest in to have the most bang for our buck. Next slide.

Okay. So now, turning to synthesis and next steps. Next slide. So what this figure is displaying are the innovation categories. So rolling up individual innovations into their Tier 1 categories from the taxonomy that Patrick displayed and comparing them across Lithium-ion and lead–acid, what we see for lead–acid is that the most common innovations – and this is just prevalence within the portfolios – the most common innovations are with advanced materials development and technology, followed by manufacturing, whereas Lithium-ion deployment, again, as I said, advanced materials, and then again manufacturing.

And so the narrative around this, in my mind, is that lead–acid is a mature industry, and it's an industry that is looking to do foundational innovations on their existing technology to achieve that high increase in cycles to drive down LCOS, whereas Lithium-ion – there's a lot of new innovation with respect to chemistries, et cetera, but it is an industry that is really just initiating deployment and really focused on deployment, so there's a lot of investment needed there to really bring it to market more quickly.

And one about manufacturing, too, that I think was insightful from the analysis and the conversations we had going into it is that manufacturing is going to be key, and new manufacturing is going to be key, for bringing new innovations within each of these classes of technologies to market. And so once you make an investment in the gigafactory, if you have a new variant or new changes in the battery, either the process that drives down LCOS or other aspects of the technology, likely the pathway to that to come to market is going to be a new manufacturing facility that really focuses on incorporating those innovations. Next slide.

And so where are we going from here? It's really exciting that DOE is standing up the storage innovations structure that Ben mentioned previously, and specifically within the work that Patrick and I have done and are continuing to do, there's a report to Congress that this is going to contribute to, and so, over this last year, we focused on developing the framework and test-running it and ensuring that it is set up to achieve the type of insights that we need it to, and then over the next six months we're going to be implementing it for a range of additional technologies shown in this bulleted list here. Many of those technologies were dictated to us by Congress, technologies that they wanted us to look at, and then some of those we added to the list as well to round out the set. But to emphasize what Ben mentioned earlier, if your technology isn't on this list, please know that the storage innovations portfolio has other mechanisms for you to engage and to help support your technologies.

So the final note that I'll leave you on is that this process for the next six months is really going to be driven by and require a lot of industry engagement and participation from all of you, so please, if you're interested, if you represent one of these technologies, reach out to us. Our emails are on the next slide. And even if you don't reach out to us, don't be surprised if we reach out to you.

MALE: Thank you.

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