VENKAT SRINIVASAN: So welcome, folks, and I’m hoping that the people in the Albuquerque region can hear what I’m saying. If you can, welcome and welcome to the Long Duration Storage and Energy Storage Grand Challenge meeting that we’re having here. Hopefully this whole setup works. It looks like it’s working. We’re going to have two meetings that are going to get merged into one for the next hour and X number of minutes.

What we’re going to talk about here is a meeting that’s going on in Albuquerque on SolarPACES, there’s obviously one in Chicago on energy storage. We’re going to talk about valuation of both [unclear] and solar and long duration storage. I actually saw an announcement from DOE that I haven't read very carefully which looks like there was some sort of a grant on CSP. So before we get started, I want to introduce the moderator for this session, on the Chicago side, Jeremy Twitchell, who’s an Energy Research Analyst at Pacific Northwest National Lab who will be helping us while we go through this session. Jeremey?

JEREMY TWITCHELL: Hello, everyone, Jeremy Twitchell from the Pacific Northwest National Laboratory. Most of my work at the Lab focuses on energy storage policy and regulatory issues. So the topic of this track of this session is near and dear to my heart and I hope that through the course of the day we can make it near and dear to you all’s hearts as well. We’re talking about policy and valuation of energy storage on this track.

 So, what we’re doing on the policy and valuation track is trying to understand what are the remaining barriers to energy storage investments form a policy, regulatory, and valuation standpoint? What types of enabling policies do we need? What types of market compensation mechanisms do we need? What type of valuation models do we need to help utilities and investors and other stakeholders understand the value of energy storage on the grid and be willing to make those investments?

Now, if you think about it, all of our regulatory structures were developed in a time when we had large central station generation plants, one way delivery to customers, and predictable loads. So with the advent of commercially available storage technologies that can go virtually anywhere on the grid and provide a wide range of benefits, they do not fit into that traditional regulatory paradigm very well. We’ve had to change the way we plan the grid; we’ve had to change the way we compensate resources and we’ve made a lot of progress on those fronts in recent years.

We’ve seen FERC orders that have ordered the wholesale market regions to better understand the energy storage assets to fully compensate them for the benefits they provide to the grid. We’ve seen utilities around the country that have been evolving their planning practices to better understand the value of energy storage and identify those cost effective investments. But we still have work to do.

And so the work we’re doing in the policy and valuation track is understanding what are those remaining barriers, and how can we leverage the assets of DOE and the labs to address those barriers? And one of the particular areas of focus that we’ve identified in recent years is long duration energy storage. This poses a unique challenge to the way that we compensate resources in the grid, to the way that we plan for the grid, the way we identify investment needs, the timing of those needs. And so that’s what we’re going to be talking about in this session.

We’re going to hear from industry representatives, we’re going to hear from researchers; we’re going to talk about concentrating solar power and its value as a thermal storage asset; we’re going to hear from the Long Duration Energy Storage Council. And with that, I will pass it over to Albuquerque to hear a little bit more about their event, and to introduce our speakers. Thank you.

MARK MEHOS: And thank you. And welcome to our colleagues, or from our colleagues at the Energy Storage Grand Summit, and this will be simulcasted with the SolarPACES Conference here in Albuquerque. So thank you everybody and welcome to this panel entitled CSP Thermal Energy Storage, Market Analysis. So for the next hour and fifteen minutes you’ll hear from three speakers, two from here in Albuquerque and the final panelist at our parallel session at the Energy Storage Grand Challenge Summit. Following the speakers’ presentations and time permitting, we’ll have a few questions from the audience. We’ll take the first question, one question if we have time, from Albuquerque. We’ll take a virtual question online and then we’ll have a final question from Chicago.

Now, here at SolarPACES this morning we heard a lot of opportunities for CSP, for long duration energy storage, for thermal energy storage. With the new Inflation Reduction Act there are certainly opportunities in the United States, and we hope to see those forthcoming, both for CSP and for long duration energy storage in general.

We also heard a lot here again in Albuquerque about CSP with thermal energy storage not as a standalone system, but as hybridized on the grid or onsite with photovoltaics, wind, thermal energy storage, battery energy storage. So you’re going to hear from each of the panelists separately. They’ll cover all of these topics and I look forward to that.

So with that, our first speaker is Dr. Paul Denholm. Paul will talk about the potential opportunities for CSP in the U.S. power grid. Paul is a principal energy analyst at the National Renewable Energy Laboratory, where he has been working since 2004 and I’ve been working with Paul luckily all of that time. His research focuses on examining the technical and economic impacts of large scale deployment of renewable electricity generation, and the role of energy storage in that mix. He holds a PhD in Energy Analysis from the University of Wisconsin in Madison. Paul?

PAUL DENHOLM: Thanks, Mark. Thanks for the opportunity to talk to you all today, this afternoon and also our friends and colleagues in Chicago at the Grand Challenge. So, yeah, I think one of the things that keeps coming up about this topic, in terms of both CSP and other long duration storage is how do we even evaluate the opportunities? What are they? What values and services should we focus on?

I think quite frankly we should also think about values and services maybe we should not focus on, or maybe focus a little bit less on and of course the equitable comparison across technologies. This goes to really I’ve been working on CSP with Mark for a long time, and this is the thing that always comes up. How do we make sure that our technology is fairly represented by utilities and developers to make sure that we get a level playing field? And I think the long duration storage is also in the same position. How do we make sure that we get an equitable comparison?

So, one of the things that always comes up at any energy storage conference is some chart, there’s a gazillion of these different charts, about all the different things that energy storage can provide, how do we valuate that? And this is just one example that focuses on largely ancillary services or central liability services. We talk about things like timescales. We often talk about policy. You heard a colleague from Chicago talking about this.

This is critically important in terms of, okay, which one of these things can we actually get paid for, through markets or through other regulatory processes? And so it’s really important that we understand these services. And it’s also really important to understand what types of different models that utilities use and developers use, to understand the different approaches.

So, one of the things that we always hear is the issue around these capacity expansion models. So that’s kind of the upper left hand model. And that’s the class of models that utilities do for something called integrated resource planning, or basically trying to understand what is the right mix of generation resources to meet load over the coming decades?

And for years one of the big challenges is these models have not treated renewable resources very well, energy storage very well, certainly CSP very well. That is changing, and it’s changed quite a bit. We’ve seen significant improvements in the commercial models, in the lab models, in the academic models treat variability, uncertainty of all these resources better. Do better, do kind of time scale resolution to make sure we’re capturing the uncertainty and variability of these resources. So we’re getting there, but there’s still a lot of deficiencies.

And that gets into, of course, the other suite of models that also have to be included, things like production cost models where you kind of simulate the chronological operation of the power grid, things like power flow and they’re getting better. So we’re not where we were five or ten years ago, but we still have some ways to go to make sure that we understand the values and services these energy storage devices can provide.

So one of the things, going back to okay, what should we be actually looking at? And I like this chart because it really kind of focuses on what are the total services needed in the U.S. power grid? And this is a U.S. focused presentation, but physics is physics and engineering is engineering, so you kind of see somewhat similar scales in other regions.

The point of this chart is, when you look across the suite of all the different things that you need in the power grid, the majority of the services provided is simply capacity, capacity for meeting the energy demand during all hours of the year. And all those other things that people like to talk about in terms of flexible ramping of products and spinning reserves and frequency response, really is a very small fraction of the total capacity in the grid.

So that’s one thing that we really have to focus to identify is that oftentimes when I go to energy storage conferences, if I say if you want to make millions of dollars, you can focus on ancillary services. If you want to make billions of dollars, you got to focus on energy capacity because that’s where the vast majority of the costs and value of grid services are. Now that said, operating reserves, specifically frequency regulation, not frequency response, but frequency regulation, has been a really important entry point for shorter duration storage.

This is the total amount of these shorter duration services provided in the lower 48, the main U.S. power grid and you can see it’s more than 20 gigawatts of total capacity need for all these services. Now again, that’s 20 gigawatts compared to 1,000 gigawatt system. So on a fractional basis, it’s not very much, but as an absolute basis, it’s a starting point.

This has been really critical in importance. Getting the current generation of fly wheels and lithium ion batteries onto the grid, getting access again, primarily to frequency regulation has been really important. So the question is, okay, what does that mean for things like long duration storage and is that kind of an important point to start with?

So that takes us off into a little bit of a diversion before we get into the main theme, which is something we hear a lot about, frequency control or frequency response. So this comes up time and time again. What about inertia, what about maintaining stable frequency? This is a classic chart, in my world, that looks at the change in frequency under a contingency event. Frequency drops and response and as long as you stay above some threshold, you’re fine.

But if you go below that threshold, the lights go out. So one question is okay, well what about the loss of inertia, you can’t respond to things quickly. And CSP can absolutely provide [break in audio]. The frequency stays higher. That’s a good thing. That said, that’s something that’s come up time and time again. We’re going to save the grid from these inertial problems and this capability will save CSP because it’ll add this value stream. And there’s a lot of other things you can do about having faster response from CSP.

My warning about this is twofold. One, again, the amount of frequency response that we need in this country or really anywhere around the world is very small on a fractional basis. But here’s the thing – the other industries aren’t standing still. This is the simulation of basically a case where instead of adding CSP, we just change the way we operate the grid and add fast frequency response with the ability of something like a wind turbine or a battery or a PV plant to rapidly change its output.

Some people use the term synthetic inertia, we’re going away from that term. It’s really about fast frequency response. Inertia gives you time. You don't need as much time if you can respond quickly. Inverter based resources can respond very quickly. So I don't see inertia and frequency response as the single handed savior of CSP. Can it add some value? Yes. But I think it really comes down to thinking about if CSP is 2 percent too expensive, or something like that, these are the kinds of services that can maybe tip it over the threshold. But don't expect inertia frequency response to double the value of CSP. It can add value, but don't expect it to be the savior.

So what is the savior, what is the primary value opportunity for long duration storage and CSP? It’s capacity. The majority of costs, the majority of value that you’re going to get out of a CSP plant is capacity and the energy associated with that capacity. So this chart is basically just the simulations we did, okay, if you simulate storage and you turn on and off its ability to provide different services, if you turn off its ability to build and provide ancillary services, it’s not really going to change the result.

But if you turn off its ability to provide capacity, you’re going to make the entire market disappear. It’s capacity that you need to focus on. The ability of CSP and long duration storage to provide energy on demand and when it’s needed.

This comes down to what we call capacity credit, which is the fraction of nameplate capacity that you can expect and you can rely on. And so it’s, again, is it available at 6 p.m. on a hot summer afternoon or is it available at 8 a.m. or 8 p.m. on a cold winter night? Those are the issues that we really have to understand in terms of valuing long duration energy storage.

The capacity credit depends on how much duration you have. If you’ve got a one hour long storage device, you’re going to have to be rated because you’ve got a peak that’s four hours long, you’re going to have to de-rate it by 75 percent. But once you get the four, six, eight hours of storage, you can address that peak. We have seen time and time again that CSP, capacity credit is high. These are summer peaking areas in California and Arizona. Once you get to four, six hours of thermal storage, this is a reliable resource. So we know that. We know CSP is reliable, we know storage is reliable in this four to six hour range.

Now I just showed you a bunch of complicated curves, right? These are non-linear, you know, weird shaped curves, but that’s hard for markets to understand and value. So what did markets do when they said okay, let’s figure out how many hours of storage we need to determine what the capacity credits? They just did this linear curve.

So the duration of storage, if you meet some threshold value, you get 100 percent capacity credit or 100 percent towards your resource adequacy credit and then you have a linear de-rate. Okay, and that’s fine, that looks linear-ish, so that’s fine. But one thing that we’re going to talk a lot about is okay, what does that actually mean in terms of long duration storage? So the upper right hand curve gives you the initial response to, the requirement, to say okay how many hours of storage do you need? You see a lot of 4s there. Basically saying okay, once you get to four hours of storage, you get full capacity credit.

So what is the marginal value of the fifth hour of energy storage in a capacity market? Zero. Once you get to four hours of storage, there’s no incremental value for going past four hours. So this is the real challenge for CSP and other long duration storage technologies is because they have low marginal energy costs. You’re storing stuff in oil or sand or something, really cheap, as opposed to lithium ion battery, which is storing something in electric chemicals, which has a high kind of marginal cost, but it may be a lower power cost.

So the savior of CSP and long duration storage is okay, we’re going to get to the point where like at eight hours of storage, we’re cheaper than lithium ion batteries. The problem is markets don't need eight hours yet. They’re not going to pay you for eight hours yet. They’re only going to pay you for four hours or maybe a little more. And California is going to what’s called an ELCC based method, and they’re kind of incentivizing somewhat longer storage. But for the most part in this country, you’re not going to get paid for capacity if you offer anything more than four hours. You’re not going to get more money for capacity.

The energy shifting value does continue to increase; however, at a highly non-linear increase. You can see kind of on the right hand side that kind of marginal value, the left hand side is the total value. So you can see those curves kind of tilt over around the four or five hour range. Here’s another way of looking at it.

By the time you get to four, six hour storage, you’ve captured the vast majority of the potential energy opportunities. In going to eight, ten hours, you’re getting small incremental value. Typically this is less than the large amount of CSP or something like that. So the point is that once you get to four hours, five hours of energy storage, the incremental value is not very much. And so this means you cannot really get paid for anything else that long duration storage can do for you because basically the market’s saying well, you’ve basically provided all the services we care about right now. We don't really care about resilience.

We don't really care about what happens in five years. We care about what’s the grid conditions today and today we don't really need more than four hours of storage. So what are we talking about then? We’re talking about the transition to some future. Not today, but something that as you add storage to the grid, the peaks become longer, you need more four hour storage for long duration storage, which is also countered by the fact that as you add more solar, you narrow the storage.

So this is one of the things that I’m really popular when I go to something like a lithium ion conference because I can basically sit here and say you’ve got a huge market opportunity for four hour storage, and that market opportunity’s going to get even bigger as we add more PV because of this huge synergy between PV clipping off the first half of the summer peak, and four hour storage clipping off of the second half of the peak. So I’m really popular at that conference and less popular here because I’m basically telling you that not only are things not great right now, they’re not going to be great for some time because PV is going to cut into that potential opportunity for long duration storage.

Now there is a saturation point. You can only go so far, but we do have a long ways to go. These are curves that show essentially how much do the opportunities for something that a four hour battery increase when you add PV? And the answer is in many part of the U.S. at least, they increase substantially, but they do ultimately saturate. And so that’s the good news.

So essentially what happens is you get to the point where yes, long duration storage is needed, but it’s not going to happen tomorrow, it’s not going to happen next year. It’s going to be a while. Essentially what we see is in our simulations of really aggressive de-carbonization, we see transition to six plus hour storage in the late 2020s and transition to eight plus hour storage somewhere after 2030. That’s the real time scale that we see the need for long duration storage. So we don't see it today; we will see it eventually. But again, that’s where I say something like you’ve got time to keep the technology improvements and things like that.

So when we do our simulations for something like CSP and look at the opportunities for CSP, we don't see much uptake, really, until the late 2030s because, again, PV plus batteries are more cost competitive for the shorter duration. Ultimately with the cost reductions, we see the opportunities for CSP being significant in the tens of gigawatts, but not happening soon.

So that’s kind of the mixed message that I guess I have is that it’s not today, it’s not tomorrow, but ultimately there will be a significant need for these longer duration storage technologies. It’s just a matter of how quickly and aggressively will we deploy these technologies to achieve that. So those are kind of my overall conclusions. I put mine there, because I think there’s some general agreement with them, but some of these things I think can be controversial.

But ultimately, I think the focus really needs to be making sure you’ve got the capacity value appropriately valuated because that’s your main attribute. The attribute of making sure that you have that energy on demand the opportunities will occur, but only after the shorter duration opportunities. Thanks.

MARK MEHOS: Okay, so Paul talked about the markets for long duration energy storage and he talked about the barriers and the opportunities for CSP within those markets. We’re going to take a little bit deeper dive. I’m going to introduce Dr. Rafael Guedez. He’s going to talk about hybrid CSP PV power plants cost effective base load power, and I would say reliable power, combining solar and long duration energy storage.

 Rafael is a Senior Researcher at the Energy Department in KTH Royal Institute of Technology in Sweden. He has over ten years of experience in academia and industry related to thermal power, solar energy, and energy storage technologies. Today he is PI and Coordinator for several EU funded R&D projects – very impressive, actually, the list of those, and Deputy Director of the Masters in Sustainable Energy Engineering at KTH. He’s also an advisor to the Kyoto Group, Odqa, Renewable Energy Technologies and Naventus Corporate Finance and has previous advisory and working experience at Mazen [phonetic] Total Energies, Ozeleo [phonetic] and Solar Reserve. Rafael?

RAFAEL GUEDEZ: Thank you, Mark. So I’ll get to the point quickly then. Well, my background is from CSP, so I guess my message might be slightly more positive than Paul’s, but we’ll see. So I will just say upfront, also of course this is coming more from a – I think Paul’s presentation was given the perspective of what the market demands and this is more okay, giving any market constraints or boundaries, what is the sweet spot for CSP, already mentioned it is around eight hours or so. Whether it is happening today or not, well Paul told us already what.

So I’ll talk about hybrids. And luckily in the morning, especially for those here in Albuquerque, we already heard a lot about, from the actual industries that hybrid, it’s basically what they are promoting. And I talk about what is it and why, but I think here, at least in this forum. I’ll show some trends, but they were mentioned earlier, but also about R&D.

And then particularly, what I’d like to talk and invite to follow us, it’s on relation to an action that we’re promoting, we’re working on a PACES Task 1, which is a model inter-comparison and case studies for hybrids, primarily to support the industry in the future.

So what’s a hybrid CSP-PV plant? And you saw many pictures like this earlier. Basically, and a simple definition is just an integrated CSP-PV plant onsite primarily. Although Mark mentioned earlier you know, it could be also that they’re both connected to a degree and somehow virtually integrated, [unclear] control.

I took this picture just because I used to work at the very beginnings of this CSP-PV project when I was in Solar Reserve, but not to harm anybody. I think you could even see some, the surrendering, but you could even see some today that are actually real projects that’s happening, like we saw earlier from Atacama.

In essence, if you look at this schematically, you see it here and this is from NREL, but it’s basically a CSP plant. And here you have a, let’s say, typical generation tube with molten salts and where the heat is feeding a steam generator that drives a turbine. The turbine then goes to the powerhouse. And then in the same powerhouse we have a PV facility that actually injects power as well. And the PV system, might or not be connected to a battery.

Why do we do this, or what are the advantages of hybridizing? We bring in a lot of, a lot in this forum, CSP because we’re aware of it is that okay, by hybridizing we basically maximize the cost effectiveness of PV production or cheap PV production during the day, while we also then are able to provide or focus, the CSP heat collection so that we can provide energy during the night. So that’s the primary of why we do that.

But there are other further advantages. So you have shared infrastructure. Like I showed before, you have the same powerhouse and all that it means electrically. But it’s also on the practicality. So contracts, permits, potentially optimizing OPEX, et cetera.

You can also benefit from earlier cash flows, so that’s also something that someone mentioned earlier. And potentially reduce performance losses from the PV side, for instance when you have an active hybridization with electrical heaters.

So that said, of course, these add other challenges and primarily it’s all connected to control. So you know, we’re adding more systems, we’re talking about well, in the day we produce PV, then we have batteries, then we have tests. When does each one come, et cetera. So that is a thing that Sergio from [unclear] mentioned, and we required, be very good EMS to handle this. At the same time, this increases CAPEX. You’re talking larger projects potentially.

This is an example of how a hybrid plant will operate. I don't want to go into full detail, so that you actually will attend Bill’s presentation on Wednesday at 10:30. But on the top here what you see, it’s in the dark color, this is an example, so hourly pricing in the N grade and then in yellow you have the solar availability, or the DNI, the solar resource. You see that the peaks are mismatching whenever we have the resource and you even see some periods, for instance, in the day three where we have price going all the way to zero, right, to exemplify what we can do.

In the second part, you have the battery, how it performed. This is a PVC-CSP battery test configuration. So you see how in the day where we’ve reached zero price where the system opted to go for full charging of the battery. And then when we had this very high peak on the fourth day, the battery was discharged or so forth. And in the third row you have how the thermal energy storage of the CSP perform in such a high reconfiguration and you see primarily just a daily cycling.

And ultimately what you see below is that such a hybrid configuration, and this is the 100 megawatt example, it’s able to provide more or less firm power, except for those days where the price was zero of course, because there was no intention to produce, so why are we doing so? So that’s what you see in the day three with the light blue. Bill will explain how this is – I mean, this is work ongoing, model happening in at NREL, so I invite you to follow his presentation tomorrow.

Now there are different plan architectures. I mentioned this earlier. You have them collocated, so you have a CSP-PV plant that basically talk to each other at the injection point. But you do have also other architectures that you see that later today or tomorrow in, especially if you join the hybrid, the analysis and simulation track.

For instance, this one here, where you have active hybridization by means of using electrical heaters. I am one of the ones that think that electric heaters actually are challenging. So there’s two component development to do, but it’s totally possible. And you have here on the left a typical molten – a parabolic trough configuration that is boosted with a little heater, or on the right a towered configuration where basically the heater can be running and piled on to the tower. This is another way to hybridize the system so you have more active between.

In terms of markets, we heard earlier today, especially for those of you in Albuquerque, so I will say for the ones in Chicago, at least in the CSP industry, it seems that by default, this is what’s happening. Hybridization, either collocate or actively hybridize, well that could be the question. But we see in recent years Cerro Dominador came online, well first with a PV plant and then with the CSP plant.

The Dubai plant, of course, is also a hybrid plant. If you think about it, they are both collocated. We’ve heard about the [unclear] from Chile, Likana and also earlier today even we saw what the center will propose for the upcoming tender. And I think this is, wrong numbers, these were based from the previous tender specifications, and they changed.

And that leads me to the next point, which is policy support. I think there is no specific policy support for this; this is just market driven. And I think it’s fair enough. But we also heard earlier today that there are some countries where such hybrid configurations can be proposed. Like Likana has been for several years now been [unclear] in Chile. Even when I was in Solar Reserve, this was something that we were trying to promote.

And in Chile, the way it works is that you have technology agnostic tenders for those who doesn’t know, and you have block hours where you can bid to. And well, that gives some room for CSP because you can focus the CSP on the night hours. But still the way Chile works at least is very, like you can do a lot of hedging. So even PV can compete in the night. So that would be a question if that’s good enough.

Then you have CSP – well, here in Europe, I am from Sweden, so in Europe, in Spain, we have an upcoming tender for CSP after many years. And I think that’s very interesting. They even refer to hybridization with PV. But in a way, they also limit how much you can optimize this CSP-PV ratio, configuration. So they are not giving that much room for optimization, either. And then we heard earlier today than in China we have upcoming legislation which explicitly welcomes hybrid projects and we will see how that develops.

In terms of R&D, in SolarPACES, we’ve seen this increasingly trend for hybrid systems. This year we have 12 out of 48 abstracts sent to the analysis and simulation track that are somehow in relation to hybrids and we have seen this increase.

If I compare to 2015 where we’re only three papers or so in relation to hybrids, so now we are in 12. That gives you a great idea of how, at least R&D-wise, from a simulation point of view, that’s increasing. And that’s connected to my next point, which is that several institutions here present and others that are not present, have developed tools or models to analyze, different layouts, techno-economics or so. And at least in Europe we see an increasing trend for projects that are dealing with hybrid systems.

And these are some examples, because these are the ones that I’m involved with. But we’re looking to hybrid systems combining molten salt and [unclear] 2, or hybrid systems combining air as [unclear]2 or new type of PCMs also [unclear] 2. And this is, again, for next generation CSP.

And that leads me to my next point, which is given that although there are many models out there and in this forum from different entities, SolarPACES started a new project led by Mark Mehos here and coordinated by NREL. And together with DLR, Politecnico di Milano, sorry, and KTH.

And our goal, if you look at the title, is Model Inter-comparison and Case Studies Concerning Hybrids, CSP-TES/PV Batteries, et cetera. Diverse objectives, but primarily it’s to somehow characterize what are the tools are out there and try to in a way report to the industry or to our peers what tools to use, when, et cetera. Limitations of each or advantages of each.

Define case studies and boundary conditions around these case studies that we perform, we provide some kind of public report where you can see how the different tools perform. Including, as much as possible, input from industries so that there we welcome you to give us input.

And finally, you have a report where we establish all the recommendations from our point of view, which are more institutional, where hybrids should go and so on. And I must say that all these models are primarily from, let’s say, the developer’s perspective, mainly energy. So even certain boundary conditions like when to operate or not or a price taking scheme, how to size the system. How to dispatch and how to size.

The project goes for 18 months, so we are just kicking it off this week, hopefully. And our first work package will deal with the definition of case studies and identification of tools that are out there starting from ours, primarily. Then we move into execution of case studies for the next months and finally last six months we will work in actually providing recommendations for the industry or for our peers, and hopefully in one sort of PACES to come, we’ll have some updates.

I can show you – my idea is not to go through all the tools that are out there, but at least the four of us that are dealing with this project, we have tools, right? And you can see in many of the papers that you are going to see in the conference how the tools are, what they do.

I think most of them, if I were to summarize, here you have KTH1 and poly-technicals are price takers, they take hourly price data. They can also take hourly weather data. They do thermodynamics at component system level. They do take cost models, et cetera. And then some of them include optimization, both for dispatch or actual sizing, like [unclear] or not.

And many of them, that’s the case at least for these two, are building on existing tools for like SAM or like tie SAM because they are open source, at least in our case at KTH. We have other tools like in NREL and DLR, so these are the four that we will compare in our study to begin with.

And in NREL, you are all familiar with the SAM, I think what is novel is the hybrid optimization performance platform which is particular or purposefully developed for hybrid systems and we will be testing it in this project. As well as for DLR, we’re proposing YACOB, which stems from or is coming from the old Greneus [phonetic].

Some examples of what the institution has published,

and again, there will be presentations for each, so I will not go in detail. But just to show that in all the publications, more or less what we concluded before is how hybrid systems, what’s the value of them? So when it comes to ours in KTH, what you see on the left is the study that I’ll be talking about on Friday where you see how hybrid systems, this is a molten salt PV-CSP with PR-s Co2.

Hybrid systems can bring value in the sense that they can be more cost effective than CSP only. If you look at the Y axis, there is less cost. But at the same time provide more base load power, so high capacity factor. And of course, they will be more expensive than PV only, but the PV only is limited in terms of capacity factor.

Then on the right you have more of many lines, so I think what is interesting there is only like depending on the capacity factor, on the hours of storage or so, which technology is more interesting. And what we see is that hybrids are, whether actively hybridized or not, like collocated or not, after 60 percent, they become more interesting even than PV plus thermal, so PV2 thermal storage or so. That study we’ll be talking about tomorrow as well.

The DLR, similar results. It’s that after roughly four hours, for a number of technologies, for a number of sites, they conclude similar that that’s when PV CSP hybrids add value compared to PV batteries. And similarly in POLIMI, they have done recently a study where they also do a hybrid system combining molten salt linear Fresnel with tests PV and electrical heater and batteries. And what it shows is how there is, depending on the capacity factor, retire the transition from only PV to PV batteries to PV CSP hybrids to PV CSP plus batteries. So that’s the one attained higher capacity factors.

These are just examples, so I invite you to follow the papers throughout the conference. And I think my main takeaways then are that okay, what are hybrids? I expect all of you to know now, at least in SolarPACES here. It’s basically onsite PV CSP plants, either collocated or with a smart control, or actively integrated with an electrical heater.

These plants according to studies from the institutions here present can to be the most competitive, like solar technology plus storage after, when you need more than five hours, with high DNI. And what we’ve seen also from earlier today, it’s that most of the commercial projects are already doing this in a way, collocating PVCP. We see that tenders are somehow being adapted to or policies for tenders to welcome PV CSP hybrids, although I think it’s not enough. And we see that most of the R&D projects are funded also in connection to hybrids.

In SolarPACES, I guess it’s my main message, we’re trying to harmonize our efforts and we’ll start this Task 1 project. I invite you to contact us, myself or mark, especially for industry, to get relevant boundary conditions and other. Thank you. [Applause]

MARK MEHOS: Thank you, Rafael. And I realize that I didn’t introduce myself. So, my name is Mark Mehos and I’m with the National Renewable Energy Laboratory.

JULIA SOUDER: Hi, I’m Julia Souder, and I’m the Executive Director of the Long Duration Energy Storage Council. And really thrilled to be here today - thank you so much and thanks Mark for the handoff. Congratulations to Sandia and Argonne and the U.S. Department of Energy for making something so difficult look so easy. Being able to simulcast two different Zoom webinars around the world. Well done. Thank you so much again for inspiring us. And again thank you for the opportunity to be here.

It’s really exciting to talk about long duration energy storage. And what we just saw from the two panelists about the innovations that continue to happen because of the need that we have to push forward to address these ongoing challenges. The future is now. We have to start building these things now. We need to start making sure our grid is resilient and reliable. Next slide please. Great, thanks.

So, really just wanted to highlight that, you know, we are all in an energy transition. We have already all seen how energy security is so important and how affordability as was mentioned earlier today is also critical. And as we’re pushing to decarbonize our global economies, these two factors are really bringing this new awareness.

You see the graph on the right on the European Union, just the immense dependency on fossil fuels. And how this is starting to change overnight. And this is just one of many perspectives as every country in the world is starting to reexamine their energy security and affordability hurdles that they have to jump and achieve in the next few years. Next slide.

And as you’ve pushed forward on this, one of the biggest things that I hope you all take away, and hi to everyone in Albuquerque and my friends there - sorry I’m not there in person but I’m glad to see you virtually - is to point out that long duration energy storage, you know we’ve heard a lot about flexibility. You heard about capacity in energy markets.

You know, long duration energy storage, whether you’re looking at a variety of the technologies, is truly a de-risk. It is de-risking our transition. It is an essential component. We are no longer a trend. Long duration energy storage is a foundational component. And this is really important and I hope to demonstrate this more through the next slide.

And so, why this is so important and brought a lot of us together was realizing the need to create a long duration energy storage council, a global council for society’s benefit, that really tries to scale up the marketplace for long duration energy storage. Doing this in a fact-based way, with executives, focusing on all the four different types of long duration energy storage that you heard that mentioned: thermal and chemical, electrochemical, and mechanical. Next slide.

So this momentum has started since COP26, almost a year later. We started off around 22 members and now we are over 60. And what’s so unique about this council and this partnership, and again that collaborative nature that is so key to everyone’s success, is bringing together technology providers, many of which are in the room - and very excited to be in partnership with DOE - many are in the room in Albuquerque. It’s very exciting to kind of see how these worlds are all combining together.

I’m highlighting the needs again that the must have of long duration energy storage. And then the awareness by customers, equipment manufacturers, financiers to really bring these perspectives together to create the marketplace so that long duration energy storage really does have that level playing field to make sure we’re decarbonizing our needs globally. This is critical. And so really just excited to see the growing momentum. Hope many of you that are not members yet will join us in our work going forward. Next slide.

So this is harder to see and some of the slides I threw in here just to make sure that you can go back to. You can do some research and then contact us if you have questions. More than happy to dive into this. But we really wanted to highlight the diversity of our membership, meeting the categorical needs in each of these areas of long duration energy storage.

There are these sub-categories, the diversity of long duration energy storage. Behind the meter, in front of the meter, local, your community, your state, your region, your country. You have options, some that are there today. And so really just want to again promote the value add of all the different types of long duration energy storage at your fingertips. Next slide.

And you’ve heard a lot of this, I’m sure in Albuquerque and here in Chicago, energy’s shifting. We have to start addressing the every hour of every day of every month of every year, with clean energy resources. And how do you make sure that happens? Long duration energy storage because it can do that energy shifting that you need.

Provide those grid services that the previous panelists highlighted on, giving you that frequency of response, that black star capability, that reliability of how you can really give you the ancillary services you need. And so again showing the value add of what long duration energy storage can do. Next slide.

And building on that, we’ve been really working on, okay, how can the storage be a transmission asset? How can storage really start with 24/7 clean PPAs? How can we have the tools to give you so that you can help meet your goals with long duration energy storage? How can we support net zero islands, whether it is an actually island surrounded by water, or you’re an island because you’re completely off the grid and you’re remote, how can long duration energy storage meet your needs? And then how do we do this with the new kind of intermittency that the importance of renewable energy is providing, but again the gaps that are there? And long duration energy storage gives you this value add because it’s unlocking different use cases in a variety of scenarios. Next slide.

So our members are really dedicated to making a difference in meeting all these different areas and really trying to dig in to getting the data and the facts behind, well how do we create a marketplace? What kind of policy toolkit can we create? What can we do for net zero mining, net zero islands? How can we work with various countries that have already gone through many different energy transitions and take from the lessons learned and adapt it to implementing long duration energy storage?

So these are the working groups that we have in process. And the next slide will show that we’ve already produced three reports and we have a fourth coming in November. We’re going to launch a COP27 that I’ll give you some overviews on. But again you can go online and download all of these, but it’s really exciting to see. We’re already trying to share the insights we’re gaining from again our diverse membership. Promoting the marketplace of three trillion dollars, a conservative number that globally looking at the value of long duration energy storage. Next slide please.

And really kind of demonstrating that when you hit the sweet spots, kind of that inflection point of renewable energy integration around 60 percent, long duration energy storage comes in the marketplace at amazing cost savings, emission reductions, and customer benefits. And so we’re there in many states, regions, provinces, and countries.

And I think what’s exciting is the momentum is building, and now it’s just producing more and more procurement and tenders to really bring out the value added long duration energy storage. And just today Australia announced over six gigawatts of energy storage with long duration energy storage by 2035. I mean this is happening now and this is so important.

And what I’m really trying to show you is that around the world there are many companies that are working on thermal energy storage, power energy storage, so many different aspects of long duration to push this forward. Next slide.

So in addition to the flagship report we launched, we also created a policy toolkit where we provided 20 different types of recommendations that you can take back to your local community and adapt to meet your needs. One of the most popular ones that you could fast is the 24 X 7 clean PPA.

We’ve been working with the World Bank and the UN State Department and other groups of how to create a certificate process that is global. So it’s kind of a one stop fits all to get the certification, to really validate the fact that you are really bringing down a mission. You are doing cost savings with long duration energy storage.

We can prove that we’re meeting every gap every hour of every day with long duration energy storage and validatedness. There’s many more elements that we wanted to highlight. Revenue mechanisms, the procurement mandates, policy incentives. There are so many different ways to get you to market on [unclear]. Next slide?

And I just kind of spoke to this a little bit, but just the constant push and all the exiting tools that exist to promote long duration energy storage. Next slide? And again, as I mentioned earlier, long duration energy storage really can de-risk the transition. And there are a lot of myths that are out there today that we really want to kind of show that there are policies.

The recent passage of the Inflation Reduction Act really kind of highlighted a standalone investment credit for storage. Huge. I mean, that’s one country. There’s many other countries that are pushing very similar elements forward. And the fact that, again, there are revenue streams that could just be bigger and move faster. We need to make sure that everyone understand that long duration energy storage is multi-hour, ten hour plus. The eight hour kind of just stackable, it’s a nice bridge, but ten hour plus, multi day, seasonal. And really kind of bringing in that, again, we’re de-risking the transition. Next slide?

So another report that we’re working on that we hope to publish at COP27 builds on the net zero power report. We did a lot of benchmarking with McKinsey partners who is a knowledge partner of ours to really demonstrate what is in the marketplace today. What are the different types of technologies and where do they stand going forward? And we’ll be updating the data in addition to providing a whole new perspective and why this ties to CSP and thermos energy storage to net zero heat. If you look at long duration energy storage, you have the net zero heat, power and positive possibly? Hydrogen. So we really want to highlight, again, this flexibility and this diversity of energy needs, and again kind of unweaving the complexity that is thermal energy storage. Next slide?

So in this report, we really want to kind of highlight again the updates to the benchmark and we want to look at the overall comprehensive heat de-carbonization. There are many industries that are looking at power, but in the next slide you’ll see there’s a lot of focus on net zero heat and kind of the unknowns. We really want to highlight that there’s the need and the industry needs very stable duration like of heat. You can’t have this up and down. So you do you make sure you have that stability and that consistency?

And then as the industry and residential sectors are starting to move to electrification, what does this look like for the current grid infrastructure? And how can we work with the existing grid, and also show that there’s value add for inter-connection, but there’s also value add for hybrid and different standalone possibilities.

And then also we’re looking at, again, these perspective of net zero islands. How can thermal energy storage provide a value add in addition to net zero power? And so we’re really trying to promote additional dialogue again, to the immense benefits that long duration energy storage can provide. Next slide?

And so I mentioned earlier like trying to meet that every hour of every day. Also want to highlight when you’re looking at heat and in an industry, you’re looking at 50 percent of the global energy demand is from heat consumption. And that’s a really big deal, and I really just kind of want to pause non this because within that you have this range of heat temperatures that we need to gauge too for different types of industries, whether you’re looking at anything, refineries, cement, alumina.

And so this whole new world opens up as needing to meet de-carbonization goals with long duration energy storage. Next slide? And so as we look at this, within that 50 percent, 70 percent is by fossil fuels today. We have a huge transition in front of us and this has got to be met with a lot of collaboration and teamwork and with long duration energy storage. And as we’re doing this, I’ve pointed out earlier just about what’s happening in the EU with their fossil fuel crisis.

The same thing is going to happen even more so in the heat industry. And so you’re looking at how climate is increasing price, the security issues, and there are a lot of different elements that are going to have to pull at this to kind of reconsider how are we going to use and reconfigure the entire heat industry in the building world.

So when we’re looking at thermal energy storage, there are three types – the sensible heat, latent heat and thermal chemical heat. And we are looking at the different types of how we’re using heat storage, the duration, not just for hours or days, but years. And being able to hold different heat temperatures is also really important.

And I think that’s what you also say from the two panelists earlier is how CSP, thermal energy storage, CSP-PV, really gives you this range of options and also kind of that duration. I think one of the last models took 18 months. It was quite impressive. And then if you look at, again, the different types here within this, it’s really exciting to see again, this could be behind the meter and in front of the meter. There can be a wide range inside this, too. Next slide?

And this is an example of the many different types of members we have within the council that are specifically focusing on net zero heat. And you can see that, again, that diversity is so key. You see those three different categories within sensible, latent and thermal chemical of why this is so important. We need that diversity to meet the different countries’ needs around the world to really validate how we’re going to do this transition to meet our net zero goals.

And what’s also really exciting is that a lot of these that are in the marketplace today are moving from commercial to really trying to scale up. But again, we’re also demonstrating that there’s the range of the sub-categories within each one. You have the different gradients of heat. Next slide?

And so the other thing I wanted to highlight is thermal energy storage already provides a range of heat temperatures that are needed in the various chemical processes and the various needed in manufacturing. What was really exciting to me was the fact that within this range of heat from 100 degrees Celsius to 2,000 degrees Celsius, you can have some of these technologies that can hold heat for years. And that reliability is so important going forward. And so again, the validation of the important of long duration energy storage as net zero heat is critical. Next slide.

And so as I mentioned, there are real world examples today. Here are two of our members who have partnered with existing companies and utilities to use thermal energy storage in today’s world. So you have the first one that’s in Norway and that’s working on a fertilizer plant, and the second one that’s in Italy that’s working with a CCGT power plant. So you already are seeing the value add of long duration energy storage performing in the roles of thermal energy storage. And again, what’s exciting is that EnergyNest and Brenmiller Energy are continuing to kind of move the ball forward and increase the conversations of the value add. Next slide.

And so what we’re really excited about is that this is kind of a first of its kind benchmarking that we’ve done at thermal energy storage and we’re really thrilled to bring this out and to have a lot of conversations with all of you about what this means to have net zero heat. And we looked at five different categories and we were looking at in the benchmarking how do we really pull out and examine these different business cases and base case data that we have.

The membership did a great job of pulling all the resources and data together so we could amplify the message of what we can bring to the table looking at these different solutions that can be for thermal energy storage. Next slide?

And so one of the biggest kind of tidbits I want to share with you now is a teaser so that when you download the report of November was the cost savings. If you’re looking already at the levelized cost to heat and you’re seeing up here within the different archetypes of thermal energy storage, you’re seeing a range of $4 to $8 dollars megawatt - $4 to $8 dollar megawatt hour. That’s not a lot to add on to your current cost.

The majority of cost, about 75 percent, come from the current electricity power costs that are needed. So again, just want to reiterate this is huge cost savings. This is not a huge additive. This is very minimal to point out that the benefits are really there for thermal storage at a very low cost. Next slide?

And one of the business cases that we looked at out of the four to six you’ll see in the report is looking at alumina refinery. This is a very needed resource around the world. It’s a very important heat dependent company that needs a lot of stability of the heat at a certain temperature always. So how do you move a company that’s been reliant on fossil fuels to renewable energy and have long duration energy storage provide that stability?

And so we were really excited to see that as we brought this together, we looked at costs, we looked at customer associated building requests, we looked at public opinion. We looked at all the various policy regulations. And it kind of came out that there is really a huge momentum push for this. There is enough space to make this work. And that you can actually have alumina product, whether it’s making something for cars of building, half of the cost savings because you have long duration energy storage give you that reliability, the stability and the cost savings. Next slide?

And so specifically kind of looking at this alumina case, you can see that thermal energy storage really is a competitive advantage to fossil fuels, especially when you add a carbon tax. The natural gas price is low at $19 dollars, but when you actually even bring it up higher, it’s even a larger cost savings. So it’s pretty exciting, again, to see that you can, this is possible in today’s numbers. And you see that even tomorrow, there’s even a greater cost savings and greater emissions reductions.

So again, it’s really exciting to kind of build on the momentum on the importance of long duration energy storage, the importance of the innovations that have happened through pumped hydro and CSP and where we’re going for the types of long duration energy storage with both net zero power and net zero heat.

And look forward to ongoing dialogue in collaboration with the labs and DOE and our global partners to really continue the conversation of how long duration energy storage is essential to decarbonizing our global economies and how it is a foundational component to meeting our net zero target. So thank you all for your time. The next slide has my contact information if you have additional questions and look forward to working with all of you.

MARK MEHOS: Okay. Now we have time, ten or fifteen minutes I think for Q and A. And we’re going to split that up between the two locations. We’ll start here in Albuquerque. So line up behind a mic, and somebody please introduce yourself.

JOE MELVILLE: Hello, this is Joe Melville from the Solar Energy Technologies Office. I have a question primarily for Paul, but I think Julia also touched on this issue. How do you think about the interface and the opportunity space, if any, for as you move from long duration energy storage, like 6 to 14 hours, to very long energy storage, weekly or even seasonal storage?

PAUL KEARNS: I guess I’d ask you, what do you mean by interface?

JOE MELVILLE: I guess I mean like the continuum of time scales. You spoke a lot about the need for increasingly long energy storage as you move from like four hours to six hours to eight hours. Where does weekly energy storage fit in that picture? Where does seasonal energy storage fir in that picture?

PAUL KEARNS: Yeah, so I think your point about continuum is exactly the right way of thinking about it because we are on this kind of continual process. And one of the things that I think it’s really important to emphasize is how do we balance the needs of grid today with the needs of the grid tomorrow? And one of the reasons why I often talk about we don't need eight hour storage now or ten hour storage right now is because historically we’ve often had this tension of people saying oh, you know, we need storage to integrate wind and solar and we didn’t need storage to integrate wind and solar.

I mean, we’ve got a lot of ways of putting solar and wind on the grid without storage. And so it’s important to emphasize the fact that there’s a place for current four hour storage technologies and not to slow down the deployment that we need right now while recognizing that need for that transition. But there will be this transition from longer duration.

And we also see, of course, the transition at which point you are going to need seasonal storage. And we don't really know when that transition is. I mean, I tend to think about it in terms of around 90 percent clean energy on the grid in which de-seasonal mismatch problem becomes extremely challenging. I don't know if that’s 85 or 95, whatever, 90 even is a good mental model. The same way we can do a lot with four hours, but eventually you need there. So the policies need to reflect that and that is one of the issues.

My point about the four hour number that markets are using is it really is up to the developers and kind of the business side of things to make those changes, make sure that the policies continually change so that the increasing value of long duration storage.

And quite frankly, what it really comes down to is that the decreasing value of short duration storage is appropriately valued. So that when the rules are constantly being remade, when we transition to okay it’s time to eight hour storage, is what’s needed to get full capacity credit or ten or twelve, those changes are made. So I think, again, my point is that it’s really up to the marketplaces and the advocacy groups and all that to make sure that the rules are constantly being updated to account for the fact that longer duration storage will be needed.

JULIA SOUDER: And if I could jump in, too. I think Paul and I would have a really fun day on a bunch of topics today, because I do think that we need the diversity. We need the ten hour plus, we need the multi-day and we need the seasonal and not every location is going to be able to have every technology. And so we really need to make sure we have that availability, especially because for example, you have wildfires. You use solar for three days, you lose wind for three days. All of a sudden you were able to charge your batteries halfway, but you need to have these other types of storage. If you don't have that diversity, you’re in trouble.

And I think we need to realize is that wildfires are continuing, drought is continuing, heat is changing. Like the drought on one side, rainfall on the other and extreme temperatures. Like we need diversity so that we can deal with the climate dependent generation that we now have.

And I think the other aspect that’s really important is we’re bringing on renewable energy. Yes, at 30 percent you don't need a ton of storage. At 60 percent, you must have it. At 90 percent, long duration energy storage is the only way that you’re going to be able to make sure that you’ve got a reliable grid that’s stable and giving you that flexibility that gets you to keeping the lights on.

So I think it’s exciting to see where we are, but again, we have to be proactive. We’re already too much reactive. So again, let’s focus on the importance of the tools we have and how to improve the marketplace, as Paul said, and others, but let’s get on this now.

MARK MEHOS: I think you two should virtually have a debate offline. I think this would be really fun to listen to.

PAUL KEARNS: I don't really think there’s much of a debate. I think we’re largely in agreement. I don't see –

MARK MEHOS: It’d still be fun to listen to. Next question from Chicago, I think.

MALE SPEAKER: Some very low cost long duration heat storage are designed for more than 100 hours for just weekend and weekday mismatch and three day wind cycles. Have you analyzed such long duration storage systems?

JULIA SOUDER: Yes, we have. In our net zero power report and in our net zero heat report that’s coming out, we give a variety of different solutions. You can see the small, the range from small megawatts to large megawatts, in addition to the heat range that occurs with the needs for net zero heat.

One other thing I wanted to highlight too is that it’s also just the power to heat, heat to power, waste heat. Like there’s so many different categories here within net zero heat that we’re also diving into more in the report. So please take a look and ping us and let’s continue the conversation, because again, even within net zero heat, there is a diversity of options that are available.

MARK MEHOS: Okay, we’ll take a question here from Albuquerque. Before I do that, I did want – Paul, I didn’t know if you mentioned your latest publication along this topic of the last 10 percent. I don't remember the exact title.

PAUL KEARNS: I think it is called “The Last 10 Percent” or something. Yeah, I mean, it gets to this issue around, the perennial issue of how do you get to complete de-carbonization, and talking about the various options including long duration storage and seasonal storage. I mean, again, I think at 100 percent seasonal storage is an imperative. I don't really see anywhere around it.

MARK MEHOS: Okay, a question from Albuquerque. I think you were next in line.

JOHN WHITE: My name is John White from Sacramento, California with the Center for Energy Efficiency and Renewable Technologies. We’ve had a recent adventure on the grid with the heat storms and the challenges that we faced. I just want to emphasize how important the point Julia just made about diversity is because our whole crisis was influenced by the lack of diversity. We had, all of us with the supply chain for batteries and panels.

We had problems with weather, the well- known monsoons that hit the southwest desert kicked in right at the wrong time. We had to discharge the storage earlier in the day than we planned. So it’s important that we recognize as we get experience with deeper and deeper penetrations, the role of long duration storage and the role of concentrating solar and the ability to provide heat is a very unique attribute that has been not linked to this discussion up until now.

So you’re right. Thank you for this presentation and I’m glad to hear this emphasis on diversity because it’s too easy to do the simple things. In California we fall in love with one thing at a time to do only that. And now we’re in love with, that the solar panels and batteries. So we’ve got to broad the conversation to geothermal and CSP and all kinds of storage. Thank you.

MARK MEHOS: Thanks. Question from Chicago?

RASHA KAMAN: Hi, Rasha Kaman from Defense Innovation Unit. So I am working on projects around long duration and I kind of hear both of you. On one side, the market’s not ready because markets aren’t designed to sort of price long duration storage properly. On the other hand, there are many people in this room and in that room that re doing long duration projects. And my customer is the Department of Defense. They’re interested in these. There’s projects with DOE, a number of projects out here.

So you know, how do we evaluate this technology, how do we think about this technology in preparation for the time when long duration storage will be the imperative? Like what should we be thinking about, how should we be evaluating all the various technologies that are out there? So I’d love to hear perspectives on both sides.

JULIA SOUDER: Thank you for the question and thank you for pushing the envelope forward by putting tenders out there, putting procurement requests out there. Starting to have a dialogue and already starting to send the market signals that this is needed. And I think the more that we do there, that’s very beneficial. And within those procurement requests, what I think needs to be improved upon, and it’s great that we’re starting to work in collaboration with many entities, is all the additional value add from long duration energy storage, CSP, and thermal energy storage. All of those different ancillary services that can meet the market needs need to be outlined specifically.

A utility looking for A, B and C, long duration can give you A, B and C, but did you request it? I think it’s having that matching of the criteria with all the different attributes that long duration energy storage can provide. You know, maybe given again that flexibility to, we’re looking for ten hour plus, we’re curious about a 24 hour. Let’s have a dialogue about additional information and continue to have this.

And I think Jeremy’s got a publication coming out and he’s done a lot of great work on long duration energy storage. There’s a lot of great work by the labs by different groups validating long duration energy storage. And I think you’ve got a lot of the research centers, you’ve got industry, you’ve got utilities and now the regulators. And I think all the pieces are there. They’re starting to throw up their hands. Now it’s just continue to support that so we have the momentum behind it.

MARK MEHOS: Okay, we have another question. And I’m going to have to ask somebody – I know we started late, so I’m assuming this session can go a little bit over. I’ll take another question from Fred.

FRED MORRIS: Fred Morris, I’m a consultant in the D.C. area. Paul, I’d like to challenge your conclusions and I’d like to use night and ducks as the reason. The duck curve in California shows ample energy from PV in the daytime, but at night at dark area is required. If California’s going to remove its gas plants, which it will, and if night still happens, which it will, I believe that CSP with six hours, eight hours, ten hours of storage today will meet a need. I don't know why the model doesn’t show that.

PAUL KEARNS: It gets there eventually. I mean.

FRED MORRIS: California – SMUT is taking, has to get their gas plants off by 2030 and I think California would like to do the same. So we spoke this morning about CSP doesn’t get appreciated and understood. And I think that the market, California set aside a gigawatt for long duration storage. It wants it now. I don't understand the mismatch between the model and market.

PAUL KEARNS: Well, let’s do a little side exercise. I mean, one of the challenges we have is – let’s talk about cost a little bit. Where is lithium going? When we talk about projections for lithium, we talk about $100 dollars for KWH and we talk about the power of costs, $400 dollars per kilowatt. What can you do with that? What is the cost of a six hour battery? That’s about $1,000 dollars per KW.

So it’s not that we’re not building long duration storage, it’s that we’re not building CSP. That’s the difference. And the reason why we’re not building CSP is it’s being out-competed by PV post batteries. So it’s not that we’re not talking about long duration storage. We’re building a lot of long duration storage – eight, ten hours, and we’re building a lot of seasonal storage.

I mean, when we did the Los Angeles 100 percent study, we built a huge amount of hydrogen capacity along with various types of long duration storage, primarily next generation battery technologies that were either eight hours or in a lot of cases ten hours, and the other thing is flexible technologies that could charge quickly and then discharge over long periods of a time.

So one of the things that we would often do is build twelve hour storage, but in the form of two six hour batteries. So two six hour batteries basically meaning you charge with that huge blast of solar in the middle of the day. And that’s one of the huge advantage, actually, of CSP is you have a higher input capacity relative to the output capacity. Right?

You can have high solar multiples so you can absorb all that midday solar energy and discharge it at a lower rate. And so that’s one of the things that we often do with batteries. So the challenge is not about whether or not we’re building long duration storage in the models and in all these capacity plans, it’s just that we’re not really seeing CSP being cost competitive because PV plus batteries is out-competing it. So that’s the difference.

We are building lots of long duration storage and we see an absolute imperative for six, eight, ten, twelve hour batteries or twelve hours – sorry, apologize. We’re technology neutral on the types of technologies we’re building. We’re building lots of long duration storage and we’re building lots and lots of seasonal storage. It’s just that we’re not seeing in this country CSP beating out PV plus batteries in the next decade.

MARK MEHOS: Thank you, Paul. So I think I’ll take, we have one person standing in line here, then I think one question, do we have anybody in Chicago?

MALE SPEAKER: Paul talked about the four hour conundrum. What next steps would we need to take to change those policies and how much of an effect would this have as a demand pull mechanism?

PAUL KEARNS: I mean, I will defer to others to talk about this. Because ultimately, it is absolutely – my whole point was ultimately the policymakers need to recognize the ultimate need for long duration storage. And as the value of the shorter duration storage decreases relative to long duration storage, those policies have to be changed. But that is, again, that is for exactly organizations like the Long Duration Energy Storage Council and American Clean Power Association. All the different entities need to recognize and make those changes. So I’ll defer to others on what the actual mechanisms look like.

JULIA SOUDER: There’s a role for short duration, there’s a role for long duration and there’s a role for long duration seasonal. And I think what’s exciting is that we’re just trying to do a lot of education and awareness of why this is so important and how all of these fit together. And so we’re really providing these fact based information in these reports, all this guidance to really demonstrate that long duration energy storage is real.

It’s here today. Projects exist. And now that we have a marketplace, we need to scale up so we can make sure we’re decreasing the emissions and bringing down costs so we have that energy security and affordability that we’re all shooting for. So it’s working with all these different partners and collaborations of just really constantly reiterating the importance of long duration energy storage and building into the market areas.

Like the debate on resource adequacy in California and the Northwest, the debate of capacity in the European Union. And I mentioned Australia, putting out a new tender for six gigawatts of storage by 2035. That’s huge. I mean, countries around the world are signifying that storage is essential and long duration energy storage is a key to this.

So we just have to keep going on these messages, keep validating these with more and more utilities, federal agencies, different governments. We’ve been given the money to help push this forward. There’s been great work in Germany and other countries and the United States of pushing these demos to scale, and then there’s also this constant partnership. So we’re doing the work; we just have to do a lot more. So again, it’s also working together.

MARK MEHOS: Okay, and I’ll take one more question from Albuquerque.

JEREMY SMENT: I’m Jeremy Sment from Sandia Labs. I’m the developer of thermal energy storage technologies. Maybe this is a question for Julia, primarily, but I noticed you had mechanical, thermal chemical. And so as a thermal energy developer, I would wonder what your opinions are on the unique importance of thermal energy long-term storage versus other technologies?

JULIE SOUDER: As you saw in my graphic with our 60 plus members, we represent a diverse group of technologies in the power and heat side. So they’re all my favorites. But I will like highlight, we did some great work with the members on net zero power and we really highlighted the benefits there and now we’re doing the same for net zero heat.

We really want to amplify business cases in both areas to highlight the importance of the value add again in net zero heat and net zero power. So there’s a role to play. There’s a lot of material in here. And again, I think it’s us hearing stories in these business cases of why this is all important. So thanks for the question because thermal energy storage is important and so is net zero power.

MARK MEHOS: Okay, and with that, I’d like to thank our speakers again in both locations. I’d like to thank our audience in both locations for I think very interesting questions, so a round of applause. [Applause]

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