US Electric Utilities & IPPs

The Storage Opportunity (Including Conference Call Transcript)

Equities

Americas
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Batteries poised to scale significantly as US deployment scales up

We hosted our last call with Sam Jaffe from Navigant Research to discuss developments in grid-scale battery storage solutions. We analogize the outlook for tremendous cost improvements, coupled with meaningful state and federal subsidies to the solar industry in the US in the last decade. While battery implementation will initially be limited to nominal sizes to meet short-term 'frequency' mandates, as can already be observed in markets like PJM, we expect a meaningful scaling to begin through mandated RFPs in states like California, Hawaii, and New York as well as likely availability of DOE loan guarantee to kick-start the industry. Coupled with global growth opportunities in both the transportation and grid-scale space, we suspect scale is likely forthcoming in the sector. Interest from both investor and corporates in batteries has accelerated in recent months – and a majority of IPPs and diversified utilities appear to be at least evaluating participation in forthcoming RFPs across a range of states. While specific technology winners appears elusive through our conversations, we suspect costs will continue to decline materially in the medium term.

Meaningful ability to bring down costs, as exemplified by recent Tesla deal

According to Navigant estimates, at the Tesla 'Gigafactory', the cost of materials going into a battery on a processed chemical basis (not the raw ore) is $69/kWh [this metric is per kW per hour of operation]. The cost of the battery is only ~10-20% higher than the bill of materials – suggesting a potential long-term competitive price for Lithium Ion batteries could approach ~$100 per kWh. Today Tesla pays Panasonic $180/kW for their batteries, which is the lowest cost data point according to Navigant, with conventional systems still selling for $500-700/kWh; Mr. Jaffe's expectation is for broader market place prices to reach the Tesla level in the next 2-3 year period.

So what would a fully loaded battery cost today?

A typical 'load shifting' 4-hour battery (designed to address the afternoon/evening peak) appears to cost anywhere from ~$720-2,800/kWh, depending entirely on the scale of the Lithium Ion battery employed/size of order. The average $500-700/kWh for a typical battery is probably closer to the $2,000-3,000/kW when including the balance of the system costs (~$400-500/kW), with a trend towards ~$1,500/kW within the next ~3-years. Navigant estimates the global market for batteries will grow from 400 MWh in 2013 (ie – 100 MW assuming 4-hour systems), to 20GWh (or ~5GW/yr) by 2020, globally.

So when does it make it commercial sense?

We still think 'merchant' entry of batteries for wholesale purposes remains a few years off, with above-market PPAs supported by utilities seeking to balance their grids through this technology largely supporting the industry. We suspect commercialization will remain biased towards 'short-usage' needs initially, given the lower cost (and higher value) of these quick-ramping usages. We also see real value for distributed customers in C&I contexts who could use it to clip their 'peak' usage charges.

Who benefits? For now, California utilities – and IPPs

We look for EIX, PCG, and SRE to benefit from ratebasing storage investments eventually, while we look towards the IPPs (DYN, NRG, NEE, and especially AES) to participate in RFPs. Similarly, we think utilities like ED and PEG could yet participate in NY's efforts. Having seen the rush towards solar development in the last few years, we suspect much of the sector will eventually pursue at least some modest investment.

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Where is the opportunity? Grid scale for renewable integration, load shifting

Given the greater cost advantages of scale, Navigant expects utility-scale storage to evolve much more rapidly compared to the residential product. However, given ever increasing distributed PV penetration, we think complementary small scale opportunity should also lead to steep price reductions for smaller systems. Navigant forecasts global grid storage market to be above 20GWh by 2020, compared to just 200MWh last year. Given the AB2514 state law, which mandates utilities in California to purchase a certain amount of energy storage, and also the high overall renewables/PV penetration in the state, California is expected to lead the US in storage system investments. Other than just costs, the regulatory compact for compensating batteries for their load-moderating characteristics will also remain key to driving widespread implementation. We highlight storage opportunity in the frequency regulation segment especially in PJM, which has changed its rules around compensation for frequency regulation ancillary service in their auction mechanism. Navigant forecasts ~ 200MWs of PJM battery storage operating in the next two years. A further interesting point relating to California's intermittency, batteries could yet dispatch in the morning (prior to the mid-day ramp), as well as in the early evening again, following the trailing off of solar.

Several technology options on table, but lithium-ion remains leader for now

Navigant expects lithium ion to likely remain the market leader for grid as well as small scale storage for the next ten years. Among the chief risks remains the uncertainty on input costs for not just Lithium, but also Cobalt and Graphite in these batteries. While new sources are clearly available, the scaling up of the industry appears tied to maintain an adequate supply of all of these commodities. While common reframe has been focused on Lithium supplies, our latest call appears to indicate a greater pinch point around Cobalt- and even graphite availability in ready quantities.

Other technologies which are being considered include flow batteries such as advanced lead acid carbon which are also functionally well suited for grid storage/long duration applications. Newer chemistries, such as the currently under research lithium sulfur and magnesium-Ion batteries may gain traction by early next decade.

Beyond batteries, pumped hydro faces the problem of limited favorable locations available, but fly wheels and compressed air storage (combined – and dispatched through gas turbines) may yet find their respective niches, although could well be excluded from ongoing state processes to kick-start the battery sector. We note recently Pathfinder Renewable Wind Energy, Magnum Energy and Dresser-Rand, announced plans to build a ~$1.5bn compressed air storage system with a maximum potential to store the energy equivalent of 60,000MWh of electricity (as part of a broader $8bn project which also involves Duke).

In the end, lower prices are coming, but the technology is not yet clear

What appears certain is the trend towards scaling of a multitude of technologies, each with the ambition to construct reliable batteries. We flag comments from a range of battery manufacturers, suggesting their prospective cost curves on scaling the technology would beat out Lithium Ion. We look for details on these prospective technologies, (such as Ambri's), to be delineated in coming years. We flag our prior conference call with EOS Storage, a Zinc battery solution (Prior Note & Transcript: Digging Deeper into the Storage Solution), expressed confidence the future was *not* with Lithium Ion.

Another gigafactory in the making – reflects gradual industry scaling

Even as Tesla's gigafactory continues to takes shape, SolarCity announced plans last week to start manufacturing solar panels at a new facility it will construct in Buffalo, New York, operational by 2016. The facility has an eventual planned capacity of ~1GW solar panels per year (as a reference, current US installed solar panel capacity is 15GW).

Continued supply development will put downward pressure on prices.

We emphasize three emerging sub-sectors for batteries:

(1) Transportation: low-cost, high-density, low-weight batteries. We emphasize this sector is likely to take a different direction from utility solutions.

(2) Utility-scale: Our main focus, with the primary consideration for these solutions being their ability to deploy quickly, into high density populations without contributing to air or water permitting hassles.

(3) Distributed resources: We see both C&I and residential applications. While many would point to the ability to move 'off the grid' entirely, we suspect the economics are unlikely palatable. Rather, the ability to clip 'peak' demand contributions by industrial customers is particularly notable.

We think rapidly increasing solar PV penetration will trigger demand for large – and *small* scale battery storage solutions and will aid prices for such systems to decline from the currently high ~$2,500/kW.

How big is the market? Gaining speed, but not so meaningful yet.

Navigant projects growth from 400 MWh in 2013 vs. 20,000 MWh by 2020 per year, globally. Assuming a 4-hour average system, this would suggest a ~5GW/yr deployment of storage globally.

California storage solutions could be delayed, as bids are too pricey

In speaking with several stakeholders, we suspect the ongoing RFPs for new capacity in California could yet result in the utilities opting to delay procurement, citing them all as too costly (or at least seemingly relative to the rapidly declining cost curves). Under the current structure of the RFO, the state's utilities are allowed to delay by 1-year should pricing not prove palatable.

Given expectations for costs to come down substantially, California utilities may delay procurement

As part of RFP efforts in the state, we flag that the investor owned utilities in the state, PG&E (PCG), Sempra (SRE), and Edison International (EIX) are able to own up to 50% of the capacity under development in rate base. Given expectations for meaningful price improvements, we flag recent comments from EIX delaying procurement of storage solutions under this approach until the latter half of the program, later in the decade.

For further details on the latest procurement process please refer to our August note '**California Dreaming**'.

For further details on the background of the CPUC's energy storage initiative, please see our note '**In Search of a Storage Solution**'.

But SCE brings online North America's largest storage project

Last week Edison International's Southern California Edison (SCE) announced that its $50Mn, 32MW (8MW-four hour) Tehachapi Storage project containing 604

lithium ion battery racks came online. SCE will test the asset for two years to assess capabilities in conjunction with the ~5,000 turbine Tehachapi

Hawaii's RFP: Initial data points on cost point

We flag the HECO storage RFP appears to be trending towards $1,500/KW, with a 90-minute frequency program. We would estimate the breakdown of the cost at $500/kW for the balance of the system, with $1,100/kW (~$733/kWh) allocated to the actual batteries.

Improving costs imply a positive read through for Tesla too

Navigant's assumptions and forecasts for battery costs are a positive read-through for TSLA. Their estimate of $69/kWh for raw material costs (not fully processed raw material in cell only) compares to UBS' $125/kWh estimate (fully processed in total battery pack).

Please click to see the **full Tesla initiation report**, which includes a battery cost analysis on page 12 and 19.

The Energy Storage Opportunity: Conference Call Transcript

The following are highlights from our call with Sam Jaffe from Navigant Research. The comments below have been edited to improve grammatical clarity and provide enhanced context. A replay of the call can be accessed using the replay dial in details below:

Replay Information (available until 10/3):

Toll Free: 800 633 8284

Toll: +1 402 977 9140

Passcode: 217 319 26

Julien Dumoulin-Smith: Good afternoon everyone and welcome to today's call on battery storage. We are joined on this call by Sam Jaffe, Principle Research Analyst at Navigant to discuss the outlook for battery technologies. So with that Sam why don't you give us a little bit of an introduction on how you're thinking about the sector and the outlook for storage.

Sam Jaffe: Great, thanks very much Julien. By way of introduction, I am a market research analyst and I do a lot of consulting in the energy storage field with Navigant, which is primarily a consulting company. I've been in the field for

ten years and I've been doing market sizing, market forecasting, and consulting for most of that.

And I think from my own personal experience one thing to say is that most of that ten years has been sitting at conferences hearing the same presentations from the same people about the same hypothetical benefits of energy storage. But I see a very important change in the last two years where most of the presentations at these conferences are now talking about actual deployment of storage. So what has been a hypothetical concept for so long is now becoming a real business.

I'm not a cheerleader of the industry. I'm an observer of the industry. But in order to do forecasting I have to take certain stands and turn my opinions into actual numbers.

And I would say overall I would be regarded as somebody who is pretty enthusiastic about the use of batteries on the grid, the potential implications for the grid, and what that means for the battery industry overall.

So I'm going to start with three numbers and I'll come to these numbers through the course of this conference.

And those three numbers are $180 per kWh, $69 per kWh, and $1400 per kWh. The **$180/kWh [Units are /kW per hour of operation] is what Tesla is paying today for their batteries on a sale basis from Panasonic** for their cars. Now although that's not for the grid, but in the bigger picture, that's now the established lowest cost price for high quality batteries.

And that's compared to about $1500/kWh even five years ago, maybe seven years ago when it was 12 to $1500 per kilowatt-hour. So $180 per kWh is the price of those batteries, not the manufacturing cost but the price that they're paying for them.

$69 per kWh is the cost of the materials that go into a lithium-ion and other advanced batteries. So in other words **the cost of materials going into the**

batteries on a processed chemical basis - not raw ore but actual processed chemicals - is $69 per kilowatt-hours. So that lays the lower band for where the cost of making these batteries is.

If you assume that we're at around a $200 per kilowatt-hour price point today for high quality Lithium-Ion batteries that are going to last ten years under frequent cycling, and if you wanted to **build a very large peaker plant with four hours of energy duration behind it, it would be about $1400 per kilowatt** on those costs**.** Interestingly, that's actually pretty comparable to the cost of building a natural gas fired peaker plant. Keep in mind, you're not buying fuel for batteries - you're essentially just arbitraging low and high cost of daily electricity.

Let's go back to the subject of batteries on the grid. We don't really have energy storage on the grid today, except for pumped hydro. Pumped hydro is almost always linked directly to nuclear. Because nuclear plants can't be shut down at night when the demand is low, they are paired with a pumped hydro plant where they can be used for eight hours of charging and eight hours of discharging during each 24 hour period.

Given you are borrowing billions of dollars to build the nuclear plant anyway, a few hundred million more for the pump hydro plant gives you a more valuable asset than just the stand alone nuclear plant.

We have over 120 gigawatt-hours of pumped hydro throughout the world. But other than that, there isn't much energy storage on the grid because all other technologies have been too expensive, not fully developed, and there have been safety issues - just as there is with any other form of power generation. The safety issues weren't necessarily well understood in early attempts to use batteries or other energy storage devices on the grid.

We essentially just developed a grid over the last 150 years throughout the world that immediately consumes what it produces and manages that by essentially

overproducing a little bit so that you can make sure you have some backup in case of unforeseen outages.

But if you have energy storage then you don't need to over produce, and you don't need backup reserves. It allows you to store electricity and use it when you need it.

In terms of battery technologies I just want to briefly touch on a few different emerging battery technologies for grid storage. The critical aspects for any technology is the need for safety, low costs and durability.

Lithium-Ion has taken over multiple industries and presented itself as a solution for energy storage problems in multiple industries. This started with the Sony Handycam – although the camera itself had been reduced in size to the point where you could hold it in your hand, there was still the big unsightly bulge for the battery pack. They wanted a higher energy density battery, so they made the first Lithium-Ion mass produced batteries in 1991. Very quickly within two years almost every video camera was using Lithium-Ion.

That same principle of using a couple years to get to know the industry, and the engineers learning how to design a system around it, and then a sudden massive takeover of the market share of that industry for batteries – this cycle has been repeated with Lithium-Ion multiple times in different industries.

Overall, we think that **Lithium-Ion is the market leader for grid storage**. Lithium-Ion will remain the leader for the next ten years or so in grid storage as well as other applications. However, that does not mean that we will only have Lithium-Ion batteries.

There are so many applications that you can use batteries for that there will be lots of opportunities for specific niches within the power industry for other battery technologies.

There's a lot of other competitive battery technologies such as advanced lead acid carbon, where you cover the electrodes with carbon and have a much deeper discharge, more durable lead acid battery.

Such as various forms of flow batteries where instead of having a solid electrode on the positive side, a cathode and a solid anode on the negative side, you have essentially a moving liquid electrolyte that moves past the membrane that collects the electrons.

If you need extra energy duration you just add more tanks of electrolytes. Thus **flow batteries are a very good ways of managing an electrochemical device for grid storage applications especially for long duration applications.**

But again, a lot of my work revolves around Lithium-Ion because it's clearly the market leader and has the most potential for delivering low cost high quality batteries that are safe enough to use in the power industry.

So if you are going to use batteries on the grid, where do you put them? And that's one of the great things about batteries compared to other energy storage devices such as flywheels and compressed air energy storage and pumped hydro, is that you can put them anywhere.

You can amass them in large warehouses in a centralized location and manage grid problems from there or you can put them at the site of the consumption, which is very unusual and most other parts of the power grid you don't have that option, so that you end up with a choice of where to put them or anywhere along that network.

And it's our philosophy that over the next ten years the **most likely places where they will be put will be behind the meter, meaning on the customer side of the meter at the building where the electricity is being consumed.**

But **also in those large centralized warehouses because that's how the power industry traditionally works and is most comfortable with and there is certain economies of scale on the system side that make sense also.**

On the residential side it's difficult right now for the economics to work out. We think that's going to change, it has changed in Japan and Germany because

of large subsidies and to some degree in California because of subsidies again, but that's not necessarily a sustainable business model.

But as prices come down we do expect to see residential systems happening in a big way in multiple parts of the globe. A slightly more present tense use of batteries on the customer side is in commercial applications, where a business is dealing with high demand charges.

We're starting to see quite a bit of that happening in places like California and New York where electricity costs and demand charges tend to be very high and you use the batteries to mitigate your demand charges. So that's an emerging space with battery packs that is just starting to happen here in the U.S.

And then like I said on the grid side going back to that $1400 per kWh number, if you can use centralized balance of system components like your inverters or your rectifiers or your transformers or all of the power control equipment, you end up with a cheaper price point.

Additionally you put those batteries all together and you can do the thermal management more cheaply and you'll end up with a system that power engineers are comfortable with.

So once you get the batteries on the grid what do you do with them? We track more than 20 separate applications and we model them out to figure out what is the price points you need to get to, to reach a positive ROI?

Most of those applications today are not in the money. Most of the things that we think of like essentially solar backup or wind power backup or full on load shifting, where you're shifting 8 to 12 hours per day from night into the day, even peak shaving.

At today's prices we're at a point where you're not going to be making money if you build, if you buy batteries and operate that as a business, **but we're really close to that break-even point.**

And as the battery prices get lower we think that a lot of those applications move into the profitability stage and then you're going to have essentially **a new business model of operating a merchant energy storage system.**

Of those applications today I think right now the most mature and the most profitable is frequency regulation. PJM had changed their rules and allowed for energy storage to be more highly compensated in their auction mechanism for frequency regulation ancillary service.

And within two years there's - there will be **close to 200 megawatt's worth of batteries operating on PJM providing frequency regulation as a service and they're making money, those are profitable enterprises.**

And it was not done through a subsidy it was done through an alteration to the regulation but not in the form of a true subsidy. And they provide a service that traditional sources of frequency regulation cannot provide because of the speed at which batteries respond to the regulatory signal to regulate up or regulate down.

So they provide something that no one else in the past has been able to provide and it's a real market. There's a cap to that market, there's only so much frequency regulation that PJM or any other grid system needs. It's a relatively small market, but it's catered to by batteries that have entered into that space and shown to be competitive in that space.

And then just going back to those three numbers. At $180 per kilowatt-hour for the batteries that Tesla is paying for the Panasonic nickel cobalt aluminum Lithium-Ion batteries, that allows them to make an affordable luxury vehicle.

Those same batteries can be used on the grid, there's nothing that expressly separates what an

automotive battery does and what a grid battery does. There's lots of different duty cycles, lots of different applications for - in both spaces.

But in the end what's important is there's a price point -- a lowest price point that is -- as literally unimaginable a couple years ago and it makes sense that it should be getting that cheap.

Tesla buys more batteries than any other company in the world. They're the single largest buyer of battery cells. They have purchasing power that cannot be rivalled, so obviously they're getting a good price.

But let's say just for the sake of argument that the overall battery industry enters into that $150 to $250 per kilowatt-hour price range, which in my opinion I think is a reasonable thing to assume.

That enables batteries to be used for grid storage, it enables a multi-gigawatt hour production of batteries for grid storage. **We forecast by the year 2020 more than 20 gigawatt hours' worth of batteries will be being sold for grid storage applications**, which means it's an entirely new industry created from scratch - that didn't exist a few years ago and is going to be undergoing dramatic growth.

And you get to that $1400 per kWh cost of a large battery plant, a large centralized battery plant and suddenly you can do things that have never been done before.

A lot of people think you tie a battery to a solar panel and boom you've got a power plant, which is technically true but managing it at the central grid level makes it much more than that.

For instance, I'm aware of one project where the idea was to put a multi-gigawatt hour battery plant at a spot in a suburban location, where the local utility was looking for a natural gas peaker plant.

However, they knew it was going to be an enormous uphill climb to site that peaker plant because nobody wants to live next to a smoke stack. People are more than willing to live next to a warehouse full of batteries.

There are certainly safety issues around that obviously, but it's not **- it doesn't have the 'not in my backyard' [NIMBY[issues that a gas peaker does [a major benefit for dense, urban areas].**

I'm talking about a hypothetical concept that has not actually won the RFP but the whole point of this concept is that you're going to have this enormous warehouse full of batteries that's taking electricity from the grid, it's not taking electricity from wind turbines or solar panels but it's taking it from the grid. Essentially what it's doing is allowing combined cycle natural gas turbines that are producing most of the electricity for that particular grid to begin with, but they're going to be able to operate as peaker plants, as combustion turbines.

This means that a 58% efficiency power plant is going to be able to provide peaking power with the batteries, instead of a 38% efficiency combustion turbine. So right there you have enormous carbon savings, you have enormous fuel cost savings, you have all kind of pollution improvements, but that - it doesn't stop there.

If you can turn all of those combined cycle turbines out there into flexible peaker plants in addition to being base load plants, then you can allow much more renewable penetration onto that grid – without actually taking an electron from a renewable resource directly.

However, what you're doing essentially if you're able to match the - on a grid scale level these combined cycle turbines with large battery plants and be able to do it affordably and profitably and you're going to allow more wind power, more solar power and mitigate the risks that having high penetration levels of those renewables onto the grid that you normally have.

So I think I will stop my comments there.

Julien Dumoulin-Smith: Thank you very much Sam, I appreciate it. So let me step back for a second – the $180 number, is that the capital cost?

Sam Jaffe: Yes, I'm talking about the capital cost of the batteries. So when you buy a battery - it's a $1 per kilowatt-hour number - can get very confusing especially when talking to people in the utilities industry because they're thinking of a dollar per megawatt-hour energy prices - but in this case I'm talking about cap cost for the batteries.

Julien Dumoulin-Smith: Right, so and generically most of these batteries are being built for four hours is that typically what you see?

Sam Jaffe: For a peak shaving or peak shifting application, four hours is about what you want. There's going to be situations where it's two hours and there's going to be situations where it goes longer than that, but four hours is probably around the size of the energy duration that you're going to want for a peak shifting, peak shaving application.

Julien Dumoulin-Smith: Excellent. So let me just come back to that cost number that you were throwing out there, $1400 for a peaker plant equivalent. Where does that come from and ultimately what is that comprised of? Also, where did that number start from and where do you think that customer could go to - just to get a sense of the client and cost structure in the industry and where you think it will go?

Sam Jaffe: So let's say that you're a merchant energy storage company, you want to build a battery peaker plant and let's say it's going to be 100 megawatts and you want four hours on it. **So on a kilowatt basis you need four hours' worth of kilowatt of batteries - so four kilowatt hours. And if let's say that we're at the $250 per kilowatt-hour price point, that's $1000 a kilowatt.**

And then an extra $400 for the balance of system add on cost so that the inverter/rectifier, the various safety engineering equipment, the transformers and the power control equipment, which on a large scale like that, like 100 megawatt sized plant, it gets pretty cheap to do that.

If you're doing it on a 25 kilowatt residential energy battery pack, you're going to be paying a lot more than $400 a kilowatt, but that's the reason why a centralized power plant filled with batteries makes a little bit more economic sense than a building sited residential storage unit.

Julien Dumoulin-Smith: Where do you see costs going? I suppose specifically her, is Lithium-Ion that the technology solution to the future or do you see another technology taking the lead and ultimately where is that $1400 per kilowatt going trajectory wise?

Should we be assuming that over time everyone will be able to procure the 180 that you talked about before?

Sam Jaffe: Well, no I don't think everybody will. Even with Panasonic, sometimes when people ask for bids from them they're quoting bids at two to four times that price for small orders.

But the point is that if you're ordering 100 megawatts, you are in the Tesla territory in terms of your purchasing power.

So however you build those packs, whether it's a large centralized plant or a lot of little distributed packs, if you're ordering that many batteries you're going to get the tier one pricing, the best possible pricing.

So will that become the de facto standard pricing? I think that's where that third number I talked about - the $69 per kilowatt-hour - which is essentially the bill of materials going into these batteries, comes into the picture.

And we look at the materials in three tiers, one is raw materials, meaning literally ore coming out of the earth.

The second is, processed materials where you're turning those into useful chemicals, useful industrial chemicals. And the third is fully processed finalized chemicals, so for instance an NCA cathode powder that you buy by the barrel and put it into the batteries at the battery factory.

So I think one of the interesting things that have come out of the giga factory concept from Tesla is that, they're thinking buying their materials at that middle tier.

They don't want to buy rocks and turn that into batteries, but they're buying industrial chemicals at - and according to our numbers that's around $69 per kilowatt-hour, at current commodities pricing.

If you say that you're bill of materials is $69 for a kilowatt hour of batteries, the bill of materials to cost of goods sold ratio is actually pretty, very high. The battery manufacturing is relatively low cost, so usually, even today it's around 80 to 90%.

So to your bill of materials you're only adding 10 or 20% more to the cost of actually making the battery. So you're essentially close to that $100 per kilowatt-hour cost of manufacturing, if you can start at that middle tier of chemical inputs.

And that's where you get to that level of cost and whatever your end price is going to be, it's going to be somewhere near there dependent on mark up.

When we get to those levels of price points strange things start to happen - like grid storage, massive grid storage. Like electric vehicles starting to get very close in competitive price to combustion vehicles.

And it changes a lot of paradigms and a lot of the old thinking about batteries being very expensive and therefore there's not much that we can do with them, starts to not make sense anymore.

Julien Dumoulin-Smith: Right. So is this all about Lithium-Ion in your mind and is that where the technology is going to stay?

Sam Jaffe: So we do ten-year forecasts. And so **for the next ten years I do think that Lithium-Ion will continue to be the dominant chemistry**.

Like I said there's lots of other ideas out there that are very promising that are going to be important players in the grid storage business, like flow batteries, or like the battery from Ambri (Liquid Metals) for which they just released the paper on how they're doing it. Their bill of materials is around $60 for their new battery.

So there's a lot of different technologies out there. I think there are emerging next generation chemistries that we're going to start to see being mass-produced probably at the very end of this coming ten-year period.

Things like Lithium sulphur batteries, things like Magnesium-Ion batteries that are in the research laboratory today, problems are being solved but we expect those to be important chemistries also.

But nevertheless, over the course of the next ten years we do expect this to be a Lithium-Ion world.

Julien Dumoulin-Smith: Absolutely, thanks. From a cost perspective, just to close the loop here, you're talking about $100 per kilowatt-hour for manufacturing; you're talking about the latest deal at $180 - how soon is it do you think before we see, the 180 decline to 100 and wide scale procurement at really low prices like this?

Sam Jaffe: That's going to take a while. I don't want to harp on Tesla too much but they said in the last earnings call that they believe that the $100 per kilowatt-hour battery will be a reality sometime in the next ten years.

Maybe for their particular model that might make sense but I'm not sure if I would agree with that throughout the world for any buyer. That said, **it doesn't really have to get to that price point to have a very disruptive impact in transportation and on the grid.**

Let's say in three to five years we may get to a $200-$250 per kilowatt-hour as the average selling price for these high quality, long-lasting batteries. That's good enough for a lot of these applications.

Julien Dumoulin-Smith: Well let me ask you this - what is your expectation for penetration on a merchant basis in PJM and by various markets nationally / or even by use, as you look forward using your costs assumptions?

Sam Jaffe: **Globally I can tell you we're expecting that the grid storage market is going to be above 20 gigawatt-hours by 2020 and that's coming off of last year's number which was around 200 megawatt-hours. So, that's quite a significant change in scale.**

Those batteries are going to be in residential units, commercial units, they're going to be in substations and small packs – but they're also going to be in the centralized tinker plant type situations too. I would say that the majority of them, because of their sheer size, will be at large centralized plants.

Julien Dumoulin-Smith: Right. So from your perspective what source do you see the batteries coming from primarily? I mean is it for the time being going to be mostly this PJM style frequency regulation that drives the growth or is it going to be more oriented towards residential given the higher, fully loaded cost of electricity and the higher voided cost that you see there? In essence, where do you see the penetration happening in the U.S.?

Sam Jaffe: **So in the U.S. I think California will be leading the way and that's because of the state law AB2514,** which actually mandates the large investor on utilities to purchase a certain amount of energy storage. **All together that's going to be 1.3 gigawatts of storage.** They didn't specific the number of gigawatt hours, so we don't know how that's going to play out, but it's a pretty significant number.

However that doesn't mean all the batteries are going to go to California. We see the significance of AB2514 in

that it is regulatory involvement in energy storage in a real way for the very first time.

Nobody has ever mandated that utilities purchase energy storage systems before and that's significant and symbolic. But I think what's to get to those tens of gigawatt hours' worth of batteries sold for grid storage what's important is that the economics work out.

And then forget about subsidies, forget about regulators, forget about the state laws. You end up with a sustainable business model where people will be buying these batteries because it makes economic sense to do that instead of building a new peaker plant, a new natural gas turbine or whatever the other options are.

Julien Dumoulin-Smith: Right, but you don't see that - I mean when do you see us getting there though?

Sam Jaffe: **I think that it will be happening in the latter half of this coming ten-year period,** maybe it's going to start happening in the next two years. So, you're going to see announcements being made in the next two years and I can't go into specific details but I know of several initiatives where people are planning merchant batteries in the market, for peaker type application.

Julien Dumoulin-Smith: Right, and for California, would it be a good expectation that it will continue to be at that $1500 or $1400 a kilowatt-hour or kilowatt range to build?

Sam Jaffe: Yes, for very large-scale systems because the economies of scale of the balance of system, that's when you get into that level of pricing for that. For behind the meter small battery packs it's going to be a lot more expensive than that.

Julien Dumoulin-Smith: What do you assume for residential systems?

Sam Jaffe: **Residential homeowners** buying battery packs to pair with their Photovoltaichis today, are doing it out of a sense of environmental responsibility – they **are paying as much as $2500 a kilowatt for that.**

So the comparison is between to spending $25,000 to buy a battery pack for your home or instead going to Home Depot and buying a little Honda generator for

about $700. In the end you get yourself the same functionality.

Julien Dumoulin-Smith: Right, so to summarize: **the bid and ask is**: **$2500 for residential per kilowatt, whereas large scale systems gets down as cheap as $1400** in your mind for the time being?

Sam Jaffe: Yes.

Julien Dumoulin-Smith: Got it, and then in terms of resource limitations that seems like a big focus. Is there adequate Lithium, especially to the extent to which that you're focused here on more Lithium-Ion technologies?

Sam Jaffe: Yes, so I've been doing a lot of work around that and around sizing each of those various material inputs. And surprisingly Lithium my level of concern about **Lithium** assets is much lower than it was before I started this project.

Lithium is mined out of salt lakes in South America and Asia, which is the cheapest way of extracting it. But there's also a lot of mineral Lithium throughout the world that's never been mined and processed before because it's so much more expensive than getting it out of the saline lakes. But you reach a little bit higher price point and you're able to do that.

And for the first time we have a very large mineral Lithium mine in Australia that is operational now and that can be repeated on every continent and the resource limitations of lithium are not nearly as dire as you would assume if you're just thinking of the saline lakes.

There are other material inputs that are worrisome if we hit these very large production numbers. **Cobalt** is by far the most important one, most of it is coming from Africa and much of that is coming from conflict zones and that's a problem and there aren't that many places that you can find cobalt.

So that is a concern, there are lots of Lithium chemistries that don't use cobalt but then you are impacting your sub-chemistry choice based on material availability.

Graphite is also a concern. Graphite can be synthesized from any carbon source but that's very expensive to do, it's easier to mine it where you have raw graphite deposits. It's very similar to coal although it's just pure carbon, there's no energy content to it. And there's spots, especially in China where they're mining it and that's where most of the graphite is coming from for the battery industry today.

That has to be expanded dramatically in North America, in Africa, in Europe and there are spots where people are planning to extract graphite but, anybody who has ever been involved with commodities knows that there's a big difference between planning a mine and opening up a mine, so, there's concern there too.

Julien Dumoulin-Smith: All right, excellent. Well I think maybe before we turn it over the audience, last question: How do you think about batteries relative to other technologies?

There is a lot of talk out there about compressed air energy storage especially in California. Obviously the legacy of pump hydro technologies, how do those stack up in your mind?

Sam Jaffe: The problem with it is that it's nearly impossible in the developed world to site a new pump hydro plant because you essentially have to site two bodies of water, one above the other.

Any seismic activity you don't want to put it there - being near population they're going to object to having it near them.

The other limitation to pumped hydro is it's not great at efficiency; you have a **round trip of efficiency often below 75%. So you're losing 25% of the electricity in the process of storing it, whereas Lithium-Ion**

batteries just as an example can be above 90% efficiency, round trip efficiency.

Compressed air energy storage is usually paired with the burning of natural gas, so from an environmental advantage viewpoint, you lose a lot of your political support for that.

You're also very low efficiencies when you look at it from a round trip efficiency perspective. And that's why we've only had two of them built in the last 30 years.

Now there was a big announcement a couple of days ago about the project in Utah that really has a chance to change the compressed air energy storage story dramatically, very interesting project.

Massive wind farms compared with a very large compressed air plant and sending a steady load out to California. A really interesting project and if it happens that story starts to change too.

There are other technologies, flywheels have a place in the sun in this space. They do make sense in certain applications and they are happening to some degree and there's lots of other crazy ideas out there that might actually turn out to not so crazy either.

Q&A:

(Question): Thanks very much and thanks to your gentlemen for taking the time to do the call. I was hoping to follow-up on that last question and actually ask specifically about ultra-capacitors and whether or not they have a place in energy storage over this ten-year time period or if it's more of a transportation solution?

Sam Jaffe: Ultra capacitors are capable of massive power output and input for that matter and they can last literally millions of cycles because you're storing the electricity not in the form of an electro chemical conversion but in the form of an actual electric field.

So there's very little wear and tear on the inner parts of the device. I do think there is a place for ultra-capacitors on the grid, I think that a lot of hybrid systems of ultra-capacitors paired with other energy storage devices.

Take a lot of the extreme swings and the very tips of the peaks and the very troughs of the valleys, ultra capacitors handle that and you can treat your batteries or compressed air or whatever the other system is much more gently and they're going to last longer.

So yes I think that's going to be the primary application. Ultra capacitors obviously are going to be great at frequency regulation and there will be a space there for them.

Of course they are now very expensive and we do believe that those prices are coming down. When you do it on a cost per cycle perspective rather than just the overall capital cost you get to value it very differently of course.

However, even when doing that **ultra-capacitors are still out of the ballpark today for most grid applications**. **But I stress that an ultra-capacitor is not a battery - they're doing different things and they're probably going to go towards applications that are different.**

You would never choose between an ultra-cap and a battery for a specific application probably, but nevertheless at the same that we've seen this massive growth of the Lithium-Ion industry we also have pretty aggressive forecasts for ultra-caps - we see it turning into a multi-billion dollar industry in the course of the coming ten years.

(Question): Thank you very much. At the end of the life of these Lithium-Ion batteries what are the disposal issues associated with them and can they be recycled?

Sam Jaffe: They're not being recycled today and the reason why is it's so hard to re-compose the input materials. So for consumer electronic batteries, which are usually Lithium cobalt oxide batteries, those are being recycled but not for the Lithium, they're being recycled for the cobalt.

You can essentially melt the cobalt down and pull it out and resell that.

But **you can't pull out the Lithium carbonate and resell that under the current technologies**. **Going forward I think that that will change and that there will be true recycling being done with these** - with the batteries being used in the grid and in transportation, but right now it's not being done.

In terms of the safety issues of Lithium-Ion disposal, they are definitely much easier to handle and less toxic than lead acid or nickel cadmium batteries.

Nevertheless they are usually lumped in those categories. So if you declare a battery pack dead you now have to treat those batteries as hazardous waste, with all the costs of disposing of them.

So, that is an issue going forward and I've heard from many of the various agencies involved in those regulations, they're all looking at the growth of the Lithium-Ion industry and figuring that we need to readjust how we approach this industry.

As changes in regulations tend to work, it happens very slowly over time. But it is going to be an issue I think and it's an extra cost to the battery that's different when if you are decommissioning a traditional power plant it's, pretty much just sell the scrap metal. If you're decommissioning a battery plant it's a different story and costs are going to be higher therefore.

(Question): This week Southern California Edison unveiled a large Lithium-Ion project from LG Chem's technology, that's eight megawatts by four hours.

And they listed a cost of $53 million for the project, which when I do the simple math there's about $6700 a kilowatt or 1670 per kilowatt hour, and that's roughly five times higher than the numbers that you're talking about.

Granted this is 1/10 the size of the 100 megawatts theoretical project you talk about, but I'm wondering if the scale is so far off to justify a 5X cost difference - how do you think about those things or reconcile the cost to clients that are leading to your 20 gigawatt or 20 gigawatt hour whatever it was, manual installation by 2020, thank you.

Sam Jaffe: Yes, thank you. So the cost numbers are explained by the fact this was a project that was part of the stimulus package. So that was essentially commissioned in 2010 I believe and it was priced at that point, and they had a number of issues that caused it to draw out pretty long, which is why they just unveiled it or they just initiated operations this past week.

So you're really talking about 2010 pricing. If you were to ask for bids tomorrow for those same batteries, I think it would be in about 1/3 that price.

For large projects like that you're probably talking on a cell basis somewhere between 500 and $700 per kilowatt-hour from the major battery manufacturers.

This $200 per kilowatt-hour number that I'm referring to is hypothetical. I'm saying I think it according to my research it makes sense that the price point will hit that price level in the next two to three years.

When I started talking about the pricing I mentioned, you go back five years and Lithium-Ion pricing was incredibly expensive and not just for grid storage and automotive and the new applications, but for consumer electronics too.

We're in a different era now. Whether I'm right about the $200 number or whether it stays at $500 – either way, we are in a different era.

I should mention also, having talked about the inefficiency issues of compressed air energy storage earlier - General Compression and a number of other companies are trying to solve those efficiency problems. So when I talk about the efficiency issues of compressed air energy storage it does not necessarily apply to these isothermal or adiabatic concepts of what you're developing and a few of your competitors are developing.

(Question): Great, actually can I follow up on that - if you were to price it today you'd get sales a price of 500 to $700 a kilowatt-hour, did I hear you right?

Sam Jaffe: Correct.

(Question): And you're saying that you expect prices to fall to $200 a kilowatt-hour for the same RFP in a two to three-year period?

Sam Jaffe: Correct.

(Question): … and that is really just from a scaling up of the industry both from a supply perspective and from a demand given California etc?

Sam Jaffe: Yes - on the supply side I think there's three separate factors. One is, just pure scale, manufacturing scale they're building big factories and the Tesla Gigafactory is of course the ultimate example of that. Until now the biggest a battery factory got was it would produce about a gigawatt-hour worth of batteries in a year. And the Gigafactory they're talking about a factory that's going to produce 35 gigawatt hours' worth of batteries each year. So scale obviously is important, but it's not just scale.

There's also a learning curve in the manufacturing process that's very important - it's combinatorial chemistry - they're baking a very complicated cake when they make a battery and it takes a long time to learn how to do that right and to experiment and fail or incrementally improve over time.

And that's one of the most important aspects to the manufacturing process that has really changed in the last few years, since they've been playing with it for a couple decades they know how to do it now -- and by *they* -- I mean the large Asian manufacturers.

And then the third part has to do with the supply chain in the sense that even five years ago a lot of the chemical inputs into these batteries would be considered specialty chemicals – many still are. They were batch processed, and they were sold by the kilogram and that's changed too. And you go to Shenzhen area in China where a lot of the battery factories are, you see an enormous battery factory, but next to that you see an enormous CASO

powder factory, next to that you see an enormous separator factory.

There's this enormous low friction supply chain that didn't exist a few years ago that's an important part in manufacturing cost reduction.

(Question): Let me ask you this real quickly - what is the life span of one of these batteries just from an hour's perspective and what do you think the levelized cost is, just to clarify?

Sam Jaffe: In terms of the life span, **for a lot of these emerging grid applications the battery manufacturers are offering eight or ten year warranty's** for some of these duty cycles that we've discussed. Whether those warranty's work or not we'll see, we don't know yet because nobody has been operating a grid scale battery for more than ten years yet.

They're basing this off of accelerated testing, which has its faults. **But I think that's a good way to think about it as an asset is probably a ten-year asset.**

If they can turn it into a 20-year asset, that becomes a completely different economic issue but let's assume that they can't, that they're going to do daily cycling at high and low charge levels so it's deep cycling on a daily basis for ten years and they're capable of doing that.

But I think one of the best way of looking at it from a financial perspective is saying that the cost of the battery is the life - the ten-year cost of fuel for that plant. If you start thinking of the battery as the fuel, then you're talking about fuel prices and that battery is slowly degrading itself over the course of that ten years and when it's done it's done - think of it as a consumable.

And you see **if you think of it that way then the battery becomes much more attractive as an investment for the power plant owner than buying natural gas at today's prices for fuel for a power plant.**

Julien Dumoulin-Smith: Got you, all right excellent. Well I think it being a little bit past the top of the hour I think we should probably leave it there but it certainly leaves a lot on the mind after this conversation.

So, Sam thank you very much for taking the time with us this afternoon.

Sam Jaffe: Thank you.

END

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