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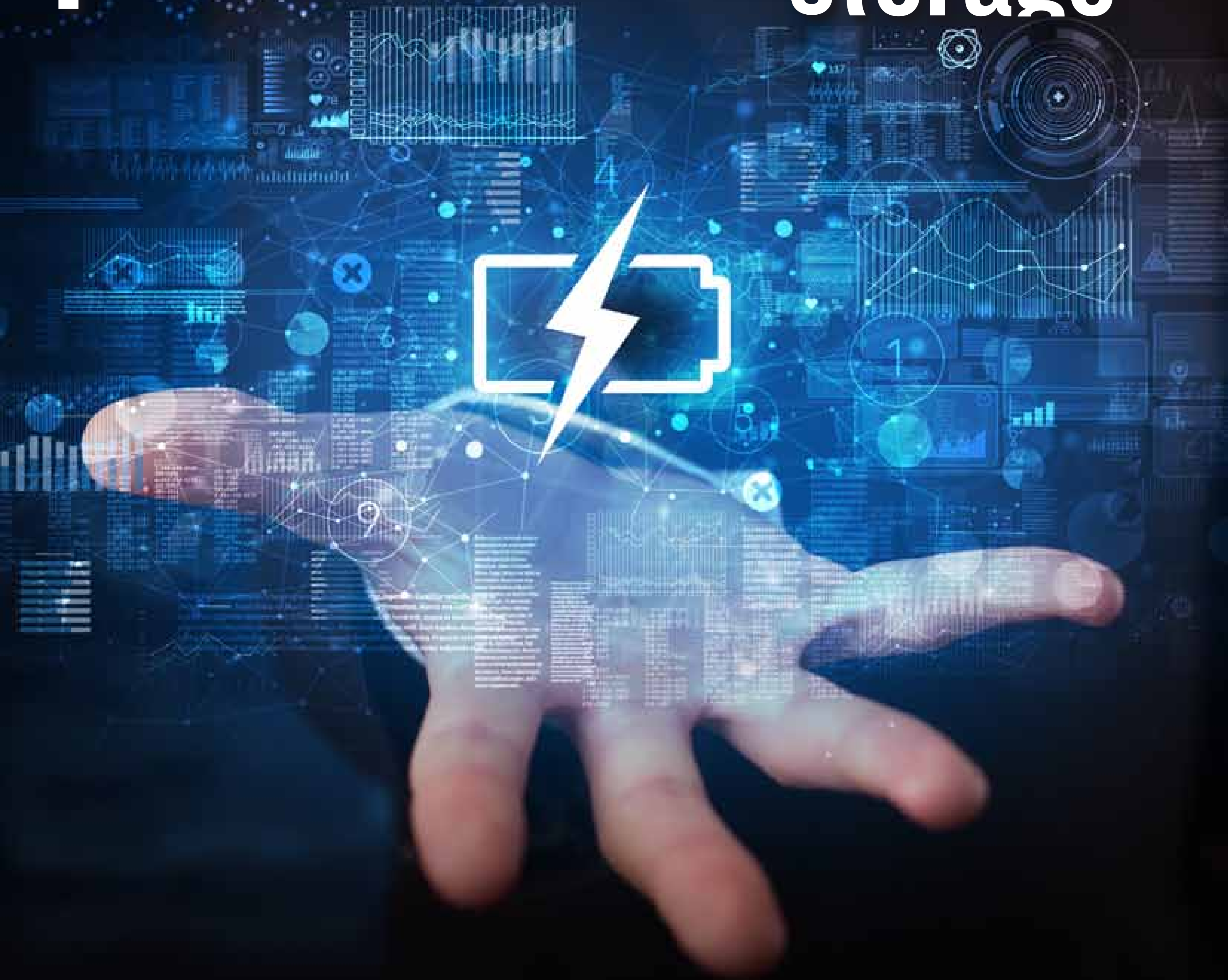


Germany and California's strategic energy partnership

Meet the global leaders of the energy transition

pp. 6 – 9

Storage is bulking up against coal

Energy storage's role is set out to act more equally in generation

pp. 10 – 13

Special edition in collaboration with

ENERGY STORAGE NORTH AMERICA

Conference and Exhibition

Making the future, together.

It's a tremendously exciting time for the energy storage industry. Not only is the U.S. market growing by leaps and bounds, but we are only at the beginning of the historic task to transform the electric grid into one that is cleaner, smarter, more reliable – and even less expensive.

But to get to where we need to go, energy storage itself will need to transform. There is a constant need to innovate at all levels, from technology to business models, to meet the evolving needs of the grid and the demands of increasingly sophisticated customers.

And when we look at what makes this all possible, it's not about any single innovation, company or other actor. It's about working together, the way that the components of an energy storage system – hardware and software – work together.

These are the two themes of this special edition of **pv magazine**, produced for the Energy Storage North America (ESNA) conference and exhibition: collaboration and innovation. This includes the historic collaboration between Germany and California, which is mirrored in the relationship between the California Energy Storage Association and Messe Dusseldorf, who jointly produce the ESNA show.

Photo: pv magazine

In this issue we look at the role that energy storage is playing to help make more resilient communities in the Caribbean (Rebuilding for resilience, pp. 14-15), while also exploring the many drivers of the explosive growth in the U.S. energy storage market (Bulking up, pp. 10-13). But we also examine the ecosystems that help to support innovation in energy storage, including insights from cleantech legend Danny Kennedy of New Energy Nexus (Ecosystems of innovation, pp. 3-5).

And of course, we review specific technical innovations, including Nexceris' solution for lithium-ion battery fire prevention (Taming the Li-ion, p. 18), Pxise's Distributed Energy Resources Management System (Operating the future grid, today, p. 19) and Fluence's work with wireless solutions (One gigawatt down…, p. 20), along with reviews of products and services from Blue Solutions, Viking Cold, Energy Toolbase, ESS and more (pp. 22-23).

And it has been a great honor to speak with the leading individuals whose collaboration on policy and innovation are making the vision of this new clean energy economy come to reality – California Energy Commission Chair David Hochschild (pp. 6-7) and German State Secretary in the Ministry of Economics and Energy Andreas Feicht (pp. 8-9).

Thank you for reading. We look forward to seeing you at ESNA, and to working with you toward our common future.

Christian Roselund
U.S. Editor


Photo: Greensmith Energy


Photo: California Energy Commission


312
311
Photo: AES Energy

The ecosystems of innovation

Energy storage is a sector marked by continuous technological development – and given the challenges created by our rapidly transforming energy systems, it needs to be. But how do innovations move from idea to reality? Specifically, what kind of environments are needed to nurture new technologies and approaches, and how do they interact with existing supports?

There are few myths as enduring in American culture as the Great Man Theory, the idea that history is shaped primarily by exceptional individuals who rise, creating themselves like the ancient Egyptian sun god Ra out of primordial chaos, independent of social circumstances, family, collaborators, education, mentorship or overall context.

And there are few places where this fantasy is as prevalent as the worlds of technology and energy. If we haven't actively participated in perpetuating the cult of Steve Jobs, the legend of Nikolai Tesla, and of course Elon Musk idolatry, then we've at least witnessed these.

But as much as we may all fall prey to this delusion from time to time, there is growing awareness of the need for concrete supports to drive the level of innovation that will be necessary to guide the rapid transformation of the global energy space.

This increased attention to the role that support plays in innovation – and the importance of innovation to economies – has led to a proliferation of incubators, accelerators, and even game-show-like contests as cities, states and nations race to see who can host the next Silicon Valley.

But what does it all result in? And for innovation to succeed – particularly in the critical fields that are driving the global energy transition – what kinds of support mechanisms are actually needed?

Different places, different needs

To answer some of these questions, **pv magazine** spoke with activist, entrepreneur and innovation mogul Danny Kennedy. Kennedy serves as the chief energy officer at New Energy Nexus (NEN), an organization headquartered in Oakland, California, that supports clean energy entrepreneurs from California to Southeast Asia and East Africa.

New Energy Nexus provides a wide range of services, including everything from arranging co-working spaces to offering funding and providing legal help. Kennedy notes that the kinds of support needed are usually determined by multiple factors. These factors include the stage of the business, with a defining feature being whether or not it has developed a prototype. At a more granular level, the stage of new products can be conceptualized using the Technology Readiness Level (TRL) scale, which was developed by NASA in the 1970s.

The U.S. government provides support for both basic research as well as early-

Photo: Voltaiq

A battery storage startup event at Voltaiq, a battery analytics software company

> *"The magic is actually in the creative collisions, and that peer-to-peer learning"*

stage technology development, with an emphasis on the lower TRL levels. This includes programs to support the development of energy technologies through the U.S. Department of Energy and the Advanced Research Projects Agency – Energy (ARPA-E).

But this is certainly not the case everywhere. And with work spanning the globe, one of the things that Kennedy stresses is that the needs of entrepreneurs are very different depending not only on the business stage, but on geography. NEN is actively working with entrepreneurs in Uganda and Indonesia, and Kennedy notes that existing supports are very different there.

> *"The energy transition of today is being advanced by challenging the energy structures of yesterday"*

"In those markets, there is almost nothing to support them," explains Kennedy. "There is no R&D budget, there is no Department of Energy, there are no national labs and innovation systems and grant programs. That's the big gap and where we are really trying to fill in that need is to try to build out the incubator and accelerator network globally, and also trying to synergize it."

He notes that despite these challenges, innovators in those nations are trying to "leapfrog" to distributed energy systems for massive populations "that want and deserve modern electricity and mobility systems."

Hard and soft supports

Even for industrialized nations, where a variety of actors fund research and development – including governments, universities and corporations – there are still ample needs. And much of the support that Kennedy and his network provide to entrepreneurs – whether in Jakarta or Oakland, California – is concrete: connections to funding, technical assistance, legal help and space to work in.

Kennedy notes that it is particularly important to support innovators in the areas where they do not have expertise. "When you think about the innovators, they are often engineering teams, whether that is hardware or software," explains Kennedy. "They have no clue about term sheets, lawyering, intellectual property, and all that stuff. You don't want them at the stage of pre-prototype devices to be spending tens of thousands of dollars of their own capital on legal counsel, but you want legal advice for them to be safe and not do anything stupid."

Also, such teams may need support in communicating their ideas – including to the people who will ultimately be paying for them. "How does a young team of brainiacs who have invented a better mousetrap relate to the procurements people inside General Electric or Exelon?" asks Kennedy.

California innovation

While New Energy Nexus has supported a number of incubators and accelerators around the world, one of the programs that it has helped to fund operates less than a day's drive south of the Bay Area – Southern California Energy Innovation Network (SCEIN), which is managed by incubator Cleantech San Diego and operates three other incubators throughout southern California.

SCEIN was initiated by a $5 million, five-year grant from the California Energy Commission (CEC). The agency saw a need to fund innovation in the context of the state's ambitious clean energy mandate, and that's what it will take to get to very high portions of renewable energy on the grid.

"CEC realized that business-as-usual was not going to work, and that we needed to come up with an out-of-the-box approach," explains Alyssa Gutner-Davis, the program manager for Cleantech San Diego.

SCEIN works with companies in the concept stage to early commercialization, including the critical step of customer discovery. It provides a wide range of services, including research and testing, market intelligence, and of course introductions to investors.

Along the way the initiative has attracted funding through the CalSEED program, which has made $25 million available for companies in round A and B grants. But that is just the beginning.

In the three years that SCEIN has

Aquacycl has developed the only modular and scalable sanitation technology capable of producing direct electricity (no methane) and recycled water from wastewater and sludge. The system generates a 50-80% reduction in overall operating costs for industrial and agricultural customers. CEO Orianna Bretschger took home the grand prize from the San Diego Angel Conference in March 2019.

Photo: Cleantech San Diego

been operating, companies that have gone through the program have raised $43 million in private capital and $5.7 million in public capital, as well as filing 193 patents.

The program's graduates include some real success stories, including EV infrastructure company eMotorWerks, which was acquired by Italian energy giant Enel in 2017.

The social aspect

SCEIN is quite well connected and the initiative's technical advisory committee includes experts from some of the top companies in the global energy transition. These include DNV GL, Enel Green Power and Engie, as well as law firm Stoel Rives, and even utilities SDG&E and SCE.

As part of the program, startups also receive mentorship. This helps them to assess how program service delivery is going, so they can keep track of progress. Kennedy says that creating a space for all these kinds of different interactions provides a great deal of value unto itself.

"One of the secrets to our success as an organization is just bringing people together," he observes.

"As crazy as that sounds, I think human or social capital is more valuable than the financial capital. The magic is actually in the creative collisions, and that peer-to-peer learning."

He also notes that given what they are up against, these energy startups can use all of the help they can get.

"The difference between a startup in clean energy, building out smart grids or better sensor technology, or AI for electricity management or mobility services – [is that] they are up against huge vested interest companies that are basically dug in and trying to protect themselves from change."

The global energy transition of today is being advanced by challenging the energy structures of yesterday. Overriding systems requires the continuous nurturing of innovation, and the networks that support innovation play a critical role in developing the smart technologies of tomorrow.

Christian Roselund

Photo: Cleantech San Diego

Nuvve, a startup under the Southern California Energy Innovation Network, has a vehicle-to-grid software platform that enables any EV battery to generate, store and sell unused energy back to the electric grid in a bidirectional manner. UC San Diego, in partnership with Nuvve, was awarded a $4 million grant from the California Energy Commission to demonstrate the benefits of advanced vehicle-grid integration applications for electric vehicles.

Driving the global energy transition

California has long been a shining global example for a clean energy economy. The state continues to implement aggressive long-term policies that support both industry and strategic decarbonization efforts – and the impacts are boosting market advancements around the world. In a collaborative effort to drive international climate action, the California Energy Commission (CEC) office initiated the Under2 MOU with the German government. Today, the Under2 Coalition has grown into an alliance of more than 200 governments, representing 43% of the global economy. Former solar executive and California Energy Commission Chair David Hochschild spoke with pv magazine about California's long-term relationship with Germany and the state's blended focus on energy policy, technology and the economy to achieve 100% renewable energy.

Photos: California Energy Commission

David Hochschild, Chair of the California Energy Commission

California and Germany are taking a joint leadership role in the energy transition. Can you speak more about the history of the partnership and how the two governments are working together?

It's been one of the most important partnerships with regard to the growth of renewable energy that we have seen. Germany played a critical role in scaling up the solar industry at a time when it was really needed, building the foundation in the very early stages for the work that California has done. This was a continual process where California watched Germany bring the costs down and take solar to scale, and then that inspired greater action and policy in California. Today, we have one million solar rooftops in California with a very strong solar industry. Germany's role in the development of the industry and the benefits it has brought to California have been significant.

It has been a meaningful relationship, and we want to continue to challenge each other to do better. We had a meeting last week with some members of the German Parliament, and I shared with them what we are doing in California with our move toward a 100% clean electricity future – both the opportunities and challenges around achieving a zero-carbon economy by 2045. The folks in Germany involved in power-to-gas are coming out to California to support. We engage across all clean energy technologies and policy opportunities and will continue to learn from one another.

The CA-Germany Bilateral Energy Conference is now going on its third year. In 2019, what are the goals of this collaboration?

As we move beyond fossil fuels in the electric grid one of the biggest challenges is flexibility and meeting the ramping down of solar in the afternoon. We are looking to storage, EV charging protocols, demand response, and all of the intelligent software and devices that we can employ to ensure continued reliability of the electric grid as we decarbonize. This is the central limitation challenge. There are many German technologies, and companies like Siemens and others, that are playing a role to meet this challenge. There is great opportunity for us to increase collaboration here, and within industries.

What type of advancements from Germany are supporting California?

One of the things that I am really heartened by in Germany is the movement of the big automakers toward electric vehicles. This is a much-needed step forward. Germany was the origin of the diesel engine, and the announcement earlier this year of the new direction that VW, Audi and others are headed is very positive. The more electric vehicles we have, the more useful opportunities to support the grid – to have charging protocols which support the grid.

The California Climate Strategy aims for a 50% reduction in petroleum use in vehicles. What role do electric vehicles and storage technologies play in this?

Electric vehicles are the future of transportation. There are roughly 140 new models planned for release into the market over the next three years. We are seeing incredible progress made on the range and diversity of the vehicles. For example, the Ford F150 truck, which is probably the most popular truck in the United States, is going electric starting next year. And VW is coming out with its new famous euro van, which will be electric. Long-range vehicles with more than a 200-mile range are coming out and being met with great enthusiasm.

Today, we are at 650,000 electric vehicles on the road in California. We are adding about 20,000 a month, and we are doing a lot to encourage that – with an incentive payment, carpool stickers, and other encouragements – plus a federal tax credit. Currently, it's about half the cost per mile to drive an electric vehicle in the U.S. when compared to an internal combustion engine car. We are doing a lot in the state to promote all of this.

Looking ahead, it is important to look at the big trends with storage. Battery pricing, which is about half the cost of an electric vehicle, is coming down. At the same time, energy density is increasing. In a few years we will increase to the 300-mile range, and then eventually a 400-mile range, with the same battery form factor of today. This is a great reason for optimism, and we are aggressively building out EV charging infrastructure all over the state.

From left to right: California Energy Commission staff member Mark Koostra on a tour of the Shiloh II wind farm, with CEC Chair David Hochschild, staff member Jim Bartridge, former CEC Deputy Director of Energy Efficiency Dave Ashuckian, and Virinder Singh of EDF

California has been a leading global example of growing a cleantech sector while stimulating its economy. How can other states and governments best support a thriving clean energy industry through policy?

The single most important thing that can be done is to provide stable, long-term policies. It is crucial to get away from the short-term, stop-start approach, which doesn't create the certainty that industries need to scale up.

If you look at programs that were successful in scaling – the solar industry, for example, our largest renewable energy industry was built in California by a 10-year, $3 billion incentive program. It had certainty, and a very well-designed feature where incentives dropped each year gradually down to zero, in an orderly and transparent way. It was not interrupted by policy changes or revisiting budgets, as it was already locked in. That was incredibly successful, and this is why we have almost 20 GW of installed solar around the state.

Germany, with its feed-in tariff – while a different policy design – is similar in the sense that it was long term with a fair amount of certainty. If there is one lesson, it is to create a stable, long-term policy environment. When you do that right, you can move mountains. It doesn't have to be a permanent policy – you can put it in place for a period of time to bring costs down – and then it becomes competitive on its own. This is what we have seen with solar and wind, and now we need to do the same thing for electric vehicles and other new technologies.

> *"It is crucial to get away from the short-term, stop-start approach, which doesn't create the certainty that industries need to scale up"*

With the recent ambitious goal set to achieve 100% renewables by 2045, what role will energy storage play in this transition?

Storage will play a very important role. We have a state target to get to 1.3 GW of energy storage by 2020. We see the storage industry as the new emerging clean energy sector, which will continue to come down in costs. Storage costs have declined 40% since 2015 – and closer to 90% in cost reductions since 2010. It's on a good path and I think it can come down a lot more. Storage is one of many solutions, but it is not the only solution for flexibility. We do a lot to manipulate electric demand as well. We believe in storage and have developed incentives and targets to help encourage its growth.

California invests heavily in R&D. What is the level of investment it is making in storage technologies, and are there particular allocations to certain types of storage?

We invest about $150 million per year in research and development funding for the smart energy sector. We created an $800 million incentive program to encourage storage last year, the Self Generation Incentive Program, and put tens of millions into R&D. We have funded almost 40 energy storage demonstration projects around the state, which includes virtually every top chemistry that's available – from vanadium to iron-chromium and flow batteries to lithium-ion. We believe in a portfolio approach to provide each technology the opportunity to show its value, understanding that not every one of these technologies is going to prevail.

Interview by Erica Johnson

Energy without borders

Germany has long been a global leader in driving acceptance of clean technologies through its progressive energy policies and regulations. Its influence in addressing climate change extends well beyond its borders, and the country is taking an active role to support the global energy transition through international cooperation. The Federal Ministry for Economic Affairs and Energy is involved in relevant multilateral organizations and initiatives such as IRENA, IEA, REN 21, the G7, and the G20. Germany also has bilateral energy partnerships with approximately 20 countries, including the United States, Russia, China, India, Japan, Australia, Brasil, South Africa and Morocco. Its strong partnership with California is focused on creating a route to the future – a carbon-neutral one. State Secretary at the Federal Ministry for Economic Affairs and Energy Andreas Feicht met with pv magazine to discuss the country's partnership with California, and its journey toward decarbonization.

Photo: BMWi

Andreas Feicht, state secretary of the German Federal Ministry of Economics and Energy

Germany and California are global leaders in driving the energy transition, with governing bodies from both sides working together on energy issues. Can you tell us the background and history of this collaboration?

California and Germany have been working together successfully for many years. We are pleased that the Germany-California Bilateral Energy Conference, which we are hosting together with the California Energy Commission for the third time, has further intensified the exchange with California. After Sacramento and San Francisco, the conference will take place in San Diego this year. The political exchange about the necessary next steps and the exchanges with business about new technologies is vital for both partners.

What are the immediate goals and objectives of the Germany-California Bilateral Energy Conference? How do you see this progressing in the future?

For decades, California has played a pioneering role in climate and energy policy. Many other U.S. states and countries have adopted Californian regulations, not least because California is a good example that environmental protection and economic development are not mutually exclusive. Therefore, an exchange of best practices with the people that drive the energy transition in California is most helpful. We will, for example, discuss the most efficient flexibility options for the power sector and the role of storage, ways to accelerate the transition in the transport sector, and how to better incentivize efficiency.

What are the policies and regulations that will be most effective in pushing Germany toward decarbonization?

There are various measures, of course. The establishment and support of renewables has been done through the feed-in-tariffs to bring in onshore and offshore wind power, biomass and PV. And for the last two years, this has been spurred by auctions, which has worked well to ensure that we receive the lowest possible costs. Ten years ago, costs for PV were €0.15 to €0.18 per kWh. And now, for rooftop we are around €0.10, and our large-scale projects are €0.50 to €0.60 per kWh. Policy drives the amount of capacity that we are looking to install each year.

Grid expansion is another key measure to the energy transition. Wind onshore, is installed mostly in the north and east of Germany, and with offshore at sea, but the highest demand for energy is in the south and west of Germany. This is of course a big undertaking to cross the whole country.

But it's even more than that. It is also heating, CHP – which we have to approve. In all different parts of the energy system, we have to give frameworks for regulation, and to step out of old technologies. We will step away from all nuclear by 2022 completely. And now, we are designing a regulation to phase out of coal. Germany has a large share of coal in our energy mix.

Yes, Germany recently announced bold plans to phase out coal by 2038, which will revolutionize its energy infrastructure. What are the next steps forward on this journey and what are the implications and challenges you face?

We are looking at an auction system to motivate people to shut down their hard-coal-fired power plants. With regard to lignite-based power plants, we are currently negotiating the terms for the shutdown of the plants. The negotiations are quite complicated because the lignite-based power plants are very important to the economies in the regions in which they are situated. The discussion is not only about energy, but also about creating viable social and economic structures for the workers, people, regions and local governments that are affected.

Germany has an aggressive goal to reduce greenhouse-gas emissions by at least 55% from 1990 levels by 2030. Where does the country currently stand?

Well, we have to differentiate between the sectors. In the energy sector, we will achieve our 2020 goals. If everything takes place that we have laid out – such as phasing out coal, establishing more renewables, bringing more gas into the system, such as CHP – then we will achieve our goals by 2030 in the energy sector.

In the heating sector, we are not there yet and will not achieve our 2020 goals. And if we don't establish additional measures, we also will not achieve our 2030 goals. The same goes for the mobility sector. We will achieve it in the industrial sector, but not in mobility, and not in heating.

This is why Chancellor Merkel has established the Climate Cabinet – to identify additional measures to achieve the ambitious greenhouse-gas reduction goals over the next decade. CO_2 pricing could be one of the essential, and crucial, instruments to achieve our greenhouse-gas reduction goals.

With a world class automotive industry, the transport sector is responsible for approximately 20% of Germany's CO_2 emissions. What are the biggest challenges for the country in addressing emission reductions for this sector?

The primary challenge is that it has a lot to do with behavior. The energy industry is quite easy by comparison, as we can develop renewables through market design and we are working with small numbers of utilities and industry companies. The mobility sector is like energy efficiency in that you have to address people's day-by-day behavior, which is a great challenge.

Secondly, the automotive industry is very important to the German economy. To switch the industry to other technologies is quite ambitious and complicated. We want to encourage more EVs on the streets, but it is not so easy for manufacturers. Vehicles running on battery technology aren't cheap, and don't provide long-distance range – so again, the people have to accept it, and drive demand.

Of course, the mobility systems in cities and rural areas are very different in their challenges.

Approximately 40% of all electricity consumed in Germany comes from renewables, and this share will increase to at least 65% by 2030. Is the government on track to achieve this goal? What is the projected energy mix moving forward?

We are on track, but it doesn't come easy. The energy mix is something that is being highly debated, and also contested, among parliament and different interest groups now. What we need is a mix of PV, onshore and offshore wind – but there is a lack of acceptance when it comes to onshore wind. It was very popular five to 10 years ago, but as the costs have come down and deployment has grown, so has reluctance. People don't want to look at windmills. There is also large debate among environmental groups. Climate activists support windmills, but conservationists and bird protection groups are in opposition.

It is complicated, and this is where politics come into play. Similar to grid expansion, we must find where support lies and then make compromises to deliver policy for onshore wind. This is what is being debated this year, and hopefully by autumn, we will have an end result.

What role will storage play in Germany's energy mix and the energy transition?

For storage we have to differentiate between technologies for electricity and gas in the first place, and the use cases for which the storage technology is needed. For durations of seconds or minutes for frequency stability, for example, batteries are one option on the market for balancing energy run by the grid operators. When it comes to storage for the duration of a day, a week, or even longer – we believe these options will be incentivized by the wholesale electricity market, and not regulation or grid tariffs.

In the north of Germany, we already have renewable penetration of about 80%, and with this amount of renewables, you need all available flexibility options. The cheapest way of integrating renewables into the system in the long run is expanding the grid. We will use other flexibility options like digitization, flexibility in demand and supply, storage, and cross border trade according to their costs, starting with the cheapest option. We are always focused on cost efficiency and technical skills and in the meantime, investing in innovation for better storage technologies over the next decade. I believe in the second half of the 2020s, from 2026 onwards, we will see more and more storage come online in the system.

How is Germany currently supporting clean technology innovation and industry to spur the necessary growth of renewables in the portfolio?

We have an R&D budget of approximately €1.3 billion for innovation in energy. This is being used for PV, and integrating PV with storage, hydrogen electrolyzers, and so on. We support large demonstration projects, so-called "living labs," for the energy transition. Actually, the Federal Minister for Economic Affairs and Energy, Peter Altmaier, just awarded project proposals from different consortia to bring forward innovation in decarbonization across mobility, heating and in transport systems through various measures. For example, integrating more renewables into the system, adding various storage, and especially by producing hydrogen and bringing hydrogen into the steel industry and transportation systems.

We are looking to scale up these energy technologies so that they are there when we need them, and we will need them by about 2030. We are now investing a lot of money in order for the private sector and science sectors to work together so that these technologies become competitive and cost efficient in the next 10 years.

Interview by Erica Johnson

Bulking up: Storage heads for center stage

Energy storage has largely served at the margin of power grids over the past decade. But the continuing cost crash in wind and solar generation are changing storage's role. A recent round of projects, from Indiana to Arizona, suggests that storage is bulking up and is set to act more equally in generation. If so, the next round of retirements in fossil fuel power may open the door not just to wind and solar, but to a network of storage that transforms the power grid.

Northern Indiana Public Service Company (NIPSCO) watches over one of the larger portfolios of coal-fired power generation in the Midwest. A provider of residential electricity, NIPSCO serves a customer base dominated by industrial firms. Just five companies – British Petroleum in particular, with its enormous refinery in Whiting, Indiana, along with Praxair and three large steelmakers – make up 40% of its energy demand.

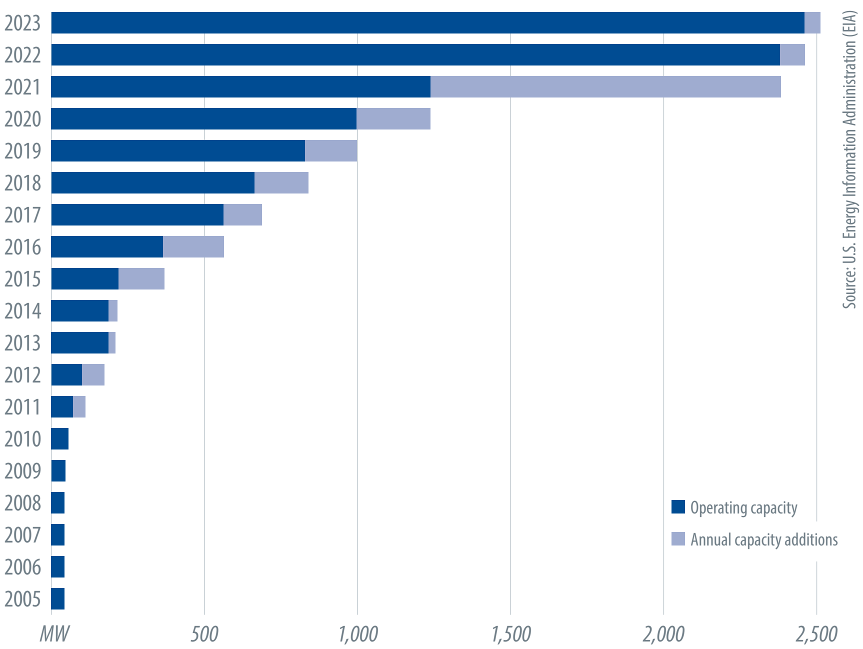
But in 2018, when NIPSCO looked ahead to the next decade, it saw a 2.09 GW portfolio of coal-fired generation that would continue to provide sufficient power, no doubt, but one that would also incur increasing economic losses. After conducting an extensive study, in which six feasible energy mixes were considered, NIPSCO chose a plan that would offer the best prices to customers: shutting 78% of its coal capacity by 2023 – the final 22% by 2028 – and replacing this capacity with a combination of wind, solar and storage. The portfolio transformation will initially be led by adding wind power through 2022, with solar and solar+storage dominating new generation thereafter.

The solar+storage component of NIPSCO's plan is notable, as U.S. projects that pair the two are becoming increasingly common. "I've recently come to the conclusion that in the future we're not going to build much solar without storage," says Cody Hill, a veteran storage engineer and developer based in Oakland, California. "All the easy-to-build solar – that supplies power midday – that opportunity is eventually going to be eaten up. So you're going to have to start time-shifting at significant scale to keep growing the solar industry."

Until recently, battery energy storage has largely served markets at the margin, offering short bursts of frequency regulation or light pricing arbitrage. Tesla's early megaproject in Australia offered an algorithmically driven battery bank that could jump into the larger grid for small timeframes to better match spikes in load, for example. In other domains, EV charging companies have started to time-shift small tranches of load, using EV fleets as demand-side management – opening the door to their use as a collective battery. Early storage projects have mostly been small, too: battery capacity to compliment emerging municipal fleets of electric buses, or local experiments with microgrids.

According to the U.S. Energy Information Administration (EIA), however, utility-scale storage is about to leap forward in the U.S., following a long period of slow growth. More than doubling from this year's 1 GW of capacity to nearly 2.5 GW by 2021, the jump is spearheaded by two megaprojects – the 409 MW Manatee unit in Florida and the 316 MW Ravenswood

U.S. utility-scale battery storage power capacity (March 2019)



The U.S. Energy Information Administration's estimated storage growth

Photo: Tesla

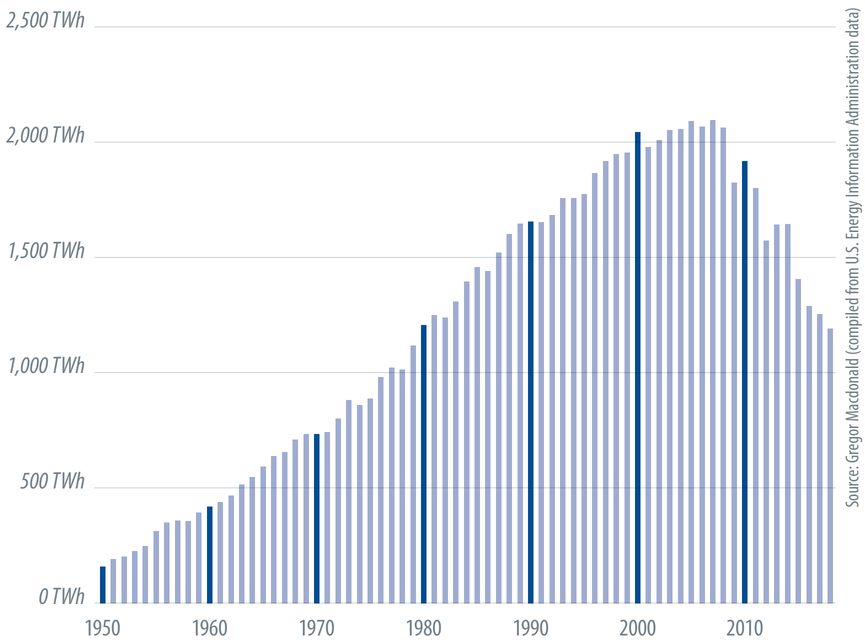
Tesla's 80 MW PowerPack substation in Mira Loma, California

unit, to be built out in stages, in Queens, New York. The growth is being driven not just by falling storage costs, but also continuous price drops for clean generation. Forecasters largely missed this emerging dynamic. Although storage's progress down the cost curve has historically been slower, whole system costs have continued to fall as wind and solar became the cheapest form of generation.

But storage also has achieved rapid cost declines. The levelized cost of electricity (LCOE) of lithium-ion dropped by 35% to $187/MWh from just the first half of 2018 into 2019, according to a report released earlier this year by BloombergNEF. Gap moves of that magnitude now open up storage for a new role, increasingly marshaled as a form of generation – at least during times of peak load. Unsurprisingly, this will place further pressure on incumbents. "The folks that are struggling are the baseload generators, those that can't shut down and start back up very fast," says Hill. "They have to generate even when they are losing money for every megawatt-hour they are putting onto the grid. They are really struggling with renewables, and that's why coal is struggling, and nuclear is struggling."

The NIPSCO resource plan decision shocked the U.S. power industry. Steelmaking and coal have long been intertwined, and that's especially true in Indiana, where the minimill revolution – a technique to use electricity to melt scrap into hot rolled steel – owes its beginnings to a plant Nucor Corp. established in Crawfordsville in the early 1990s. Minimills can exert a large pull for power

U.S. power generation from coal (1950–2010)



Despite a pro-coal U.S. administration, there has been a strong downward trend in the county's coal generation capacity.

Arizona Public Services announced plans earlier this year to add 850 MW of battery storage and at least 100 MW of new solar generation by 2025.

grids when their electricity demand spikes upward. But this decade has seen a far more extended wave of coal retirements than expected, with 55 GW of capacity closed from 2007 through 2017. Most assumed this would eventually slow under a coal-friendly administration in Washington. Alas, not so. Last year saw more than 10 GW retired, the second-highest year since 2015, when over 14 GW were closed. With coal's contribution to U.S. electricity generation having fallen from 50% to nearly 25%, there's a reasonable prospect that coal generation in the U.S. will, as it has done in Britain, head toward zero.

> *"Storage is now pulling into peer position with wind and solar technology"*

NIPSCO is not the only utility sending out a warning signal. California's Pacific Gas and Electric (PG&E) and Arizona Public Services (APS) both recently announced plans to deploy storage, either obviating the need to build new generation, or in the case of PG&E, to replace existing generation. Taken together, storage is now pulling into peer position with wind and solar technology. And in time, storage will likely be regarded as standard when deploying new capacity of any kind. While assessing the economics of storage can be more complicated due to its broad menu of revenue-generating services (the ROI can vary depending on how it's utilized by the owner), utilities now recognize that building storage creates an asset of real versatility, no matter the mix of their generation portfolio.

"Solar, once it's built, looks like a fixed income type of asset. It looks like a bond," says Hill. "Storage however is not like a bond, but really more like a basket of options. The option to sell power at different times. What's interesting is that peaking power also looks like a basket of options – albeit with a different mechanical structure around it. But financially speaking, storage looks more akin to the development of peaking generation."

In the case of APS, Arizona was in a perfect position to purchase surplus power when vast solar capacity lit up midday across California's deserts, exceeding load. More telling is that APS initially thought of adding a much smaller amount of storage but, seeing the attractiveness of the bids, added more. By the mid 2020s, APS plans to have built 850 MW of storage. One conclusion that might be drawn from the APS strategy is that new generation growth, especially from wind and solar, is becoming common and routine. The strategy to build storage, therefore, is obviously for the purpose of arbitrage – buying supply when power is cheap, and selling it back into the market when it's more valuable. The difference here is the scale: As with similar projects, the battery storage design is generally aligning to four hours of output. APS will be able to use this storage capacity to provide power, likely during the high demand window between 4 p.m. and 8 p.m.

Back across the state line in California, PG&E also announced last year its own plan to replace 670 MW from three retiring natural gas plants with 567 MW of total storage. Storage economics benefit from scale of course, and the size of each battery unit is important. APS had already retrofitted an existing solar facility with 50 MW and plans a 100 MW unit. Now comes PG&E with plans for a 300 MW unit, and the next decade will bring the 400 MW unit from Florida Power and Light's Manatee project. This is how the learning rate works in practice: Size expansion improves unit economics for the owners, but also drives manufacturing costs downwards as output rises. Eventually, all future buyers of storage will benefit from the low prices created by early demand.

But replacement of existing generation in the United States is not entirely tied to price. Arcane financing structures – ones that create separate income streams for generators even on loss-making capacity – and also varying regulatory environments, can mean that legacy generation can carry onward. The recent bailout of existing nuclear and coal capacity in Ohio, for example, offers an instructive contrast to NIPSCO's plan, as the future losses from Ohio Valley Electric's coal plants are being subsidized. Leah Stokes, a professor in the Department of Environmental Studies at UC Santa Barbara, observes that Ohio is looking to cover losses in the same way that NIPSCO is looking to avoid them. “If you’re not building the future, you’re continuing to invest in old technology. And, that will have a cost at some point when you use billions to invest in coal plants, instead of building new wind, solar and storage that would create longer life value.” The plan unsurprisingly will add new fees to ratepayers’ bills and raises the specter that Ohio residents will face a double loss: having to pay extra in the present for old technology, while also missing out on the opportunity to own new technology. “Eventually, there will be some federal climate legislation and Ohio is going to be way behind the mark, and its citizens will have to pay for that. It’s tragic,” says Stokes.

Clean generation paired with storage is moving fast. At the end of July, NextEra announced it was building a 700 MW triple hybrid project for the Western Farmers Electric Cooperative in Oklahoma, composed of 250 MW of wind and solar generation each, plus 200 MW of storage. While storage is not yet in a position to act as long-duration supply, there are indeed systemic effects likely to appear. Hill points out that historically, pumped-hydro built in the middle part of the 20th century offered a way for original coal and nuclear generators in the West to improve their economics on a plant-by-plant basis. And he speculates that lithium-ion battery storage is about to echo that history, as pairing becomes more common.

“Right now, in terms of [larger battery] duration, we are in the realm of single digit hours. Not all day, and not many days,” says Hill. But even that short duration is enough to vastly improve the value of new wind and solar capacity.

With wind and solar quickly becoming cheap commodities, built easily across various regions, their collective presence is disrupting power markets and triggering a new set of decisions by utilities. As storage starts to become as ubiquitous, it too will start to influence how power grids evolve. Battery units of 300 MW or even 400 MW are certainly large, standalone units. But what will happen when 10 such units are located in a single region? A network effect now seems inevitable for storage. Rather than replacing generation with single battery projects, collective capacity will act like virtual generation as regional storage resources move from the MW level to the GW level. If storage is indeed a basket of options, that makes for a very large basket. *Gregor Macdonald*

NIPSCO Coal Power Plant Cooling Tower on the Lake Michigan shore

Rebuilding for resilience

The islands of the Caribbean have been focusing on the deployment of storage solutions, minigrids and microgrids in response to the damage their power systems suffered during the 2017 hurricane season. But with the opportunities, there are also challenges.

"Without a resilience plan, there is no action"

Hurricanes have devastated vast swathes of the Caribbean in recent years, with recent Category 5 storms such as Hurricanes Irma and Maria wiping out the electricity systems of numerous islands. As the region recovers, many islands are starting to use decentralized renewable sources and storage technologies to build more resilient energy systems. The Rocky Mountain Institute (RMI) is at the forefront of encouraging island communities to incorporate resilience planning in their energy strategies now, rather than waiting for disasters to hit.

"Most of the countries that were not hit did not necessarily make any changes to their systems to make them more resilient," says Stephen Mushegan, a project manager for RMI's islands program. The organization is actively using Resilient National Energy Transition Strategy (R-NETS) processes to change thinking about resiliency. "The emphasis has always been on cost and reliability, and lately environmental energy independence. Without a resilience plan, there is no action."

Rethinking resilience

The region's islands are at different stages of rethinking system design. In July, British Virgin Islands Electricity Corp. – whose grid was left in tatters by Irma – unveiled a new R-NETS to create a cleaner, more resilient system. And in Antigua and Barbuda, the utility is developing Category 5-resilient solar and battery systems.

Several smaller islands are also aggressively transforming their energy systems. On Bonaire, for example, Wärtsilä recently commissioned a 6 MW/6 MWh storage system that the Finnish industrial group claims will double renewables penetration.

Bigger islands devastated in 2017, such as Puerto Rico, are also trying to create resilient systems. "Because it is a U.S. territory, many of the microgrid developers in the U.S. have wanted to jump on that," says Isaac Maze-Rothstein, a research associ-

Photo: Greensmith Energy

Greensmith Energy, a Wärtsilä company, commissioned a 6 MW/6 MWh energy management and storage system for ContourGlobal Bonaire on the Caribbean island of Bonaire.

ate for Wood Mackenzie. The consultancy classifies microgrids as systems offering 24 hours of backup, which does not include most solar+storage setups.

Definitions of systems vary – in the Dominican Republic, for example, many microgrids in the 500 kW range have been built. But some standalone grids in the country are bigger than the entire capacity of other islands, notes Clemens Findeisen, project manager of Germany's international development agency GIZ.

"Storage will play a major role in all the Caribbean as renewable energy penetration increases," Mushegan says. "Any island that has high renewable energy targets should expect to be a great opportunity for storage."

Solar successes

At grid scale, the Dominican Republic and Cuba lead in regional PV deployment, with roughly 166 MW and 96 MW of respective cumulative capacity at the end of 2018, according to the International Renewable Energy Agency (IRENA). The Dominican Republic operates a robust large-scale PV tendering process, but has also installed a significant amount of commercial and residential capacity under its net metering scheme.

Meanwhile, Wood Mackenzie is "optimistic" Cuba could install more than 50 MW over the next five years, due to issues with Venezuela's PetroCaribe energy alliance. "That change in Venezuela – they're sort of looking to diversify outside of oil," Maze-Rothstein explains.

He notes the importance of thinking about "resilience" at the grid level but also the facility level, especially for commercial-industrial projects. The consultancy views the latter as separate from typical solar+storage installations. Policymakers need to consider multiple options, from "hardening" traditional infrastructure to focusing on renewables-backed microgrids, but few have figured out how to get the policy right to create new utility business models.

Active market

RMI estimates that several hundred megawatt-hours of storage have been deployed in Puerto Rico. Wood Mackenzie sees it as one of the most active customer-sited microgrid markets in the Caribbean and expects it to more than double in size by late 2024 to 228 MW, with a projected investment of $419 million.

RMI also believes Puerto Rico is emerging as a model of resilience and energy planning for other islands. The outcome of the Puerto Rico Electric Power Authority's (PREPA) restructuring and privatization remains unclear, but Siemens recently submitted a new draft for the utility's 2019-2038 integrated resource plan (IRP), which accommodates 1.8 GW of PV and 920 MW of storage in its initial five years. It also calls for eight minigrids, integrated with the island's transmission and distribution (T&D) infrastructure, to improve resiliency by splitting the grid into load pockets supplied by distributed resources.

"Really novel – we haven't seen anything like that to this point. We've never seen an IRP that integrates microgrids as a core conceptual framework – sort of saying 'we need microgrids to make this the most resilient system' possible," says Maze-Rothstein.

Concerns remain over PREPA's creditworthiness, as well as interconnection issues. PREPA is expected to soon announce its new T&D operator, but growth in storage deployment is also expected below the grid scale, with Wood Mackenzie estimating that 1,400 residential solar+storage systems were installed in Puerto Rico over the last year.

Paying for resilience

The road to resiliency remains rocky, and one of the challenges is paying for it. A dearth of incentives, as well as real and perceived risks, make it tough to get the economics right.

In Haiti's nascent off-grid market, which Wood Mackenzie says could grow by 40 MW in the next five years, EarthSpark International is already building community solar+storage microgrid systems.

"On a prepay, local vending basis – there's a lot of remote access to the data," says Madison Sturgess, project manager for the non-profit organization.

This lowers operational costs, which Sturgess says is a "big step" in moving microgrid markets toward market. And the past six months have been "really exciting" for policy development, she says.

"The needle has started to move with the Haitian government. It's really building a market from scratch," she explains. "You've got to derisk this whole process by just doing it. So we're building the grids. The grids generate the data. And the data informs thoughtful policy advocacy."

Brian Publicover

Photo: AES

Two 10 MW storage installations in the Dominican Republic helped keep power running on the island during 2017 hurricanes.

> *"Storage will play a major role in all the Caribbean as renewable energy generation increases"*

A banner year for advancing non-battery storage

This has been a breakthrough year for non-battery storage, with key advances in pumped hydro, power-to-gas, and thermal storage technologies. Many industry players are moving beyond pilot projects to contracted projects, which could lead to increased scale and lower costs.

Pumped hydro storage

Pumped hydro storage, a tried-and-true technology for long-duration storage, involves using electricity to pump water to an upper reservoir from a lower reservoir or lake. When power demand is high, the water flows downhill from the upper reservoir, powering hydroelectric turbines that generate electricity.

"One cost projection concluded that pumped hydro storage with more favorable financing is cost-competitive with lithium-ion battery storage"

Closed-loop pumped hydro uses two man-made reservoirs, with no connection to a natural body of water. A closed-loop system can be designed to generate power for eight to 10 hours, and to recharge by pumping water uphill for 10-14 hours, as indicated by plans for projects in Montana and Arizona.

Most of the 27 licensed pumped hydro projects in the United States, ranging across 16 states and totaling 18.8 GW, are at least 30 years old. However, there is also a robust pipeline: Preliminary permits for 20 GW of new capacity have been awarded by the Federal Energy Regulatory Commission, and applications have been submitted for another 19 GW.

There may be even more feasible pumped hydro sites in the United States, as an estimated 500,000 sites are technically suitable globally, meaning that they have potential locations for both high and low reservoirs.

Cost projections for pumped hydro are scarce, perhaps because there is only one modular component used – the reversible hydro turbines. All other costs are site-specific, from engineering and earth moving, to construction of the powerhouse containing the turbines.

One cost projection concluded that pumped hydro storage with more favorable financing is cost-competitive with lithium-ion battery storage.

Copenhagen Infrastructure Partners appears to back that assessment, given the firm's equity investment last summer in a 400 MW pumped hydro storage project in Montana. The project has a license for construction and operation, and construction could begin next year.

Simon Bourne, CTO of ITM Power, inside Thüga Group's power-to-gas plant

Photo: ITM Power

Power-to-hydrogen (or other fuels)

Power-to-hydrogen is another established technology, at least for installations of modest scale. Hydrogen that is produced using electrolysis can be stored and used later to generate electricity via fuel cells. This is a potential long-duration energy storage option.

At least three small industrial installations have been announced over the past year, all using the proton exchange membrane (PEM) electrolysis technology to produce "green" hydrogen by using solar or wind power to electrolyze water into hydrogen and oxygen.

The resulting hydrogen may be stored in pressurized vessels, while it awaits use in fuel cells. Because the hydrogen storage is separate from the electrolyzer units, there is no technical limit to hydrogen storage capacity for a given system of electrolyzers.

While PEM and other electrolysis technologies are well-established, achieving economies of scale is challenging. Hydrogen technology may need to expand its foothold across a range of markets, scaling up and driving costs down, before it can become a cost-competitive storage option.

That scaling-up process has begun. Last February, Hydrogenics Corp. announced plans to build a 20 MW PEM electrolyzer system in Canada for Air Liquide. At the time, the system was described as the world's largest hydrogen electrolysis project, with an output of just under 3,000 tons of hydrogen annually.

Also last February, a framework contract for a 30 MW electrolyzer project in Switzerland was announced by a division of Norwegian-based hydrogen company Nel ASA. The project will begin with a 2 MW containerized PEM electrolyzer and will sell hydrogen to Hydrospider AG, an affiliated company of H2 Energy, for a planned fleet of fuel cell trucks.

Finally, ITM Power has announced a 10 MW PEM electrolyzer in Germany, and has a design for a 100 MW system – a size for which it reports increasing interest from potential industrial customers. ITM reports that electrolyzer costs are now under €800 per kW of capacity, and will decline to under €500 per kW by the mid-2020s.

Looking ahead, an industry and academic consortium in the Netherlands has set a goal to build a gigawatt-scale electrolysis plant. They aim to produce green hydrogen by 2025 or 2030, at a cost of about €350 million.

Another possible storage solution is to use green hydrogen to manufacture ammonia. Japan's JGC Corp. has reported an efficient method of converting hydrogen to ammonia, which can later be combusted to generate electricity. JGC argues that this offers various advantages over hydrogen in terms of safety and cost-effectiveness.

Thermal storage

A well-known application of thermal storage is molten salt storage, typically associated with the Solana concentrating solar power plant in Arizona. The heat is used to drive a steam turbine. Yet thermal storage can involve other means of storing heat, and can also involve storing "cold."

England-based Highview Power began operating a pilot-scale 5 MW cryogenic energy storage facility near Manchester in June 2018. The technology uses electricity to chill and liquefy air at -320˚F, store the liquid air in insulated, low-pressure tanks, and later expose the liquid air to ambient temperatures to rapidly re-gasify the air, expanding it to 700 times its liquid volume in order to provide power to turbines.

Highview Power estimates a levelized cost of $140/MWh for a 200 MW/2 GWh (10-hour) system. And similar projects are on the way. Last July, for example, Highview Power announced a contract with Nebraska-based Tenaska Power Services to help develop up to 4 GWh of cryogenic energy storage plants in the U.S. over a two-year period.

Thermal storage can be as basic as storing ice for later use in air conditioning. Instead of generating electricity, making ice can shift power demand, especially to peak solar generation hours during the summer months, with the ice later used for air conditioning.

California-based Ice Energy is currently installing 1,200 ice-energy systems under a contract with Southern California Edison (SCE). The systems will be centrally controlled to manage peak demand and load shifting.

Siemens Gamesa offers what it calls a cost-competitive technology: electric thermal energy storage. Electricity is used to heat volcanic stones in an insulated container to up to 600°C. The heat is later converted to electricity using a conventional steam turbine, achieving a 45% round-trip efficiency. The company says the technology could be used to retrofit retired fossil-fired power plants and plans to begin operation at a pilot facility later this year.

Looking Ahead

The storage developments of the past year have shown that battery storage is not the only game in town. Other technologies that are capable of longer-term storage are also moving forward. Cost projections are starting to be made public, and these technologies should be gaining more attention in the year ahead.

William Driscoll

Photo: Highview Power

Highview Power's 5 MW pilot-scale cryogenic energy storage facility cools and liquefies air.

Photo: Consumers Energy - CMS Energy

Resevoirs such as this one, which is being used for a pumped hydro plant in Ludington, Michigan, could become more common in the United States.

Photo: Absaroka Energy LLC

Copenhagen Infrastructure Partners has invested in Absaroka Energy's 400 MW hydro project in Montana.

Nexceris: Taming the Li-ion

In an emergency, every second counts. With this premise in mind, a team from Ohio-based manufacturer Nexceris set out to improve a warning system to protect lithium-ion storage systems from fires, after working with the U.S. Navy on the response to a lithium-ion fire outbreak on a vessel 10 years ago. What they came up with is a highly sensitive gas detector: the Li-ion Tamer.

Photo: Nexceris

Li-ion Tamer is designed for battery safety, providing information about the condition of the battery by monitoring for an off-gasing event from the cells.

Though an unpopular topic, a look toward South Korea brings the extent of the battery fire issue into focus. In the last 18 months, we have seen 23 fire outbreaks in large-scale lithium-ion storage systems in the country, with 500 currently still shut down, pending safety reviews. Randy Stacy, the chief commercial officer of Nexceris, claims that the issue is prominent in South Korea because it has such a large fleet already installed.

If a fault occurs with a battery cell – either by production failure, temperature, mechanical or electrical abuse – the electrolyte inside the cell will begin to break down, setting off a sequence that ends with a thermal runaway event, or a battery in flames, in layman's terms. The sequence is outlined in the UL 9540A testing method for evaluating thermal runaway containment in lithium-ion batteries. Gases release as a result of electrolyte breakdown, which leads to pressure buildup in the battery cell, until the gases vent, which is dubbed "off-gassing." Only after the venting has occurred, the temperature rises, followed by smoke emissions and eventually the outbreak of fire. So rather than relying on smoke and temperature sensors, Nexceris trusts gas detectors to identify issues at an earlier stage.

The time between the start of off-gassing detection and thermal runaway can vary significantly depending on the nature and intensity of the problem.

"In most cases, we are detecting the off-gassing between eight to 12 minutes before the thermal runaway," Stacy says. He adds that anything between two to 30 minutes is possible, however. In this time, the system will communicate with the battery management system (BMS) or the system operator to electrically isolate the faulty cell and have it replaced.

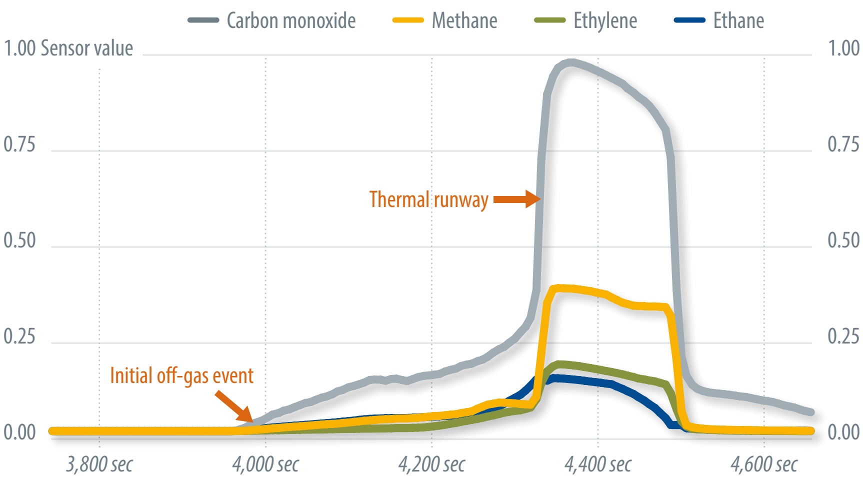
"The BMS and the cell manufacturing quality are the first two lines of defense," Stacy explains. There are thousands of cells integrated into a utility-scale project, so it cannot be assured that none of them will, at some point, stop working flawlessly. The same goes for battery management systems, which can have shortages. The company says that the Li-ion Tamer is a redundant independent chemical perspective of the situation, which does not require electrical or mechanical contact with the battery cells.

Nexceris has integrated its Li-ion Tamer solution across multiple market segments. In the marine and automotive industry, the gas sensors are placed on the battery module level. For utility-scale storage systems, it is typically sufficient to place sensors on each of the racks evenly, just in different zones within the containerized solution.

Stacy claims that adding its safety solution to the system would incur no more than a 1% increase in capex for any storage system. According to estimates, the fires in South Korea have created losses of around $32.8 million. Steve Cummings, director of the sensors business unit at Nexceris, points out that this includes only the actual system costs – footing the bill for the chemical clean-up, remediations, PR damage and other externalities would likely be five to tenfold that amount. And that is certainly a costly emergency to be tamed. *Marian Willuhn*

Gas release profile for a lithium ion battery cell from Initial off-gas through thermal runaway

Source: Nexceris



Pxise: Operating the future grid, today

As higher concentrations of renewable energy and storage capacity come online, the control systems of today cannot solve the problem of a two-way predictable grid of the future. Enter Pxise Energy Solutions (pronounced "Pice"). Using real-time data and algorithms to make intelligent decisions, the company's software technology is breaking down barriers for grids to operate with high levels of renewable penetration. Pxise says its software can unleash the benefits that batteries are able to provide.

The power plant of today is primarily based on data that feed into it – using what is called the SCADA (Supervisory Control and Data Acquisition) system. Operators are served with data every few seconds, which is refreshed on the screen, and a human has to take action in order to control the power system. And this is how power systems are still being controlled around the world. But energy intelligence tech company Pxise has a new system software operating solution.

"In order to transition to a more automated system, you have to build in intelligence to gain information," says Patrick Lee, president and co-founder of Pxise, an offshoot of Sempra Energy. "And you also have to build it on a technology to address scalability and flexibility."

Lee explains that Pxise's software operates in a manner similar to running an airplane on autopilot – it takes in information, makes decisions, and then controls what happens, with or without the intervention of people. Developed in partnership with the software developer OSIsoft, the Windows-based system provides high-speed data and insights with intelligent algorithms to control the systems for utility-scale renewables, microgrids and islands, and electric utilities.

Pxise uses a time-synchronized technology called phasor measurement units (PMUs), originally developed by Virginia Tech in 1988 for system coordination and then later adapted for transmission networks for blackout control. "We further expanded the application of that technology into streaming control," says Lee. Pxise secured a number of patents to use PMU technology to control the power grid.

The resulting grid control product uses data management tools with time-synchronized sensors to provide just-in-time controls across the entire system – from behind the meter all the way up to the utility. "This is the only way you can manage dynamic, unpredictable resources and flow grid," says Lee, explaining that the intermittency of solar, wind, and other resources providing power to the grid is a challenge taking place around the world. "System-level thinking is the only way you can manage dynamic, unpredictable resources and flow grid."

And this could enable greater opportunities and benefits for battery storage systems. Lee explains that batteries today are being used for peak demand shaving, peak shifting, and frequency regulation of the grid – all of which just control one parameter of the battery: real power. "Pxise can control all parameters of the battery from different perspectives," he says. "We can control real power and reactive power simultaneously."

Today, many battery systems respond from one to 10 seconds when you command it to move, which Lee says is fairly slow and creates limitations for the battery to realize its full benefits. "Pxise enables the battery to be controlled 60 times per second, or even faster if we wanted to. Being able to control the battery fast or slow enables achievement of the value stack of the battery.'"

While other distributed energy resource management system (DERMS) technologies being deployed are typically engaging and controlling one asset or battery at a time, Pxise's software is able to control multiple resources, coordinated at the same time. By doing so, the technology unifies control of a hybridized energy system. The operating system remains the same regardless of the energy mix – and the software simply reconfigures to provide flexibility and scalability.

"Utilities are beginning to worry about capacity and asking how much solar and wind they can actually integrate within their systems. Using our technology, unifying control, you can increase hosting capacity of renewable energy," says Lee. "Pxise removes the technology roadblock to mitigate intermittency and enables reliable, scalable, and safe grid control integrating high levels of renewables." *Erica Johnson*

Photo: Pxise

Fluence: One gigawatt down, portfolios of a gigawatt next

Fluence has been awarded or built more than 1 GW of energy storage capacity in 95 unique projects across 20 countries. Now, the company – a joint venture between Siemens and AES –is modeling the future of the power grid to predict where its expertise will be utilized next. The company expects significant future volume to come from two pathways: "wireless solutions" – that is, storage as transmission – and reaching into the natural gas mid-merit market.

Wireless solutions allow for strategically distributed energy storage systems (sometimes plus solar) to replace powerline upgrades or installations. The California Independent System Operator (CAISO), which manages the state's power grid, last year canceled or modified powerline and grid upgrades that would have cost $2.6 billion due to efficiency efforts and distributed solar. And Eversource – a utility in New Hampshire – is installing a 1.7 MW / 7.1 MWh battery instead of a $6 million, 10-mile powerline.

"One must assume Fluence is giving a lot of pipeline attention to California-connected projects"

Recent research conducted by Carnegie Mellon's Tepper Business School, along with Fluence, found that solar plus six-hours duration storage can solidly compete with load-following gas combined-cycle plants. This is the case for the majority of the country, and is only failing to be financially viable in the New England ISO jurisdiction (for now, at least).

These findings have been driving Fluence's market applications team to draw up a systemwide analysis across global power grids. The company says it is looking to offer portfolios, or fleets of solutions – such as distributed batteries and fossil replacements – because that's what you do when you're a gigawatt player.

While there's been no official announcement from the company, one must assume Fluence is giving a lot of pipeline attention to California-connected projects, considering that CAISO – which serves 90% of the state's electricity – announced estimated 2020 shortfalls of 2.3 GW during the peak annual demand hours of September. CAISO further projects peak capacity shortfalls of 4.4 GW in September 2021 and 4.7 GW in 2022.

If anyone can deliver 2.3 GW of grid support in strategic positions, it is Fluence. AES Energy Storage, now part of Fluence, delivered the 30 MW / 120 MWh Escondido energy storage project within six months of regulators making an emergency procurement authorization in the summer of 2017.

Whole states are now considering doing what Fluence envisions.

The Massachusetts 2017 "State of Charge" report, which looked at 1,497 nodes and 250 substations in the state, modeled up to 1.7 GW of strategically distributed energy storage to bring ratepayers up to $2.3 billion in benefits. Since then, the state has instituted its SMART program, which is pushing 260 MW of energy storage. Massachusetts is now developing a four-hour energy storage "Clean Peak" program to specifically tackle expensive, dirty electricity generated from gas peaker plants and to backup coal and oil facilities across the power grid.

With that, we're at the very front edge of contract signings – such as the one between Fluence and UK Power Reserve, a flexibility provider in the United Kingdom. The partners recently announced a planned fleet of lithium-ion energy storage projects totaling 120 MW / 120MWh. Fluence is also undertaking a 100-MW/400 MWh project in Long Beach for major utility Southern California Edison, which is now under construction. The project, Alamitos, will provide grid support, and is the first standalone project specifically procured to replace a gas peaker in the country. Seems like a good time to be Fluence.

John Weaver

The Escondido 30 MW / 120 MWh energy storage project was installed by AES Energy Storage, now part of Fluence.

Photo: AES Energy

Kore Power: Battery storage, simplified

With a partner company in China and a supply chain backed up by years of experience in the mining sector, Idaho-based Kore Power has ambitious plans for battery manufacturing, as well as the utility-scale energy storage and microgrid market segments.

The company is in the process of ramping up a manufacturing facility in China, where it expects to have 1 GWh of battery module production up and running by the end of 2019. It also plans to expand this to 6 GWh by the third quarter of 2020.

In addition, Kore Power is in the early stages of planning a vertically integrated lithium-ion battery manufacturing facility in the United States, the location of which it is finalizing and expects to announce by the end of the year. This plant will be built 2 GWh at a time, with an eventual planned capacity of 10 GWh.

"We believe we'll start production [in the U.S.] by the end of next year, and we'll be shipping before the end of 2022," says CEO Lindsay Gorrill. "And by the time the plant in the U.S. is ready for production, we'll have expanded our sales pipeline to take care of the additional supply."

Kore Power has a partnership going back more than a decade with Chinese chemicals company Do-Fluoride Chemicals Co. Ltd., which manufacturers battery materials among other products, and is also a shareholder of Kore Power.

"We had been business associates for 10 years, and then about two years ago we looked at, and we agreed that they had – on a safety and energy density basis – one of the best cells in China," explains Gorrill. "We think there's a lot of opportunity outside of China and that energy storage is the way to go, so we worked with them in developing Kore Power."

Focused entirely on energy storage projects, Kore Power is already bidding on utility-scale projects all over the world, and is also developing a microgrid package with a particular focus on providing power to remote mining operations.

The first of its Mark1 battery systems is set for delivery in March 2020. The system operates at 1,500 Vdc and offers a storage capacity of 110 kWh per rack – features Kore Power says will help the company offer industry-leading energy densities and fast, easy installations at a large scale. The system, according to Gorrill, was designed "from the ground up," incorporating feedback from engineers and industry veterans to address downfalls of some other storage systems already on the market – with a focus on user-friendliness in installation and operation, as well as optimizations in energy density and the heat dissipation mechanism.

On both the commercial and the technical side, Kore Power aims to offer a product that simplifies the process of installing and operating an energy storage system. The Mark1 system is offered with what Gorrill describes as a "living warranty," which allows customers to extend their warranty period at no extra cost – depending upon a set of factors, including the number of cycles. "We differentiate ourselves with a strong warranty, unique 'Pay as You Grow' pricing, short lead times, and better customer engagement through our Customer Advisory Group," says Gorrill. "We think it's a pretty interesting concept – so far, we don't see anybody doing that."

Mark Hutchins

Photos: Kore Power

Lindsay Gorrill is the CEO of Kore Power, a new vertically integrated battery manufacturer.

Show floor at a glance

Energy storage is one of the most innovative and fastest-growing industries in the world, and Energy Storage North America is the largest conference and exhibition for grid-connected storage in North America. Taking place in San Diego, California, from Nov. 5-7, this year's event will showcase a range of cutting-edge product solutions across the full spectrum of the industry.

Cooling the costs of refrigeration

Viking Cold Solutions' Thermal Energy Storage System

Cold storage has the highest electricity demand per cubic foot and is the third-highest consuming category for most utilities. In the United States alone, there are thousands of frozen food warehouses, and walk-in freezers inside tens of thousands of grocery stores and hundreds of thousands of restaurants. Viking Cold provides the only Thermal Energy Storage (TES) technology in the frozen refrigeration sector. Comprised of intelligent controls and Phase Change Material (PCM), the company's TES systems have no mechanical components and require no additional energy.

The PCM is formulated for the specific temperature range of the freezer to maximize its latent heat properties. The intelligent controls make real-time decisions to maintain required temperatures and minimize refrigeration run-time based on temperatures inside the freezer, the PCM's "state of charge," utility rate structures, and site-specific energy strategies.

Viking Cold says its solutions can save up to 50% of refrigeration energy costs, shedding loads for up to 13 hours per day.

Photo: Viking Cold

Bringing storage to a new solid-state

Blue Solutions' LMP (Lithium Metal Polymer) 250/ 400 Rack

While experts suggest that solid-state batteries will not play a significant role in the storage space until 2025, one company may be leading the race. Blue Solutions says it has developed the only commercialized solid-state lithium battery. The LMP (Lithium Metal Polymer) battery avoids the risk of thermal runaway events, eliminating the potential for fires. The company says that its solid-state technology provides higher density and performance than Li-ion products. Available in 252 kWh and 400 kWh cabinets for outdoor installation, there are no warranty limitations on the depth of discharge or operating temperature. Eliminating cobalt, nickel and solvents, and capable of being recycled, the company's solid-state battery shows promise for a more environmentally and socially responsible battery solution than lithium-ion.

Photo: Blue Solutions

Avoiding the over-promise: what storage can deliver

Energy Toolbase's Energy Storage Modeling Software

To support the project development process and increase deployments of energy storage systems, developers need the ability to accurately quantify dollar savings and project economics. Energy Toolbase's Energy Storage Modeling Software allows developers to run storage dispatch simulations and quantify dollar savings of behind-the-meter storage projects in a matter of minutes. The tool provides users the ability to specify project variables, including storage system hardware, software control strategies, customers' load profiles, utility rate schedules and net metering and/or feed-in-tariff assumptions. By simplifying these complex variables, developers are able to lean on the third-party software provider for increased transparency and consumer protection.

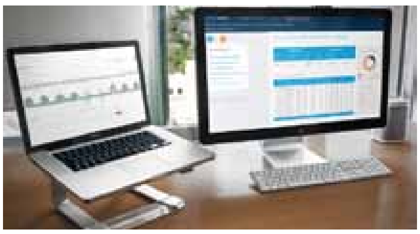


Photo: Energy Toolbase

Energy Toolbase is now launching its energy storage modeling capabilities in international markets.

Longer durations flowing to 'battery-in-a-building'

ESS Inc.'s Energy Center

The energy storage market trend is now accelerating towards six- to eight-hour durations to meet the grid requirements caused by increased renewable penetration and the duck curve. To support utility-scale long duration energy storage, ESS Inc. is now offering its energy storage technology as a "battery-in-a-building" platform. Energy Center systems can be configured in various power capacities and cycling durations, ranging from four to 16 hours. The systems enable installations to be tailored to meet virtually any project size or requirement. Designed as standalone battery systems, the platform can be directly integrated into large-scale renewable energy projects, transmission and distribution level services, and for utility peaker replacement applications.
ESS Inc.'s energy storage solutions utilize an innovative iron flow battery system built on the redox process. Redox involves a contraction of reduction (a gain of electrons) and oxidation (a loss of electrons), which is a reaction in which electrons are transferred between chemical species. As flow batteries have more energy storage capacity than typical batteries packed as fixed cells or modules, the company says that its solutions provide additional flexibility to control both the flow and amount of electricity that is stored.

Photo: ESS Inc.

Avoid peak demand with prepackaged thermal storage

Trane's Thermal Battery Cooling Solution

The thermal loads and electrical loads of buildings are responsible for about 40% of U.S. energy consumption, half of which is due to HVAC. To mitigate peak demand charges for such buildings, Trane stores cooling loads with its Thermal Battery system and a portion of the electric loads in an electrochemical battery.
The company's Thermal Battery system acts like an air-conditioning battery by using standard cooling equipment, plus an energy storage tank to shift all or a portion of a building's cooling to off- peak periods. A Trane-controlled chiller charges ice bank energy storage tanks when excess or inexpensive energy is available.
The tanks discharge when demand and rates are high or when the utility asks for the discharge to occur.
The company says that its technology can increase renewable energy usage by up to 50%.
It also says that cooling is stored at one-third of the total cost of other electrochemical battery systems. The system can come prepackaged and can be specifically engineered for a turnkey design.


Photo: Trane

Single cabinet for the best of both worlds

Alencon Boss Cabinet

The unique bidirectional Alencon Boss battery optimizer has just received an upgrade: an outdoor-rated cabinet.
Alencon Systems says the new cabinet for its Boss battery, which has patented galvanically isolated DC-DC conversion topology, offers storage users "the best of both worlds." By this, it is referring to the granularity of rack level battery charging and isolation within a single location.
The company's architecture provides the ability to incorporate grounded PV systems with floating batteries on the same BC-bus and to pair high voltage 1500-volt PV with lower voltage battery chemistries.
Alencon Systems says that by addressing each battery rack individually to limit fault currents in the case of a sudden short to ground, it can cut down costs by eliminating the need for additional safety devices.
The technology supports the deployment of DC-coupled storage capacity with string inverters, allowing for the integration with 600, 1000 or 1500-volt PV strings.

Photo: Alencon

Photo: Pxise

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