Meeting Summary

The Climate Resilient Grid

A Forum on Energy, Climate, and the Grid

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EXECUTIVE SUMMARY

The U.S. Energy Information Administration forecasts that non-hydro renewables will rise, from 2% in 2005 to a total of 10% of electricity generated in 2018. Not only essential for meeting energy demand, wind, solar and hydro are cost competitive with conventional generation.[1] Central to this discussion is the ability to transform the nation's long-distance transmission lines to move energy from decarbonized-production areas to centers of energy consumption. Industries are gearing up for business in the new era and balancing and optimizing intermittency resources.

The evolution of the energy system over the next 25 years will be spectacularly complex compared to the steady-state progress of the previous 100 years (see Figure 1). Calling renewables "a foregone conclusion" industry representatives are raising the level of investment in efficient transmission lines and new systems of microgrids. Climate and environmental intelligence can provide important information in this decision-making process, with the grid on the frontlines.

The Climate Resilient Grid: A forum on Energy, Climate, and the Grid, was convened to learn from the energy industry what environmental and climate data and information is needed for moving forward in an integrated energy future.

Broadly speaking the energy system consists of power generation, transmission and distribution lines, and consumption components (Figure 2). A power system is instantaneous supply and demand. Each component requires advanced analytics that maximize efficiency. Weather and climate factor into both operating the components efficiently, and factor into planning the energy assets effectively in the long term.

Weather is the primary factor in power outages. Intense and frequent storms affect operations and influence decisions on investments in the long term. To provide power no matter what the weather is doing, industry builds resiliency in the short term by hardening assets in-place, and in the long term by relocating assets at risk. Weather and climate impact every component of the energy system (Figure 3). And in general terms, the US is experiencing protracted and persistence cases of extreme drought, coastal inundation, extreme heat, and other extremes of weather (Herring). These impact operations and infrastructure design. In the past, much capital investment went to building conventional power plants, but as more renewable energy comes on line, future investment will be in the transmission system.

[1] Source: *Lazard Levelized Cost of Energy Analysis 10.0*; Weblink

Highlights of Main Points

Clearly, the industry leaders in this forum stated that they need to make new investments to improve both short and long-term resilience. Investing means making the rate case. An area that they need support is bringing the information data case to regulators to convince them of costs of resiliency.

High on the list of needs is demand for sea level rise data to inform infrastructure investments. Particularly, they need information on the probability of the level of and rate of sea level rise. Currently, estimates range from inches to several feet of sea level rise. Many assets would be flooded under the higher scenarios. The rate case for the cost of relocating assets needs coordinated authoritative data.

In addition, inundation data for coastal and inland assets is needed. FEMA flood maps do not seem to use NOAA projections of future intense rainfall projections. More intense rainfall brings higher risks on twenty-year investments. In addition, considering most of the grid assets are in low lying areas, water elevation data during storms, and the 500-year and 1000-year inundation levels, are needed.

In the future, solar power will displace a growing amount traditional generation. To operationally dispatch these higher levels of generators, high-resolution radiance data from GOES may be useful. This needs more analysis.

Environmental data at a 20-minute resolution would allow utilities to make better use of the transmission lines already existing. Line lag, a function of temperature, wind, and radiation, factors into dynamic load ratings. Are data from gridded weather analysis products useful here?

In the specific case of building resilience for long term outages, more information about both probability and potential consequences of an event would enter into the assessment of the overall risk. The National Climate Assessment plays into scenario planning for low probability and high impact events.

How extreme the temperature ranges will be will have a profound effect on the load curves, the basis of energy transmission. Peak consumption may expand by a hundred times. How can they use the projections of extreme temperature to match to their present-day summer and winter energy load curves? The anticipated effect on heating and cooling degree days with climate change will have a profound effect on their planning for future infrastructure.

Long term thinking, involves transitioning to a new normal. In making transformational changes for climate resiliency it is important to distinguish between reliability of (as in hardening against short-term outages) and resilience in a longer-term context. Even if we improve resiliency against extremes of weather and transition to a new normal, rapid change can cause surprise (Figure 4). Scenario plans, with supportive data, are needed to increase our long-term resiliency.

And it is in the realm of scenario planning where the keynote speaker prevailed. Long-term threats to our future require significant decarbonization, with great expanses of solar and wind generation, along with existing natural gas, nuclear, and hydro power. In addition, the national security threat of a low probability high impact event of an electromagnetic pulse (from a natural Carrington event, or a bomb) combine to form a high-risk scenario. Decades of past weather data were paired with hourly consumption data in a linear least cost algorithm to see if it were possible to generate sufficient electricity at low cost to power the US, while at the same time lowering greenhouse gas levels below the level of serious life-threatening consequences. Fortunately, the physical scale of the US is such that it is possible to power it (Figure 5). What is needed in this most important scenario is a national energy market fed by a high voltage direct current transmission line, an underground interstate for secure, reliable, resilient power for our future generations.

INTRODUCTION

Structure

Initially convened by the AMS Committee on Climate Services, The Climate Resilient Grid meeting was also supported by NOAA's National Centers for Environmental Information (NCEI), the Cooperative Institute for Climate and Satellites (CICS-NC), and CASE Consultants International. The meeting was held in Asheville, North Carolina, June 14 - 15, 2017 at The Collider, who sponsored the event in part.

The AMS Committee on Climate Services served to engage government, academia, and industry to explore the grand challenges posed by climate and energy, striving to seek solutions in common. NCEI, which provides access to the world's most comprehensive archive of atmospheric, coastal, oceanic, and geophysical data, engaged heavily in the meeting. Specifically, NCEI sought to improve their understanding of its products and services by getting feedback for how to make its environmental information more useful to the energy industry. CICS-NC built upon its history of engagement activities with the energy sector (Arguez) to further its aims in climate data research applications. CASE acted as subject matter experts, and The Collider facilitated the meeting space. The meeting's structure allowed strong exchanges amongst the participants.

Publishing these proceedings widens the audience to the important concepts presented by the speakers. Ultimately, the success of the meeting depends on actions taken. To that end, members of the Advisory and Organizing committees, as follows, invite the reader's reaction to these proceedings.

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Advisory Committee:

Mr. John Curry, JD., Member National Board of Environmental Defense Fund (former)

Phil Hanser, The Brattle Group, Lecturer at Boston & Harvard University

Dr. Otis Brown, NOAA Cooperative Institute for Climate and Satellites - North Carolina (CICS-NC) / NC State University

Dr. Michael Brewer, NOAA NCEI, Customer Engagement Section Chief

Organizing Committee: s

Dr. Stephanie Herring, NOAA Climate Scientist & Senior Advisor; American Meteorological Society Climate Services Committee Chair

Jenny Dissen, NOAA Cooperative Institute for Climate and Satellites - NC (CICS-NC) / NC State University

Ellen Mecray, NOAA NCEI Regional Climate Services Director

Marjorie McGuirk & Doug Copenhaver, CASE Consultants International

James McMahon, CEO, The Collider

Purpose

The organizers designed The Climate Resilient Grid meeting to bring together thought leaders from industry, government, and academia to determine the use of environmental and climate data for meeting industry needs in bringing renewables online. Utilities executives shared perspectives on the current state of their grid, their climate risks and vulnerabilities, and the future of renewables in their portfolio. Solution providers demonstrated how environmental information has been used in asset planning and strategy, resilience planning and strategy, and load planning. Thought leaders discussed the critical role of renewables and the right mix of energy to build an adaptive infrastructure while reducing carbon dioxide. Scientific experts from NCEI and its partners interacted with the energy industry leaders and solution providers to provide insights into and receive feedback on its environmental information.

Stephanie Herring charged the symposium participants to focus on means to optimize and adapt to renewable energy in a changing climate. How do changing patterns of extreme events and a new climate normal impact your generation, delivery strategy, and plans for generational capacity? How does authoritative, predictive, high-resolution data effect your business?

SESSION 1: INDUSTRY LEADERS INTEGRATE RENEWABLES INTO ENERGY SYSTEM

The session opened with perspectives from utilities (Duke and SCANA) on distributed technologies, including renewables, and closed with a case study by Secure Futures on financing and implementing nano grids for solar. Broadly speaking, the session covered some of the challenges and barriers to advancing, the grid's role with distributed energy resources, and how we should we prepare to optimize it. All spoke of the role of environmental information in optimizing plans and operations and ensuring return on investment.

John Gajda from Duke

Distributed energy resources, John Gajda explained, "are a key part of our energy future" and when you understand that energy systems evolve (Figure 1) "renewable growth is really a foregone conclusion." Furthermore, renewable energy "is intractably connected with the transmission system." Whereas in the past, much capital investment went to building conventional power plants, the transmission system is the area that needs future investment.

More transmission is necessary to integrate more solar and wind. Along with renewables, their Smart Energy Future project includes battery storage, microgrids, service businesses, and distributed generation. Duke recently announced a grid investment plan for the Carolinas called the Western Modernization Project. It involves retiring two coal units and replacing them with natural gas-fired combined cycle plants. It also puts on line the Mt. Sterling Microgrid, a with a 10kW solar installation and a 95kW battery. Importantly, it is completely independent, operating non-synchronously with the rest of the Duke Grid. With distributed generation a likely important characteristic of our energy future, control of the grid will likely be more distributed in the future as well.

Developing distributed energy has economic impacts that serve a lot of different people. "At Duke, we choose to be part of it and help it move forward." Distributed energy technologies "encompass regulated and unregulated businesses, but also commercial business solar, wind, and micro grids." Duke has a dedicated department to distributed energy, and acknowledges that "if we invest smartly, everybody benefits." Because regulated utilities center around capital investment, "Duke has made significant solar investment in its regulated side of the business in solar". (Gajda)

When you look at a map of utility-scale solar projects presently in advanced development or under construction in the USA, you will see that solar sites were not driven by solar climatology. Solar was driven instead by incentives, renewable portfolio standards, tax credits, and a legacy holdover for the way the rate proceedings and cost avoidance attracted solar development. Utility-scale solar "came really big and fast, now with 15,000 facilities connected, with 2,000 mW range, with a lot of 5-mW projects on the distribution system." Moving forward, however, climate data may be used in facility siting decisions.

The most immediate need, however, is data for operations, especially of higher temporal and spatial resolution. Power systems are instantaneous demand and supply, and work on a 4-second refresh cycle. In operating, we "chase the loads curve," matching supply and demand. And critical load is weather dependent. To meet demand in a typical summer load curve, "a dispatch stack shows how nuclear, combustion cycle, and hydro, all differ in capacity, turn on, stop and start." Since Samuel Insull created the integrated electrical system in the 1930's, "utilities have capitalized on combining the load curves from all the sectors, residential and industrial, and dispatching from all the capital assets systems," while dealing with the heavy dependence of load on weather, more so with domestic than for industrial.

Daniel Kassis from SCANA

Daniel Kassis from SCANA spoke first to the large commitment in South Carolina to decarbonize the energy supply. He explained that their power generation portfolio has already made progress by shutting down some coal and moving towards natural gas, and by investing 1.1 billion in equipment systems to reduce emissions at our coal fired plants. They plan of 60% coming from solar. He "doubts national policy would derail what is happening with renewables there because solar is so cost effective now" and because their strategy includes nuclear, one of two states building now.

A main effort is using the legislative pathway (not regulatory) to shift to solar, and in general toward renewable energy and a climate resilient grid. A new law in South Carolina requires utilities to develop their own renewable energy plans. Though they looked to North Carolina for guidance for integrating solar, South Carolina's energy plan is written to accommodate the customers of South Carolina, including roof top and community solar. As a result, they have one of the larger solar projects in the country that is regulated by a utility.

Interestingly, residential is the largest contributor of solar energy in South Carolina at 31 mW, largely attained through net energy metering. They are hitting goals today that were not expected until in 2020. It is causing a public policy discussion because, as prices plummeted, they had to terminate their commercial incentive program when they hit the caps. Their incentives prefer smaller solar sites with storage facilities, but with proper incentives, community solar is a stronger option. If installed near the load area, it gains economies of scale. Community-scale solar takes the most disruptive assets and converts it to something with the best pricing. As for utility-scale solar, farms are sited based on land cost, and interconnectedness. Many are near the coast, and not near the load center. While there are many considerations when siting renewables, environmental information is but one factor.

The future of renewable energy means doing things differently; integrate power generators, optimize the entry to storage, place intermittent generators near the load, install advanced metering infrastructure, and include nuclear, which does not emit greenhouse gases, in the plan. And it means a new regulatory framework; one that works for all, that evolves with economics, that rethinks our policies, our approaches, and our attention to consumerism.

Kassis ended with a call to work together to develop a strategy going forward legislatively. He noted that consumers in South Carolina are paying what is a proxy for a carbon tax, and along with community solar, it could be a good strategy for the footprint for how we will move forward.

Anthony Smith, Secure Futures

Anthony Smith, Secure Futures, delivered an innovative case study in the renewables market in Virginia. There they developed and adapted a business model that takes into account the regulatory, environmental, and policy environment. Under 20-year contracts, they finance, build, sustain, and maintain solar arrays. In 2010, they were the first commercial-scale solar installation on the kW scale (as opposed to mW). The solar nanogrid holds less than 100 kW of battery storage; a microgrid is a much larger storage solution comparatively. As a market leader, they developed the first Power Purchase Agreement (PPA), a pilot program with Dominion Power, and shepherded the legislation to allow for PPAs.

They use NCEI's environmental data every day to model solar production. They themselves have been gathering data at five-minute intervals for systems since 2010. As a result, they are finding that year-to-year they are producing enough solar to shave local grid demand by 50-55%. Besides these data, which let them measure variability throughout the days, they need to know what these arrays are going to produce over long time frames. Though they are in the midst of installing irradiance sensors themselves, "solar set generation agreements" requires climate data. Hence, they use climate data to determine true value of an installation over time.

In their business model, customers assume climate risks, making them a stakeholder in climate policy. Furthermore, the model is distributed. Understand that distributed solar provides energy on the customer side of the meter, utility scale solar provides energy on the utility side of the meter. Therefore, the grid-supplied power does not have financial benefits to the customer. Precipitous drops in solar and storage costs, 20% per year, will cause a huge increase in investments in this area. On the investment side, innovation like this is driven by market demand. Customers may demand analytics and justifications for their investments. In a sense, nano grids provide grid services. Nano grids can shave peak demand, reduce supplemental fossil fuel use, and increase resilience to grid outages in extreme weather events.

Extreme weather--like the Derecho wind event of summer 2012 that knocked out power to half a million customers, some for 10 days--often cause huge widespread impacts. In Virginia's event, an emergency shelter had no power because they could not get diesel to run the generators. Nearby Carillion Hospital, however, did not lose power. It became the shelter for the elderly and it saw an eight percent spike in Emergency Room visits. The momentous impact of this event sparked community conversations over the next couple of years that eventually led to developing a nano grid as part of their emergency response and resiliency.

Economics are changing so fast, they decided to do a proof of concept to provide 17% of their electric supply. It was a modest solution, but many other solutions are in play.

Following the project, other leading institutions also want to do the same. Hospitals, universities, churches, non-profits, municipalities, and schools began investigating nano grids, but many states do not allow private PPAs. To make possible significant private investment in those states, their solution is a Solar Self-Generation Agreement, in which they are "selling a service" not "selling electricity". They are also engaging with county extension officers and farmers. For example: Making solar work in real communities, where solar farms provide grazing for local farmers, and sheep provide vegetation management, wins community support.

Session Discussion

Moving forward, where could climate data be used?

Going forward it's not just chasing the load curve, it is "chasing the generators" (Gajda). These bring the need to predict a multivariate system with intermittent generators that independently dispatch themselves, detached from load demand, inducing changes of four to five mW within four minutes. That solar power displaces a certain amount of generation. The question is, could high-resolution radiance data help anticipate dispatch of this level of solar generators operationally? Would it help plans to integrate a 5-mW solar farm into their clean energy future?

Besides critical load and solar dispatch, there is need for dynamic line rating. Conventional science is to put monitoring stations *in-situ* at the transmission line, but placing sensing equipment at critical areas is at the research and development stage. Real-time telemetry on one-minute resolution is an extremely localized measurement, which is not scaled to all transmission lines due to sensing technologies and return on investment as sensors are expensive. Environmental data with 20-minute resolution or less could help better use of the transmission lines already up. Accounting for sag--a function of temperature, sunlight, and wind--would improve efficiency.

Other data used in making energy systems more reliable are the seven-day forecast, the 24-hour forecast, and of course, real time current conditions. In particular, the seven-day forecast is used for load forecasting and is built into the unit commitment forecast. In the future, even higher temporal and spatial resolution will be essential. Forecasts in seconds at plant-level spatial scale, data on cloud movement that impact the generation of solar farms, and other data in real-time.

Continuing in the area of predictive weather data, the greater spatial and temporal resolution from GOES (Matthews), needs to be married with finer resolution data from the grid. Distribution generation means "we will be managing on a smaller scale, load forecasting on a small-scale level also, seven-day, next day. For fine planning at the distribution scale, we'll need finer resolution data" (Gajda).

Secondly, besides data for operations, there are data needs on the planning side. Beyond weather forecasts, the kinds of environmental data needed for informing decisions on where to place solar farms may be helpful. As more solar gets brought into the system, the intermittency will begin to smooth. Reliability improvements are central to plans to harden systems, and for that, better information on the severity and frequency of storms would be helpful. Furthermore, data for long range planning is needed. Planning for wintertime load shaves, for reserve power, for ramping, and for anticipated changes in the load curves require climate knowledge.

Environmental data “is used throughout for risk assessment” (Kassis). Hurricanes, flooding, earthquakes and ice impact the operations and design of a diversity of power infrastructure. “People expect service no matter how harsh the weather conditions are.” From a utility aspect, “the Atlantic hurricane season, the rise of sea level, and harsher more severe weather, focuses our attention to keep services to our customers.” South Carolina has major climate concerns and a system that is able to withstand the impacts is key. Through the integration of resource planning and renewable assets, “we get it to market.” Smith adds “We need more risk prevention for hurricanes, flooding, earthquakes, and ice with diversity of infrastructure.” We have “demands for sea level rise data to inform our infrastructure investments.” And more than data, we need some agreement on the probability of the level of and rate of sea level rise (Smith). Knowing what is possible in the weather and climate world helps us plan to invest, develop, and integrate systems. If the grid isn’t operational, “we are out of business” (Kassis).”

The discussion turned to macro level data, which is critical for investment decisions. Smith cited the National Climate Assessment. With it, they know to “anticipate higher levels of rainfall, which has significant impacts on our assets.” More intense rainfall brings higher risks on twenty-year investments. In addition, considering most of the grid assets are in low lying areas, water elevation data during storms, and the 500-year and 1000-year

inundation levels, is needed. The grid “has to be able to move energy to where it is being used. Assessment “information is highly significant,” and they “want our customers to become more aware of what is ahead.”

KEYNOTE MacDonald

KEYNOTE: An Energetic Evening - Energy’s Future in this Climate

Alexander MacDonald, with Spire Global, delivered the keynote address, Building an underground Interstate highway for Wind, Solar, Hydro, & Nuclear Power.

MacDonald’s work in NOAA proposed a design to move us towards achieving America’s goals of reducing carbon dioxide emissions by more than 30% by 2030 without increasing costs. His work allowed him to examine the issue of the scale of solar and wind generation both quantitatively and economically (MacDonald) (Clack). His work also allowed him to examine the issue of the relationship between the electric system and national security, as having no electric power over a large area for a large period of time endangers our ability to survive. These two problems the US faces are essentially both sustainability; preparing for the robustness and resilience of the electric system while building a sustainable, secure, and affordable electric system by 2030 (Shepherd). MacDonald suggests building an overlay to solve both problems, with a large enough domain to maximize wind and solar across the US and secondly, to guard against threats to our national security.

Based on the spectrum of atmospheric kinetic energy density (Figure 5), the amount of energy obtainable from weather declines significantly below synoptic scales. Weather energy is concentrated at large scales, and wind and solar energy need large domains to be affordable, a domain about the size of the continental US. Given the size of the energy wave, the wind is always blowing somewhere in the US, and we can greatly reduce emissions if we can move power around effectively coast to coast. Inherent in our present Alternating Current lines lies a loss of energy over distances. A national network of high voltage direct current lines (HVDC) can carry energy farther and with greater efficiency.

The design uses a least cost approach to site new wind and solar, leaving in place existing hydro and nuclear. Unsurprisingly, wind power potential was greatest in an area looping through the central US and solar power production was greatest in the southwest. The most load is at population centers on the east and west coasts. Would it be possible to move energy from maximum production centers to the centers of consumption?

Advances in weather modeling, computing, and optimization techniques now allow for much more intelligent system design to find a least cost solution. Using thirty years of hourly weather data, along with coincident load data, we designed a system based on a theoretical HVDC network, to meet the energy load demands at every hour at each of 200 nodes used in the program, spanning 25,000 miles of 2.6 gW cable, with 200 converters.

In addition, “with the threat to our national security” from an Electromagnetic Pulse (EMP) from a coronal mass ejection from the sun, which carries a 10% chance this century, a Carrington event, or a threat from human created bombs, “it is prudent to prepare.” Laying the HVDC lines underground would protect them from EMP and cyber-attacks. A national “underground energy interstate” would create a real-time electricity market that would keep electricity costs low through competition among all types of power generation. But primarily, building an underground highway for our future energy grid would build resilience to increasingly severe weather that is associated with climate change (Herring) and make real progress towards avoiding the most extreme effects of a warming world as described in the literature (Hansen).

SESSION 2: DATA ANALYTICS FOR ENERGY RESILIENCE

In what can be described as an open exchange between data providers and data users, this session highlighted the data provided by NCEI and the data used by disparate energy sector industry experts. Three speakers from NCEI address stewardship, products, and services. Three industry experts described contrasting uses of data, with applications in tactical operational decisions on the one hand, and strategic planning decisions on the other. In addition, the session garnered insight from two utilities engaged in climate resilience.

NCEI leading authority

Mary Wohlgemuth, Margarita Gregg

With a goal of having "the nation's observations effectively stewarded, made accessible and useful," NCEI Director Wohlgemuth and Deputy Gregg stressed that at NCEI "Our science and products are inspired by the demand of the users; we want to make sure that what we are producing is going to be useful." They described the aim of data stewardship by saying "we unlock timely, actionable, and reliable information that then can be used by broad sectors of the economy and the public in making informed decisions." Gregg spoke of several cases where past weather archives were valuable to studies in the energy system from generation to transmission, distribution, and to customers' consumption. In one example, San Diego Gas and Electric utilized data from NCEI to quantify and reduce risk from storms. Cost avoidance in terms of liability, determining usage in Colorado, and temperature extremes for future planning were three additional examples raised. NCEI offers working partnerships, along with data to address a sector's pressing problems. Beyond efforts to store and preserve data, NCEI also integrates data across the range of science disciplines. As the leading authority for environmental information, NCEI uses forums like this in order to understand "what it is that you need and how you need it," for future requirements, adding that it is important to make sure that "the Nations' investments in observations is effectively stewarded, made accessible and useful."

Russ Vose

Speaking specifically of temperature "normals", NCEI climate scientist Vose described them as "one of our most popular product lines" which they had historically produced every ten years. Now, they produce alternative normals. Over 7,500 weather stations' data went into the 1981-2010 normals. He explained that each batch is "a little warmer than the last batch" with "increases in temperature over the last century over most of the nation," adding that particularly over the last 30 years, the warming has been rapid. Couple that with changes in the ways energy is used, that is, with an increase in demand for air conditioning, and a decrease in demand for heating, industry began using normals differently. Normals serve dual purposes, both as a predictive tool, and a tool for monitoring. If it keeps warming up, normals lose value as a predictive tool. NCEI heard from energy managers a need to "Do something other than just 30 years normals we need something that can be adaptable and productive, and make it accessible." NCEI now produces a range of normals, from a NOAA 30 year normal to a five-year normal, and industry self-selects the product that is most valuable to their decisions. In short, "Climate change reduces the skill of traditional normals. Normals are still a great tool, but at this point, alternative approaches may be more appropriate."

Gregory Stunder

Continuing the discussion of normals, Stunder of Philadelphia Gas Works confirmed their usefulness. Owned by the City of Philadelphia, the company has a rate structure that differs from utilities-owned structures. Between 1944-1973, there was a cooling trend, meaning more Heating Degree Days (HDD), followed by a warming trend in the latter years. With even more warming, the company began losing sales volume with less gas sold. Subsequently, a Weather Normalization Adjustment, a real-time adjustment, is applied to each billing cycle, lowering bills when it is colder than normal and raising bills when it is warmer. The 30-year trend in the HDD day "progressive weather normal" used in about 30 utilities. Independent of heating and cooling degree days, customers' demand changed due to net zero buildings, and better consumption efficiencies. NOAA's switch from 30-year normals to new, non-traditional normals was key. If they "had just stayed at 30-year normals the increase in rates would have been significantly different" (Stunder). Having clear, authoritative NOAA references to cite opened a dialog with their sustainability offices and led to good policy discussion.

Yet, a great deal of complexity remains. He further explained that "even while gas volume sales may be going down, they still have to deal with how to maintain a system that is sized to meet the demands of temperature extremes. No one has the answer, but it is a very active discussion right now, on what is the business model going forward."

Pearl Donohoo-Vallettare

Along the same lines, The Brattle Group confirmed: "Weather Normalizing Adjustments are becoming increasingly important for utilities", however, it is not a cure all for utilities to deal with weather-warming-induced decrease in demand, and getting progressive normals approved "is tricky business" (Donohoo-Vallett). For longer-term planning, "No part of the electrical system is unaffected by climate change" as highlighted in Figure 3. For examples, more heat waves make dynamic line loads more difficult. More storms make vegetation management more difficult with increased wind-blown damage.

For long-term energy planning, 20-30-year outlooks are necessary. Using MacDonald's analogy of superhighways to supplemental roads, Donohoo-Vallett said "every lane of the energy system is susceptible to climate change", from decisions on what kind of power plant to build, to anticipating summer daily demand patterns, to deciding transformer size. Temperature affects line ratings. Ambient temperature affects how much electricity you can push down line. Warming nighttime temperatures increase wear and tear on assets. Transformers wear out faster at higher operating temperatures. That drives a capital budget need to plan for more frequent replacements, and a larger supply of backup inventory. As important as temperature is, water is equally pressing. Water is used for energy production, cooling, and operations. Some plants cannot cool sufficiently because there is not enough water available. Both the water temperature and quantity effect the cooling ability. Specific long-term modeling requires good hydro data, and getting this is difficult. All this influences the decisions that utility companies make.

As changing demand patterns follow changing weather patterns, Donohoo-Vallett cautions that as we start to look at a new normal in our climate, "consider that peak consumption may not be 10 or 20 hours a year, but maybe 100 hours with really high loads." When making decisions on the efficiency of a power plant, or to see which technology utilities should use in their plants, or the best resource on hand that can meet this peak, "real investment decisions have to look out over 20-30 years". Stunder, referring to the National Climate Assessment, says that "the anticipated effect in heating and cooling degree days with climate change will be profound" affecting both short-term operational and long-term tactical decisions.

Both speakers were asked about the value of NOAA climate data and information, and the work of climate scientists when they are approaching their constituency for making changes in their business operating principles. They stated that they need that "third-party-respected source" of independent measurements that come from NOAA; that it is very useful and informative for our industries, adding that "constituents want us to use the trusted NOAA data in our weather models". The speakers also found it very useful to be able to refer to the NOAA publications on new weather normals (Arguez) which they called “an incredible helpful reference for us”, adding that “it says NOAA recognizes that this has changed explicitly for planning in the utility industry” (Donohoo-Vallett). Stunder added that “There is a lot of acceptance for our measured data, but when we need independent measurement NOAA is a great reference, and what they did with the transition from the 30-year to the other progressive normals really was a shot in the arm for us and I think you can clearly see that there wasn’t a progression to different types of normals until the last 5 years.”

Ria Persad

Turning the discussion toward managing weather and climate risk for grid resilience and reliability, Persad discussed how weather and climate prediction help in evaluating long-term risk and overload to the grid. As weather is to operations, climate is to planning. Her company uses past data sets in order to look ahead, mentioning in particular, heat waves, maximum temperatures, droughts, high winds, lightning, rain storms, and floods. Persad estimates that “each year large-scale power outages costs 45 billion dollars,” and their frequency has dramatically increased in recent years, with further increases expected. The climate-change associated increase in extremes is causing greater volatility and as a result, measurable impact on every aspect of energy from production to consumption.

The company builds probabilistic forecasting models, looking 90 days ahead, to predict weather. Examining within certain tolerances, the company finds actionable information within trends, catered mainly to the energy industry. Their model generates information on timing and load estimates, for the engagement of renewables and for greater grid resilience and reliability. Models also enable energy managers to minimize brown-outs, black-outs, and impacts of extreme conditions on their infrastructure. Employing renewables bolsters grid resilience and reliability. Stating that their methodology captures the volatility on a week to week basis, they aim to predict extreme event frequency a season ahead using data mining. Having continued access to all levels of data at high spatial and temporal resolution drives the business model.

Insights from Utilities Engaged in Climate Resilience

In his opening remarks, session moderator Dr. Michael Brewer, NOAA NCEI Customer Engagement Section Chief, challenged the speakers to convey specific information. What are you doing? What actions are you taking? What are the information needs?

Michael McPeck

A lead engineer with National Grid, Michael McPeck, who also serves as a liaison to the Department of Energy Partnership for Energy Sector Climate Resilience, explains that having better quantitative data on storms and other information for preparedness, would help their efforts. Though they are careful to not be regulatory driven, regulatory authorities do penalize for outages. To avoid outages, the company spends capital money on hardening systems, such as putting in flood protection and installing higher-class distribution poles. People expect the power to be on all the time, despite seeing “more intense weather patterns, with associated damaging winds, and frontal storms of greater strength, becoming more frequent” (McPeck). Weather systems cause outages, as in one example presented, a microburst that came off Lake Ontario (identified later as a derecho, triggered by a long period of intense heat) “blew freight trains and snapped off transmission poles like toothpicks for a mile-long section.” Besides storm systems, McPeck explained “warmer temperatures, especially warmer summers, affect power transmission, with line sag and clearance issues” that can lead to outages (McPeck).

Their commitment, keeping the power on, necessitates constantly trying to improve the power system, even with some Infrastructure that is very old and susceptible to weather conditions. With log books dating to Westinghouse, Tesla, Edison, and McKinley, the legacy of their company serves to remind us that energy systems continue, even in the midst of upgrades. Today, they might have 24-36 hours or several days to prepare for outages. But in the future, building overall resilience to storms and climate change is part of their efforts.

Among the Partnership's climate resiliency initiates, a storm hardening collaborative involves a rate case called KEDNY, which includes gas system hardening and long-term planning based on climate change projections. It was the result of superstorm Sandy. This Partnership, with 16 companies across the country, formed in 2015, to "share amongst companies what we are doing and experiencing in our own geographical areas so we can learn from others." All the partners have drafted climate resiliency plans. They identify the climate variables that affect the assets, quantify the threshold for action, and prescribe mitigating actions. For example, induced voltage flow from lightning strikes can damage pipe linings. Actions to inspect more frequently and repair become part of the maintenance code. Another climate resiliency initiative involves efforts to reduce methane emission.

Among the initiates of DoE's Partnership for Energy Sector Climate Resilience, it has taken as its initial priority a focus on increased flooding and heavy rainfall, with efforts to install floodproofing. While hardening more vulnerable locations with the temporary measures available, they may displace floodwaters and impact areas in the cross section or upstream (which may create its own challenges with the regulatory community).

As for a national scale resilient grid, consider interestingly, that many of these power grids units, e.g. substations and transmission lines, have been placed in low lying areas. Consider also that FEMA maps from the 1970s have been the best tools they had at the time, all based on previous data, not data going forward. Future projection information should be incorporated into the process so that FEMA "can update their maps that we use as tools in this industry."

Geographical areas across the country experience dramatically different threats to their energy infrastructure. For example, wildfires pose more of a threat in the West, and ice storms accompanied by strong winds and flooding pose more of a threat in the Northeast. The National Grid "has been seeing over the last few years a substantial change in regards to our need to respond to climate events that are affecting our system." In addition to what has been mentioned already, sea level rise, costal erosion, and increased temperatures and vegetation growth" are important to resiliency as well.

Bringing these climate effects into the rate case is paramount, and is "an area in which better information is needed." While working with DoE is beneficial, more needs exist. Taking historical storm data, combined with the most recent impacts and with climate projections, would be helpful to develop "what to expect the next 10 years—and is something we can take to the rate cases." They work with 10-year analysis, not trending information. McPeck, speaking directly to the NOAA moderator, emphasized that the area that they need support in is bringing the information data case to regulators to convince them of costs of resiliency.

Industry has made progress with working with DoE on using data on normals and how to plan for short and long-term, but "when we are engineering assets as a company we are engineering them for the next 80 years, so we need to know not only 5 years from now, 10 years from now, but 50 years from now, and we need to engineer to that standard." Doing so means we need "reliable data to provide to engineers to make reasonable and sound decisions about how to construct for the future" and to push the information into organizations so that they can "get it written into the standards that everybody uses" mentioning, in particular, the American Society of Civil Engineers and the International Electronical and Electronics Engineers Association.

Judsen Bruzgul

Speaking as a senior manager of resilience for DoE, Judsen Bruzgul reflected on the experience with the Partnership for Energy Sector Climate Resilience. He noted that taking action has to be in a decision context and framework in which people are working through change, whether through extreme events, transformative change to a new normal, or unexpectedly rapid change (Figure 4). Bruzgul points out that "the notion of investing 50-80 years out, requires thinking about the tolerable risk condition under which the infrastructure needs to operate, which itself changes over time. Do we need to be designing to that or managing risk to something different? Do we have infrastructure in the future flood plain? What do we need to know to make future decisions? Realistically, energy companies are having underlying change in the risk profile. You can make transformational change to a new normal state, but there is going to be continual change throughout that time period with threshold surprises along the way that lead to rapid adaptation. Wait too long to plan a sub-station, 10 years or more just to get the planning started, and the company has moved out of the tolerable range the sub-station was designed for.

Session Discussion

A discussion on the costs and benefits of making changes for climate resiliency began with thoughts on transformative change. As to what type of data helps prepare for transformational change, Bruzgul responds "scenario planning for low probability and high impact events can be very powerful in preparing to operate in a new normal state." In the specific case of building resilience for long term outages, more information about both probability and potential consequences of an event would enter into the assessment of the overall risk. That would include, for example, an awareness of supply chain dependencies, that is, where is the supply chain for the materials that you are dependent on for the power. In the specific case of sea level rise, the speaker illustrated from readily available data how sea level rise and a category 1 storm surge would inundate the power assets for Boston. Again, however, the mapping is based on NOAA and FEMA data that, particularly in flood tables, are out of synch, and generally the speakers urged NOAA and FEMA to "get together" on flood tables so that they can be useful to plan for resiliency planning, and to operate in greater extremes.

Clearly, the industry leaders in this session stated that they need to make new investments to improve resilience over the long-term. Although having better data would be very informative for thinking about overall risk, in this highly regulated industry there is need to go to regulators and get cost recovery for new investments. The costs and benefits drive the case around new investments, especially where incremental change is insufficient, like just hardening the assets in place, when there is need to do significant change, such as relocating assets. All of the costs and benefits need to be presented along with the risk scenarios in order to see that happen.

Industry leaders also provided a clear statement of the need for authoritative data. Peck adds "there is a tremendous amount of data but tapping it correctly presents problems." But what constitutes "authoritative" depends on the client's preferences, past history, and the other existing sources.

Transparency and third-party sources are important of course, but NOAA is not the only authoritative source, and industry is not the only client. DoE for example is both a client of NOAA data and a source of other authoritative data. Providers and constituents must both view the source as authoritative. Federal sources are most often considered the best sources of reliable data and information, especially as they add scientific rigor and transparency.

As specifically related to the regulators as a “client” of data, an education process is key. Regulators are critical to accepting authoritative data sources. Through their rate cases, industry struggles to educate the regulators, who vary like “a Chevy and a Cadillac” (less so the commissioners than their agencies’ staff who may be “old school”)

In making transformational changes for climate resiliency it is important to distinguish between reliability of (as in hardening against short-term outages) and resilience in a longer-term context. For the latter, the Executive Leadership in a company ultimately owns the responsibility for addressing it, but staff have the responsibility to get them the information they need. Data providers thus have a responsibility to help make decision-makers aware of the data that already exist, and that is being developed citing previous work (Arguez) (Matthews). Though they are excited to discover a new dataset on the NCEI website, it is incumbent upon NCEI to make it known, make it accessible and discoverable and make it understood and useful. A critical role of climate solution providers is bridging between the scientists and data providers and the decision-makers.

At the close of the session, responses to three questions remained outstanding. The first concerns availability of water quantity and temperature data. Riverside Technology asks if water engineers in industry or if NCEI archives the water information data. The second concerns the need in climate information and communication, which was determined to depend on the particular commission and regulator for each utility. Judson reported that ICF is working with ConEdison to bring in climate scientists at Columbia, generate a discussion, to examine load planning, potential new design standards, and risks to assets in the long run. How is climate change considered as a measure of risk part of rate proceedings in in their regulatory procedures filing. And the third open question centered on big data gaps. Access to higher resolution, precision, and accuracy of past data continues to be a need, but also access to outlook farther out in time is required.

SESSION 3: ADVANCING CLIMATE RESEARCH AND SERVICES FOR RENEWABLES

This session provided insights into the latest in technological advances in climate-related technology, with a preamble on the in human factors on grid resilience.

Michael Legatt

As we move towards a more reliable, robust and resilient clean energy grid, Michael Legatt, CEO and Founder of the Resilient Grid, said that we need to account for human ingenuity, and to build systems that maximize human critical awareness in a complex socio-technology infrastructure. The power blackout of 2003 (DOE) reminds us that while systems become more complex, and data more diverse, "we still count on humans to make the right decisions." Robustness in grid design necessarily must include human behavior as it acts "across all layers of the grid." It is evident in developing software and firmware for "smart" Internet of Things devices, in real-time and day-ahead control room operations, and in individual consumer behavior". Maximizing situational awareness in any new design of energy systems is key, and that involves incorporating cultural norms, and motivational tools. Ultimately when people are under lower stress they make better decisions. Solutions that are needed to reach resiliency, in a system as complex as the energy grid, requires understanding that variability and uncertainty are inherent in complex work. We need climate scientists to make it clear that we are heading for a new normal. Normal is "what everyone else remembers and wishes were still true." Increase the understanding, lower the stress, and improve the thinking about our potential future.

Dr. Jessica Matthews

In an exciting new development, NCEI and its national research partners displayed a new application of data from geostationary meteorological satellites that can be valuable for solar energy site selection, optimization, and monitoring (Matthews). Their analysis of the latest GOES satellite cloud cover data is possibly useful for load balancing. The product involves calculating clear sky days, diurnal cloud patterns and potential for higher solar output with smaller variability. Based on NEXGEN GOES, it uses 16 channels versus five, has four times the spatial resolution of the previous GOES sensors, and most importantly has five times faster coverage. It loads full disc imagery every five minutes with a time resolution of 30-60-seconds, and a latency of about a two-minute lag. The entire dataset process may come to NOAAs big data partnership. Google, Microsoft, Amazon, cloud consortium and IBM are interested in this data and may make it available to public.

Tom Flarety

Flaherty, with MES International, reminded the forum that reasons to invest in renewables are many—to reduce negative impact on the environment, to reduce the climate footprint, and to meet sustainability needs of the future as well as the present. Biomass from multiple sources (waste water treatment, food and animal waste), hydropower, geothermal, wind, solar, waves and tides all demand innovative solutions in cost, efficiency, effectiveness, reliability, and durability. Because better proximity between power production and use is a good operating principal, on-site power as in micro-grids and distributed generation are in principal innovation solutions. So are anaerobic digestion and gasification technology. Energy storage is another innovative solution, and electric Vehicles—which still need accessible, fast-charging stations—are one type of innovative energy storage. But we should be looking globally and internationally as well as locally and nationally. Human poverty is single most destructive force to the environment. And poverty is inextricably linked to energy supply. When we look more broadly at technical solutions, keep in mind that the grid we have relied upon since the 1930's is designed for one-way traffic, and now we have multiple points of entry. The solutions we as an industry design today, must work on costs and efficiency; there is no room to wander.

Figures

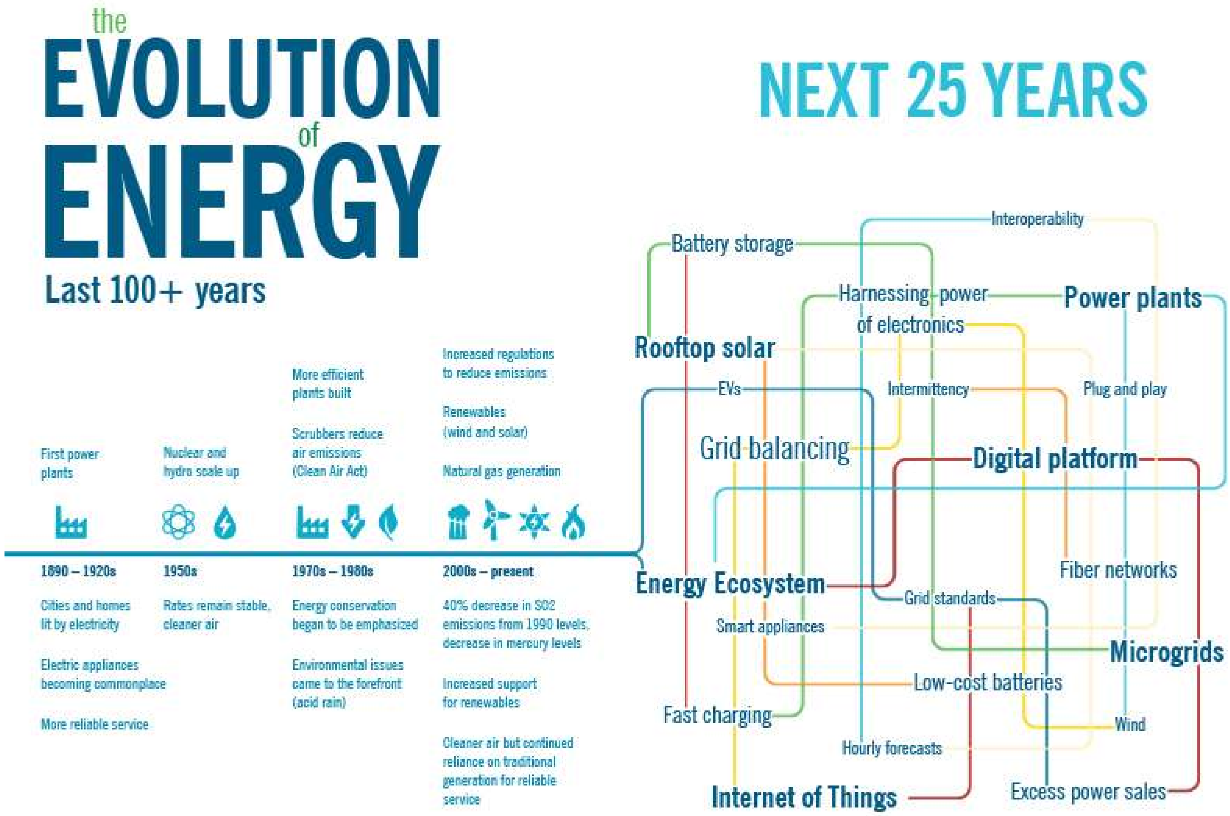

Figure 1 The Evolution of Energy, Duke Energy, "Distributed resources are a key part of our energy future" John Gajda. Infographic by Jonathan Abernathy.

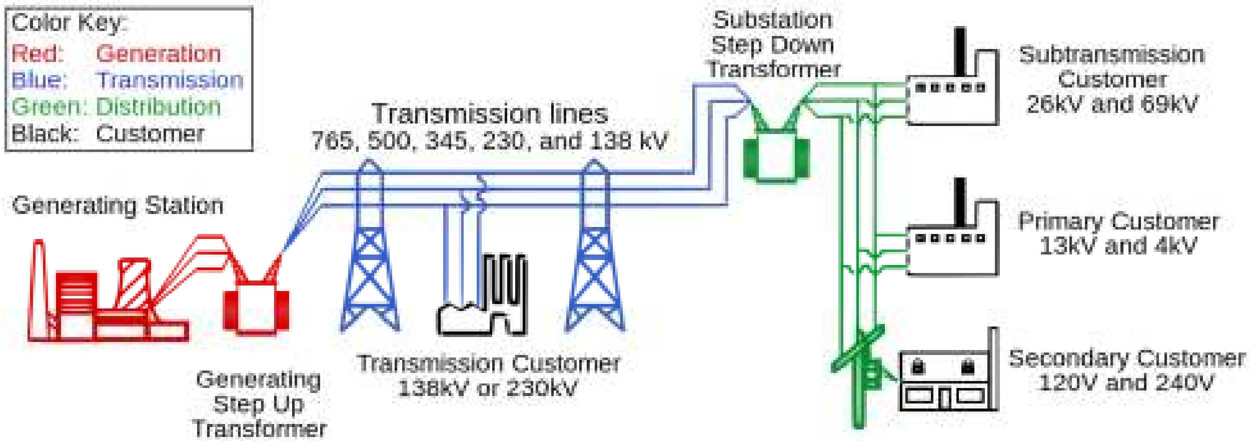

Figure 2 Components of the Energy System, US Department of Energy

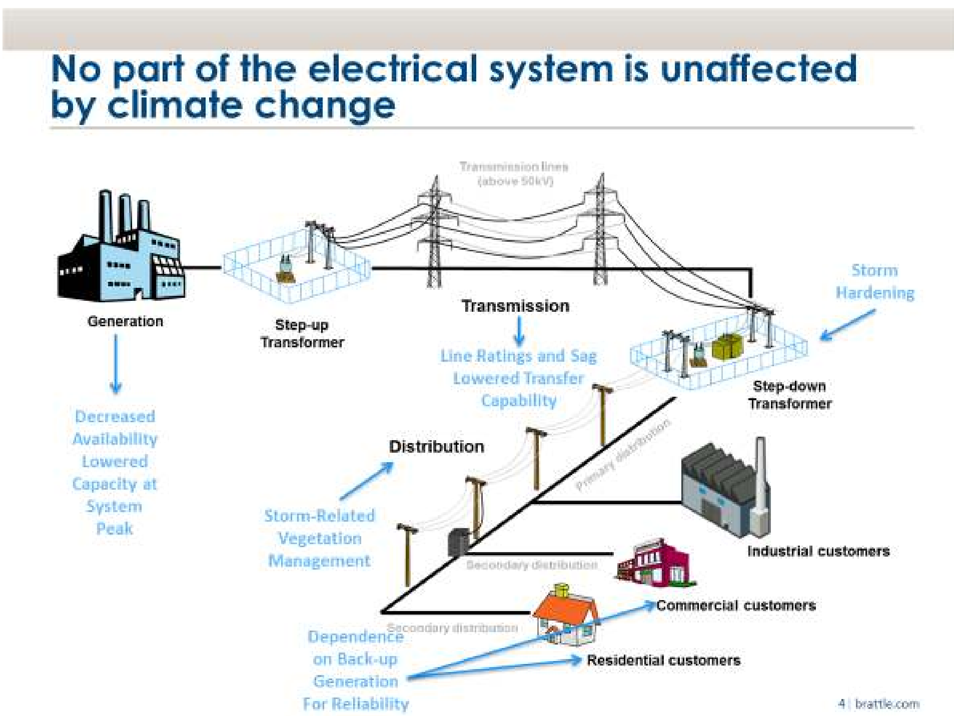

Figure 3 "Climate Change impacts every aspect of the grid" Donohoo-Vallett, Associate, The Brattle Group.

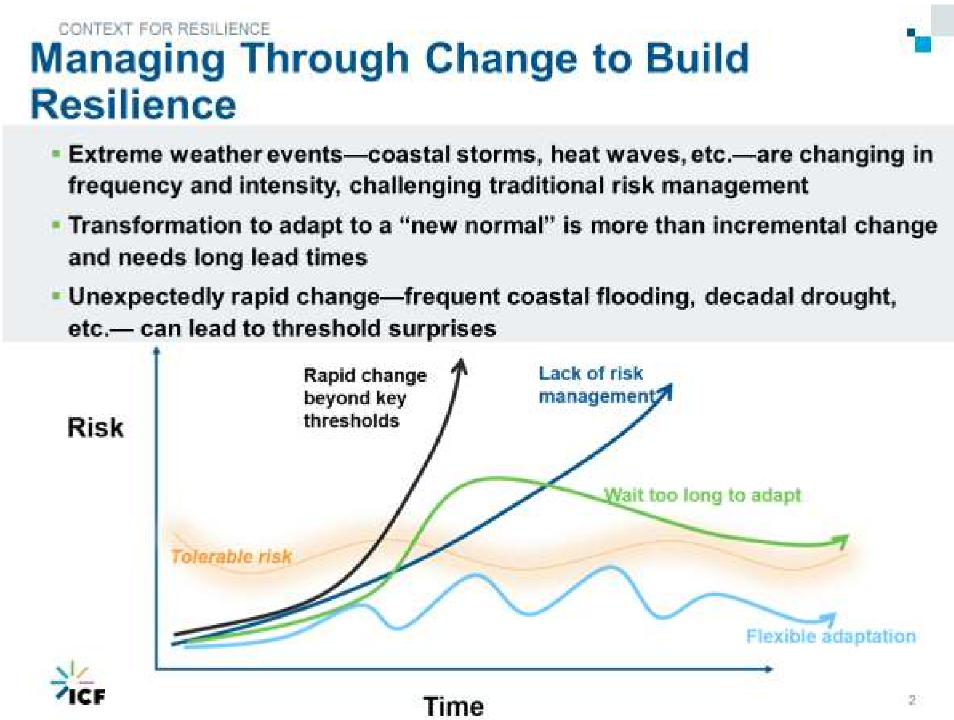

Figure 4 "Even as we manage change, the threshold can suddenly change". Judsen Bruzgul, Senior manager of resilience for DOE department of energy

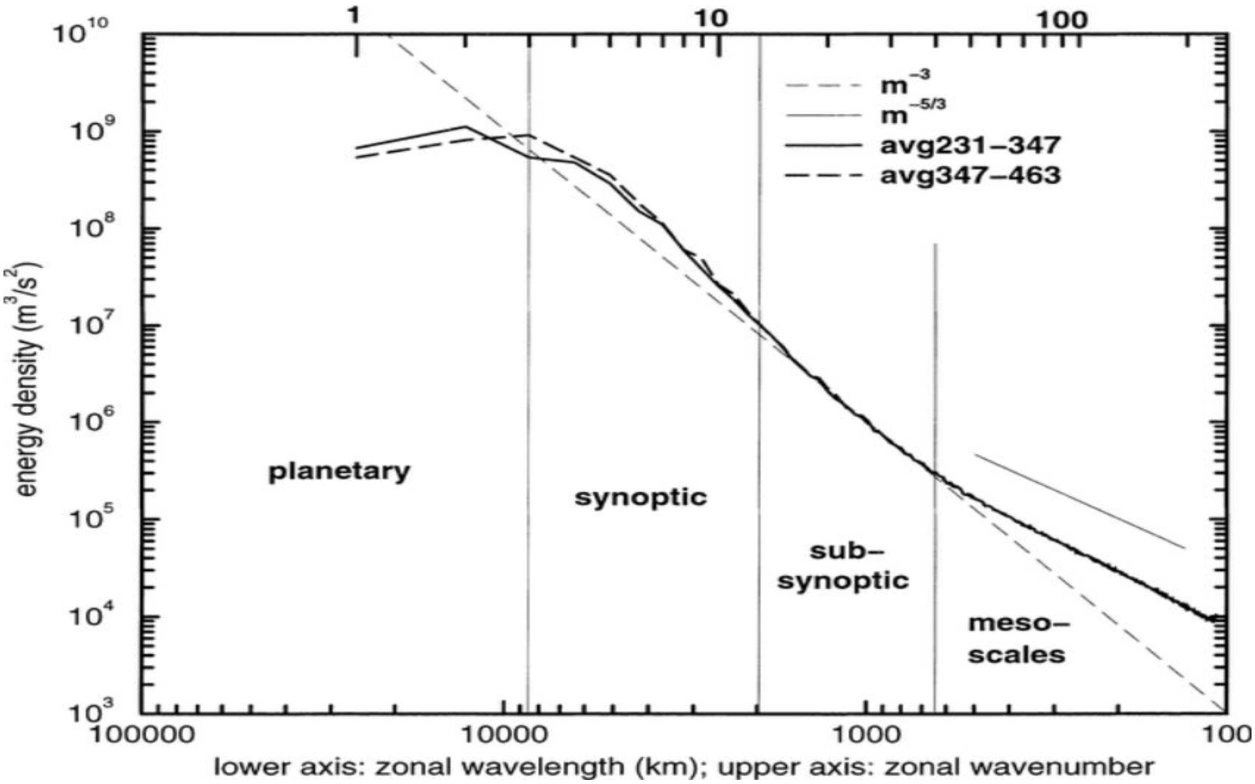

Figure 5 "Wind and solar energy are most effective at large scales." MacDonald.

Works Cited

Arguez, Anthony, Russ Vose, Jenny Dissen. "Workshop on Alternative Climate Normals: Impacts to the Energy Industry." *Bull. Amer. Meteor. Soc., 94, 915–917, https://doi.org/10.1175/BAMS-D-12-00155.1* (2013 (Workshop held 24–25 April 2012)).

Bruzgul, Judsen, PhD, ICF International. "Climate Resilience: Examples from Working with DOE and Utilities." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Clack, C. T. M., Xie, Y. & MacDonald. "Linear programming techniques for developing an optimal electrical system including high-voltage direct-current transmission and storage." *Clack, C. T. M., Xie, Y. & MacDonald, A. E. Linear programming techniques for developing an optimalElectr. Power Energy Syst. 68, 103–114* (2015).

DOE. *Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations*. Washington, D.C.: United States Department of Energy, U.S.-Canada Power System Outage Task Force, April 2004.

Donohoo-Vallett, PhD, The Brattle Group. "Utility Impacts from a Changing Climate." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Gajda, John, Manager, Operations Support, Distributed Energy Technologies Department, Duke Energy. "Duke Energy's Distributed Future." *The Climate Resilient Grid*. Asheville, 2017.

Gregg, Margarita, PhD, Deputy Director of NOAA’s National Centers for Environmental Information. "The Value of NCEI Environmental Data." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Hansen, J. et al. "impact of increasing atmospheric carbon dioxide. Science 213, 957–966 (1981)." *Science 213, 957–966* (1981).

Herring, S. C., Hoerling, M. P., Peterson, T. C. & Stott, P. A. (eds). "Explaining extreme events of 2013 from a climate perspective." *Herring, S. C., Hoerling, M. P., Peterson, T. C. & Stott, P. A. Bull. Am. Meteorol. Soc. 95, S1–S96 (2014).* (2014).

Kassis, Daniel, Vice President, South Carolina Gas and Electric : A Utility Perspective. "A Utility Perspective." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Legatt, Michael, PhD, CEO and Founder, The Resilient Grid. "Moving Towards a More Reliable, Robust, and Resilient Clean Energy Grid." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

MacDonald, Alexander, PhD, Christopher Clack, et. al. "Future cost-competitive electricity systems and their impact on US CO2 emissions." *Nature Climate Change 6* (25 January 2016): 526–531. doi:10.1038/nclimate2921.

Matthews, Jessica, PhD, NOAA CICS-NC, NCSU. "Next-Generation Environmental Intelligence for the Solar Industry." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

McPeck, Michael McPeck, Lead Engineer, National Grid, and Liaison to DOE Partnership for Energy Sector Climate Resilience. "Insights from Utilities Engaged in Climate Resilience." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

NOAA. *Rapid, affordable energy transformation possible*. January 24,, 2016. <http://www.noaanews.noaa.gov/stories2016/012516-rapid-affordable-energy-transformation-possible.html>.

Persad, Ria, PhD, CEO, StatWeather. "Managing Weather and Climate Risk for Grid Resilience and Reliability." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Shepherd, Marshall. "How Weather nnd An 'Interstate of Renewable Energy' Could Save The Climate By 2030." Forbes Magazine On-Line, 15 February 2016. Interview.

Smith, Anthony, PhD, President and CEO Secure Futures. "Confronting the Reality: A Virginia Case Study)." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Stunder, Gregory, J.D., Vice President Regulatory and Legislative Affairs, Philadelphia Gas Works. "What's Normal Anyway?" *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Vose, Russ, PhD, NOAA NCEI, Climate Science Branch Chief. "What is Normal Anyway?" *The Climate Resilient Grid*. Asheville, June 14-15, 2017.

Wohlgemuch, Mary, Director NOAA's National Centers for Environmental Information. "The Value of NCEI Environmental Data." *The Climate Resilient Grid*. Asheville, June 14-15, 2017.