Pacific Northwest
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Seattle City Light

PNNL-37255

Grid Resilience to Extreme Events (ResiliEX 2.0)

Workshop Report

January 2025

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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under Contract DE-AC05-76RL01830

Printed in the United States of America

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Pacific Northwest National Laboratory
Richland, Washington 99354

Suggested Citation:

Homer, J., R. Strauch, N. Voisin, U. Siddiqi, J. Fuller, D. Logsdon, and S. Bates. 2024. *Grid Resilience to Extreme Events (ResiliEX 2.0): Workshop Report*. Richland, WA: Pacific Northwest National Laboratory. PNNL–37255. https://www.osti.gov/biblio/2499810.

Summary

The Grid Resilience to Extreme Events (ResiliEX) 2.0 Summit, co-hosted by Pacific Northwest National Laboratory and Seattle City Light, was held at the Seattle City Hall April 23–25, 2024. This is the second workshop of its kind, with the first one having occurred in Seattle in November 2022. Participants from the second workshop hailed from research organizations, utilities, professional associations, consultants, government organizations, and communities. The purpose of the workshop was to:

- Connect scientists, energy professionals, and policy experts to build knowledge and partnerships
- Advance the understanding of the science of extreme weather events and application to the energy system
- Promote grid planning and engineering that addresses the increasingly complex interdependencies as society responds to extreme weather events
- Understand the role of different decision-makers and policymakers in increasing and accelerating grid resilience
- Identify new approaches, processes, and structures that should be pursued to increase grid resilience to extreme events.

Key Insights

Some key insights from the workshop are summarized below.

1. Multi-disciplinary teams are needed to address the multi-faceted challenges of achieving grid resilience. “We need to exercise the science to planning and policy pipeline.”
2. Scientists and policymakers need to understand the resilience needs and decision-making approaches of utilities, communities, and Tribes at the local level. They may not need to physically get down into the trenches, but they need to know that the trenches exist and where they are. Scientists and policymakers need to make time to listen.
3. Uncertainties in weather extremes, policies, and load growth, among others might be the most challenging technical gap across disciplines, and communicating about uncertainties is critical to designing risk-informed actionable solutions. We increasingly live in an era of unforecastability.
4. Coordination and communication across climate scientists, power system engineers and policy makers are as important as technological solutions.
5. Establishing understanding and building trust with communities and Tribes is essential to advancing resiliency. “Relationships are built at the speed of trust. People don’t care what you know until they know that you care”.

Recommended Actions

Specific actions that were recommended relative to (1) the science of extreme weather events, (2) grid planning and engineering, and (3) decision-making and policy are listed below.

Extreme weather science

- Data and information suppliers should work to **advance vetting of data** and easier **dissemination** though more guidance, translation, and examples.
- Data users, such as electrical engineers, utility planners, and policymakers, should let extreme weather data providers know what data and information they need to **support their decisions**, including the time and spatial scales, as well as desired certainty levels.
- To address accelerating weather extremes, earth system modeling science should **prioritize research on characterization of weather extremes**, including seasonality, compounding, and cascading events with historical context and associated uncertainties.

Grid planning and engineering

- Establish **better data, tools, and methods** to get agreed-upon future forecasts for extreme weather events. Institute coordinated planning that aligns goals for stakeholders.
- Advance **measurements and quantification** of resilience practices, leading to improved **design standards**.
- Address **workforce capacity, evolving jobs, and training constraints** by investing in grants for apprenticeships, building networks within the national laboratories, and supporting investments in critical manufacturing supply chains.
- Increase **good communications across the entire energy ecosystem**, bridging gaps between policymakers and planners, continuing industry collaborations, learning from our neighbors, and breaking down silos.

Decision-making and policy

- Utilities, regulators, and researchers should develop **processes and programs that benefit from local, community, and Indigenous expertise**. Steps toward doing this may include mapping out community and stakeholder connections, providing opportunities for community leaders to lead engagement, engaging with community and Indigenous voices early in the process, using community and Tribal liaisons, and building a network or consortium of community-based organizations.
- Address **capacity, supply chain, jobs, and community and utility resource constraints**. Grant programs and new advanced manufacturing training and capacity development should be considered for Tribal and rural communities. National laboratories can help build networks, share best practices, and develop new programs. And policymakers can explore programs to incentivize domestic production of grid equipment that supports resilience.
- Develop a **consistent approach to evaluating risk and resilience tradeoffs** in the context of utility regulation and investment decisions. Obtain agreed-upon forecasts of future extreme weather events, characterizing the potential consequences of inaction, and considering risk and resilience tradeoffs across a broader context, including interdependent sectors of electricity, water, gas, and telecommunications.
- Develop and support **pathways for regulatory decision-making for grid resilience**. This may include having regulators act as facilitators and conveners, aligning on a set of quantifiable grid resilience metrics for weighing investment options and developing a

comprehensive planning and engagement structure. National laboratories can convene a forum for exploring model regulatory pathways and create a “safe space” for regulators, utilities, researchers, Tribes, and communities to explore options in a non-binding setting.

Conclusions

Climate scientists and utility planners can work together to achieve “fit-for-purpose” energy-relevant data for extreme weather events. Scientists can help non-scientists understand which datasets best fit different planning and analysis needs. Utilities can clearly communicate their design and analysis needs to scientists. National laboratories and state regulators can create forums for these conversations to occur. Patience and persistence are needed as different parties come together to understand the perspectives and language of others.

Different approaches work in different areas. Just as all real estate and all weather are local, so too is resilience. Scientists, engineers, and policymakers need to really listen and understand utility and community challenges. Solutions should be developed together with communities and Tribes.

Utilities and regulators need a framework to consider investment and affordability risks and tradeoffs. In addition, there has to be room for regulators and utilities to take some risks and try new things, or else utilities may be paralyzed by concerns about cost recovery and revenue impacts.

Acknowledgments

The authors would like to thank the City of Seattle for hosting the workshop. We would also like to thank our many speakers listed in this report, the technical notetakers and moderators from Pacific Northwest National Laboratory (PNNL) (Cameron Bracken, Casey Burleyson, Vishvas Chalishazar, Alan Cooke, David Judi, Karma Sawyer, Kevin Schneider, Abhishek Somani, Vincent Tidwell, Brie Van Cleve, JoAnna Wendel, and Jennifer Yoshimura), support staff at both PNNL and Seattle City Light who helped organize the event (Cassie Clark, Michele Witzki, and more), our report editor (Jennifer Blake), and our attendees who contributed to the discussion.

The event and this resulting report were co-funded by PNNL and Seattle City Light.

Acronyms and Abbreviations

BPA	Bonneville Power Administration
DOE	Department of Energy
ERCOT	Electric Reliability Council of Texas
IEEE	Institute of Electrical and Electronics Engineers
NERC	North American Electric Reliability Corporation
NOAA	National Oceanic and Atmospheric Administration
PNNL	Pacific Northwest National Laboratory
ResiliEX	Grid Resilience to Extreme Events (2.0 workshop)

Contents

1.0 Introduction

The Grid Resilience to Extreme Events (ResiliEX) 2.0 workshop, organized by Pacific Northwest National Laboratory (PNNL) and Seattle City Light, was held at Seattle City Hall April 23–25, 2024. The purpose of the workshop was to:

- Connect scientists, energy professionals, and policy experts to build knowledge and partnerships
- Advance the understanding of the science of extreme events and application to the energy system
- Promote grid planning and engineering that addresses the increasingly complex interdependencies as society responds to extreme weather events
- Understand the role of different decision-makers and policymakers in increasing and accelerating grid resilience
- Identify new approaches, processes, and structures that should be pursued to increase grid resilience to extreme events.

The workshop, the second of its kind, brought together a diverse set of participants, including utilities, industry, policymakers and regulators, researchers, and community members to discuss gaps and explore approaches for resilience to climate extremes. More than 110 people joined in person, many of their organizations are listed in Table 1. The workshop and this resulting report are intended to spur conversations and collaborations as well as catalyze additional action to increase grid resilience to extreme events.

Table 1. Workshop Participant Organizations

Participant Type	Participants
Utilities	Bonneville Power Administration
	Con Edison
	Electric Reliability Council of Texas
	National Grid
	Pacific Gas & Electric
	Portland General Electric
	Puget Sound Energy
	San Diego Gas & Electric
	Seattle City Light
	Tacoma Power
Consultants	Burns & McDonnell Engineering
	CarbonPlan
	Eagle Rock Analytics
	Northwest Power and Conservation Council
	Rocky Mountain Institute

Participant Type	Participants
Professional Associations	Aspen Global Change Institute Electric Power Research Institute MITRE Corporation National Rural Electric Cooperative Association North American Electric Reliability Corporation Pacific Northwest Utilities Conference Committee Western Electricity Coordinating Council
State Organizations	California Public Utilities Commission Oregon Department of Energy Oregon Public Utility Commission Washington State Energy Resilience & Emergency Management Office Washington State Governor's Office
Federal Organizations	Federal Energy Regulatory Commission National Oceanic and Atmospheric Administration U.S. Department of Energy, Grid Deployment Office U.S. Department of Energy, Office of Electricity U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy
National Laboratories	Argonne National Laboratory Lawrence Livermore National Laboratory National Renewable Energy Laboratory Oak Ridge National Laboratory Pacific Northwest National Laboratory
Universities	Boise State University Princeton University University of Washington
Tribes and Communities	Affiliated Tribes of Northwest Indians City of Seattle Duwamish River Community Coalition King County Klickitat Valley Health

To begin day one, participants were asked to express what they desired to take away from the conference experience. Responses varied across the range of participants, but several common themes emerged. Many participants stated that they looked forward to building connections with other participants, both to network and to gain an understanding of what other people are doing to promote resilience in their realm. Particularly, several participants mentioned that they were hoping to learn about “regional efforts,” “collaboration opportunities,” and “new partnerships” close to home. “Sharing real-world experiences” among the varied participants or similar thoughts were often identified. Additionally, participants were curious about the crossovers

between science and policymaking, with several mentioning that they are striving to build "closer ties" to align the two. The identification and utilization of extreme weather data was also a common desired takeaway. Notably, participants stated that they wanted to learn how to use data to "inform cost-effective decisions." Furthermore, numerous participants expressed unease over extreme event mitigation and adaptation, citing concerns like grid hardening and resilience, wildfire preparation, and integrating uncertainty of future extremes into long-term planning.

> "Incremental adaptations will be insufficient—transformational adaptation is absolutely necessary."
>
> ResiliEX Summit attendee

Participants were also asked what was currently going well in their industry in terms of grid resilience. The most common responses centered on the increased level of interest in addressing resiliency in recent years. Many participants noted that interest in addressing resiliency is at an all-time high, and that people are becoming more aware of the importance of addressing it every day. One participant highlighted that, "We're becoming more proactive with resilience instead of being reactive." Alongside growing interest, participants stated that increasing investment in extreme event science/research and development and modern technology development has greatly aided their resilience efforts. "Ongoing research and collaboration amongst institutions" was also a central theme, and participants often noted the value of gatherings and events like ResiliEX to facilitate these collaboration opportunities.

In the second activity session of day one, participants were asked to describe the most significant challenges they faced in addressing resilience. Responses varied significantly, highlighting the variance of difficulties that each industry faces in the context of resiliency. However, several central themes emerged, including concerns related to policy, cost, metrics, data, standardization, and community engagement. Several participants noted challenges in aligning the science of extreme weather events and policy, with concerns about "acceptance of paradigm changes by public and change-makers," as well as "[ensuring] that policymakers have the right information to make policy decisions on resilience." In addition, a significant amount of participants mentioned challenges related to cost, both for the industry and for the consumers/customers. Concerns about "how to pay for certain things" and "how much is enough" when considering expensive upgrades to equipment like transmissions or redundancy measures like feeders frequently arose. Participants also worried about "affordability for customers" and "identifying the role of taxpayers/ratepayers" in costing out solutions. Metrics and data availability and standardization were also major challenge areas, with many participants expressing interest in addressing data gaps and the lack of standardization in data presentation and metrics to assess resiliency. Concerns were also presented in dealing with uncertainties in extreme weather data and it's use in long-term planning, and how to "forecast and plan for confluences of events." Participants across technical disciplines also highlighted struggles with knowing when to engage communities in resilience work and identifying best practices for engagement, such as "incorporating community needs/voice into risk," "how to meaningfully involve impacted environmental justice communities in planning," and "[including] more community engagement in analytical efforts."

In the last activity, participants were tasked with identifying potential solutions to the identified challenges, toward advancing grid resilience in their technical discipline. Similarly, responses varied and an array of solutions were identified. Common solutions that emerged included increased research and development in earth systems science and extreme weather events,

embrace community engagement, standardization and centralization of metrics/data processes, and collaboration between entities. Specific research and development opportunities were identified, mostly around technological advances and renewable energy growth. Participants frequently mentioned the benefit of increased community involvement, especially through bringing youth and “local community/Indigenous knowledge” to the table to co-design solutions. Several participants also mentioned that they would benefit from working with community engagement specialists. Standardization was identified as a major challenge, and several solutions, including the development of a centralized database for climate/resilience information and identifying standards for climate data collection and organization were presented. Collaborative opportunities, specifically events that included participants from a wide range of disciplines/institutions, were also frequently noted as an imperative step toward building nation-wide resiliency.

2.0 Workshop Presentations and Panels

This section contains brief summaries and key points made by presenters and panelists during ResiliEX 2.0. It is not comprehensive of everything that was stated or shared.

Opening Remarks

PNNL's **Dr. Jud Virden** and Seattle City Light's **Dawn Lindell** welcomed the attendees, provided brief overviews of their respective organizations, and spoke about the importance of grid resilience to weather extremes. They emphasized the value of forums like ResiliEX 2.0 that can facilitate rapid and informed action. **Tanya Woo**, Seattle City Council, welcomed the attendees to Seattle on day one. On day two, U.S. House **Representative Dr. Kim Schrier** discussed the importance of grid resilience, the impact it has in Washington State, and the legislative momentum on this topic in Washington, DC. **Marco Lowe**, City of Seattle's chief operating officer, spoke on day three and further emphasized the resilience challenges faced in Seattle. Opening remarks emphasized the importance of taking time to come together in venues like this to collaboratively understand and address challenges posed by changing weather extremes on the electrical grid.

Department of Energy's (DOE)'s Grid Deployment Office

Director of the DOE's Grid Deployment Office **Maria Robinson** talked about how her office is advancing grid resilience through planning, analysis, decision support, and financing. She highlighted DOE's deployment and assistance programs that are available to utilities, Tribes, and states. Funds are available to support solutions.

DOE's Office of Electricity

Assistant Secretary of DOE's Office of Electricity **Gene Rodrigues** talked about the dynamic world we live in, calling it an "era of unforecastability." He noted the need to engage, embrace the challenges of our time, make decisions, and move forward. He emphasized that the grid is over 100 years old and utilities need to avoid complacency as they draw a road map with tomorrow in mind. Gene stated that progress can be made with hard and soft solutions, historic funding levels, and through "deploy, deploy, deploy."

Climate Policy Keynote

Washington State Senator Joe Nguyen stated that people need to "show up and listen." The climate challenge is about people's lives. The grid is the backbone of society serving the needs for today and future generations. While the energy system is evolving to address weather-extremes-driven impacts, engineering is not the biggest challenge, it's people. More capacity is needed to identify and implement solutions that work for the communities who host new infrastructure (e.g., siting) or can benefit from solutions (e.g., community assets).

Climate & Science Keynote

Dr. Kevin Werner, the director of National Oceanic and Atmospheric Administration's (NOAA)'s Northwest Fisheries Science Center, provided an overview of his career through applied climate agencies, reflecting on the evolution of how climate science has informed policy across the decades. He noted that we must make informed decisions with the best scientific information

available. Kevin also highlighted that climate change is changing our oceans and, specifically, that marine heatwaves are threatening the ocean ecosystem and fisheries.

Climate Science Panel

The climate panel, moderated by NOAA's **Dr. Joe Casola**, featured **Dr. Crystal Raymond** (University of Washington's Climate Impacts Group), **Dr. Moji Sadegh** (Boise State University), **Katie Meyer Corradi** (National Grid), and **Dr. Owen Doherty** (Eagle Rock Analytics). Crystal highlighted key findings from the Fifth National Climate Assessment (USGCRP 2023): energy supply and delivery are threatened by climate-related hazards, there is a billion-dollar disaster every three weeks on average, and lower-income urban neighborhoods experience higher surface temperatures. Moji discussed compounding extremes, highlighting how the frequency of dry and hot years have increased substantially and how this leads to longer-term impacts. Katie shared National Grid's climate change vulnerability study and resilience plan (National Grid 2023a, 2023b) and revealed how climate science fed into their storm hardening measures. Finally, Owen discussed Cal-Adapt analytics[1] engine used to support California's energy sector with high-quality weather and climate data.

Grid Planning and Engineering Panel

PNNL's **Jason Fuller** moderated the grid panel, which included **Nelson Yip** (Con Edison), **Dr. Venkat Banunarayanan** (NRECA), **Anna Lafoyiannis** (EPRI), and **Dr. Srijib Mukherjee** (Oak Ridge National Laboratory). Nelson shared Con Edison's integrated strategy (Con Edison 2023), which spans climate resilience, but also clean energy, core service, and customer engagement. Venkat provided an overview of electric cooperatives and the challenges they face related to reliability and resiliency, which are increasingly interdependent. Anna shared on Climate READi (EPRI n.d.), EPRI's initiative for climate resilience and adaptation, discussing the three workstreams and the deliverables/guidebooks that EPRI is working on. Finally, Srijib shared an analysis that looked at scenarios within 10 years, focusing on extreme events, policy changes, infrastructure vulnerabilities, and the interdependence of infrastructures.

[1] https://analytics.cal-adapt.org/about/cal-adapt/

Decision-making and Policy Panel

Spanning local to national, this panel highlighted resilience policies in place or being put in place. Moderated by PNNL's **Dr. Karma Sawyer**, **Marissa Aho** (King County), **David Miller** (California Public Utility Commission), **Anna Lising** (Washington Governor's Office), and **Dr**. **Mahmood Mirheydar** (Federal Energy Regulatory Commission [FERC]) described areas where we can improve and the potential for scaling resilience from local to regional to national. The panel also discussed how the effects of changes in weather extremes won't follow state boundaries, making regional approaches as important as state-by-state planning. With each state having its own policies and values, the panelists agreed this wouldn't be easy. The panelists also discussed how FERC "has teeth" and can require investigations and reliability standards while also serving as an enforcement power.

Building Resilience with Communities Panel

This panel led us through a powerful conversation that reminded us of our history, going back generations. Moderated by PNNL's **Jennifer Yoshimura**, panelists **Patrick Freeland** (Affiliated Tribes of Northwest Indians), **Paulina Lopez** (Duwamish River Community Coalition), and **Jonathan Lewis** (Klickitat Valley Health) discussed opportunities and challenges in working with Tribal, rural, and urban communities. Engaging with—and building trust with—communities is necessary before planning for projects surrounding energy infrastructure, and that engagement needs to continue through the life of the project. Tribes have inherent rights and leadership roles and need to be engaged as equal partners throughout. The panelists urged researchers, planners, and agencies to think of ways to bring economic or educational benefits to communities, but also to better frame the importance of grid resilience as it pertains to their community.

Standards Panel

This panel covered standards being developed both by Institute of Electrical and Electronics Engineers (IEEE) and North American Electric Reliability Corporation (NERC). Moderated by Seattle City Light's **Uzma Siddiqi**, panelists **Gary Huffman** (IEEE Distribution Resiliency Working Group Chair) and **Scott Barfield-McGinnis** (NERC) discussed how standards can help us achieve resilience in the face of climate extremes. IEEE published their Distribution Reliability Indices in 1998 and has been methodologically publishing methods, white papers, and assessments ever since. Gary shared IEEE's proposed definition of resilience, "The

capability of electric power distribution systems to deliver electric energy to end-use customers by avoiding interruptions and/or recovering this capability following exposure to naturally occurring high-impact, low-frequency events," and talked about tools and approaches available for measuring resiliency. Scott talked about how planning for extremes is essential for the bulk power system. He shared an update on standards being developed at NERC and highlighted Project 2023-07, which is focused on modeling extreme heat and cold weather. He discussed how, for extremes, climatological data and adequate scenario planning can help unwind the complexities of uncertainties.

Resilience Experience: Bonneville Power Administration (BPA)

Representing BPA, **Dmitry Kosterev** described an extreme cold snap that occurred in the Pacific Northwest in January 2024. The result was several days of record high loads in both Oregon and Washington. During the event, Northwest land-based wind generation reduced to zero, solar power plants operated at very low capacity, and there were several unplanned transmission outages. The Northwest, though, was able to import power from California, British Columbia, Idaho, and Montana, with lines and power services eventually being restored to all customers. This demonstrates the power of collaboration and utility interdependencies.

Resilience Experience: Electric Reliability Council of Texas (ERCOT)

Representing ERCOT, **David Kezell** described challenges Texas faced during winter storm Uri in February 2021. The largest controlled firm load shed event in U.S. history, there were 4,124 outages, derates, or failures, and more than 200 people died as a result. In response, legislation required weatherization of facilities, ERCOT staffed up, winter weather emergencies standards were created, and weatherization inspections began (more than 2,100 inspections occurred between December 2021 and February 2024). In subsequent storms, ERCOT's performance was encouraging. David's overview provided an operational view of what utilities are doing on the ground. He noted that for future viability of low-carbon or no-carbon energy systems, utilities need to begin planning for weeks or months of energy storage. He stated that as an industry, we may need to begin talking about energy storage not in terms of megawatt-hours, but in terms of gigawatt-months.

Student Session: Climate and Energy Resilience

Seattle City Light's **Nika Hoffman** moderated a panel of student presentations on Climate and Energy Resilience. A university course, titled "Community Resilience," is offered in the Department of Urban Design and Planning at the University of Washington and taught by **Professor Bob Freitag**. The course introduces students to a systems approach for resilience thinking and applies concepts through differing resilience metaphors, including engineering resilience, hazards mitigation and risk reduction, and panarchy (Freitag 2021). In engineering resilience, the approach is driven by stressing a trajectory and recovering to that same path. In hazards mitigation and risk reduction, the goal is to reduce vulnerabilities through mitigation. Panarchy is defined as the ability of a system to reorganize through nested adaptation cycles. **Leyla Church,** a student in the course, introduced student presentations on each of these metaphors using a storytelling approach.

3.0 Breakout Discussion Summary

Disciplinary-specific breakouts were held throughout the workshop, after keynotes and panel discussion, to reflect collectively on cross-disciplines' coordination needs and opportunities. Below are outcomes of those discussions.

3.1 Climate Science

Climate science provides the foundation for understanding changes in extreme weather that grid engineers, planners, and decision-makers need to evaluate risks and inform plans, projects, and policies toward a resilient grid. During the workshop, climate scientists gathered in breakout groups to identify challenges and solutions related to the science and its application in meeting the needs of grid engineers, planners, and decision-makers.

3.1.1 Essential Insights

> "Future ain't what it used to be."
>
> ResiliEX Summit attendee

Climate science has advanced substantially over the years and, as important, recent years have shown intentional and widespread effort in making climate data available through open access, web-based platforms, and customizing formats for enhancing their usability. However, users of climate data and information still struggle to confidently know what data is most reliable, high-quality, and fit for the purpose they need. While some breakout participants resisted the notion that climate data are not broadly accessible, climate scientists conceded that data on climate and impacts need to be more broadly findable, understandable, and well-vetted to increase confidence in its use. Data users, such as electrical engineers and policymakers, need to supply climate data providers with more specifics about what data is relevant for their needs, including the time and spatial scale needed, as well as level of certainty desired.

There is still work to be done to have good, robust climate data readily available using approachable technology. As we write this report, we also note the most recent National Academy of Sciences' recommendation to consider model-based approaches to develop traditionally statistics-based reliability metrics of Probable Maximum Precipitation (NASEM 2024). This recommendation is important, as it further opens the discussion on how traditional engineering metrics have been developed so far, so that the next generation can integrate novel and established science and might open discussions across disciplines on consensus about data needs.

Nonetheless, discussions at the workshop identified a remaining dilemma concerning the diversity in available data to address the multitude of studies and the expectation from users to find the right data easily. Highly-trained climate translators, experienced with the uses and the

nuances between datasets and fit-for-purpose, are vital. Timing is of the essence, as more extreme weather is occurring at an accelerating pace with complex combinations and interdependencies. Additionally, more equitable and affordable approaches to resilience are needed to complement the consideration of climate science in decision-making.

3.1.2 Challenges

Participants in the climate science group identified numerous challenges related to grid resilience to extreme events. These challenges can be categorized into three categories related to information, complexity, and capacity, in no order of priority or ranking. Specific examples of each challenge are sub-bulleted below.

1. **Information** on climate science is challenging to **consume with confidence**.
    a. Well-vetted and clearly communicated data/information on climate and impacts specific to the grid are needed. These data should be filtered, trustworthy, and at the appropriate spatial/temporal scales.
    b. Needed are consensus on definitions of extreme weather and selecting definitions that promote robust selections of datasets based on impacts.

> "We need to figure out how to talk about this ..."
>
> ResiliEX Summit attendee

    c. Decision models, including bulk power system models, most often cannot ingest the amounts of data necessary to fully characterize climate extremes, reducing the impact assessment and exploration of opportunities.
    d. Insufficient approaches in isolated, remote, and data-scarce area, create inequity. For example, the state of the art for Alaska and Hawaii is different from that of the mainland.

2. More frequent uncertain and concurrent extremes and associated impacts on electricity supply, demand, and delivery **create complex pressures** to address vulnerabilities.
    e. Weather extremes are happening more frequently, spanning a prolonged period during the year, and are more intense than existing systems (also changing) can respond to.
    f. Dangerous combinations are occurring (e.g., drought, wildfire, heatwave, and public safety power shutoffs).
    g. Simultaneous climate-driven impacts affect habitat and communities.
    h. Uncertainties (real or perceived) on trends, severity and frequency can limit adaptation actions.
    i. Greater system interdependencies can exacerbate and mitigate vulnerabilities.
    j. It's hard to plan for both gradually changing climate and peak/extreme events.
    k. Managing for reliability (System Average Interruption Duration Index and System Average Interruption Frequency Index numbers) doesn't necessarily lead to resilience in the face of low-frequency, novel, high-impact, and life-altering events.

3. There is **limited capacity in utilities to address numerous demands** for incorporating climate science in planning and responding to weather extremes today.
    l. Responding to stressful events today is taking resources that could be used for adapting to tomorrow.
    m. Utilities are focusing planning on near-term timescales rather than planning out to mid-to-late century.
    n. Hyperactive science reporters regularly misrepresent impacts of events or technologies, and scientific resources are diverted to correct and refute.
    o. It is new for utilities to incorporate more complex weather extremes into utility decisions and information systems, as well as community engagement. These are not typically integrated.
    p. There are challenges with supply chains when equipment is either damaged or in need of expansion.
    q. There are challenges understanding and addressing equity and impacts to vulnerable populations.

3.1.3 Solutions

While acknowledging that all these challenges need to be addressed, participants in breakout groups decided to focus on the first **two challenges** related to (1) the vetting and dissemination of data/information and (2) accelerating extreme weather. Proposed solutions and details of these solutions are listed below.

Solution 1 – Improve Vetting of Data and Information
This solution maps to Challenge #1 (Climate Information)

Several nuances were identified related to well-vetted data and information. These included: clearly communicating biases, uncertainty, and limitations; the need to reduce or narrow down from the vast quantity of information available; and characterizing compound events and future normal. Some specific solutions identified by participants included

- Prioritize **vetting of extreme data** that are fit-for-purpose. Start with a subset, such as temperature or precipitation, and then expand into wind, sea level rise, etc., and develop collaboratively with data developers and users.
- Define extreme events **based on users' needs** (e.g., type, duration, planning horizon, timestep, accuracy).
- Create or support **third-party evaluation** and vetting of datasets to increase confidence and facilitate filtering or distillation of available, trusted data (e.g., government standards for climate data).
- Develop a "**super table" of variables and uncertainty** that is use-informed.

Solution 2 – Enhance Dissemination of Data and Information
This solution maps to Challenge #1 (Climate Information)

While participants emphasized the need for well-vetted data and information, they also stressed the importance of better dissemination of these data and information for users to sensibly and pragmatically apply. This solution emphasized data and information fashioned into a usable

format needed for the intended purpose and required clear and concise communication on what is provided, how it was developed, and how to use it. Suggested approaches to advance this solution included

- Create **more guidance** on how to use existing ("the right") data effectively and efficiently, including how to communicate changing risk; consider developing a workflow to describe how to use data.
- More funding for climate data providers and **data curation/maintenance** to make data broadly accessible and consistent across extreme events.
- Consider **using a range of studies**, such as threshold-based impacts, storylines, complex sequential, and cyclic studies, to inform on the range of fit-for-purpose data and expand dissemination.
- Support **translational hubs** for climate data and impacts, tailored to regional needs, including more outreach of existing efforts.

Solution 3 – Characterizing Weather Extremes
This solution maps to Challenge #2 (Complex Pressures)

Participants proposed several solutions to enhance our understanding of the rapid scale of changes in extremes and evolving impacts on the energy industry. It was also noted that new extremes can come from compounding events that lack historical analogs. It was also acknowledged that grid planning is typically shorter duration than changes in climate trends, but this may not be true for extreme weather. To advance solutions to accelerating weather extremes, participants suggest numerous tactics listed below:

- Increase research and development on regional **compounding**, including back-to-back and **cascading events**.
- Support better **seasonal and sub-seasonal** predictability of extreme events.
- Create more tools that simulate **historical extremes with future grid** architecture and demand, which adds context to impacts given grid system changes.
- Facilitate more sharing of **real-world experiences** close to home to advance understanding of impacts and response, particularly community input.
- Expand **characterization of "extreme,"** as it means different things, in context, to different people and in different locations; understand and accommodate extremes related to decision variables used by utilities.
- Expand analyses and understanding of **underground infrastructure** vulnerability and value in hardening efforts.

Solution 4 – Characterizing Uncertainties and Propagation into Risk Assessment
This solution maps to Challenge #2 (Complex Pressures)

Participants discussed the scientific advances in characterizing uncertainties. Uncertainties can be confused with an inability to evaluate risk. Participants also discussed that many policies do not encourage risk in investments. Proposed solutions to discuss uncertainties and risk across communities include

- **Characterize uncertainties** and innovate on climate uncertainty reduction methods toward developing climate datasets that are within the user's tolerance for uncertainties.

- Advance understanding of **accommodating uncertainty** in systems and processes (e.g., sensitivity analyses).
- Use **analogs of stressful events** (locally or elsewhere) to get probability/statistics and impacts from similar events happening in the future (e.g., one region's climate transforms into another region's by when).

3.2 Grid Planning and Engineering

Utilities and developers need to coordinate with decision-makers and policymakers, as well as climate scientists, for grid resilience. As part of the workshop, we explored challenges and opportunities for grid planners and engineers.

3.2.1 Essential Insights

The current rate of change is much faster, and this makes it challenging to keep up with the incoming customer requests, especially of multiple scenarios of what a future grid might look like. Planning processes are becoming outdated, and, in the future, rules like the "percent of peak-load-based planning reserve margin" will no longer be a good measure for resource planning. Also, the existing analysis tools are becoming more stressed. New processes will be computationally intensive, so better tools, algorithms, and more computational firepower are needed.

> "We can't look to the past to know the future."
>
> ResiliEX Summit attendee

Utilities and developers are relying more heavily on the planning process, and investment decisions are being made quickly. The depth of the planning process changes when results are needed. The process must move much more quickly because the multi-year planning process to provide guidance is not responsive to the needs of stakeholders. The many players need to be more agile and flexible and learn to be more comfortable with solutions that are less than perfect.

Another topic covered in this group was about specifying planning needs (i.e., how will the metrics and performance standards need to evolve). Current standards are based on a certain degree of risk quantification and tolerance. The assessment of risk will certainly need to evolve (when, how long, how big, and how frequent). Additionally, the risk tolerance, for example the 1 day in 10-year standard, may not be adequate, and follow-up conversations will be required to explain why a longer planning time horizon may be necessary. We will likely need multiple metrics for planning purposes, but that can be a challenging process to internalize and integrate into the existing, well-established planning processes. However, these changes and adaptations will also enable tailoring of the storytelling to

different audiences. A related topic addressed in breakouts was forecasting. Participants pointed out the need to change to load forecasting instead of net-load for the distribution system. This ties directly with weather and climate. Utilities can no longer plan for generation, transmission, and distribution in silos; in fact, they can no longer just plan for the electricity system. Instead, we need to plan across the entire energy system. Beneficial electrification is moving transportation and building energy usage to the electrical grid, but this will continue to stress the current planning process.

3.2.2 Challenges

The grid planning and engineering group developed the following list of key challenges related to grid resilience to extreme events. These are not in priority order.

1. **Evolving System Requirements**. Current planning standards are based on a certain degree of risk quantification and tolerance. The system will likely need multiple metrics for planning purposes, but that can be a challenging process to internalize and integrate into the existing, well-established planning processes. Consumers are asking for more from their power system, while simultaneously maintaining reliability and affordability. Changing resource adequacy needs, reduced system inertia, increased frequency of extreme events, integrating distributed energy resources, related scenarios and uncertainties, and more are pushing toward new ways of planning that require new data, tools, and methods. The new processes will be computationally intensive, so we need better tools, algorithms, and more computational firepower.

> "We are solving a constantly evolving jigsaw puzzle."
>
> ResiliEX Summit attendee

2. **Speed of Change**. The current rate of change within the power system and the way we operate and plan for new resources is faster than we have seen in decades, and this makes it challenging to keep up with the incoming customer requests, especially across multiple scenarios. Planning processes are becoming outdated, and, in the future, rules like the "percent of peak-load-based planning reserve margin" will no longer be a good measure for resource planning. The existing analysis tools are becoming more stressed to meet the needs.
3. **Capacity Challenges**. The power system workforce is under pressure due to rapid industry growth and change, as well as continuing staff retirements. There are insufficient resources in transmission planning, distribution planning, distributed energy resource integration, local communities, and more. Fostered knowledge transfer, skill exchange, and continuous learning are imperative to building skilled professionals.
4. **Communication and Messaging**. These changes and adaptations will also enable tailoring of the storytelling to different audiences, requiring new ways of communicating complex topics to a wide variety of stakeholders. In addition, increased communication across utilities (e.g., neighbors) and within utilities (e.g., operations and planning) would enhance performance and optimal outcomes.

3.2.3 Solutions

Breakout groups explored solutions to the challenges identified in the section above. Below is a summary of solutions discussed in breakout groups at the workshop.

Solution 1 – Better Data, Tools, and Methods
This solution maps to Challenge 1 (Evolving System Requirements)

Grid planners and engineers identified gaps in currently available data, tools, and methods. The following suggestions were developed during the ResiliEX workshop:

- Create processes to develop agreed upon climate and extreme event forecasts that are designed to address planning for the future. Historical weather trends are no longer sufficient to forecast those future conditions. Regulators, policymakers, utilities, and researchers should work together to establish aligned methods for resilience planning, risk assessment, and risk-resilience trade-offs.
- Coordinated planning that aligns goals for stakeholders. Planning efforts should be integrated and interrelated with documented assumptions, including those happening due to changes in the market. Study efforts should also extend beyond any particular entity to model neighbors for both causality and impacts, and should cross domain boundaries (e.g., grid and natural gas) where appropriate.
- Non-wire alternatives, such as dynamic line ratings, energy efficiency, targeted demand response, and grid-edge technologies, have immediate and long-term benefits that need to be evaluated as part of a broader resource mix to support energy transitions.
- Multiple energy storage use cases with stacked benefits are beneficial for improving grid operations.
- Minimize the differences between planning and real-time operations. Incorporate operational feedback to planning activities, to better align and prioritize capacity expansion, resource adequacy assessments, and other exercises.
- Improve data and knowledge on asset fragility, specifically improving localized data related to extreme events. Make the data more widely available to industry to improve reliability and resilience assessments.

Solution 2 – Enhanced Measurements, Metrics, and Design Standards.
This solution maps to Challenge 1 (Evolving System Requirements) and Challenge 2 (Speed of Change)

Grid planners and engineers identified a need to improve measurement and quantification of resilience practices, leading to improve design standards. The following suggestions were developed during the ResiliEX workshop:

- Industry should continue innovating to quantify multi-metric load events, moving beyond peak annual load analysis to multiple dimensions. Traditional methods of that have relied on peak load studies are no longer valid considering variable generation resources.
- Industry needs to move more quickly, allowing for some comfort with uncertainty and the potential for experiments that do not lead to fully successful outcomes. Investment decisions need to happen rapidly, interconnection processes need to be improved, and siting approval needs to be accelerated. Stakeholders need to be more agile and flexible.

- Weather extreme event scenarios should be fully incorporated into planning processes. Emerging NERC standards for bulk system reliability metrics for system performance and FERC Order 1920 on scenario-based transmission planning are good steps, but these should be expanded.
- Design standards in potentially vulnerable and exposed regions need to be updated, with clear and actionable changes that have quantifiable benefits to reliability and resilience. Rules need to reflect recent and changing conditions, allowing design standards to adapt.
- Potential consequences of inaction and failure to take proactive resilience measures needs to be characterized and shared with industry. Information should be included in planning activities alongside resilience investments options.

Solution 3 – Address Workforce Capacity, Evolving Jobs, and Training Constraints
This solution maps to Challenge 2 (Speed of Change) and Challenge 3 (Capacity Challenges)

Capacity building is an important part of preparing the grid to be resilient to changing extreme weather events, and other emerging changes. The following suggestions were developed during the ResiliEX workshop:

- Invest in grants for capacity building and apprenticeships for critical engineering, construction, electrician, and line worker roles.
- National Laboratories can act as a bridge, enabling communities to share best practices and build wider networks. DOE and the National Laboratories should consider new programs and initiatives that address grid resilience and supply chain needs in ways that create jobs and opportunities in rural and Tribal communities.
- DOE and the federal government can support investments in improving critical manufacturing supply chains (e.g., transformers) and the necessary U.S. workforce to address those manufacturing shortfalls.

Solution 4 – Increase (Good) Communication
This solution maps to all challenges

Grid planners and engineers identified strong communications as a key factor in accelerating change and increasing resilience across the entire energy ecosystem. The following suggestions were developed during the ResiliEX workshop:

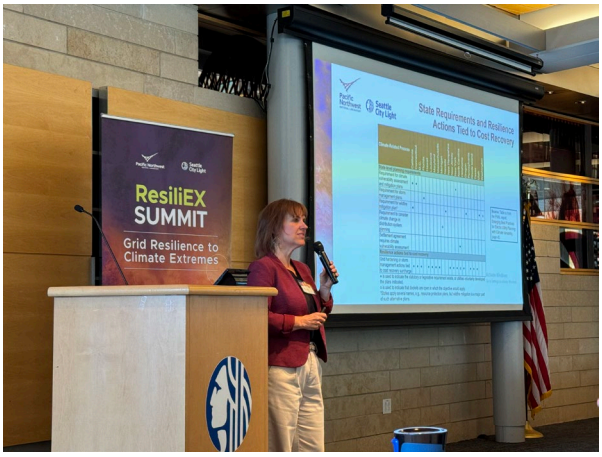
- Bridge gaps between policymakers and planners. Hold forums where information and needs can be shared, aligning goals and outcomes. Use these events to educate policymakers on system requirements and planners on the needs of the consumer.
- WestTEC, WRAP, and other industry collaborations are important parts of communicating shared experiences and objectives. The community should continue to support these activities and others that drive toward regional goals.
- Learn from your neighbor. Sharing experiences and lessons learned around deployments, community engagement, data and tools, and other topics can accelerate innovation while decreasing costs and risks. Developing and supporting forums for information exchange should be further encouraged.
- Increase (good) communications across communities. Within various organizations (e.g., laboratories, utilities, regulatory bodies), provide communications training for

whoever will be speaking directly to communities about the role of power systems in the community and understanding how power systems can increase well-being.

- Develop programs to educate consumers and consumer advocates on changing technologies and grid resilience landscapes, and what it means to the consumer and how it impacts their power system.
- Increase communications across domains and expertise. Silos of excellence exist within companies and across the energy industry, but breaking down these silos allows for creative solutions. Finding ways to increase effective communications (e.g., forums, conferences, etc.) between researchers and practicing engineers, operators and data scientists, policymakers and planners, climate scientists and planners, and more can drive innovation.

3.3 Decision-making and Policy

Grid resilience depends on the actions of decision-makers, including regulators and other policymakers. Decision-makers and policymakers need to coordinate with planners and scientists for grid resilience. As part of the workshop, we explored challenges and opportunities for decision-makers and policymakers.



3.3.1 Essential Insights

Communities and Tribes should be part of the grid resilience conversations from the beginning. Utilities, regulators, and researchers can benefit from local, community, and Indigenous perspectives and expertise. Tribes and communities can also be part of creative solutions to capacity and supply chain challenges. Policymakers and regulators can work with utilities to ensure that community and Tribal voices are heard.

Decision-making under uncertainty has become the norm rather than the exception. Decision-makers need help from climate scientists and grid planners to understand the risks and potential consequences of extreme weather and how those impact investment decisions and utility customer costs. Regulators and other decision-makers need to work more closely with utility planners, communities, and Tribes to understand risks and co-develop solutions. Traditionally, the relationship between regulators and utilities has been adversarial, with a significant imbalance/asymmetry in access to information and expertise. Often, communities and Tribes are left out of conversations altogether. This results in mistrust and drawn-out, contested proceedings. To plan for and develop the resilient grid we need today, given all the changing natural and technological conditions, this dynamic needs to change, and the relationship between utilities, regulators, communities, and Tribes needs to be more collaborative and balanced.

> “Our future resilience depends on decisions made today.”
>
> ResiliEX Summit attendee

This group also discussed the costs of achieving resilience and the affordability tradeoffs that decision-makers must consider. A key question is how much to spend on planning for resilience. If money were not a constraint, utilities could build extremely robust and resilient systems. But regulators and utilities need to weigh and balance building for resilience with affordability and impacts to communities, including those traditionally disadvantaged or left out of decision-making. Decision-makers need information and tools that can help them weigh alternatives and prioritize action.

3.3.2 Challenges

The decision-making and policy group developed the following list of key challenges related to grid resilience to extreme events. These are not in priority order.

1. Decision-makers aren't benefiting from **local, community, and Indigenous expertise** and knowledge in framing questions and devising solutions.
2. **Capacity challenges** in the following areas limit grid resilience: people/workforce, community and utility resources, and supply chains.
3. Regulators, policymakers, and decision-makers don't have **usable information about resilience risks and tradeoffs**.
4. Utilities and regulators aren't communicating and coordinating enough, or learning from other states.

3.3.3 Solutions

Breakout groups explored solutions to the challenges identified in the section above. Below is a summary of solutions discussed in breakout groups at the workshop.

Solution 1 – Utilities, Regulators, and Researchers Can Develop Processes and Programs to Benefit from Local, Community, and Indigenous Expertise
This solution maps to Challenge 1 (benefit from local expertise) and Challenge 2 (capacity challenges)

> "Incremental solutions move the needle, but transformative solutions turn the ship."
>
> ResiliEX Summit attendee

Utilities, regulators, policymakers, and researchers should include community and Indigenous voices in decision-making, investments, technology, holistic solutions, workforce development, and training. Community and Indigenous voices can be brought to the table to help co-design solutions. Specific potential actions include

- **Map out community and stakeholder connections**. When proposing new efforts, take time to understand whose lives will be impacted or disrupted by changes, even incremental changes, and work with those people to mitigate negative impacts.
- **When designing cross-sector solutions**, understand who community decision-makers are and map out who has authority over what.
- **Provide opportunities for community leaders to lead community engagement**. Work with community engagement specialists to design and implement a

comprehensive community engagement process that aligns with project goals and is carried throughout the project's life. Allow community leaders to lead community engagement.

- **Engage early in the process with community and Indigenous voices**. Don't wait to engage until after decisions have already been made. Work to get alignment on goals and outcomes. Move from planning to implementation and action together. Align on and deploy pilots and programmatic solutions toward resilience outcomes. Create actionable steps together.
- Utilities, regulators, state agencies, and city and local organizations can **use existing community and Tribal liaisons and community engagement specialists** where they exist. For example, the Washington Department of Commerce already has engagement specialists. Where needed, organizations can create new positions, hire liaisons, and foster liaison relationships.
- In utility regulatory processes, **address intervener/community funding** to bring more people and voices to the table.
- Develop a program to **educate consumer advocates** on changing technologies and grid resilience landscapes.
- Build a **network or consortium of community-based organizations** with the necessary resources and access to the technical expertise required to participate in infrastructure decision-making processes. Rather than a one-and-done model, this network/consortium should be resourced and durable for future projects.
- **Organize workshops and events with Indigenous and community leaders** with equal collaboration and representation.
- **Work with Indigenous scholars**. Treat Indigenous scholars with the same respect given to technical researchers. Work with Tribal and community representatives who have a connection to the places under consideration, so Indigenous scholars can provide an impact-focused representation of the place.
- **Develop harmonized processes** with community and Tribal participants in mind. Currently, different organizations and parts of the same organization have their processes, with their timelines and language. It's difficult for communities to participate in many activities. Organizations and parts of organizations need to work together and present a cohesive message to communities and Tribes. There's a need for fewer but more coordinated processes that include cooperative utilities, public utility districts, emergency management, and response organizations, non-governmental organizations, community associations, customer organizations, Indigenous groups and representatives, and regulators.
- Within various organizations (e.g., laboratories, utilities, regulatory bodies), **provide communications training** for whoever will be speaking directly to communities and Tribes; engage with community and Tribal leaders first so they can work with their communities.
  - Utilize best practice engagement guides that may already exist.
  - Include consideration of the Americans with Disabilities Act (ADA) and language obligations.

- When communicating with communities and Tribes, **consider the focus of messaging** and whether the focus is or should be on the function (grid resilience) or the impact (extreme heat, fires, etc.). In some cases, it may be better to focus on the impact rather than the function.
- Translate questions and decisions into **accessible language**.
- **Involve the youth** in processes and solutions.

Solution 2 – Address Capacity, Supply Chain, Jobs, and Community and Utility Resource Constraints
This solution maps to Challenge 2 (capacity challenges)

Capacity building is an important part of preparing the grid to be resilient to extreme events. The following suggestions were developed during the ResiliEX workshop:

> "Extreme events don't respect governmental boundaries."
>
> ResiliEX Summit attendee

- **National laboratories can help build networks, share best practices, and develop new programs**. They can also develop an understanding of community strengths and resource and capacity needs. Laboratories can consider new programs or initiatives for DOE that address grid resilience supply chain needs in ways that provide jobs and other opportunities to rural and Tribal communities.
- Advance something like the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act to **incentivize domestic production of grid equipment that supports resilience** to extreme events. Grid equipment that could support resilience includes covered conductors, transformers, inverters, and composite poles.
- **Invest in grants for capacity building and apprenticeships** for critical engineering, construction, and community engagement roles. Develop advanced manufacturing training capacity development for Tribal and rural communities. Consider competency-based programs versus programs focused on hours/degrees. Classrooms can be micro-factories. A model that was proposed was the 1/2/7 model, where programs target the ratio of 1 PhD, 2 engineers, and 7 technicians for educational micro-factories.
- Establish (or support) a **forum for regional Tribal communities to come together and coordinate** the work. The forum can aggregate needs and demands so resources can be considered together. The forum/collaborative could respond together to requests for proposals and could support local supply chains for grid resilience equipment. Utilities could **engage** with the forums.
- **Help consumers access technology, systems, and controls** to help them do more and improve service resilience.

Solution 3 – Develop a Consistent Approach to Evaluating Risk and Resilience Tradeoffs in the Context of Utility Regulation and Investment Decisions
This solution maps to Challenge #3 (usable information for policymakers)

Policymakers and other decision-makers need a better understanding of extreme events and how they may impact the grid, so they can understand consequences, probability, and value,

and conduct the necessary risk and resilience tradeoffs relative to resilience investments and costs to customers. Below are specific proposed solutions.

- Establish processes and methods to **get to agreed-on future forecasts for changing weather extreme events** to be used in regulatory guidance and utility planning. Historic trends are insufficient to forecast future conditions for investment purposes. Regulators can work with utilities and researchers to establish a process and methods to obtain future forecasts that can be the basis of utility grid resilience planning, including risk assessments and risk resilience tradeoffs. There's a need to **align on future forecasts and standards at the federal level**.
- **Characterize the potential consequences of inaction** and failure to take proactive resilience measures and include that information in planning activities alongside resilience investments options.
- Develop mechanisms and forums to consider risk and resilience tradeoffs **information across a broader context**. Move to more systems thinking. Consider a higher, enabling entity to coordinate understanding risks and tradeoffs across this broader context (e.g., electricity, water, gas, and telecom). The gas network is a dark space from a data perspective and from the perspective of how gas impacts the electric grid. This is a problem that needs to be addressed.

Solution 4 – Develop and Support Pathways for Regulatory Decision-making for Grid Resilience
This solution addresses both Challenge 3 (usable information for policymakers) and Challenge 4 (Utility/regulatory communication)

New regulatory pathways are needed to support grid resilience to extreme events. Solutions related to this are summarized below.

- **Regulators can be both facilitators and enablers of resilience outcomes.** Regulators can break down barriers that prevent information flows and help electric planners access gas data to support comprehensive resilience planning.
- Laboratories, agencies, and research organizations can **align on a quantifiable set of grid resilience metrics.**
- Connect **research science to data science**—use information processes to support pathways for regulatory decision-making.
- Regulators can work with parties to develop **a comprehensive planning and engagement structure to support grid resilience to extreme events**. Distribution system planning should be a part of that. Oregon provides a good example of robust stakeholder engagement in distribution system planning. The structure should also include coordinating across regions and up to the federal level. Regulators can also focus on and address issues related to sharing between federal (FERC) and states.
- **National laboratories can convene a forum for exploring model regulatory pathways** for grid resilience to extreme events. Laboratories can create a "safe space" for regulators, utilities, researchers, Tribes, and communities to exchange ideas, challenges, and solutions through sustained, non-binding resilience working sessions to flesh out issues, options, and tradeoffs. This type of collaborative engagement supports flexibility for utilities as they move into new approaches for addressing growing resilience risks. Regulators and utilities need to pick a model or approach and adapt it, but they need to start somewhere.

3.4 Open Discussion and Cross-discipline Reflections

Success within a workshop is community building. One expression of successful community building is when participants build on each other's impactful and inspiring statements and quotes. Those themes keep being developed as a group, which is the principle of ideation. In this section, we highlight a few of those common themes as they support some of the syntheses and recommendations provided earlier and represent the community building established through common language. We also had two more structured and organized community building exercises. One was about climate literacy to develop common language and discuss flexibility in language and accuracy in meaning. The second exercise was an open discussion that complemented the UW students' presentations on resilience concepts; specifically, the community exercise was to identify and discuss concepts that participants relate to the most and use. All three community building exercises shaped the summit.

3.4.1 Common Themes and Quotes

The power grid is the backbone of our economy. We need to partner to deliver expanded solutions to grid resilience. Scientists, engineers, decision-makers, policy experts, communities, and Tribes all have important roles to play in realizing grid resilience. We need to make investments and decisions now for the future, and we need sustainable and equitable solutions. **These investments will support our society for future generations**.

Climate is already changing. **Climate extremes are intensifying and becoming more complex** as they interact with human systems. We need to understand better how to predict the evolving risks associated with those events.

Climate scientists and utility planners can work together to achieve "**fit-for-purpose" climate data**. Climate scientists can help non-climate scientists understand which datasets best fit different planning and analysis needs. Climate scientists can help make data and information more "accessible." Utilities have an important role to play, as well. Utilities need to clearly communicate their design and analysis needs (e.g., data type, temporal and spatial granularity, etc.) to climate scientists. This can take time. National laboratories and state regulators can create a forum for these conversations to occur. Patience and persistence are needed as different parties come together to understand the perspectives and language of others.

We need to exercise the **science to planning and policy pipeline**. Examples of where this is happening include PNNL scientists supporting BPA to understand fire risks and support decisions around public safety power shutoffs. Another example is climate scientists working with state agencies in California to develop Cal-Adapt, which is a cloud-based analytics engine that can support specific applications in the energy sector. Cal-Adapt has a working group that includes all three large investor-owned utilities in California (Pacific Gas & Electric Company, Southern California Edison, and San Diego Gas & Electric) and climate scientists working with utilities and regulators in California. In advance of the rulemaking requiring utilities to develop climate adaptation and vulnerability assessment, scientists and utility planners worked together for many months to come to an understanding of what data and information would be most useful. They are focused on giving engineers the type of numerical outputs they need. **More of this type of coordination needs to happen.** These are things we can build on.

Different approaches work in different areas. **Just as all real estate and all weather are local, so too is resilience local.** Communities and Tribes can be important parts of the solutions.

Scientists, engineers, and policymakers need to really listen and understand utility and community challenges. Solutions should be developed together with communities and Tribes.

> "Relationships are built at the speed of trust."
>
> ResiliEX Summit attendee

With coordination and relationship-building, **continuity matters**, particularly when people in different fields are trying to harmonize efforts, such as when scientists are working with utility planners or policymakers. Engagement and coordination should avoid just one and done. Building trust really takes time. **Trust happens slowly, deliberately, and through shared experience.**

Utilities, policymakers, and researchers need be patient, as well as proactive, rather than reactive when working with communities. Organizations within a municipality or across utility types that serve a community should collaborate before reaching out to communities. Overburdened communities are dealing with many things at the same time, and communities lack the time or bandwidth to participate in many different but related engagement processes. Trust is important. Relationship-building may include listening and acknowledging the injustices of the past.

Coordination and situational awareness are important aspects of resilience, in addition to technological solutions. Leading up to the ERCOT 2021 Cold Snap, there was poor situational awareness and communication about what truly were critical loads, like power to gas compressor stations. In some cases, circuits with these critical facilities were subject to load shedding.

In investment decisions and program design, utilities and regulators are constantly prioritizing focus and investments. Utilities and regulators need a **framework to consider investment and affordability risks and tradeoffs**. It is easy to see the costs of new investments and the impacts of those new investment costs on customers. However, it isn't so easy to see the potential costs of inaction. Better ways to characterize the risks and consequences of inaction are needed. In addition, there has to be room for regulators and utilities to take some risks and try new things, or else utilities may be paralyzed by concerns about cost recovery and revenue impacts. Utilities need more flexibility in decision-making and fewer limitations that can narrow opportunities.

3.4.2 Climate Literacy

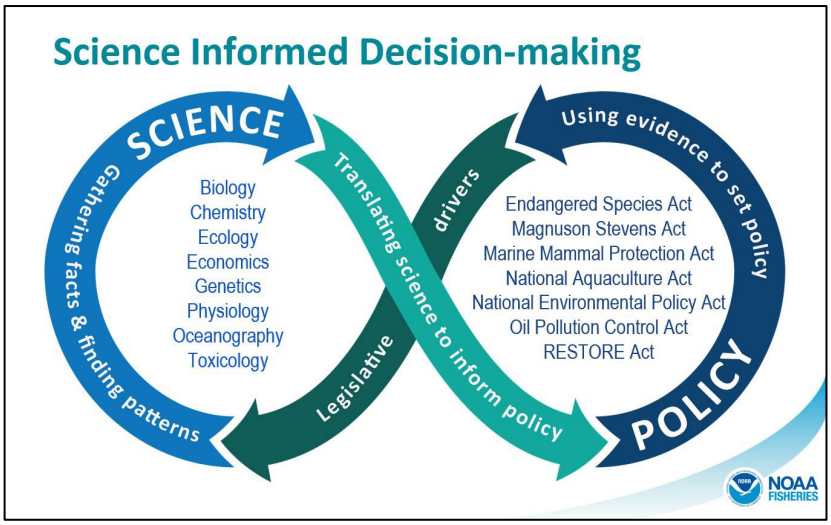
Advances in climate sciences are regularly touted and the availability of datasets and information flourish. Yet, a common feedback and request is to simplify the jargon in climate science and a request to have a simple guideline on which climate planners should use, with the expectation that this one climate dataset would address all questions. This is a normal interdisciplinary trade-off on how much jargon is needed.

A climate-themed crossword game was developed for tables to solve as a team. An open discussion followed to address this general trade-off. The general opinion converged on the need for climate translators and also praised the use of a translators to ensure that innovation in climate sciences gets promptly integrated into power system and policymaking efforts.

3.4.3 Concepts of Resilience

As mentioned in section 3.0, students from the University of Washington presented three concepts of resilience: threshold-based or engineering resilience, storylines or hazard mitigation and risk reduction, and panarchy. The threshold-based approach relies on quantitative assessment of impact, typically on combinations of intensity and frequency to help assess and design for resilience. Storylines are based on narratives that allow the exploration of causality and sequential impact assessment. The threshold-based approach is used in defining extreme events for rating standards. Storyline is currently used in fundamental research for exploring sequential and compound extreme events. Panarchy takes into consideration the diverse system responses to re-evaluate the evolving resilience of systems. Participants were invited to share which resilience concept their activities and discipline used the most.

For example, Dr. Kevin Werner in his keynote presentation referred to a figure to discuss the interactions between climate and policy. This is a representation of the panarchy concept. Both Dr. Crystal Raymond and Dr. Moji Sadegh used a storyline approach to explain the evolution of climate extremes and compounding impacts. In fact, many presentations leveraged a storyline approach to describe events and responses, anticipating human behavior and responses and ripple effects. However, discussions among participants focused on metrics and uncertainties and were most often oriented toward a threshold-based approach. The session concluded that identifying and embracing the diversity in resilience concepts is key for successful multi-sectoral engagement and collaboration toward solutions that can be adopted and implemented by all.



4.0 Conclusions

Some key insights from the workshop are summarized below.

1. Multi-disciplinary teams are needed to address the multi-faceted challenges of building resilience. “We need to exercise the science to planning and policy pipeline.”
2. Scientists and policymakers need to understand the resilience needs and decision-making approaches of utilities, communities, and Tribes at the local level. They may not need to physically get down into the trenches, but they need to know that the trenches exist and where they are. Scientists and policymakers need to take time to listen.
3. Uncertainties might be the most challenging technical gap across disciplines, and communicating about uncertainties is critical to designing risk-informed actionable solutions.
4. Coordination and communication are as important as technological solutions.
5. Establishing understanding and building trust with communities and Tribes is essential to advance resiliency. Relationships are built at the speed of trust. People don’t care what you know until they know that you care.

To conclude the final day of ResiliEX, participants were asked about how they planned to utilize what they learned during the summit in their work. Most responses related back to other central themes mentioned previously and described how they planned to incorporate the knowledge they gained into their research and planning efforts. Additionally, many recognized the “importance of listening to other people’s perspectives” and left feeling inspired to dig into areas of research that were revealed to them through talking with other participants. Most frequently mentioned was the participant’s plans to utilize and continue to build upon the connections they forged through attending the conference, and comfort in the “awareness of all the work being done in various energy professions.”

ResiliEX organizers aspire to continue these discussions with future conversations and gatherings, advancing connections between climate scientists, grid planners, and decision-makers while growing engagement with communities.

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Appendix A – ResiliEX Agenda

Grid Resilience to Extreme Events (ResiliEX) Summit

April 23-25, 2024
Seattle City Hall, Bertha Knight Landes Room | Seattle, Wash.

OUTCOMES

- Connect scientists, energy professionals, and policy experts to build knowledge and partnerships
- Advance the understanding of the science of extreme events and application to the energy system
- Promote grid planning and engineering that addresses the increasingly complex interdependencies as society combats the climate crisis
- Understand the role of different decision-makers and policymakers in increasing and accelerating grid resilience
- Identify new approaches, processes, and structures that should be pursued to increase grid resilience to extreme events

AGENDA

Tuesday, April 23

TIME	TOPIC	PARTICIPANTS
08:00 – 08:30am	Registration Opens	All attendees
08:30 – 10:40am	Summit Kick-off	
08:30 – 08:40am	PNNL, SCL Welcome	Jud Virden (PNNL) Dawn Lindell (SCL)
08:40 – 08:45am	Welcome to Seattle	Tanya Woo (Seattle City Council)
08:45 – 09:15am	DOE's Grid Deployment Office	Maria Robinson (DOE Grid Deployment Office)
09:15 – 09:45am	Introductions and Expectations	Moderators (Juliet Homer, PNNL and Ronda Strauch, SCL)
09:45 – 10:10am	*Keynote 1:* Climate Policy	Sen. Joe Nguyen (WA State)
10:10 – 10:40am	*Keynote 2:* Climate & Science	Kevin Werner (NOAA)

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TIME	TOPIC	PARTICIPANTS
10:40 – 10:55am	**Break**	
10:55am – 11:40am	Overview of Summit Topics	Summit organizers
10:55 – 11:10am	Climate Science	Ronda Strauch (SCL and Nathalie Voisin (PNNL)
11:10 – 11:25am	Grid Planning and Engineering	Uzma Siddiqi (SCL) and Jason Fuller (PNNL)
11:25 – 11:40am	Decision-making and Policy	David Logsdon (SCL) and Juliet Homer (PNNL)
11:40am – 12:40pm	Working Lunch—Resilience Experience	Dmitry Kosterev (BPA)
12:40 – 02:00pm	Breakout Session 1	All attendees
02:00 – 02:45pm	Report back from first breakout	Moderators
02:45 – 03:00pm	Break	
03:00 – 04:15pm	Panel 1 – Climate Science	**Panelists:** Crystal Raymond (UW Climate Impacts Group), Moji Sadegh (Boise State), Katie Meyer (National Grid), Owen Doherty (Eagle Rock Analytics) **Moderator:** Joe Casola (NOAA)
04:15 – 04:45pm	Activity: Advancing Climate-energy Literacy	Ronda Strauch (SCL) and Nathalie Voisin (PNNL)
04:45 – 05:00pm	Recap and Closing Remarks	Moderator, all attendees
06:00 – 08:00pm	Optional No-host Happy Hour **Collins Pub** (526 2nd Ave., Seattle) **Flatstick Pub** (240 2nd Ave., Seattle)	All attendees

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Wednesday, April 24

TIME	TOPIC	PARTICIPANTS
08:00 – 08:30am	Registration Open	All attendees
08:30 – 10:55am	Morning Session	
08:30 – 08:50am	Welcome, Day 1 Recap, and Check-in Activity	Moderators
08:50 – 09:20am	DOE Office of Electricity	Gene Rodrigues (DOE Office of Electricity)
09:20 – 09:40am	Federal Perspective	Rep. Kim Schrier (U.S. House of Representatives)
09:40 – 10:55am	Panel 2 – Grid Planning and Engineering	**Panelists:** Nelson Yip (Con Edison), Venkat Banunarayanan (NRECA), Anna Lafoyiannis (EPRI), Srijib Mukherjee (ORNL) **Moderator:** Jason Fuller (PNNL)
10:55 – 11:10am	**Break**	
11:10am – 12:10pm	Breakout Session 2	All attendees
12:10 – 12:25pm	Report back from second breakout	Moderators
12:25 – 01:25pm	Working Lunch—Resilience Experience	David Kezell (ERCOT)
01:25 – 02:40pm	Panel 3 – Decision-making and Policy	**Panelists:** Marissa Aho (King County), David Miller (CPUC), Anna Lising (WA Governor's Office), Mahmood Mirheydar (FERC) **Moderator:** Karma Sawyer (PNNL)
02:40 – 02:55pm	**Break**	
02:55 – 03:40pm	Standards: IEEE and NERC Cold Weather	Gary Huffman (IEEE Distribution Resiliency Working Group Chair), Scott Barfield (NERC) **Moderator:** Uzma Siddiqi (SCL)

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03:40 – 04:30pm	Student Presentations – Climate and Energy Resilience	Bob Freitag and Leyla Church (UW) **Moderator:** Nika Hoffman (SCL, UW)
04:30 – 05:00pm	Discussion and Closing Remarks	Moderator, all attendees
06:00 – 8:00pm	Optional No-host Happy Hour **Yard House** (1501 4th Ave., Seattle) **Flatstick Pub** (240 2nd Ave., Seattle)	All attendees

Thursday, April 25

TIME	TOPIC	PARTICIPANTS
08:00 – 08:30am	Registration Open	All attendees
08:30 – 10:10am	Morning Session	
08:30 – 08:35am	Welcome	Marco Lowe (City of Seattle, Chief Operating Officer)
08:35 – 08:50am	Day 2 Recap, Check-in Activity	Moderators
08:50 – 10:10am	Panel 4 – Building Resilience with Communities	**Panelists:** Patrick Freeland (ATNI), Paulina Lopez (Duwamish River Community Coalition), Jonathan Lewis (Klickitat Valley Health) **Moderator:** Jennifer Yoshimura (PNNL)
10:10 – 10:25am	**Break**	
10:25 – 11:25am	Breakout Session 3	All attendees
11:25 – 12:00pm	Report back from third breakout	Moderators
12:00 – 12:10pm	Closing Remarks	Jud Virden (PNNL)
12:10pm	Adjourn	

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