Resilient Energy Platform

Power Sector Resilience: Flexible Adaptation Pathways

Background

Power sector planners routinely make investments in major assets (e.g., power plants, substations) with expected operational lives lasting 30 years or more. For assets such as these, the uncertainties associated with projecting conditions and potential threats far into the future make resilience planning both critical and challenging.

What Is Power Sector Resilience?

The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions to the power system through adaptable and holistic planning and technical solutions.

Uncertainty around future economic conditions, technological change, climate change impacts, and other factors presents a wide range of potential futures that power sector planners must account for in the investment decisions they make today. This creates tension for planners as they balance preparedness for the range of potential threats during an asset's lifetime against the imperative to prudently minimize costs despite significant uncertainty about what the future will bring.

The flexible adaptation pathways approach is a solution to this challenge that has been gaining popularity worldwide among resilience planners and that some electric utilities are beginning to apply.

U.S. Army reservists repair a power line in Puerto Rico that was damaged by Hurricane Maria. Photo credit: U.S. Department of Defense

Flexible Adaption Pathways in Use Today

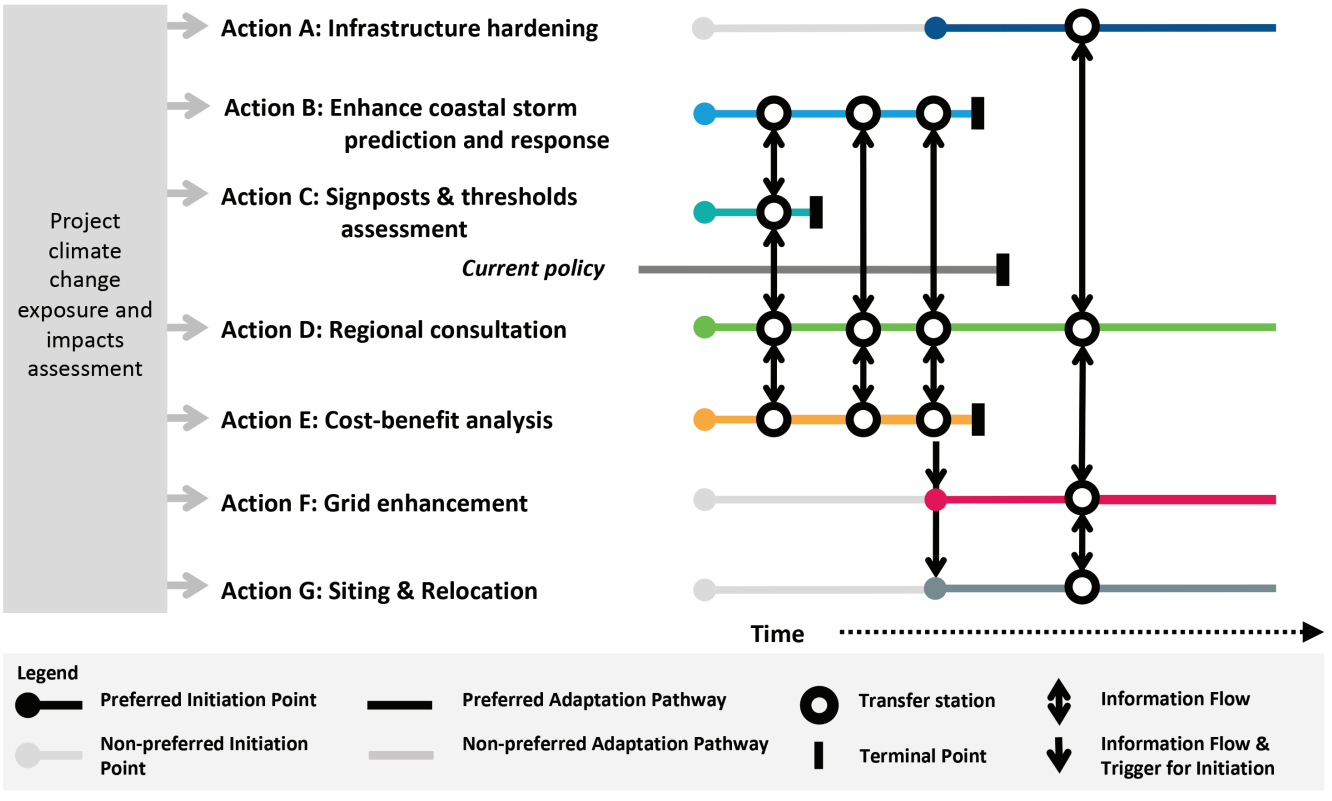
An increasing number of major national, regional, and local jurisdictions are incorporating the principles of flexible adaptation pathways into their climate adaptation plans. The Government of the Netherlands and the City of London have already implemented flexible, adaptive, and monitoring-based strategies for responding to the threat of increased flooding (Netherlands Delta Programme, 2018; Reeder and Ranger, 2011). New York City and the State of California have also made flexible adaptation pathways a key element of official climate adaptation planning guidance (Solecki et al., 2015; California Governor's Office of Planning and Research, 2018).

What are flexible adaptation pathways?

The flexible adaptation pathways approach seeks to optimize planning in the face of uncertainty by creating resilience plans that allow decision-makers to monitor and adjust to changing conditions. Resilience plans are structured such that low-cost, "no-regrets" actions are taken immediately, while more expensive measures can be implemented (to the degree possible) when conditions indicate that they are needed—minimizing the possibility of adapting too early or too late.

Developing Flexible Adaptation Pathways at a California Utility

San Diego Gas & Electric (SDG&E), a major utility in southern California, is currently exploring a flexible adaptation pathways approach to managing the risk of sea-level rise to its coastal assets. This approach was selected following a vulnerability assessment of SDG&E's infrastructure, which identified the need for a flexible long-term adaptation planning strategy. The diagram below illustrates a flexible adaptation pathways strategy for SDG&E. Key elements of the pathway are defined in the legend beneath. As shown, the preferred pathway begins with a set of preparatory capacity-building and monitoring actions. These are followed later in time by a set of physical adaptation measures whose implementation is triggered by information flows stemming from the other measures, indicating the exceedance of relevant thresholds. In this pathway, these triggers for additional adaptation come shortly before the "terminal point" of current policy—in other words, before current policies become insufficient to manage coastal flooding risks in the face of rising sea levels.



Source: Bruzgul et al, 2018.

A critical element in pathway development is determining which of an asset manager's objectives will be impacted by climate change. This ensures that adaptations are implemented in a sequence that ensures objectives are met. The power sector is well-suited to this approach, given that there are often clearly defined service obligations (e.g., reliability) and/or regulatory requirements.

Monitoring change

Effectively monitoring and responding to change is at the core of the flexible adaptation pathways approach. Flexible adaptation pathways are based on a set of indicators (or signposts) and thresholds. Indicators are specific measurements of relevant conditions that may affect the asset. Examples of relevant indicators may include changes in annual peak load, changes in annual maximum temperature, or rising sea levels at a nearby tide gauge. Thresholds are specific values of these indicators that signal that new adaptation action is needed (Haasnoot, 2013).

As an example of these concepts in practice, a flexible adaptation pathway applied to a transmission line might include annual maximum temperature as one of its relevant indicators, given the capacity-reduction impacts of heat on electric transmission. If annual maximum temperatures exceed a set threshold value, this informs asset managers that continued increases in temperatures could soon put the line at risk of overcapacity as a result of both increased demand and reduced transmission capacity. As such, the exceedance of the threshold value triggers adaptation action, which could include increasing transmission capacity or reducing load through distributed energy resources. This sequence of steps allows planners to

recognize and plan for future temperature increases, while avoiding costly upgrades until they are actually needed.

Benefits of flexible adaptation pathways

Flexible adaptation pathways offer a number of key benefits to power sector planners:

Economic value. Flexible adaptation pathways can provide significant economic value by deferring expensive adaptation measures.

Construction flexibility. A pathways approach can build valuable flexibility into construction of adaptation measures: power plant managers, for example, might construct a flood barrier using a modular design that can be easily increased in height in the future.

Evidence-based investments. Flexible adaptation pathways help planners see individual adaptation actions within a holistic long-term context, reducing the chance of "dead end" adaptation actions. At a substation threatened by sea level-rise, for example, asset managers may face uncertainty as to whether elevating the substation will be a sufficient long-term adaptation measure, or whether the asset will need to be moved entirely. If the asset must be moved, raising the substation prior to that could be a costly but ultimately short-term measure. In this scenario, a flexible adaptation pathway analysis might prompt planners to protect only the most critical assets through lower-cost waterproofing and emergency pump systems that are sufficient interim risk reduction measures until the time at which the substation must be moved.

Designing effective adaptation pathways

As power sector planners begin to design flexible adaptation pathways for assets and systems, there are several important questions to consider, including:

- What are the key risks facing assets and systems?
- What is the maximum amount of tolerable risk to a particular asset or system?

Indicators of Change

Flexible adaptation pathways can utilize a variety of different indicator types to monitor the need for adaptation actions or revision of an adaptation plan, including:

- Environmental conditions (e.g., temperature, sea level, runoff)
- Operational metrics (e.g., number of summertime outages, number of operational emergencies)
- Economic or demographic conditions (e.g., new urban development, changes in electricity demand)
- Public policy (e.g., new regulations)

- What sources of information are available to monitor changing risk conditions?
- What are the thresholds of external conditions at which unacceptable risk triggers adaptation action?
- What adaptation actions are available, and how effective is each option?
- How much time will it take to implement an adaptation measure once the decision is made to do so?
- How much will each adaptation option cost?
- How much will each sequence ("pathway") of adaptation options cost?
- Can adaptation options be easily extended or removed if conditions change?
- Are there low-cost, low-regret actions that can be implemented immediately?
- Can different adaptation actions complement one another, or are they substitutes?
- Would some measures be incompatible if implemented together?
- Would some measures be precluded or less feasible to implement under future scenarios?

Answering these questions helps design a flexible adaptation pathways plan that is robust to an uncertain future.

Resilient Energy Platform

The Resilient Energy Platform helps countries address power system vulnerabilities by providing strategic resources and direct country support to enable planning and deployment of resilient energy solutions. This includes expertly curated reference materials, training materials, data, tools, and direct technical assistance in planning resilient, sustainable, and secure power systems. Ultimately, these resources enable decision-makers to assess power sector vulnerabilities, identify resilience solutions, and make informed decisions to enhance energy sector resilience at all scales (including local, regional, and national scales). To learn more please visit the Platform at: resilient-energy.org.

Resources to Learn More

Bruzgul, Judsen, Robert Kay, Andy Petrow, Beth Rodehorst, David Revell, Maya Bruguera, Tommy Hendrickson, Kevin Petak, Dan Moreno, Julio Manik. (ICF and Revell Coastal). 2018. "Potential Climate Change Impacts and Adaptation Actions for Gas Assets in the San Diego Gas and Electric Company Service Area." In *California's Fourth Climate Change Assessment*. (California Energy Commission). doi: CCCA4-CEC-2018-009.

Bruzgul, Judsen, Robert Kay, Andy Petrow, Tommy Hendrickson, Beth Rodehorst, David Revell, Maya Bruguera, Dan Moreno, and Ken Collison. (ICF and Revell Coastal). 2018. "Rising Seas and Electricity Infrastructure: Potential Impacts and Adaptations Actions for San Diego Gas & Electric." In California's Fourth Climate Change Assessment. (California Energy Commission). doi:CCCA4-CEC-2018-004.

California Climate Safe Infrastructure Working Group. 2018. "Paying It Forward: The Path to Climate-Safe Infrastructure in California." (California Natural Resources Agency).

California Governor's Office of Planning and Research. 2018. "Planning and Investing for a Resilient California."

Haasnoot, Marjolijn, Susan van't Klooster, and Jos van Alphen. 2018. "Designing a monitoring system to detect signals to adapt to uncertain climate change." *Global Environmental Change* 52: 273-285.

Haasnoot, Marjolijn, et al. 2013. "Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world." *Global Environmental Change. 23(2):* 485-498.

Netherlands Delta Programme. 2019. "Continuing the work on the delta: adapting the Netherlands to climate change in time."

Reeder, Tim and Nicola Ranger. 2011. "How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 project." *World Resources Report*. http://www.worldresourcesreport.or

Solecki, William, et al. "New York City Panel on Climate Change 2015 Report Chapter 6: Indicators and Monitoring." 2015. *Annals of the New York Academy of Sciences.* 1336 (1): 89-106.

Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Van Garderen, E. A., & Campbell, B. 2013. "Reconceptualising adaptation to climate change as part of pathways of change and response." *Global Environmental Change*. 28:325-336.

Written by Cole Wheeler, Robert Kay, and Joanne Potter of ICF

www.resilient-energy.org

Jennifer Leisch
Clean Energy and Climate Change Specialist
U.S. Agency for International Development
Tel: 303.913.0103
jleisch@usaid.gov

USAID FROM THE AMERICAN PEOPLE

The Resilient Energy Platform provides expertly curated resources, training, tools, and technical assistance to enhance power sector resilience. The Resilient Energy Platform is supported by the U.S. Agency for International Development.

REexplorer MAPPING OUR ENERGY FUTURE | Greening the Grid | I-JEDI | Resilient Energy Platform