Valuing Adaptation and Resilience Interventions in the Power Sector

Flooded electricity pylons in Thailand (Image: Shutterstock)

Background

By 2040, the global power sector will require an estimated $30 trillion in investment to keep pace with current trends and achieve the Sustainable Development Goal of universal electricity access (Global Infrastructure Hub, 2017). As global efforts to combat climate change increase, a growing proportion of this investment will be spent on lower-emitting power resources.

As decision-makers plan and undertake these investments, climate change is also shifting the investment risk calculus for the power sector. If new global power infrastructure fails to incorporate resilience measures that protect against climate hazards—including more frequent and intense storms, droughts, sea level rise, and heat waves—massive amounts of investment and hundreds of millions of people who rely upon it could be put at risk.

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.

Investments in power system resilience can reduce impacts and associated costs, but effective methodologies that estimate the added value of resilience are needed to assess, justify, and prioritize these investments.

Fortunately, there is a growing body of knowledge regarding how to value energy system resilience. Decision-makers and system planners can take advantage of these emerging practices to ensure that current power system investments are prepared for the hazards of a changing climate. The [Resilient Energy Platform](https://www.resilient-energy.org) was created to help energy professionals access these techniques. This fact sheet provides an overview of innovations in analytic practice that are helping to strengthen energy systems around the world.

What is the value of power sector resilience?

Appropriately timed resilience measures can reduce costs and avoid damaging impacts and service interruptions. Potential consequences include both direct impacts to electric utilities and indirect impacts to the populations they serve.

For utilities, resilience measures can prevent or reduce damage to equipment and facilities, and/or disruption of operations, that can result from a range of natural hazards, including extreme storm events, long-term sea level rise, or extreme heat.

For the public, a resilient power system translates to protection from the broad array of harms and costs associated with loss of electric service. These impacts can range from lost business revenue due to a factory shutdown, to health risks from loss of air conditioning, to the failure of critical lifesaving equipment at hospitals.

In theory, all of these benefits are quantifiable in dollars that decision-makers should be willing to spend to avoid adverse impacts—effectively placing an economic value on the various benefits of resilience. Indeed, an increasing number of effective tools and methodologies exist to estimate this "resilience value" in certain cases. However, challenges to accurately valuing all the benefits of resilience measures remain, and these can limit the realization of the full benefits of resilience in many decision contexts.

What are the challenges in quantifying the value of power sector resilience?

While the benefits that utilities and societies stand to receive from resilient power systems are clear, translating those benefits into a resilience value associated with specific measures like microgrids and flood barriers can be a challenging task. The barriers to placing a value on resilience include:

Lack of standardized metrics

Whereas metrics for measuring reliability (defined mostly based on short duration outages) are clearly defined in the power sector, a set of standard metrics for measuring resilience has yet to emerge.

Uncertainty around future hazard events

In a changing climate, the frequency and severity of hazard events may differ substantially from the historical record. While global climate models and information derived from them (e.g., flood risk) can provide projections of future exposure, analyzing the implications of these projections on power sector performance is expensive and time-consuming. Furthermore, model results are characterized by significant uncertainty, both between models with differing assumptions and between various potential scenarios of global greenhouse gas emissions and earth system dynamics (Chiabai et al., 2015).

Resilience Benefit-Cost at the U.S. Federal Emergency Management Agency

Applicants to the U.S. Federal Emergency Management Agency's (FEMA) hazard mitigation program must show net-beneficial results from a benefit-cost analysis. To facilitate this analysis, FEMA provides a standard methodology and software tools that estimate frequency and risk of floods, high winds, wildfire, and other hazards. The methodology assesses a variety of potential benefits of hazard mitigation measures, including avoided casualties, avoided property damage, and avoided electricity loss. FEMA has begun to incorporate climate change considerations into this tool, including sea level rise and flood risks. (Li et al., 2014; see Cooper et al., 2016 for a sample analysis that uses the FEMA tool and further incorporates elevated risk from sea level rise.)

Difficulty estimating the effectiveness of resilience measures

Placing a resilience value on investments requires making assumptions about the degree to which a given measure will reduce relevant climate risks. Given the large range of potential resilience measures and the lack of readily applicable data, this can be a major barrier to the quantification of resilience benefits (Chiabai et al., 2015).

Difficulty accounting for indirect benefits

While damage to equipment is relatively easy to quantify (e.g., the cost of replacing a transformer), the impacts on society from the loss of energy services are harder to value. Dollar cost estimates of the per-hour value of electric service exist for the U.S., but even these do not consider the impacts of outages longer than 16 hours or downstream impacts to critical public services (Sullivan et al., 2015). Translating the number of customers without power or impacts to power-dependent services (e.g., gas stations or hospitals) into economic costs can pose a barrier to valuing resilience.

How can power system planners better value resilience or quantify resilience benefits?

While the barriers listed above are substantial, failure to value resilience measures at all will lead to suboptimal investments. Even in the absence of perfect information, there are several strategies that energy system planners and financiers should consider:

Value a broader stream of resilience benefits in cost-benefit analyses

Identifying cost-beneficial resilience measures requires a thoughtful accounting of a number of benefits that may not be captured in standard cost-benefit analyses. While indirect societal benefits such as avoided outage costs or avoided impacts to critical downstream services may be difficult to quantify, they are potentially very large. Estimating the value of these benefits, even using conservative assumptions, may prove relevant in justifying resilience investments to regulators and investors.

Similarly, appropriately valuing resilience measures requires careful consideration of a broader set of direct benefits. Selecting an inland location for a power plant, for example, could produce significant benefits by reducing coastal flood risk. Given climate-driven changes in the risk environment, planners should ensure that such risks are appropriately considered.

Even when accurate cost and benefit estimation is challenging, including conservative, order-of-magnitude estimates of future impacts may reveal benefits from many resilience measures.

Use alternatives to benefit-cost analysis

In some cases, other analytical tools may be more practical or appropriate in characterizing resilience options.

A ***break-even analysis*** is in many ways similar to benefit-cost analysis, but reframes calculations in terms of the minimum conditions required to "break even" on expenditures. In resilience terms, this could mean assessing the need for storm-hardening measures by determining the minimum number of Category 4 storms that would need to affect the area over 10 years to make the investment economically worthwhile. This approach allows for a simplification of uncertainty projections into the determination of a reasonable lower bound of risk, rather than a precise expected value. If this lower bound indicates that the incremental costs of resilience measures will break even, planners and investors can regard resilience investments as "no-regrets" measures with only upside potential.

Another such method is ***multi-criteria analysis***, in which decision-makers rank qualitative or quantitative factors such as resilience on a numerical scale (e.g., a 1 through 5 "resilience index") or simply present non-financial metrics alongside financial figures. This framework even can be linked with benefit-cost analysis, with the benefit-cost ratio serving as one of several criteria. An advantage of this style of analysis is that it is not necessary to convert all benefits into economic terms. Rather, benefits such as avoided outages for critical customers or continuity of public services can be ranked and evaluated separately—allowing decision-makers to make quantitatively scored judgments without monetary valuations. This style of analysis allows for the quantified consideration of resilience "co-benefits" that may be ancillary to the core function of a project, but may still be relevant to consider in selecting between different options.

Other non-monetary methods of evaluating resilience exist as well (DOE, 2016). For example, the box on the following page describes the method a U.S. utility used to prioritize resilience measures without calculating benefits in dollars.

Select and implement metrics that capture resilience

While industry-standard resilience metrics do not yet exist, planners can still adopt simple metrics that can capture important elements of resilience. Such metrics can provide a framework for evaluating resilience goals and scoping the associated costs. Examples of resilience metrics might include (Vugrin et al., 2017):

- Cumulative customer outage hours
- Time to restore power for 90 percent of affected customers after a major outage
- Number of annual hours that critical services (e.g., hospitals, schools) are without power

Consider resilience co-benefits (particularly emissions mitigation)

Many resilience measures have secondary benefits that provide public value, and some projects with non-resilience goals have resilience co-benefits. There is an especially strong link between resilience and low-emissions development. Energy efficiency measures, often implemented for cost-savings or emissions reductions, can also enhance resilience by keeping indoor conditions comfortable for longer in the event of an outage, or allowing backup generator fuel to last longer. Distributed solar not only reduces emissions relative to total reliance on the grid, but can also increase resilience to outages by reducing dependence on a single generation source, especially when coupled with energy storage. Energy system planners should attempt wherever possible to value the resilience benefits of low-emissions strategies and vice versa, strengthening the economic case for both. Planning for resilience should also be part of the development of low-emissions energy resources, as these investments may also be vulnerable to climate hazards.

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 material, 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 about the technical solutions highlighted in this fact sheet, please visit the Platform at: resilient-energy.org

Con Edison's Prioritization of Resilience Measures after Hurricane Sandy

Following major power outages caused by Hurricane Sandy in 2012, the New York City electric utility Con Edison developed a methodology for quantifying the resilience benefits of potential storm-hardening investments. Con Edison subsequently used this methodology to prioritize the investments that provided the most significant reduction in risk from wind- and flood-related outages. The utility's prioritization analysis was based on a model that combined the following inputs:

- Probability of wind or flood impact event: Modeled based on past impacts to the Con Edison system and future sea level projections.
- Probability of wind and flood damage causing outage during an impact event, before and after asset hardening: Estimate based on engineering analysis of flood vulnerability and asset damage during past wind events.
- Duration of outage: Estimate of length of outage, informed by past impacts.
- Population affected by outage: Residents or commuting workers in the area experiencing an outage.
- Critical infrastructure affected by outage: Important public assets or facilities in the area experiencing an outage, including schools, police stations, hospitals, subways, and tall buildings dependent on elevators.

Con Edison combined this information to produce a "Risk Reduction Priority" index, in which all proposed system-hardening measures were ranked. Notably, Con Edison chose to avoid quantifying risk in dollars. Adaptation measures that most significantly reduced the duration of outages—weighted by population, critical infrastructure, and probability—received the highest scores. Con Edison also calculated a ratio of risk reduction to cost, identifying measures with high risk reduction values per dollar of investment (Con Edison 2014).

Resources to Learn More

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Additional Resources

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