Resilient Energy Platform

Power Sector Resilience: Integrated Resource and Resilience Planning

Background

Various threats—natural, technological, and human-caused—can compromise the safety, reliability, and affordability of power delivery. Among these threats is climate change, which can affect power generation, transmission, distribution, and the ability to meet demand by driving changes in rainfall amount and distribution; rising temperatures and more intense heat waves; sea level rise and storm surge; more frequent large wildfires; more frequent and intense droughts; and related hazards, such as flooding and landslides. As the climate warms throughout the century, these stressors are expected to continue to intensify (Bruzgul et al., 2018; Hellmuth, Cookson, and Potter, 2018). As a result, it is in power providers' interest to consider potential climate impacts when undertaking long-term power system investment planning.

What Is IRRP?

Integrated Resource and Resilience Planning (IRRP) is a strategic energy planning approach that enables power providers to identify a "least-regrets" power resource investment portfolio or one that is most resilient to potential future risks.

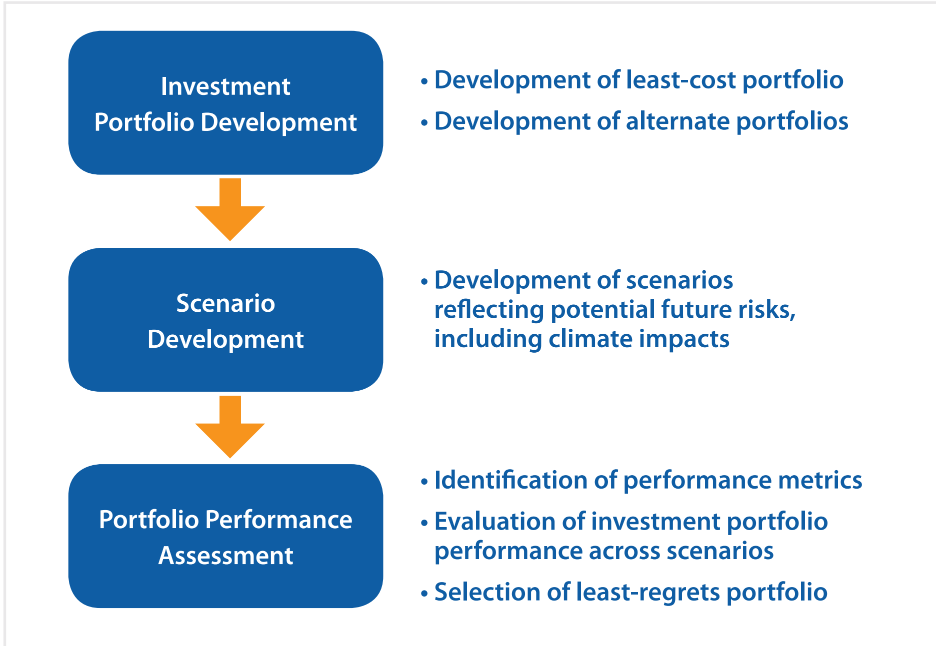

Figure 1. Overview of the IRRP process

Managing risk with IRRP

In power system planning, considering sensitivity to future risks and uncertainties—such as climate change impacts—can be challenging. However, Integrated Resource and Resilience Planning (IRRP) enables power providers to identify investment portfolios that are resilient to a range of potential futures. Specifically, IRRP leverages scenario analysis to assess how investment portfolios perform under various possible situations—including where threats manifest—to determine which portfolio is most successful across a range of potential futures (ICF International, 2014).

IRRP is rooted in the traditional integrated resource planning (IRP) approach. In IRP, power providers identify a least-cost power resource investment portfolio based on supply, demand, and transmission performance and cost. IRRP uses IRP to create several least-cost portfolios based on power provider interests (e.g., ramping up renewables, investing in a given fuel). Scenarios are developed to represent potential futures, including those where risks—natural, technological, or human-caused—arise. Based on power provider performance objectives (e.g., environmental impact, cost, energy independence), metrics are identified to test the portfolios' performance across the scenarios. The power planner uses the results of the performance assessment to select the least-regrets portfolio, meaning the portfolio that best satisfies power planning objectives across the array of potential futures. Figure 1 summarizes this process.

Through the performance metrics, IRRP enables power planners to explore performance against sustainability criteria (i.e., greenhouse gas emissions, criteria pollutant emissions, and water consumption, among others). As a result, IRRP can help power providers not only plan for a wide range of risks, but also more effectively achieve environmental targets.

Case Study: Applying IRRP in Tanzania to enhance power system resilience to drought

The U.S. Agency for International Development (USAID) recently supported Tanzania's national utility, the Tanzania Electric Supply Company Limited (TANESCO), in developing a national Integrated Power System Master Plan (IPSMP) for present day through 2040, with support from ICF.

IRRP Step 1: Investment portfolio development

TANESCO and ICF developed three energy planning investment portfolios, reflecting alternative options to meet expected growth in demand:

1. **Reference Portfolio,** the optimal portfolio for meeting the business-as-usual energy demand, and transmission development, which includes investment in large hydropower.
2. **Limited Financing Portfolio,** which moves away from large hydropower and toward using fossil fuels to supply baseload.
3. **Renewables Portfolio,** which continues to invest in large hydropower and ramps up development of renewables.

IRRP Step 2: Scenario analysis, a focus on drought

The team developed seven scenarios reflecting the risks that concerned TANESCO most, including the impact of drought on hydropower reliability. The drought scenario enabled TANESCO to explore how extended drought might affect hydropower production and, in turn, affect investment portfolio performance.

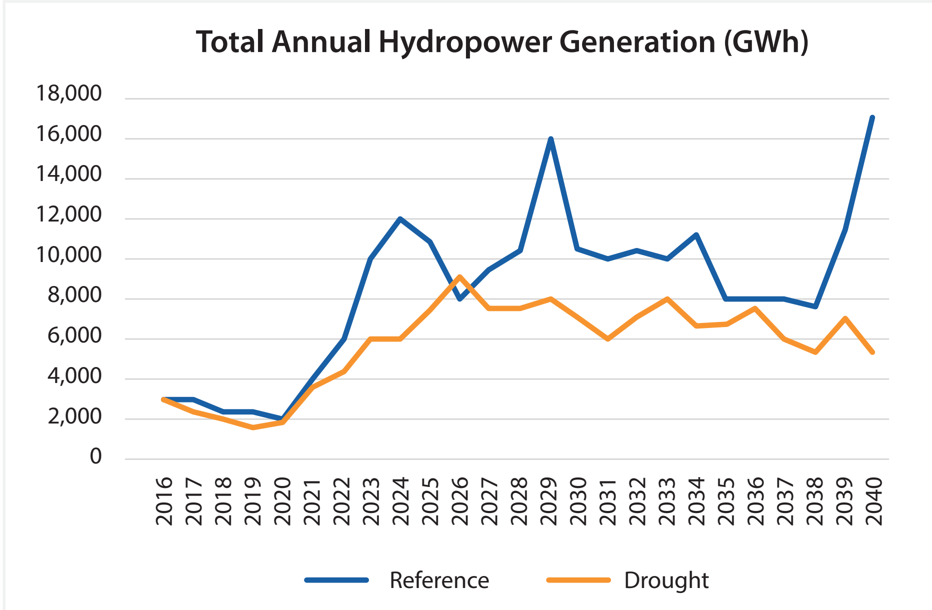

Figure 2. Total annual hydropower generation (GWh) in Tanzania for baseline (blue) and drought (orange) scenarios

ICF constructed the drought scenario conditions using historical drought conditions and projected changes in temperature. The team then simulated streamflow and hydropower output under the scenario using the Water Evaluation and Planning (WEAP) model, a quantitative water resources simulation tool.

Over the analysis period (2016–2040), the analysis found that drought may reduce streamflow by over 30%, reducing hydropower output by around 12% (Figure 2) (Hellmuth, Bruguera, and Potter, 2017).

IRRP Step 3: Assessing portfolio performance

TANESCO and ICF identified five key criteria to evaluate investment portfolio performance:

- Cost
- Environmental impact
- Fuel security and reliability
- Resource adequacy
- Financial risk exposure

The team then developed metrics within these areas to score the portfolios' performance.

IRRP Results: Portfolio performance and drought sensitivity

Based on the weighted average scores across the full suite of metrics, TANESCO identified the Reference Portfolio as the least-regrets portfolio for the IPSMP. However, there are tradeoffs: though the Reference Portfolio has the least financial risk exposure, the most balanced mix of generation sources, and effectively reduces greenhouse gas (GHG) emissions, it is more expensive than the Limited Financing Portfolio. Additionally, because the Reference Portfolio relies heavily on large hydropower, it is highly sensitive to drought; drought would increase unmet demand (+8%), costs (+14%), and GHG emissions (+13%) (see Box 1). Under the Reference Portfolio, TANESCO would likely experience several years of significant power shortages driven by drought.

Meanwhile, the Renewables Portfolio ranked second overall. This portfolio also relies considerably on large hydropower, and therefore drought results in GHG increases and reliability issues. However, across the range of scenarios, it performs better on fuel diversity, reliability, and GHG emissions compared to the Reference Portfolio. This indicates that diversifying renewable investments beyond large hydropower could provide benefits.

Figure 3. Inside hydropower plant facilities in Tanzania. Photo credit: Paul Shaffner via Flickr
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Managing weaknesses of the selected portfolio: Adapting to drought

As discussed in the previous section, while the Reference Portfolio was chosen as the least-regrets portfolio, given its performance across the suite of scenarios and performance metrics, it is particularly sensitive to drought.

In order to help TANESCO begin to consider how to manage changing climate conditions, including drought, more intense flooding, increased temperatures, and other climate-related risks, ICF worked with TANESCO to assess and prioritize risk, and to identify potential adaptation measures. These measures focus on adapting to reduced hydropower generation capacity during drought conditions, as well as adapting to other climate change-driven risks, such as reduced transmission and distribution capacity and increased demand due to higher temperatures and more intense heat waves. Adaptation measures ranged from no-regrets actions, which benefit power system services regardless of changes in climate, to climate-justified measures, which include actions that might only be justifiable if expected changes in climate materialize.

The adaptation measures that ICF and TANESCO identified focused on:

- **Improved water resource management.** Examples: Designing irrigation schemes downstream of hydropower (instead of upstream); evaluating operational changes (reservoir rule curve changes) in light of climate change to optimize water management and use, including flood control, power generation, agricultural consumption, and other priority uses.
- **More efficient electricity transmission and distribution.** Examples: Automating the transmission and distribution systems to better control losses; upgrading transmission and distribution infrastructure to reduce losses; ensuring that routine operation and maintenance schedules are implemented.
- **End-user energy efficiency and conservation.** Examples: Educating the public on energy conservation; implementing time of use tariffs; installing smart meters.
- **Increased generation capacity.** Examples: Increasing power generation capacity; seeking new peak generation and purchasing sources for summer months; investing in decentralized power generation.

Box 1. Climate Impacts to the Power Sector Can Compromise GHG Emission Goals

While hydropower provides a low-emissions alternative to fossil fuel energy, these benefits may be tempered by climate change. Climate change is projected to drive more frequent and intense droughts, which can limit hydropower generation capacity (Hellmuth and Bruguera, 2019). When hydropower generation declines, carbon-intensive alternatives are often used as substitutes, leading to spikes in GHG and criteria pollutant emissions, undermining progress toward GHG reduction goals (Harvey, 2018). Drought can lead to further GHG emissions by depleting surface water supplies, resulting in reliance on more GHG-intensive supplies, such as desalinated and recycled water (Hendrickson and Bruguera, 2018). If a country were to experience extended or repeated drought, the benefits of hydropower as a low-emissions resource will be reduced.

Implications for power sector planning

When conducting long-term power planning and making decisions around major investments, it is prudent for power providers to consider how various threats might affect potential investments and their ability to meet their cost, as well as environmental, fuel security, and other objectives. In particular, when considering investments in large hydropower, it is important to explore drought projections and potential impacts, and identify adaptation options if power planners decide to pursue a drought-sensitive portfolio. IRRP enables power planners to consider these and other natural, technological, and human-caused risks in power system planning decisions, while simultaneously considering the ability to meet GHG emission and sustainability goals. Additionally, given that even a least-regrets portfolio is likely to be sensitive to risk, it is prudent to consider risk management measures to address sensitivities in order to further enhance power system resilience.

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

Resources to Learn More

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