RALI Series: Promoting Solutions for Low Emission Development

Risky Business? Climate Change, Power Planning, and Resilience in Tanzania

The RALI Series is a collection of papers developed by the RALI project to share examples of low emission development in practice. The series features case studies, tools, and innovative new approaches in this space, highlighting user benefits and lessons learned. To learn more about the RALI project, visit https://www.climatelinks.org/projects/rali.

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EXECUTIVE SUMMARY

Many countries face the challenge of strengthening and expanding electricity generation and infrastructure while incorporating climate resilience and greenhouse gas (GHG) reduction targets into long-term power planning. Increasingly, climate change impacts threaten investments in renewable energy, particularly hydropower, and thus compromise the ability of countries to meet their GHG reduction targets.[1]

This paper provides a detailed case study of how the **Integrated Resource and Resilience Planning** (IRRP) framework was applied in Tanzania to help power sector planners assess the climate risks to the country's primary renewable energy source—hydropower—given expanding electricity demand and the government's commitment to reducing GHG emissions. By evaluating the performance of different investment portfolios under a variety of conditions, IRRP provides a process for utilities to take into consideration climate risks and resilience when selecting a portfolio.

In particular, the IRRP framework can assist energy planners to i) meet competing objectives, including cost reduction, GHG emission reduction, and climate resilience; and ii) consider trade-offs in long-range planning that aims to scale up energy resources, including clean energy sources.

In Tanzania, the government requested that USAID support a multi-year effort to develop a national, integrated power system plan for the national utility, the Tanzania Electric Supply Company Limited (TANESCO). The USAID IRRP team

For hydropower, the analysis showed that drought in Tanzania, made more likely by climate change, could increase GHG emissions because reductions in hydropower generation are currently compensated for by increased use of fossil fuel-based sources. The analysis provided several other insights for power utilities and planners in similar circumstances.

- Plans that aim to meet GHG emissions objectives through expanded renewable energy sources such as hydropower should take into consideration back-up generation, as replacement generation may be just as important as primary electricity sources.
- Other solutions, such as adjusting hydropower operations during drought, improving water use efficiency, and adapting hydropower designs that take into consideration climate change, may also be beneficial.
- The impact of drought and increased temperatures could be even greater if their effects on power generation by other renewable energy resources (e.g., biomass, solar) are also taken into consideration.

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[1] Hellmuth, M., Cookson, P., and Potter, J. 2017. Addressing Climate Vulnerability for Power System Resilience and Energy Security: A Focus on Hydropower Resources. Produced by ICF on behalf of USAID RALI; Harvey, C. 2018. Dry weather drives up energy emissions in the West. Energy & Environment News: Climatewire. https://www.eenews.net/climatewire/stories/1060110333

worked with TANESCO to identify several plausible investment portfolios (i.e., potential future energy resource mixes) and then tested their performance in meeting several objectives across a broad range of potential futures.

After considering the trade-offs, including those related to hydropower expansion, TANESCO selected the "best" performing investment portfolio to serve as a roadmap to guide future investment planning decisions.[2]

GLOBAL CONTEXT: THE RISKS TO HYDROPOWER FROM CLIMATE CHANGE

Hydropower can serve as a key component of low emission development strategies (LEDS), enabling countries to enhance energy security while also furthering their ability to reduce GHG emissions and meet their Nationally Determined Contributions (NDCs).[3] Currently, hydropower makes up two-thirds of global renewable electricity generation and is growing rapidly; capacity increased nearly 22 GW in 2017. Additionally, $48 billion of investment was committed to hydropower projects in 2017—nearly double that of 2016—indicating strong future growth.[4]

While the value of hydropower as part of a low emissions development strategy is well known, the risks that climate change pose to hydropower performance can be substantial. These risks should be considered when evaluating potential hydropower investments. Climate change may compromise hydroelectricity generation and delivery through changing rainfall patterns, rising temperatures, more frequent and intense floods and droughts, and related hazards such as rainfall-induced landslides. Hydropower projects are particularly dependent on reliable rainfall and streamflow, and thus drought can severely affect hydropower-dependent power systems. Additionally, when hydropower generation is reduced, the substitute is often a carbon-intensive fossil fuel-based source. This substitution results in higher GHG emissions and criteria pollutants,[5] and undermines progress toward GHG reduction objectives.[6]

While most hydropower facility managers and operators do not yet consider projected changes in climate in their business risk analysis or power planning, hydropower financiers are increasingly emphasizing the importance of climate resilience. For example, the World Bank developed and is testing new guidelines on incorporating climate resilience into hydropower projects.[7] Additionally, the Climate Bonds Initiative requires that hydropower projects demonstrate evidence of climate resilience to receive financing.[8]

INTEGRATED RESOURCE AND RESILIENCE PLANNING (IRRP)

IRRP enables power providers to assess the performance trade-offs of different investment plans against a range of criteria—such as cost, reliability, and GHG reduction goals—across a range of potential future scenarios, including scenarios reflecting climate change impacts.

IRRP is a method for developing a power system investment plan that is more resilient to various risks, including climate change (see Figure 1). It builds on a traditional planning approach in the energy sector—integrated resources planning—by explicitly addressing risks and resiliency concerns associated with key uncertainties, including potential impacts from a changing climate and other disruptive events. The approach identifies a range of feasible investment portfolios, then evaluates them using a set of criteria, including cost, reliability, and social and environmental impacts. Next, an assessment is made of portfolio resiliency to uncertain variables, such as climate change, fuel price fluctuations,

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2 The IRRP process in Tanzania explored many scenarios, but the aim of this paper is to illustrate how the IRRP framework was applied to hydropower resources specifically.

3 Hellmuth, M., Cookson, P., and Potter, J. 2017. Addressing Climate Vulnerability for Power System Resilience and Energy Security: A Focus on Hydropower Resources. Produced by ICF on behalf of USAID RALI.

4 International Hydropower Association. 2018. 2018 Hydropower Status Report: Sector Trends and Insights. https://www.hydropower.org/sites/default/files/publications-docs/iha_2018_hydropower_status_report_4.pdf.

5 Criteria pollutants refer to six common air pollutants that affect human health and welfare: carbon monoxide, lead, ground-level ozone, nitrogen dioxide, particulate matter, and sulfur dioxide.

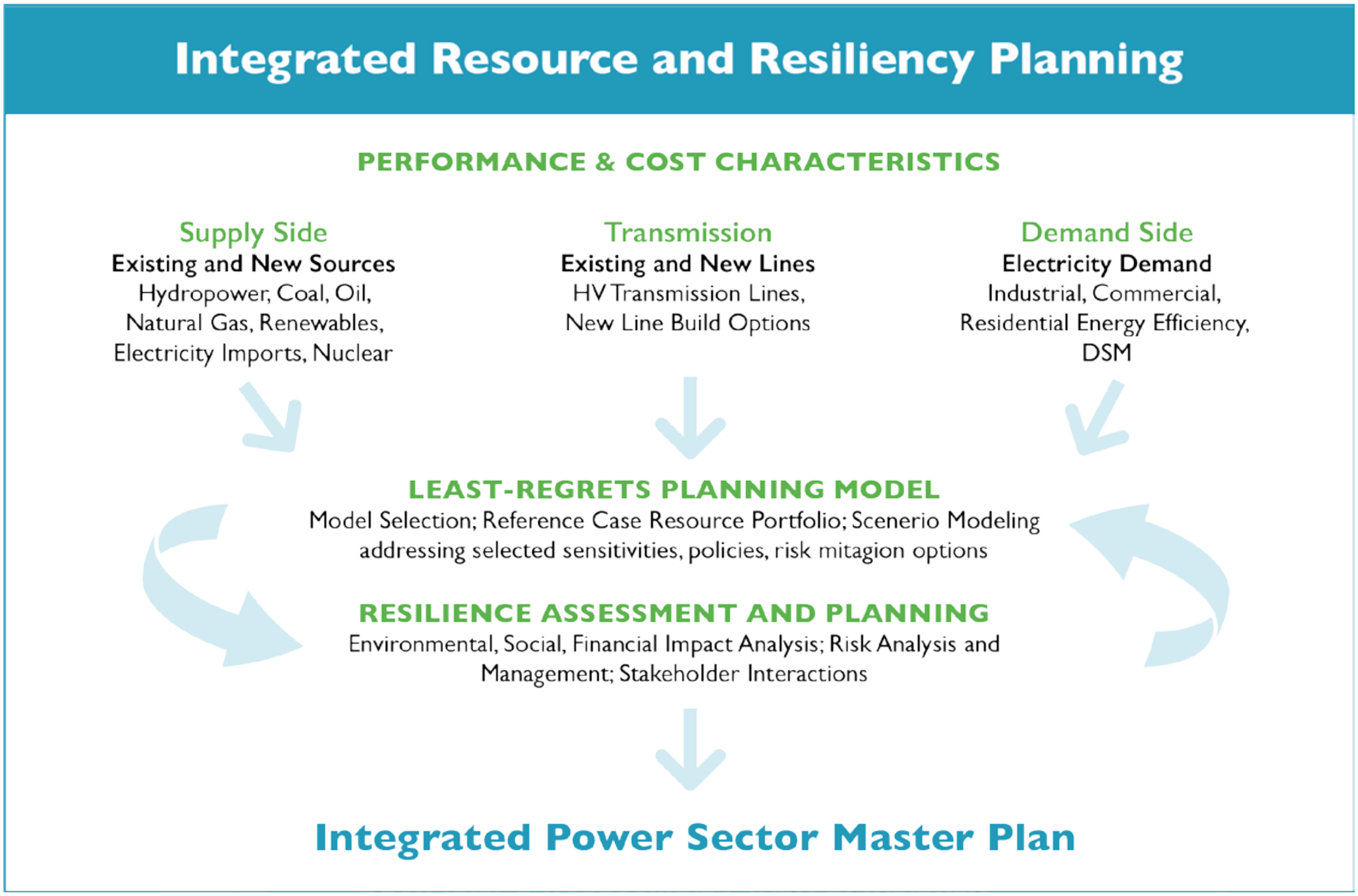
6 Harvey, C. 2018. Dry weather drives up energy emissions in the West. Energy & Environment News: Climatewire. https://www.eenews.net/climatewire/stories/1060110333

7 World Bank Group, International Hydropower Association, European Bank. N.d. Creating Climate Resilience Guidelines for the Hydropower Sector. https://www.hydropower.org/sites/default/files/publications-docs/climate_resilience_guidelines_-_two-pager.pdf

8 International Hydropower Association. 2018. 2018 Hydropower Status Report: Sector Trends and Insights. https://www.hydropower.org/sites/default/files/publications-docs/iha_2018_hydropower_status_report_4.pdf

regulatory changes, and more. The resulting "least-regrets" plan is more resilient than a least-cost plan, as it is robust and resilient under a range of possible futures that reflect inherent risks and uncertainties.[9]

Figure 1. Overview of the IRRP Process



THE TANZANIA IRRP PROJECT: POWER SYSTEMS INVESTMENT PLANNING

The following case study on how the IRRP process was applied in Tanzania includes the following:

- An **introduction** on how hydropower dependence exposes the national utility, Tanzania Electric Supply Company Limited (TANESCO), to climate change-related risks;
- An overview of the **investment portfolios** developed through consideration of existing plans, government commitments, stakeholder consultations, and financial and timing considerations;
- A summary of the **scenario analysis** conducted to determine how the portfolios perform under various potential future scenarios; and
- An analysis of the **investment portfolios' performance under drought conditions**, which evaluated the performance of the portfolios against a select set of metrics under the baseline and drought scenarios.

[9] ICF. 2014. Integrated Resource Planning Models Need Stronger Resiliency Analysis. White paper by Maria Scheller and Ananth Chikkatur. https://www.ourenergypolicy.org/wp-content/uploads/2014/10/Integrated_Resource_Planning_Models_Need_Stronger_Resiliency_Analysis.pdf

INTRODUCTION

Tanzania has made substantial economic progress in recent years and aims to continue expanding access to electricity to a greater portion of the population.[10] However, TANESCO faces a variety of challenges, including financial and power supply reliability risks, due to the significant proportion of hydropower in its electricity generation mix.[11]

Large hydropower makes up one-third of Tanzania's generation capacity.[12] While the country has recently developed natural gas resources, the national power grid was primarily built on distributed run-of-river hydropower facilities, with an estimated capacity of 600 MW that generates 1,200 to 3,000 GWh per year.[13] Because of the significant capacity of hydropower resources in Tanzania, drought can have substantial consequences for the utility. Inadequate water supply has regularly led to power shortages and rationing, which occurred on average one out of every three years between 1991 and 2010.[14, 15] These shortages necessitate the use of emergency fossil fuel-based power plants, which are GHG-intensive and particularly costly. In the winter of 2004-2005, the incremental cost of substituting thermal resources for hydropower losses in Tanzania was $67 million.[16] These effects may worsen in the future, as climate change is projected to lengthen dry spells in the country and reduce river flows in some areas.[17]

To manage power system growth and hydropower-related risks, TANESCO has steadily diversified its energy supply over time, ramping up investments in fossil fuel-based natural gas. From nearly 96% reliance on hydropower in 2003, the proportion decreased to 34% in 2015. While diversification may increase system resilience, continued movement towards higher GHG-emitting and low-cost fuels would increase the challenge of meeting Tanzania's NDC objective of reducing total GHG emissions by 10–20% by 2030. The NDC also calls for increased investment in non-hydropower renewable generation resources, such as wind and solar.[18,19,20] These sometimes competing objectives—enhancing climate resilience, reducing GHGs, and minimizing costs—were used to evaluate the performance of several feasible investment scenarios using the IRRP process.

Songo Songo gas power plant in Tanzania.

Photo: Iain Cameron [CC BY 2.0]
https://commons.wikimedia.org/wiki/File:Songo_Songo_Gas_Plant.jpg

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[10] Tanzania Ministry of Energy and Minerals. 2013. Power Systems Master Plan: 2012 Update; World Bank, Sustainable Energy for All (SE4ALL) database. 2016. https://data.worldbank.org/indicator/eg.elc.accs.zs
[11] Hellmuth, M., Cookson, P., and Potter, J. 2017. Addressing Climate Vulnerability for Power System Resilience and Energy Security: A Focus on Hydropower Resources. Produced by ICF on behalf of USAID RALI.
[12] Large hydropower is defined as systems with an installed capacity of 100 MW or greater.
[13] Tanzania Ministry of Energy and Minerals. 2016. Power System Master Plan Update.
[14] Keeler, R. 2010. Tanzania: Electricity in the Grip of Graft. *Ratio Magazine*.
[15] Tanzania Ministry of Energy and Minerals. 2013. Investment Plan for Tanzania: Scaling-up Renewable Energy Programme.
[16] Watkiss, P. Downing, T., Dyszynski, J., Pye, S. 2011. The Economics of Climate Change in the United Republic of Tanzania. Report to Development Partners Group and the UK Department for International Development. http://economics-of-cc-in-tanzania.org/
[17] USAID, 2018. Climate Change in Tanzania: Country Risk Profile. https://www.climatelinks.org/sites/default/files/asset/document/20180629_USAID-ATLAS_Climate-Risk-Profile-Tanzania.pdf
[18] Lucía, Ana. Berlekamp, Jürgen. and Zarfl, Christiane. 2017. Estimated cumulative sediment trapping in future hydropower reservoirs in Africa. Geophysical Research Abstracts. http://www.qualenergia.it/sites/default/files/articolo-doc/art%253A10.1007%252Fs00027-014-0377-0.pdf
[19] United Republic of Tanzania. 2016. Intended Nationally Determined Contribution. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/United%20Republic%20of%20Tanzania%E2%80%8B/1/INDCs_The%20United%20Republic%20of%20Tanzania.pdf
[20] Makoye, Kizito. "As hydropower struggles, Tanzania turns to natural gas." *Thompson Reuters Foundation*. September 24, 2014. http://news.trust.org/item/20140924110200-rznw6/

INVESTMENT PORTFOLIOS

The USAID project team worked with TANESCO to develop three different energy planning investment portfolios that could be used to meet projected demand. All portfolios include existing generation resources, as well as transmission and distribution lines, and each offers a different option to grow the portfolio to meet projected demand growth.

- The **Reference Portfolio is** the optimal portfolio for meeting baseline energy demand and transmission development. This portfolio primarily increases hydropower and import capacity from neighboring countries, while increasing the capacity of other generation types by only three percent. TANESCO would expect to produce over 5,300 GWh of hydroelectricity annually by 2036, and three small-scale (<100 MW) hydropower plants would come online (Rusumo, Kakono, and Malagarasi Stage III), as would the large-scale Stiegler's Gorge hydropower plant (2.1 GW).
- Under the **Limited Financing Portfolio,** TANESCO begins using fossil fuel resources to supply the base load, and provides limited financing to large-scale (>100 MW) hydropower projects—due to assumed inability of TANESCO to take on the significant financial burden of large-scale generation projects. Under this portfolio, the three small-scale hydropower plants would come online (as in the Reference Portfolio), but TANESCO would not invest in the large-scale Stiegler's Gorge hydropower project, and thus would produce only around 2,000 GWh of hydroelectricity per year.[21]
- In the **Renewables Portfolio,** TANESCO invests in large hydro and focuses on developing small-scale hydropower and other renewable resources, including utility-scale wind, solar, and geothermal resources, as well as small-scale biomass. By 2036, this portfolio would serve 10% of electricity demand with non-hydro renewables. Additionally, as in the Limited Financing Portfolio, TANESCO would build three small-scale hydro plants and Stiegler's Gorge, resulting in around 5,300 GWh of hydroelectricity annually.

SCENARIO ANALYSIS

Next, to assess the performance of the three investment portfolios across a range of potential futures, TANESCO identified seven future scenarios—a baseline and six alternatives—taking into consideration anticipated climate change impacts:

1. **Baseline** – financing for incremental generation is unconstrained.
2. **Drought** – future hydropower output is limited (see description below).
3. **High load** – annual load growth is nearly twice that of the baseline scenario.
4. **Moderate load** – annual load growth falls between the baseline and high load scenarios.
5. **Gas pipeline contingency** – natural gas supply is limited due to pipeline outages.
6. **Stiegler's Gorge outage** – the major hydropower dam temporarily fails.
7. **Delayed development** – Stiegler's George hydro development is delayed by three years.

Drought Scenario

TANESCO identified drought as the priority concern, as it has posed significant reliability and financial challenges in the past. By testing the sensitivity of existing and planned hydropower generation to drought, power sector stakeholders could better identify and assess the implications on the performance of the various investment portfolios due to changes in hydropower output.

While TANESCO also identified sedimentation and flooding as additional key impacts to hydropower performance, these variables were not modeled within the IRRP process.

The Mtera Reservoir during drought, 2012.
Photo: Massimiliano [CC BY 2.0 (https://www.flickr.com/photos/bellimbooster/7985873223/)]

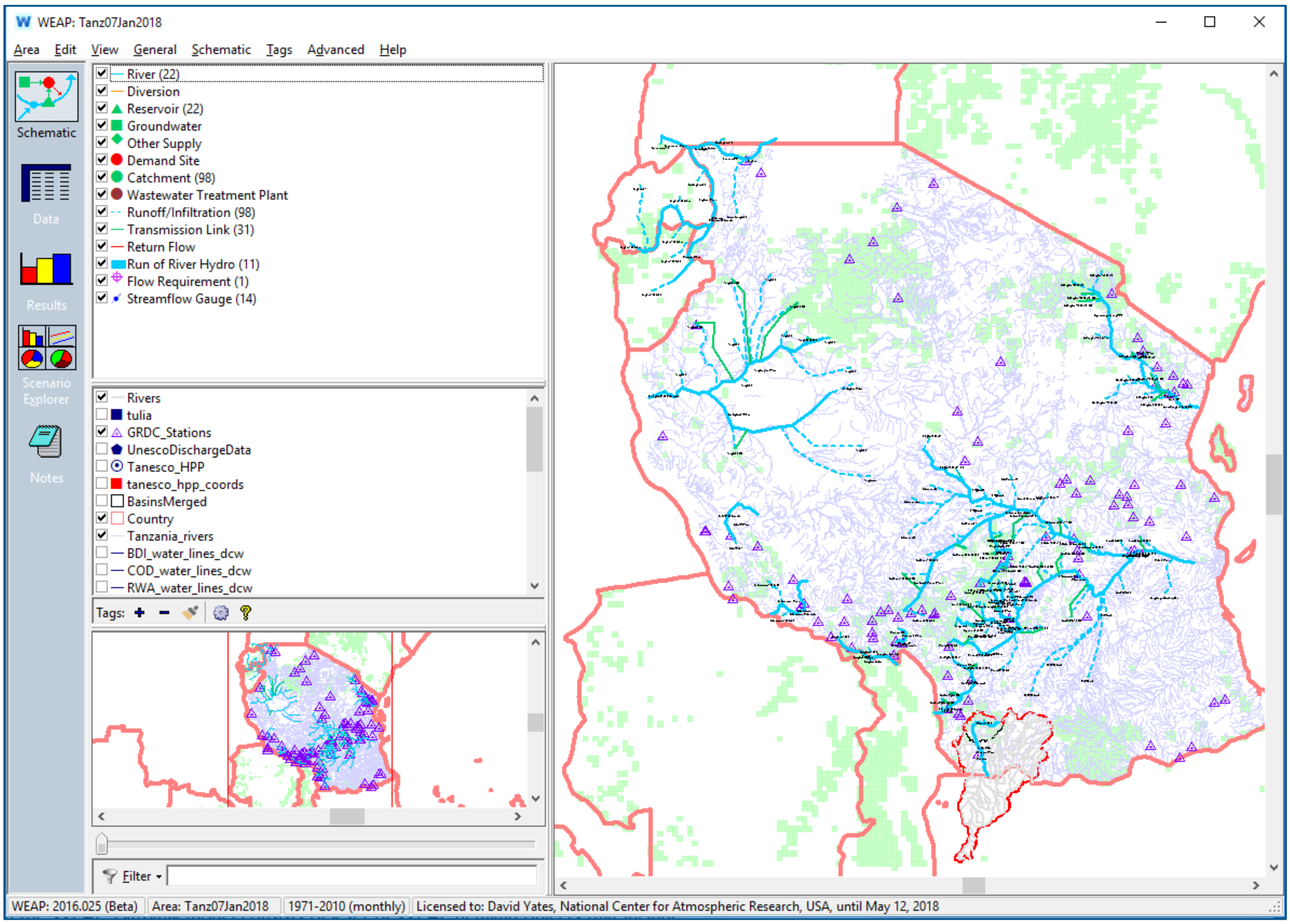
[21] Failure to add substantial additional hydropower capacity would significantly limit Tanzania's ability to meet its NDC GHG reduction goals.

The project team developed the drought scenario by analyzing historical precipitation, temperature, and drought duration. The drought scenario also includes a rising temperature signal from 2016 to 2040 to reflect climate change, with annual average temperatures increasing by 1.4°C to 1.9°C by 2040. Because the drought scenario is informed by the observed climatologic record (which also indicates an increasing trend in temperature over the past 40 years), it represents a plausible manifestation of drought in Tanzania.

To simulate generation of hydropower under the drought scenario, the team used the Water Evaluation and Planning (WEAP) model, a computer-based quantitative simulation tool for integrated water resources planning. The tool facilitates water simulation, forecasting, and policy analysis by tracking water supply and demand, runoff, storage, and hydropower generation, and by considering multiple, competing water uses, including for agriculture.

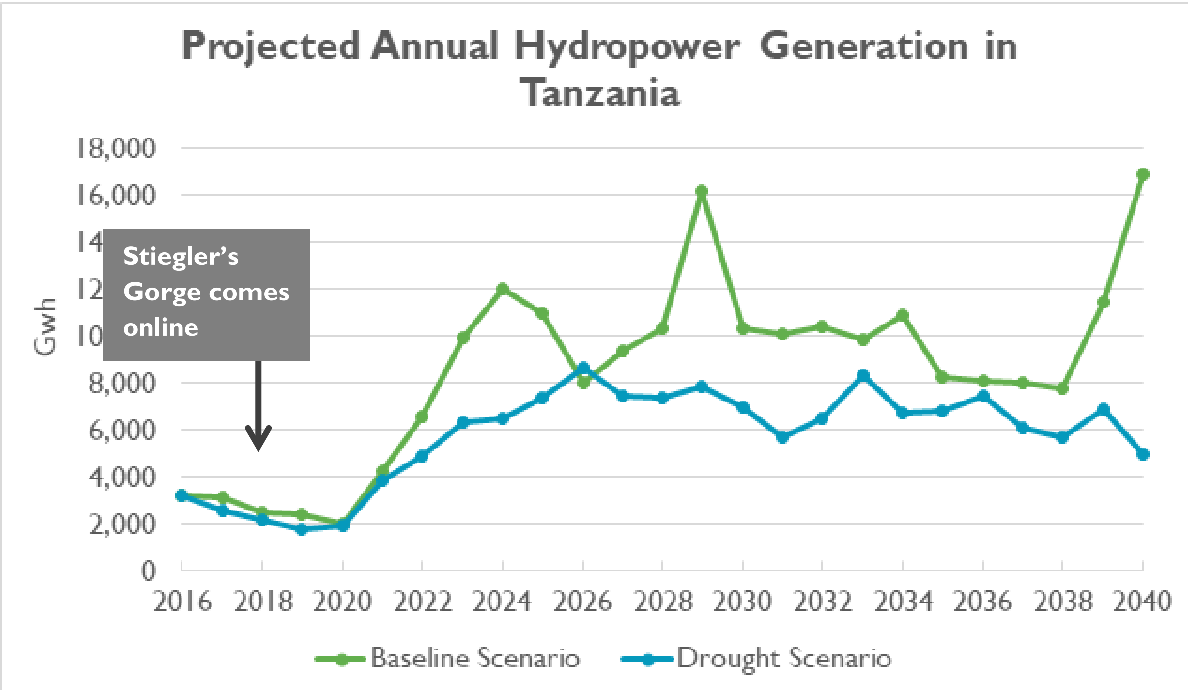
WEAP was used to model streamflow discharge for Tanzania's main rivers that feed into key hydropower plants, as shown in Figure 2. The model also produced information on total water supply delivered and electricity produced by the various hydropower plants under the drought scenario.

Figure 2. Screenshot of the WEAP-Tanzania model showing enhanced detail around the regions of the country with hydropower generating capacity and the location of the major river systems included in the model.



The analysis found that over the 25-year period, streamflow in Tanzania's major river systems is expected to decline by over 30% under the drought scenario, reducing total hydropower production by around 12% relative to the baseline scenario, as shown in Figure 3. Notably, in both scenarios, hydropower output grows over time as new capacity comes online; the annual hydropower generation variation is driven by new investments in hydropower capacity (primarily Stiegler's Gorge), inter-annual inflow variability (driven by rainfall and temperature variations, and competing water demands), and hydropower generation releases.

Figure 3. Total annual hydropower generation (GWh) in Tanzania for the baseline (green) and drought (blue) scenarios.



PERFORMANCE OF THE INVESTMENT PORTFOLIOS UNDER THE DROUGHT SCENARIO

To select the least-regrets portfolio, the USAID project team collaborated with TANESCO to identify five criteria for evaluating the investment portfolios' performance:

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

The project team then worked with TANESCO to identify specific metrics to evaluate the investment portfolios' performance for each criterion. In the end, 33 metrics were selected and weighted according to the relative importance as determined by TANESCO's decision-makers.

Table 1 below displays a select set of these metrics under each of the performance criteria.

Inside hydropower plant facilities in Tanzania.
Photo: Paul Shaffner via Flickr [CC BY 2.0 (https://flic.kr/p/3bZzV8)]

Table 1. Performance criteria and select metrics used to evaluate performance of the investment portfolios.

PERFORMANCE CRITERIA NAME	APPROXIMATE RANGE OF VALUES	DESCRIPTION
COST		
System cost	2,800 – 12,000 NPV (million 2016$)	Net present value (NPV) of unplanned investment and system production costs averaged across all scenarios
ENVIRONMENTAL IMPACT		
CO_2 emissions	3.9 – 11.1 million metric tons/year	Average annual CO_2 emissions
FUEL SECURITY & RELIABILITY		
Fuel type diversity	4,000 – 7,000 <HHI>	Diversity index (Herfindahl-Hirschman Index [HHI]) of generation shares by fuel type
RESOURCE ADEQUACY		
Unserved energy	300 – 3,300 MWh/year	Average annual unserved energy across all years
FINANCIAL RISK EXPOSURE		
Variation in variable cost	N/A	Standard deviation in annual variable production costs

After selecting the metrics, the project team scored investment portfolio performance under the different scenarios using each of the 33 metrics. For the purposes of this paper, Figure 4, Figure 5, and Figure 6 summarize the investment portfolios' performance under the baseline and drought scenarios for a representative set of metrics. The graphics highlight performance tradeoffs under drought conditions, within and across the investment portfolios. For instance, while the reference portfolio is costlier and has lower fuel type diversity than the limited financing portfolio under both the baseline and drought scenarios, it also results in lower CO_2 emissions.

Figure 4. System cost in net present value (NPV) across investment portfolios under baseline and drought scenarios.

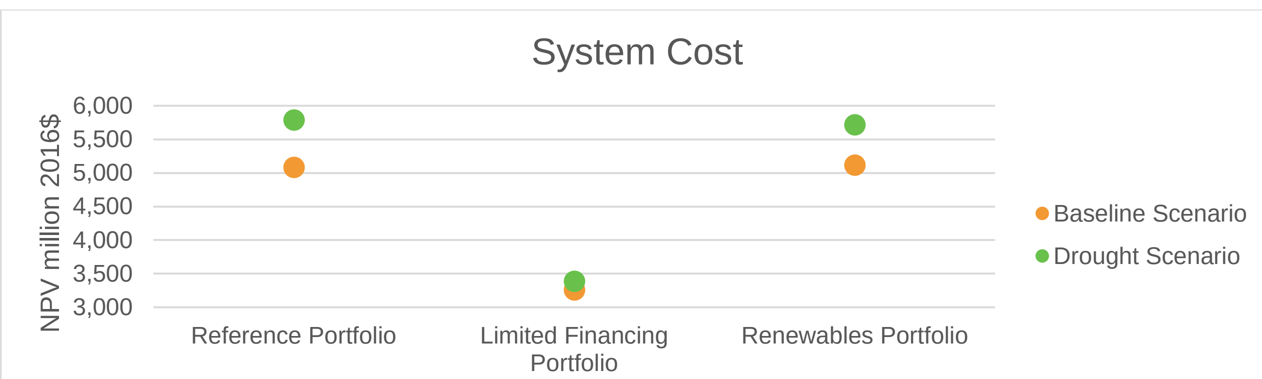


Figure 5. Annual CO_2 emissions in million metric tons (MMT) across investment portfolios under baseline and drought scenarios.

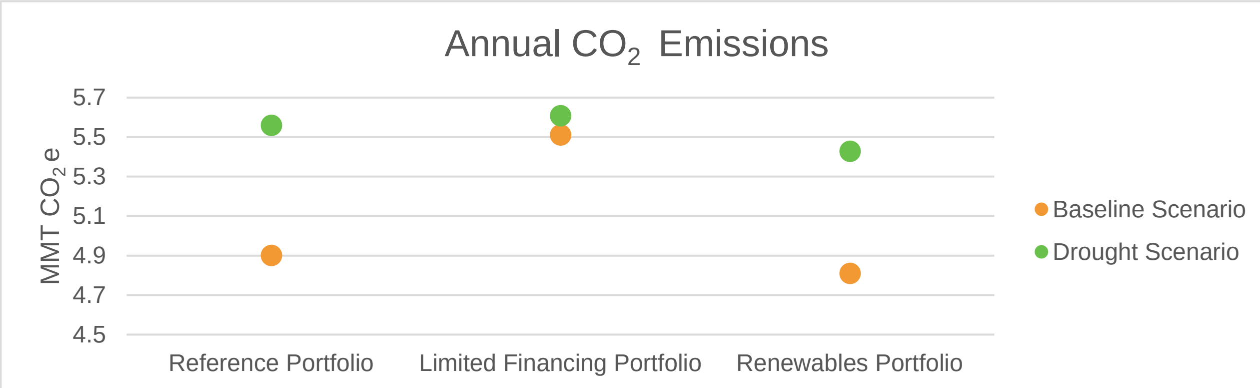
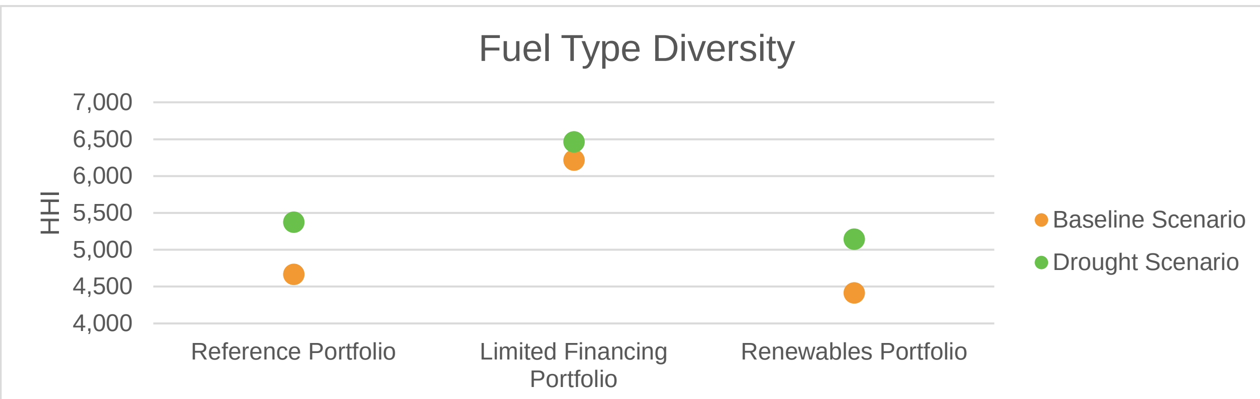


Figure 6. Fuel type diversity as measured by the Herfindahl-Hirschman Index (HHI) across investment portfolios under baseline and drought scenarios.



Reference Portfolio Performance

This portfolio ranked first in the performance assessment, and has the least financial risk exposure, the most balanced mix of generation sources, and results in lower GHG emissions than the Limited Financing portfolio. However, it is highly sensitive to drought.

The Reference Portfolio relies on large-scale hydro, and therefore it has the most significant exposure to drought; unserved energy, costs, and GHG emissions increase +8%, +14%, and +13%, respectively, as more expensive fossil fuel-based generation (primarily gas) is substituted for hydropower. Due to the high dependence on large-scale hydro, with this portfolio there might be several years with significant power constraints due to outages. This portfolio also has significantly higher costs (+35%) than the Limited Financing Portfolio, the least expensive of the three portfolios.

Renewables Portfolio Performance

This portfolio ranked second in the performance assessment. It is more costly than the other two portfolios and is also sensitive to drought, but it provides greater fuel security, reliability, and GHG benefits than the Reference and Limited Financing portfolios. This indicates that benefits exist for diversifying renewables beyond large hydropower.

The scenario's high performance on the fuel security, reliability, and environmental metrics indicates that benefits exist for diversifying renewables beyond hydropower, particularly under drought conditions. Additionally, because this portfolio relies on a greater diversity of generation sources, including small-scale hydro plants located in a variety of locations (rather than just one large hydro plant in a single location), the scenario is slightly less exposed to drought risk. However, the Renewables Portfolio is still sensitive to drought, which leads to increased unserved energy (less reliability), higher costs, and decreased fuel diversity due to higher gas consumption. Note that the sensitivity of non-hydropower renewable resource (e.g., solar) generation to increasing temperature is not considered, but this climate impact could result in reduced solar generation and efficiency, and decreased battery storage efficiency and life.

Limited Financing Portfolio Performance

This portfolio ranked last in the performance assessment. While it is the least-cost portfolio and is less sensitive to drought, it ranked lowest in terms of security, reliability, and GHG considerations.

Under the Limited Financing Portfolio the new Stiegler's hydropower plant is not built, reducing cost but also negatively impacting power reliability and security. GHG emissions are also higher; for example, under the baseline scenario, emissions for the Limited Financing Portfolio are approximately 510,000 tons of CO_2 equivalent (CO_2e) (or about five percent) higher than emissions for the Reference Portfolio. However, under drought conditions, emissions for the Limited Financing Portfolio grow very little (less than two percent) because it is less hydro-dependent, while those for the Reference Portfolio increase substantially (13%), indicating that the Limited Financing Portfolio would produce only around 270,000 tons CO_2e (one percent) more than the Reference Portfolio.

CONCLUSION

By evaluating different investment portfolios' performance under a variety of conditions, IRRP provides a framework for utilities to consider both GHG mitigation and climate resilience goals when identifying an investment portfolio. In particular, power sector portfolios that emphasize investments in large-scale hydro to meet their GHG emissions objectives may be undermined by drought-driven emission increases. The experience of applying IRRP in Tanzania provided several insights:

In countries with significant hydropower, drought can increase GHG emissions if reductions in hydropower generation are compensated for by increased use of fossil fuel-based sources. Should Tanzania, for example, experience extended or repeated drought periods, GHG emissions could accumulate substantially over the planning horizon. In fact, the impact of drought and increased temperatures could be even greater if their effects on power generation by other renewable energy resources (e.g., biomass, solar) are also taken into consideration. In Tanzania, more frequent and intense drought and increasing temperatures could become a bigger problem in the future, contributing to water stress.[22] In other parts of the world, increasing intensity of rainfall, glacial melt, and other climate-related changes are already altering hydropower generation, with implications on power reliability and GHG emissions.[23]

Power utilities and planners looking to meet GHG emissions objectives should be mindful of back-up generation, as replacement generation may be just as important as primary electricity sources.[24, 25] In Tanzania, that may involve considering trade-offs between coal (cheaper but higher emitting) and natural gas (more expensive but lower emitting), or other alternatives. In developing countries like Tanzania, coal may at times be a default option due to cost realities and energy supply pressures.

Solutions such as adapting hydropower operations during drought, improving water use efficiency, and adapting hydropower designs that take into consideration climate change, may be beneficial for countries in similar circumstances. For example, measures to improve water use efficiency (such as improved irrigation practice) and regulation (such as better monitoring of water withdrawals, and enforcement of penalties for illegal water abstraction) could reduce stress on water resources during the dry season. Taking climate change into consideration during design of new hydropower plants is critical given the capital-intensive nature and long lifespan of

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[22] Hellmuth, M., Bruguera, M., and Potter, J. 2017. Tanzania Integrated Resources and Resiliency Planning Program: Risks and Resiliency in the Tanzania Electric Power Sector. Prepared by ICF for the United States Agency for International Development.

[23] Hellmuth, M., Cookson, P., and Potter, J. 2017. Addressing Climate Vulnerability for Power System Resilience and Energy Security: A Focus on Hydropower Resources. Produced by ICF on behalf of USAID RALI.

[24] Harvey, C. 2018. Dry weather drives up energy emissions in the West. Energy & Environment News: Climatewire. https://www.eenews.net/climatewire/stories/1060110333

[25] Herrera-Estrada, J. E., Diffenbaugh, N. S., Wagner, F., Craft, A., & Sheffield, J. 2018. Response of electricity sector air pollution emissions to drought conditions in the western United States. Environmental Research Letters, 13(12), 124032.

these fixed assets. Accounting for potential changes can help reduce risk to investors of over- or under-building, or failure.[26]

IRRP can enable power providers to not only identify plans that are robust across a variety of potential futures—including those where risks are manifest—but also help them identify plans that more effectively achieve environmental targets. While the priority focus of the analysis in Tanzania was on the impact of increased temperature and drought on hydropower, the IRRP framework can be used to test the implications of additional climate sensitivities (e.g., increased rainfall intensity and flooding, higher temperatures) across the power system (generation, transmission and distribution, and demand).[27] The IRRP process could also incorporate additional performance metrics related to environmental sustainability (e.g., water consumption, waste production, criteria pollutant emissions), or environmental and social impacts resulting from dam construction (e.g., inundation, resettlement, sediment and nutrient transportation).

For more information about IRRP, visit: https://www.icf.com/resources/projects/international-development/energy-efficiency-for-clean-development-program/integrated-resource-and-resilience-planning-irrp

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Visit: climatelinks.org/projects/rali

[26] World Bank Group, International Hydropower Association, European Bank. N.d. Creating Climate Resilience Guidelines for the Hydropower Sector. https://www.hydropower.org/sites/default/files/publications-docs/climate_resilience_guidelines_-_two-pager.pdf

[27] Hellmuth, M., Bruguera, M., and Potter, J. 2017. Tanzania Integrated Resources and Resiliency Planning Program: Risks and Resiliency in the Tanzania Electric Power Sector. Prepared by ICF for the United States Agency for International Development.