Case Study A:
Integrated Resource and Resilience Planning in the Energy Sector

Importance of Power Sector Planning

- Planning: ***Preparing for the future in an organized way***
- Traditional objective: Meet projected demand for electricity at the **least-cost**
- However, the power sector is evolving, and least-cost planning no longer suffices…
  - New technology
  - Climate change goals
  - Distributed resources
  - Digitalization

Integrated Resource and Resiliency Planning (IRRP)

A method for developing a power system investment plan that explicitly **addresses risks and resiliency concerns**, including potential impacts from climate change.

- Identifies and evaluates a range of investment portfolios using a set of criteria, including cost, reliability, and **environmental impacts.**
- Assesses portfolio resiliency against **uncertain variables, such as climate change**, regulatory changes, etc.
- Generates a **"least-regrets"** plan that is robust and resilient under a range of possible futures that reflect inherent risks and uncertainties
- Insurance against worse outcomes
- Leads to better outcomes and **informs decision making**

Traditional Power Sector Planning vs. IRRP

Traditional Planning	Cost	Cumulative investment; system costs
	Reliability	Unserved energy; unserved peak demand; transmission congestion
Added by IRRP	Resilience	Energy security (GWh from domestic resources); fast ramp capacity; local reserve margin
	Local Environment	Air quality (SOx, NOx emissions); ash production
	Land Use	Land area used for power plants
	Climate Change	CO_2 emissions

IRRP Informs Decision-making

IRRP

IPPs
- Do attractive development opportunities exist?

PPPs, Developers
- Do structural developments support investment?

Financial Investors
- Are IRRP plans sound in the face of risks?

Regulators
- Are utilities making prudent decisions?
- Are rate increase request justified?

Government Agencies
- What can be done to encourage market participation?
- Are environmental policies in order?

Grid Operators
- How will IRRP plans affect the grid?
- Where are infrastructure developments needed?
- What are the merit order dispatch expectations?

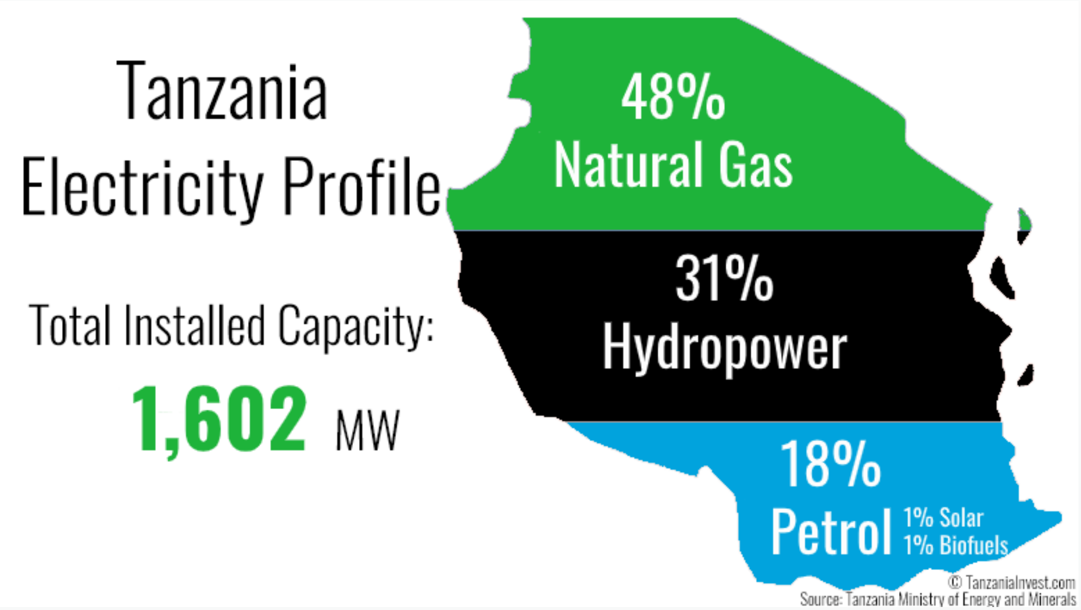
Consumers
- Are electric rates competitive?
- Will IRRP plan support reliability of supply?

Utilities
- Can investment alternatives be prioritized to meet customer demand?
- Do regulatory policies support growth opportunities?
- Perform cost/benefit of procurement options
- Are revenue requirements adequately accounted for in rates?

IRRP in Tanzania

Considering Climate Risk

Energy Sector in Tanzania



- Demand for electricity in Tanzania is estimated to be growing at 10–15% per year
- Only 24% of the total population has access to electricity (2016)

The Telegraph

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Tanzania turns off hydropower as drought bites

Low water levels mean power cuts as electricity crisis bites in East African nation

By Our Foreign Staff

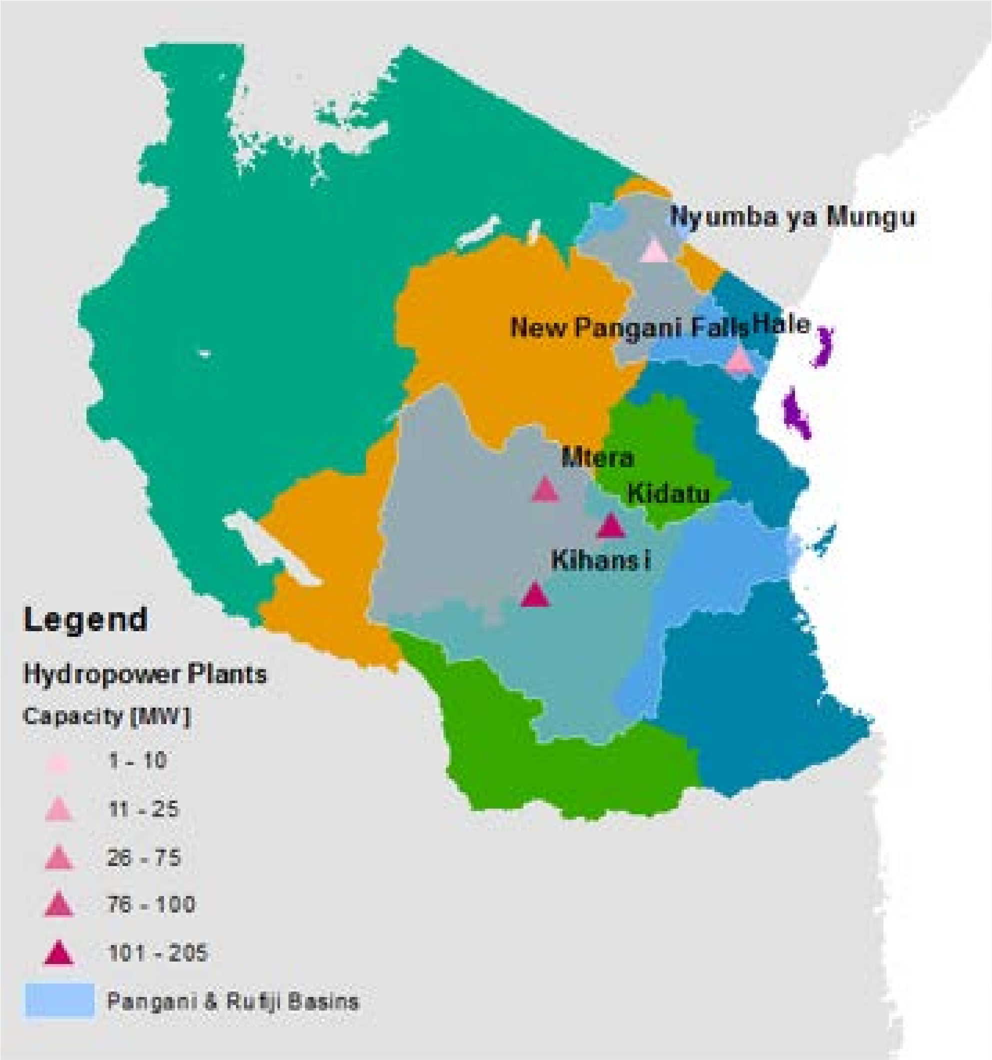
11:32PM BST 09 Oct 2015

Tanzania is shutting down all its hydropower plants because drought is causing low water levels in its dams, plunging the country deep into an electricity crisis.

The East African nation relies on water to produce more than a third of its power.

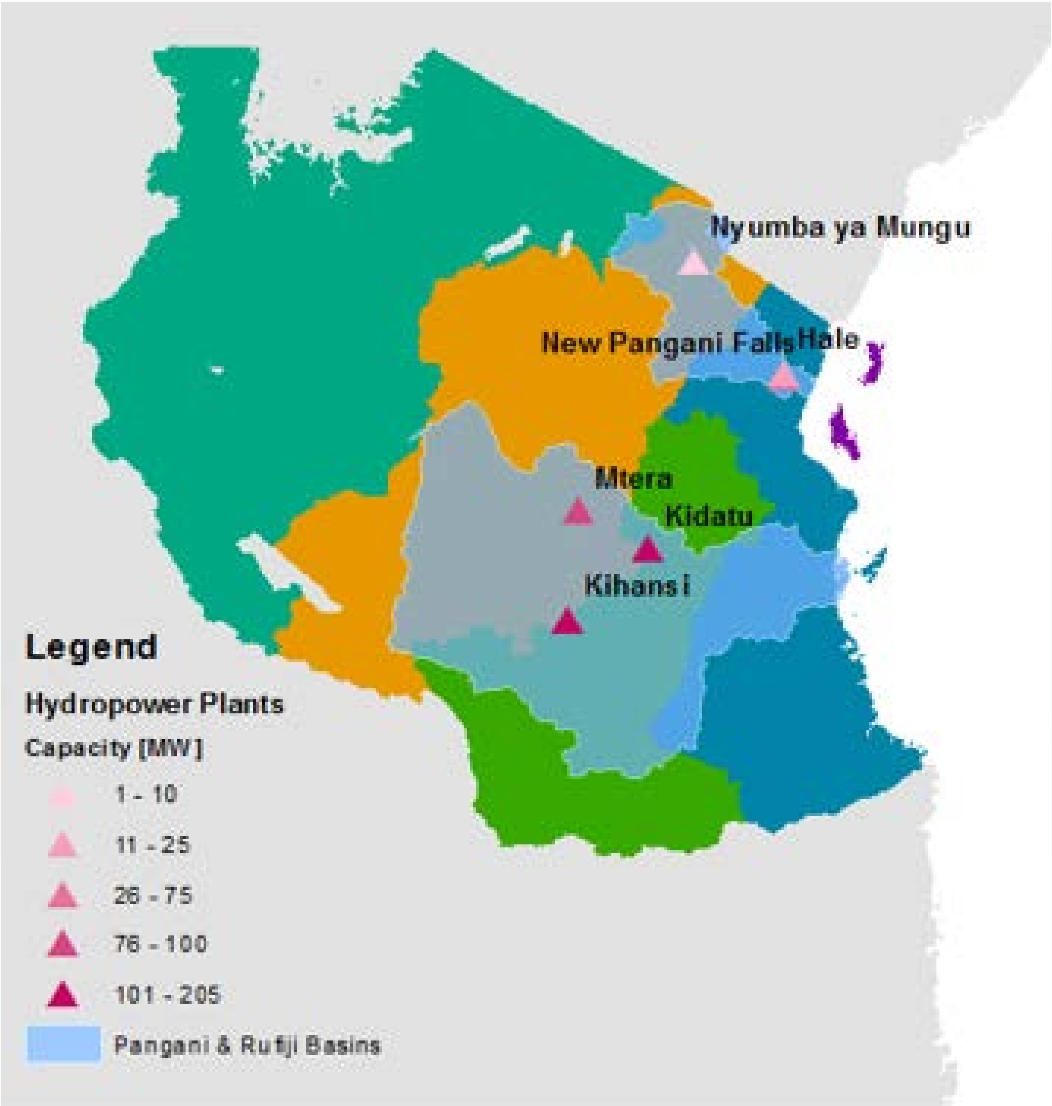
Climate Risks to Hydropower Generation

- Historically largest source of electricity
- Decline in hydropower reliability in recent years
- Currently 46% of generation capacity
- Changes in hydropower generation predominantly affected by changes in flow, which closely tracks rainfall
- **Severe consequences as a result of drought:**
  - High costs (~$70 million) from the use of incremental thermal generation plants, and reduced economic growth in drought years by more than 1% (Watkiss et al., 2011)

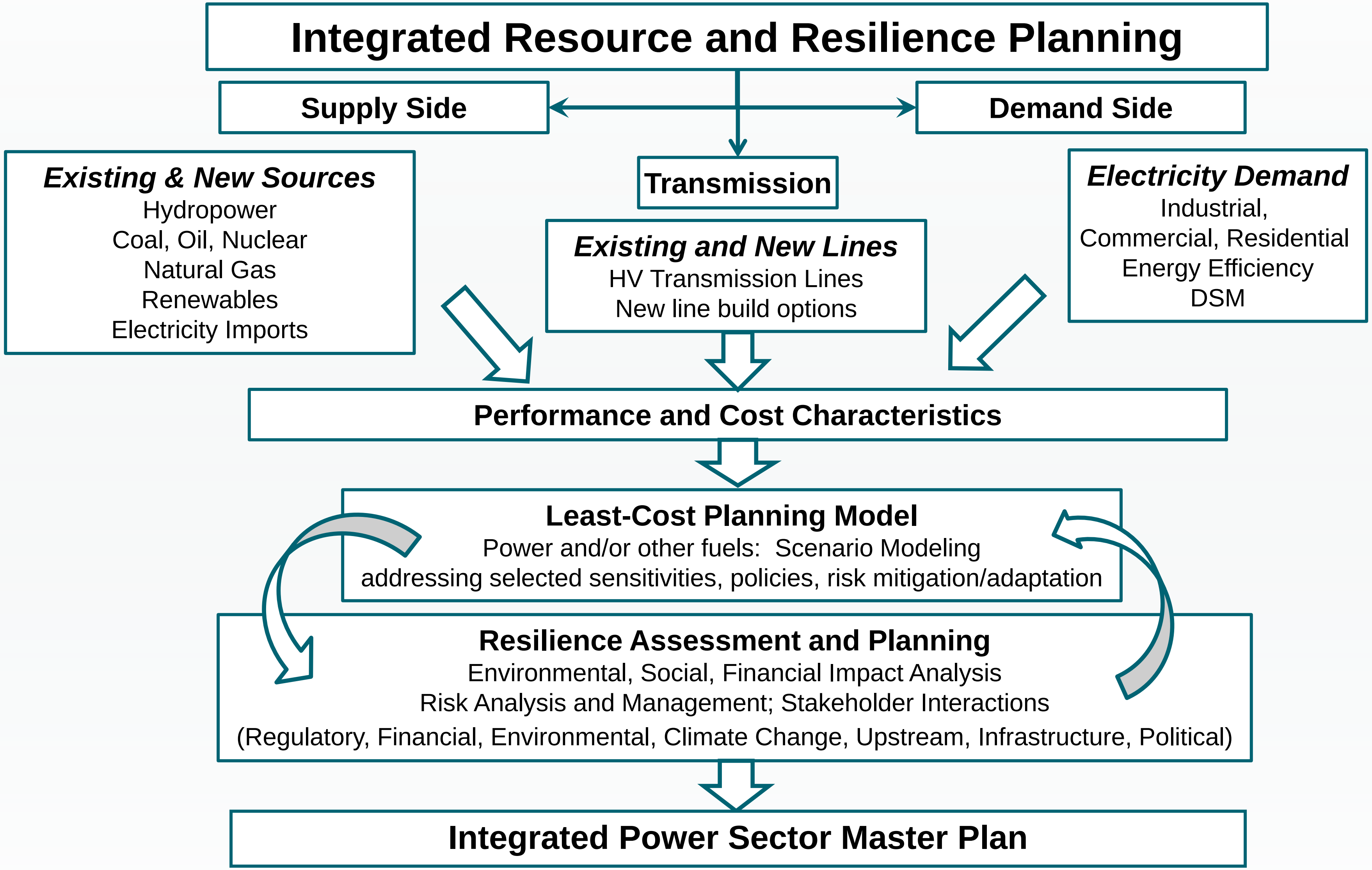


Tanzania IRRP

Goal: Identify **least-regrets** power sector plan that is **robust and resilient** performs the best under a broad range of potential techno-economic futures that **reflect inherent risks and uncertainties**

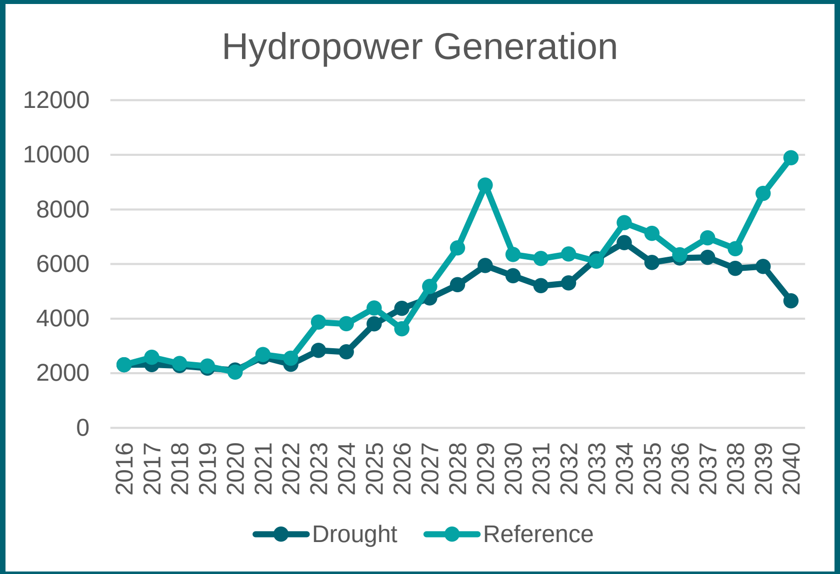


Framework for IRRP



Model Selection and Data Collection

- IRRP is a **planning framework** and **requires the use of data and models** to generate projections
- Models:
  - **Integrated Planning Model (IPM):** used to examine a limited number of portfolio strategies under a range of scenarios
  - **Water Evaluation and Planning (WEAP):** used to model hydropower output under drought and increasing temperature scenarios



Resource Portfolio Development

Three Portfolios (Strategies) were Examined

Portfolio A	Portfolio B	Portfolio C
▪ An optimal capacity expansion plan under the Base Scenario	▪ Focuses on baseload fossil resources in the near to mid term. ▪ No hydro resources above 100 MW prior to 2027	▪ Sustainable resources--10% of end-use demand is required to be served by non-hydro renewable resources. ▪ Relative to the Portfolio A, this portfolio has 406 MW more non-hydro renewables and 147 MW less oil in 2036

A **"Strategy"** is a set of modeling assumptions about policy framework and technology decisions

Scenario Development

- **Fuel and Investment Risks**: Heavy dependence on a single fuel can increase volatility of supply and costs.
- **Climate Risks:** Frequent drought in Tanzania has reduced hydro-electricity generation and increased cost of service
- **Demand-side Risks**: Rapid demand growth and poor load factor increases load shedding, resulting in customer dissatisfaction

"Sensitivities" test performance of various Strategies under changing conditions, that are not fully under Tanzania's control

Scenario Development

Drought risk incorporated into the IRRP analysis

Seven sensitivities analyzed to assess the performance of the Strategies under a range of uncertainties

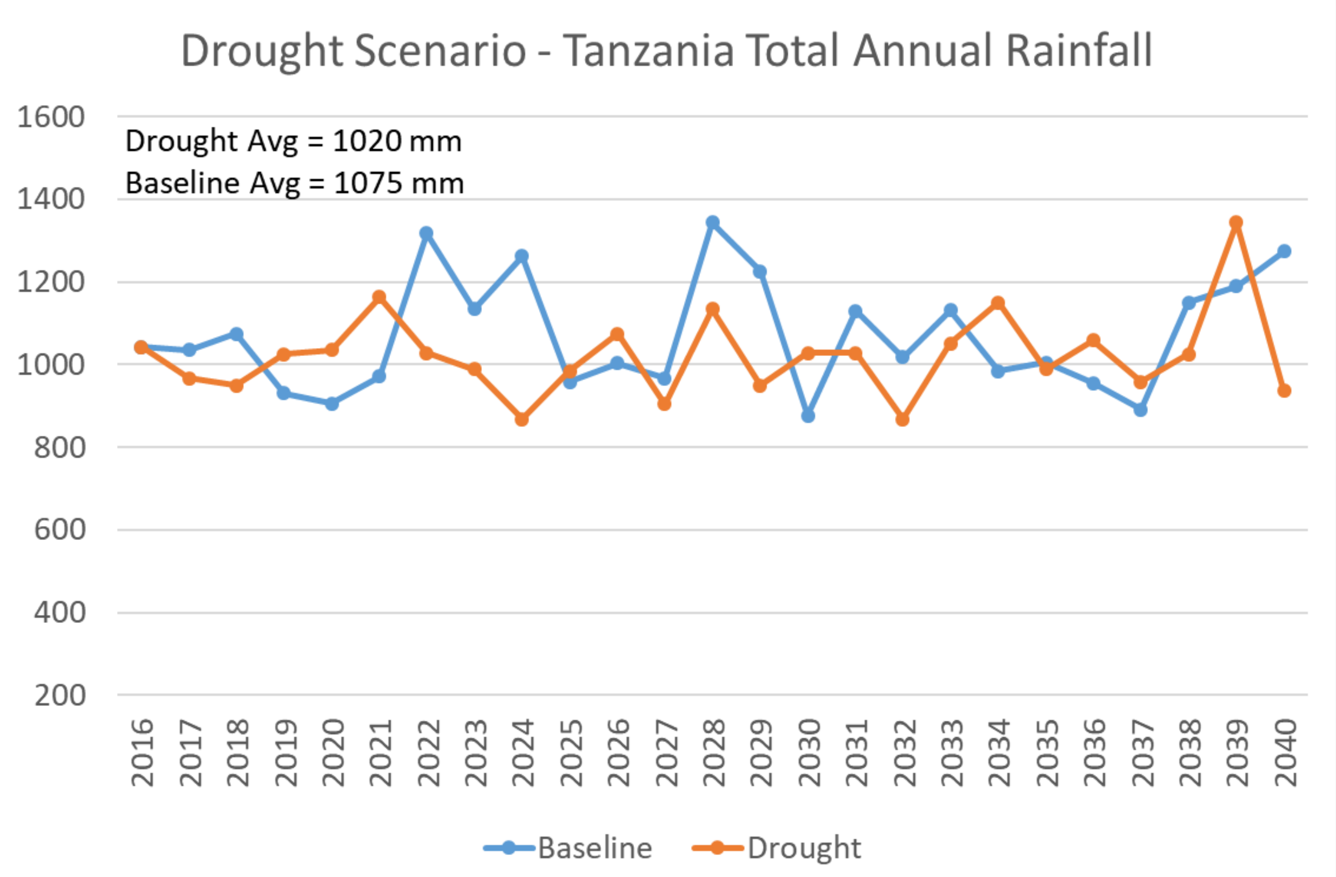
1. Baseline
2. **Drought sensitivity**
3. High load sensitivity
4. Moderate load sensitivity
5. Gas pipeline contingency sensitivity
6. Stiegler's Gorge outage sensitivity
7. Delayed development sensitivity

"Sensitivities" test performance of various Strategies under changing conditions, that are not fully under Tanzania's control

Scenario Development & Key Uncertainties (Sensitivities)

Drought Sensitivity Assumptions:

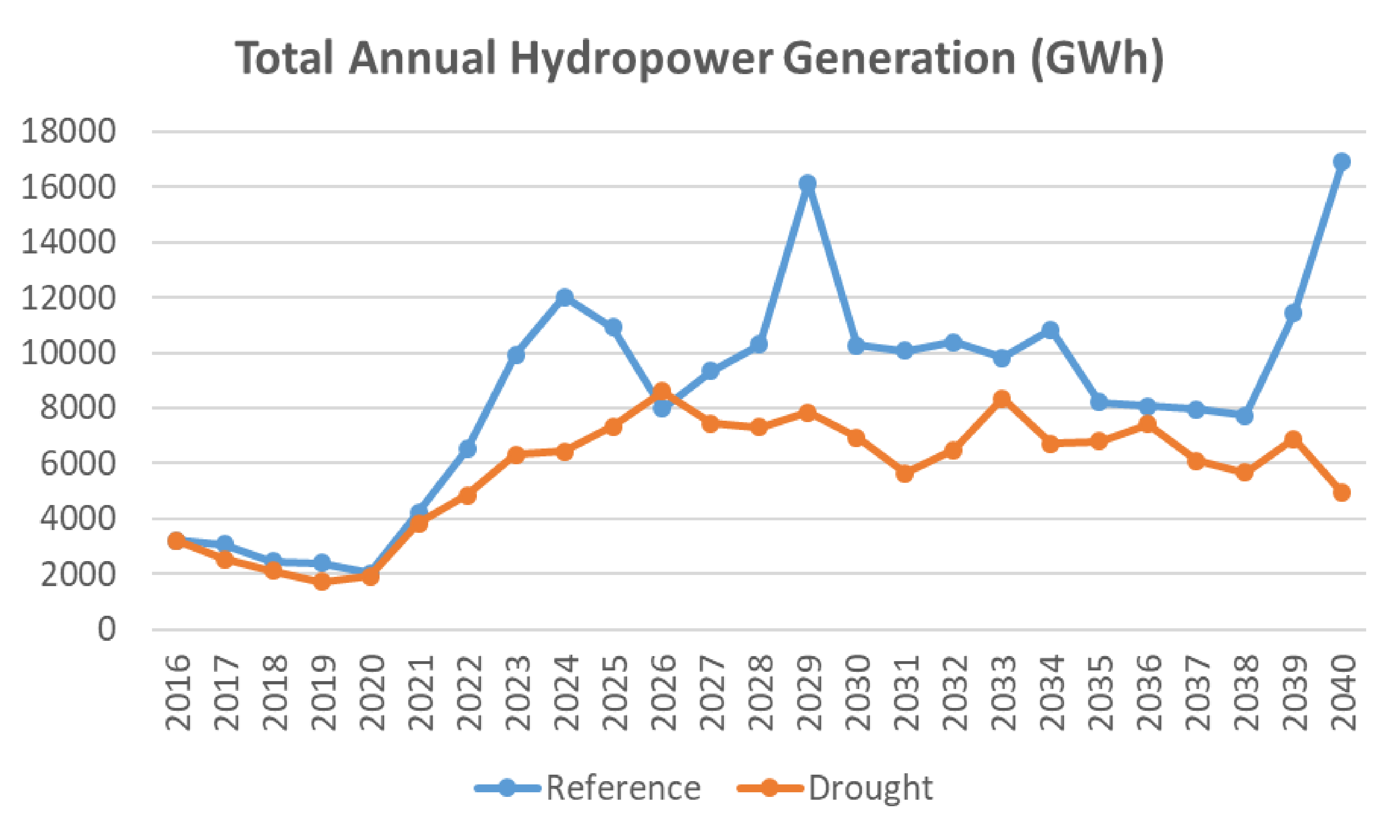
- Representative of power system performance under extended drought conditions that reduce amount of water available for power generation.
- Decline in annual average precipitation
- 5% for Tanzania, 8% for the Ruaha basin
- Increase in annual average temperature by 1.5°C relative to 1970 - 2000



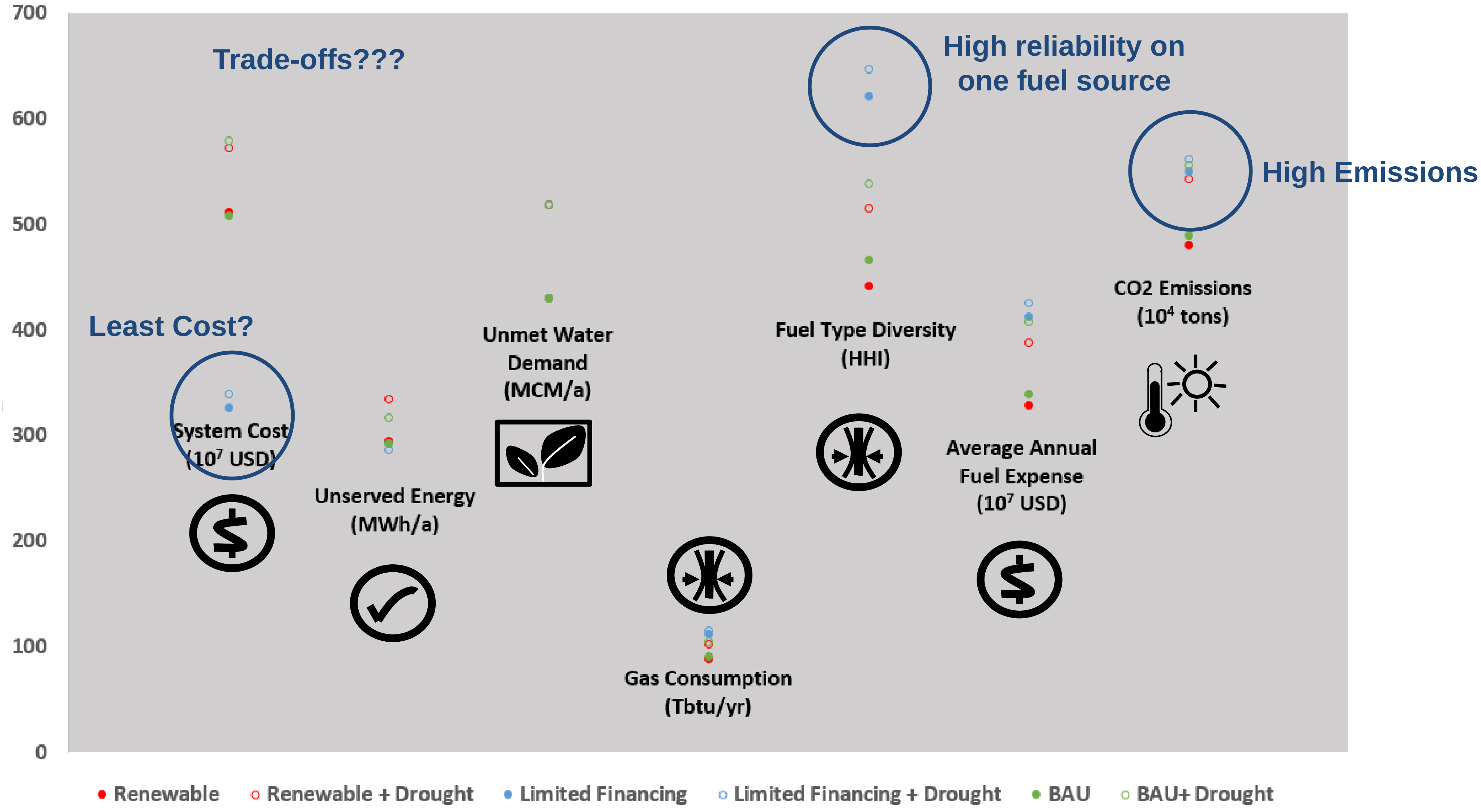
Scenario Development & Key Uncertainties (Sensitivities)

Drought Scenario Results

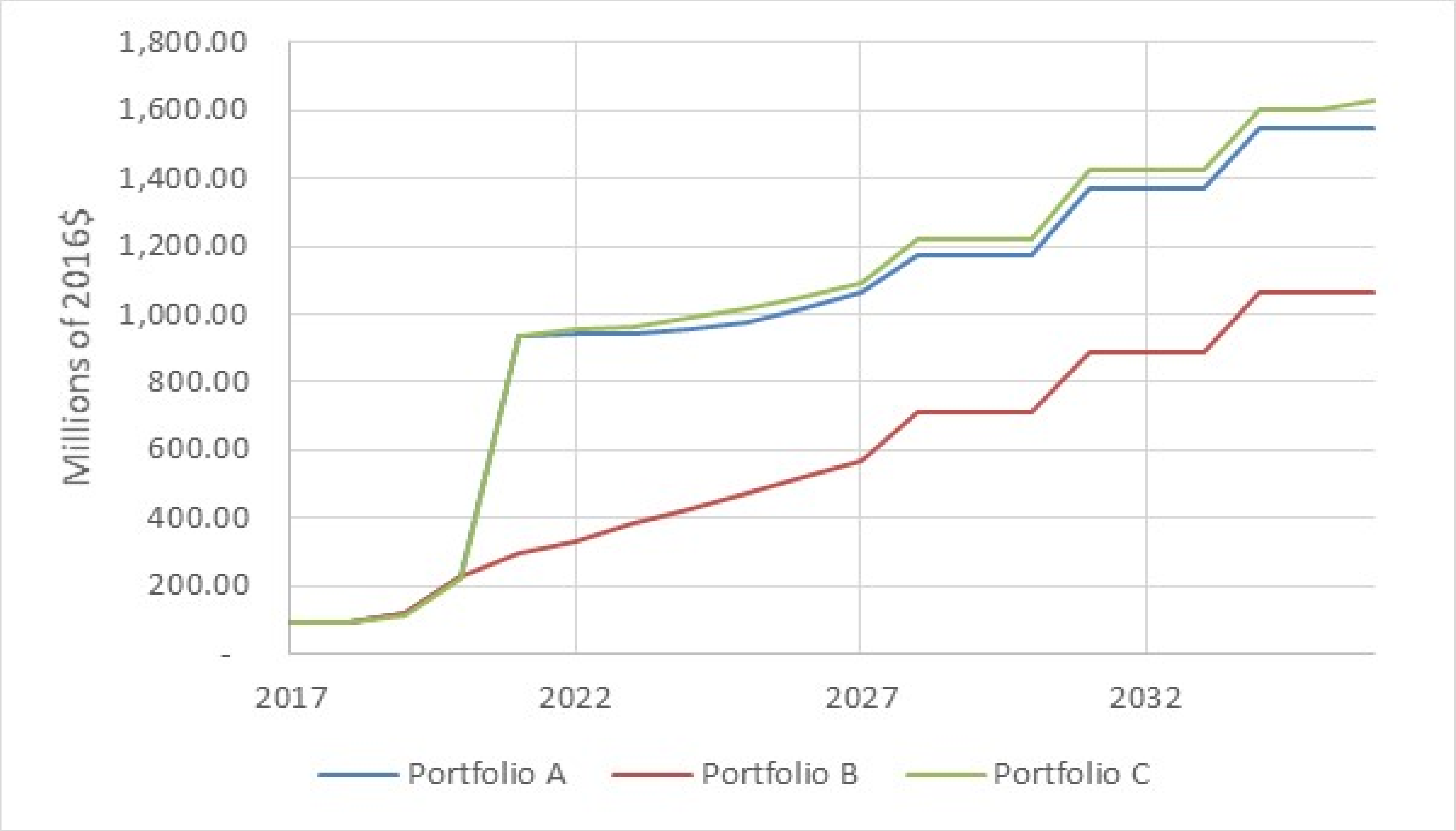
- **30%** reduction in streamflow
- **8%** reduction in water supply delivered
- **12%** reduction in hydropower generation



Strategy Performance and Drought Sensitivity (20 Year Planning Horizon)

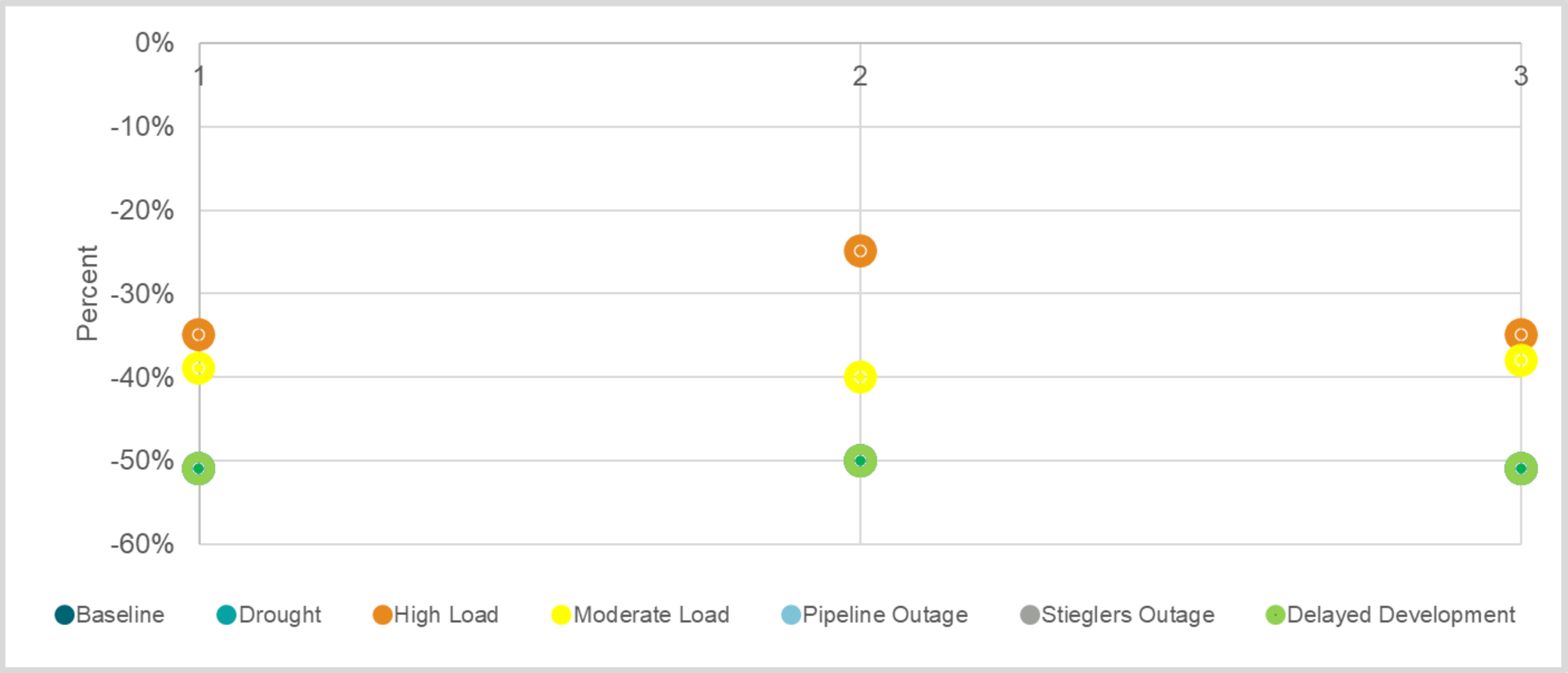


Outputs: Cost



Outputs: GHG Emissions

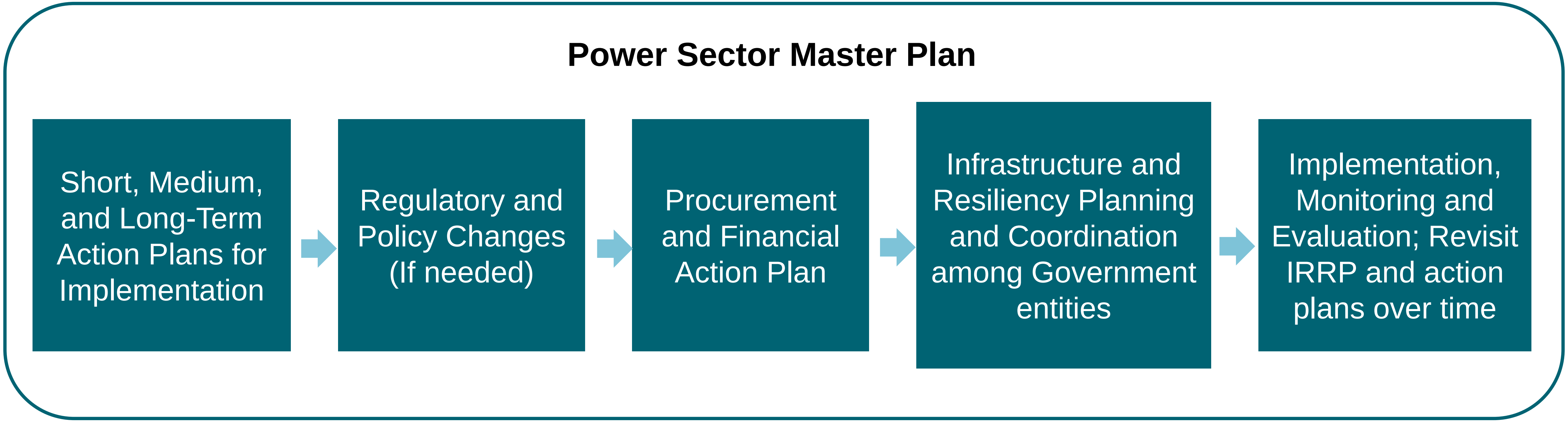
Portfolio	Units	00 Baseline	01 Drought	02 High Load	03 Moderate Load	04 Pipeline Outage	05 Stiegler's Outage	06 Delayed Development	Max - Min	Average
Reference (A)	%	-51%	-51%	-35%	-39%	-51%	-51%	-51%	17%	**-47%**
Limited Investment Case (B)	%	-50%	-50%	-25%	-40%	-50%	-50%	-50%	25%	**-45%**
Renewable-centric (C)	%	-51%	-51%	-35%	-38%	-51%	-51%	-51%	17%	**-47%**



	Cost Metric	Reliability Metric	Resilience Metric	Water Resources Metric	Climate Metric
Business as Usual **Strategy I**	14%	8%	-15%	20%	13%
Limited Financing **Strategy II**	4%	-2%	4%	20%	2%
Renewables **Strategy III**	12%	13%	-16%	20%	13%
	Incremental Investment and Production Costs ($)	*Unserved energy*	*Fuel Type Diversity*	*Unmet water demand*	*CO_2 Emissions*

Interpret Results → Decision-Making

The Power Sector Master Plan supports decision-making:



Key Takeaway

Integrating climate risk management into power planning and projects can help power planners and investors **better understand implications, and manage climate risks** to hydropower and power system performance, in order to more effectively **ensure energy security** and **meet low emission objectives** over time

Monitoring, Evaluation, & Learning (MEL)

- IRRP is a **<u>process</u>** and it is not one-size fits all!
- Ensure internal capacity exists so that the IRRP can be improved with new needs, scenarios, and technology changes
- Establish the value of IRRP to the policymakers and planners
- Institutional and human capacity is critical → Affects implementation of IRRP