Case study 1

Run-of-river hydropower facility

IIGCC Legacy Programme

Asset Overview

Investment has been made in development funding for the construction of a ~40 MW run-of-river hydropower project.

Asset objectives
- Lifetime of 40 years
- Average annual energy generation of roughly 200 GWh/year

Estimated project impact
- 200 GWh/year clean electricity
- 25000 tCO_2eq/year emissions avoided
- +300 construction jobs
- ~600 000 people reached

Sector
- ■ Power generation (renewable)
- □ Power generation (other)
- □ Power transmission
- □ Other energy infrastructure
- □ Rail
- □ Water resources/network
- □ Airport
- □ Highway
- □ Telecommunications
- □ Data centres

Climate variables analysed
- ■ Drought
- ■ Precipitation
- □ Heat
- □ Flooding
- □ Wind

Finance type
- ■ Blended finance facility
- □ Private sector funding
- □ Government funding
- ■ DFI funding

PCRAM Methodology

	1	2	3	4
Steps	Scoping and data gathering	Materiality assessment	Resilience building	Economic and financial analysis
Objectives	Determine data sufficiency	Assessing asset resilience	Identifying resilience options	De-risk asset exposure to PCRs
Sub-tasks	Project initiation Project definition Data gathering and sufficiency	Hazard scenarios Impact identification Impact severity Risk quantification	Resilience options: Hard (structural/capex) Soft (operational/systems)	Cost/benefit analysis IRR comparison
Outputs	Initial climate study Critical components KPI selection (the 'Base Case')	Detailed climate study List of impacts and severity by component The 'Climate Case'	Revised climate study for new elements The 'Resilience Case'	Recommendations Value implications
Decision gates	Gate A Is data good and sufficient?	Gate B Are PCRs material to this asset?	Gate C What resilience options are available for this asset?	

Step 1: Scoping and data gathering

A series of asset objectives were compiled by reviewing the available asset data and the financial model in detail.

Global and regional climate projection models were analysed and utilised to identify potential climate hazards in the area. Preliminary analysis determined that exposure to extreme heat, drought, and precipitation events are relatively high in the catchment area and is likely to rise under the chosen climate scenario.

The climate data was then matched to the asset objectives and these objectives shortlisted to focus on climate change events that affect energy generation.

Given the nature of the asset (being dependent on precipitation and river discharge) and the preliminary climate screening, this study focused on the materiality of drought risk (both acute events and chronic changes in precipitation) to hydropower plant itself and the associated energy generation. The structural elements and downstream infrastructure were excluded from the assessment.

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Step 2: Materiality assessment

For the materiality assessment of two future climate horizons analysis was conducted on the chronic risk associated with changes in annual precipitation were utilized to adjust the existing hydrological model. This adjusted hydro-model was then fed into an energy model to calculate the expected change in energy generation. The future climate projections revealed minimal reduction in river discharge through to 2040 and a 15–20% reduction in discharge from 2040 to 2060.

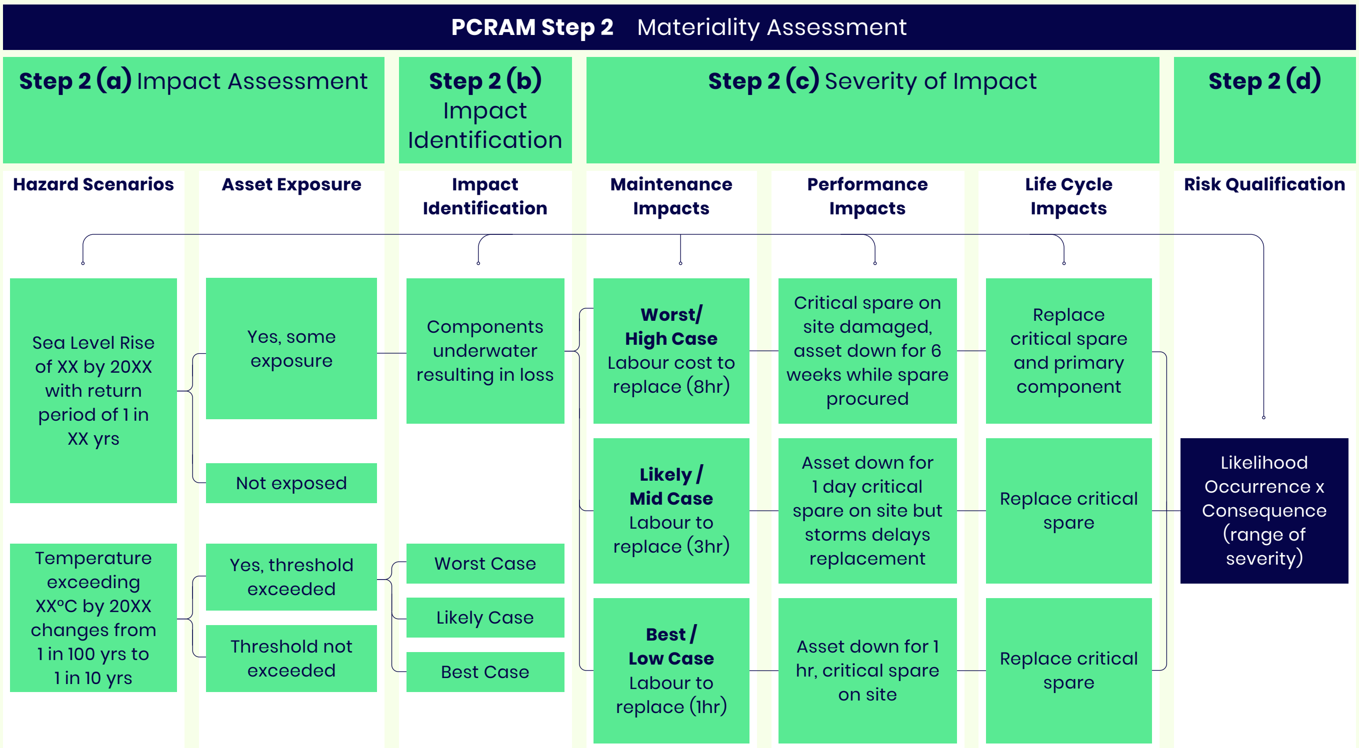
These adjustments indicated unanticipated changes in energy production per annum.

Rising acute drought risk, which will likely double by 2060, could affect the productivity of the dam. 3-month prolonged droughts are likely during 2021–2040, and for even longer periods after 2040. Projected seasonality changes in precipitation will likely result in drier and longer wet season, with an increase in extreme precipitation.

Under a high scenario, river flow is likely (>66%) to decrease annually by approximately 8%, mostly during the wet season with a projected decline of between 25% to 35%, while increasing slightly in the dry season.

A suite of structural and functional resilience actions were identified to enhance management, efficiency and a quicker recovery from decreased rainfall and drought events.

Summary of analysis undertaken



Decreasing precipitation and changes in flow rates lead to adjustment to energy generation[1]

Mid Term (2041–2060)

- Significant decrease in annual energy generation
- Increase in dry season (Q1) and major decrease in wet season (Q2/Q3)

Near Term (2021–2040)

- Small net increase in annual energy generation
- Despite lower annual river discharge (P50), there is an increase in river discharge during dry season (Q1) which results in an overall increase in generation
- 1% increase in Opex

1 Note that this production estimate is based on the original hydrological assessment and the same set of assumptions (design inputs) related to energy production provided in the associated technical report. The validity of the hydrological assessment and the design assumptions have not been completed as part of this exercise.

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Step 3: Resilience building

A series of potential structural and functional resilience measures and their impact on CAPEX or OPEX were identified, leading to increased efficiency and quicker recovery from decreased rainfall and drought events (combined with operational improvements). Some structural measures were already in use, the rest were carried through to Step 4 and added to the cash flow modelling analysis.

	Hard (structural) resilience measures	Cost	Benefits	Financial benefit to quantify*	Added to Cash Flow Model Analysis
1	Additional flushing and sediment management structures	1-3% CAPEX	Measure in use		NO
2	New access road direct to river to aid sediment management and clear debris	<5% CAPEX plus OPEX	Enhances sediment and debris removal/ specialist equipment not needed	↓ downtime ↓ O&M costs	YES
3	Sediment excavator for excavation of sediment	1-3% OPEX	Measure in use		NO
4	Installation of variable flow turbines and electro-mechanical equipment designed to take into account greater uncertainty in flow rates.	1-2% CAPEX	Allows turbine operation at a greater range of variable river flows	↓ downtime	YES
5	Design intake to allow some flexibility in vulnerable areas		Allows variable intake for the plant to operate under changing conditions	↓ range of operating head/flows	YES
6	Additional slope protection and stabilisation measures	1-2% CAPEX	Reduces the risk of earth and debris from subsidence or landslide entering the river and damaging the civil structures	↓ downtime due to landslides and slope failures ↓ O&M costs debris clearance operations	YES
7	Slope stability monitoring/surveying				
8	Installation of corrosive resistant turbine blades	10-20% turbine CAPEX	Measure in use		NO
9	Replacement and reassessment of the two rubber dams, their location, alignment, material and size at end of 25-year life	TBD	Increased resilience of key assets to ensure longevity of project	↓ likelihood of catastrophic failure of rubber dams	NO

Step 4: Economic and financial analysis

Internal Rate of Returns (IRRs) were derived for the new climate base cases and drought sensitivities and compared against the in-built resilience measures.

The analysis was done over 20 years to align with initial concession term.

One month drought in the dry season and three months drought in the wet season were selected based on findings in the climate data.

Their effect on expected energy production was applied as a sensitivity in specific years throughout the cashflow projections.

IRR	1 month drought in dry season (% change from baseline)	3 month drought in wet season (% change from baseline)
P90	+1.36	+0.27
P75	-0.32	-1.24
P50	+0.08	-0.77

Key financial results:

- Climate base cases have net lower IRRs except the P90 case due to projected increases in precipitation during dry seasons.
- Marginal negative impact of 1 month drought.
- Significant impact of 3-month drought in wet season.

Key takeaways:

Different types of investors with divergent time horizons may use different probability scenarios. P90 and P99 (extremes) potentially more salient for credit risk, and P75 and P50 potentially more relevant for equity returns.

The case study reveals two different outcomes over this asset's lifetime:

- Less impact in the near to medium term (<20 years) due to projected dry season flow increase.
- Material impact in longer term (>20 years) with a significant loss of energy production anticipated year on year.

This above difference in outcome depending on period within the asset's lifecycle may suggest there is less relevance vs. the equity holding period (20 years). However, if the asset's sale is expected to realise returns, the valuation over the final 20 years may be less than expected at the time of proposed sale.

Extreme drought events during the wet season early in the project lifecycle (e.g., year 1 to 3 of operating term) would materially affect IRR (i.e., >1% decrease)

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Lessons learned

In applying the PCRAM methodology to this case study, the following lessons have been learned:

- Benefits of infrastructure assets can be expressed in many ways, not just financial. In this case, the asset management objective is purely financial, so the wider benefits are not expressed. The PCRAM (and the investment decision making process in general) is focused on understanding financial costs and benefits and further work may need to be required to integrate for non-monetary benefits of investing in resilience.
- Many infrastructure assets operate as part of a wider system or network of assets and it can be very difficult to assess the costs and benefits of investing in resilience of a single asset in isolation from the wider system. Resilience often needs to be considered at the system or network scale and investment focused on improving the resilience of the overall system to physical climate risks.
- There is currently no insurance for hydropower projects for a lack of generation from drought.
- Caution is needed on the selection and use of downscaled climate projections, over-reliance on climate data, avoiding the use of one climate scenario, one plausible future and only one value of change in the hydrological and power energy modelling. Advice from climate scientists is needed on which climate data to use and how it can be used should be taken.
- There are a variety of reasons and compounded issues that mean a Technical Due Diligence that considered potential changes in future climate and a full climate change risk assessment are not always considered, these include but are not limited to:
  - Best practice to incorporate climate change not established at the time of the early and detailed design stages of the study;
  - Lack of awareness of the various stakeholders involved;
  - Differing quality levels of due diligence reporting;
  - Companies selling the turbines and systems often do not get involved in checking or specifying the size or type of systems better matched to the specific project, location of challenges;
  - Lack of funding available for due diligence for pre-financial close; and
  - Over dependency on indemnity insurance for some climate-related risks such as flood events and wildfires. Therefore, there is little to no incentive to invest in factoring in resilience against some of the more expected climate impacts such as additional flood protection, adjusting the design to deal with larger volumes of water etc.

Limitations and caveats

The physical climate risk assessment for this case study has not included an end-to-end climate change risk assessment, technical due diligence, detailed drought risk or the compound effects of a prolonged drought followed directly by an extreme rainfall or flood event for hydropower plant.

Glossary

- **Climate projection** – The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, e.g. future socioeconomic and technological developments that may or may not be realised (IPCC 2018[2]).
- **Climate base cases** – Base case evaluations are a part of scenario analysis, which helps decision-makers visualize and compare the most realistic outcomes for a business. With foresight into all possible outcomes, an organization can greatly improve its financial planning and modelling, allowing management to make decisions with confidence.
- **GWh/year** – Gigawatt hours per year (a measure of power)
- **m^3/s** – Cubic metre per second (a water volume flow rate)
- **Functional resilience measures** – non-structural modifications to operating policies to alleviate the impacts of climate change.
- **Structural resilience measures** – physical or hard modifications in order to alleviate the impacts of climate change.
- **Internal Rate of Return (IRR)** – A metric used in financial analysis to estimate the profitability of potential investments. Annual return that makes the net present value (NPV) equal to zero or is the annual rate of growth that an investment is expected to generate.
- **P50** – 50th percentile or central estimate

2 IPCC (2018). Annex I: Glossary. In: Global Warming of 1.5°C. Available at: https://www.ipcc.ch/sr15/chapter/glossary/