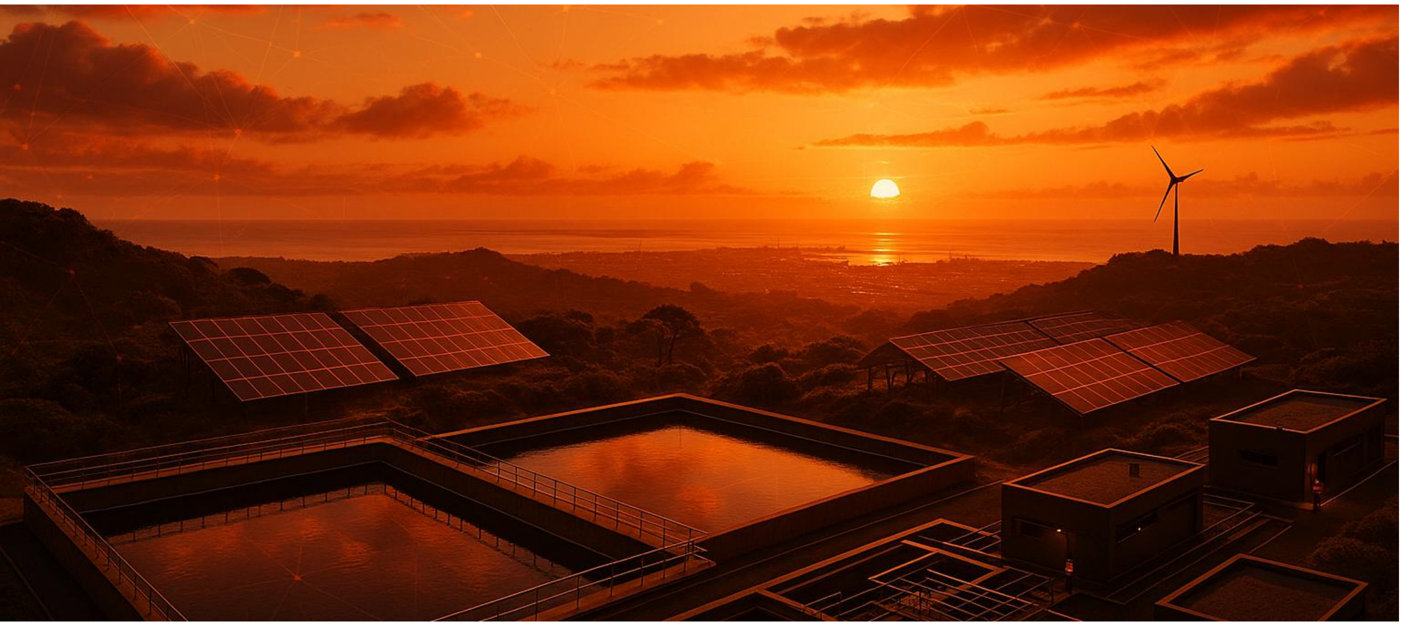

From Sensing to Strategy A C4ISR–DMDU Framework for Energy and Water Security in Mauritius

Combining Defence-Grade Situational Awareness with Robust Planning to Identify Low-Regret Investments under Deep Uncertainty

Preface

This report has been prepared to support Mauritian decision makers at national and local level as they confront a new generation of risks to energy and water security. Mauritius, as a small island developing State (SIDS), faces a convergence of pressures: volatile global fuel markets, rapid technological change, a tightening global climate regime and a measurable shift in rainfall patterns and extreme events. These developments create not only risk but also a compelling opportunity to rethink how infrastructure decisions are made, financed and governed.

The analysis draws on publicly available data and policy documents from the Government of Mauritius, including the Ministry of Energy and Public Utilities' Annual Report 2022–2023, the Renewable Energy Roadmap 2030 for the Electricity Sector, the National

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Water Policy, and recent UNFCCC submissions, notably Mauritius' NDC 3.0. It also uses international evidence and guidance from the World Bank, the International Monetary Fund (IMF), the International Energy Agency (IEA), the Global Center on Adaptation, UN Water, and the academic literature on decision making under deep uncertainty (DMDU) and robust infrastructure planning.(Rand Corporation)

The report adapts the concept of C4ISR—Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance—from its military origins to a civilian context, focusing on energy and water infrastructure. C4ISR is treated not as a set of weapons adjacent systems, but as an organising principle for integrated sensing, data fusion and real time decision support.(Northrop Grumman) When such a "nervous system" is combined with DMDU methods, it can help public authorities to identify low regret investments—actions that perform acceptably across a wide range of future conditions, including futures that differ sharply from standard forecasts.

The authors acknowledge the indirect contributions of many institutions whose research and statistics underpin this analysis, including Statistics Mauritius, the Central Electricity Board (CEB), the Central Water Authority (CWA), the Utility Regulatory Authority (URA), and development partners active in the Mauritian water and energy sectors. Responsibility for interpretation and any remaining errors lies solely with the authors.

Executive Summary

Mauritius has long been recognised as a success story amongst small island developing States, combining political stability with relatively high incomes and diversified services exports. However, its structural dependence on imported fossil fuels, limited freshwater resources, ageing network infrastructure and fast-evolving climate risks are exposing the country to a new class of complex, interacting shocks. The IMF estimates that Mauritius already spends around 2 per cent of GDP per year on climate-related investments, with adaptation accounting for roughly 1.6 per cent of GDP, yet a further financing gap of about 1.6 per cent of GDP must be closed to meet 2030 climate objectives.(IMF)

On the energy side, Mauritius imports approximately 85 per cent of its total energy use, one of the highest import dependencies in the world, leaving it highly exposed to global fuel price volatility and supply disruptions.(Maxinomics) In 2022, about 80.8 per cent of electricity generation was derived from non-renewable sources, mainly fuel oil and coal, while renewables (bagasse, solar, hydro, landfill gas and wind) accounted for roughly 19.2 per cent.(SACREEE) Government policy, as articulated in the Renewable Energy Roadmap 2030 and updated NDC submissions, aims to phase out coal and reach 60 per cent renewable electricity, though the target date has recently shifted from 2030 towards 2035, reflecting implementation constraints.(SDG Knowledge Hub)

In water, Mauritius is already classified as water-stressed, with renewable water availability per capita estimated at around 1,083 m^3 per year in 2013, and projected to fall below the 1,000 m^3 per year water-scarcity threshold.(World Bank) Climate change has contributed to longer dry seasons, shorter and more intense wet seasons, and more severe droughts, with over 20 per cent of the population experiencing recurrent intermittent water supply in dry years.(World Bank) At the same time, Non-Revenue Water (NRW) remains high: the Ministry of Energy and Public Utilities' Annual Report 2022–2023 reports NRW at around 61 per cent against a target of 55 per cent, reflecting physical losses, metering issues and ageing pipes.

These challenges are occurring under conditions of deep uncertainty. Future rainfall patterns, cyclone frequency, global fuel prices, technology costs for renewables and storage, the pace of electrification

KEY FINDINGS

Here are the **very brief key-findings bullet points**, distilled to their essentials:

- Mauritius faces **deep uncertainty** in energy and water due to climate variability, global fuel volatility and ageing infrastructure.
- Current systems show **high structural exposure**: ~85% energy import dependence and ~61% Non-Revenue Water.
- Existing strategic plans are valid but **not built on real-time data or robust exploratory modelling**.
- A civilian-adapted **C4ISR architecture** can provide integrated sensing, data fusion and coordinated decision-making.
- **DMDU methods** (RDM, DAPP) help identify strategies that perform well across thousands of plausible futures.
- Combining C4ISR + DMDU enables government to identify **low-regret investments** that remain valuable regardless of how conditions evolve.
- Priority low-regret investments:
  - Digitalisation & data governance across utilities
  - NRW reduction and targeted network renewal
  - Distributed solar + storage for critical facilities
  - Energy efficiency & demand-side management
  - Wastewater reuse and adaptive desalination pathways
- Strong need for a **National Energy & Water Resilience Cell** to coordinate cross-sector situational awareness and robust planning.
- A unified framework improves Mauritius' **bankability** for climate finance and concessional funding.
- Urgent shift required from deterministic "masterplanning" to **adaptive, robust infrastructure pathways**.

(including transport), and the trajectory of tourism and services exports all remain uncertain in both magnitude and direction. Conventional deterministic planning—anchored on a "most likely" scenario—is increasingly ill-suited to these conditions. Decision makers need tools that help them to cope with multiple plausible futures, contested assumptions and rapid feedback.

This report proposes an integrated approach that combines:

- **C4ISR principles**
  Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance—as a civilian "nervous system" for sensing, data fusion and coordinated operational response across the energy and water sectors;(Northrop Grumman)
- **Decision making under deep uncertainty (DMDU)**
  Methods—such as Robust Decision Making (RDM), Dynamic Adaptive Policy Pathways (DAPP) and related techniques—to test strategies across thousands of plausible futures and to design adaptive pathways rather than static masterplans.(Rand Corporation)

Together, these elements form a C4ISR–DMDU framework that can support Mauritian authorities to identify *low-regret* investments in energy and water infrastructure and governance—investments that produce value across a wide range of future conditions and can be scaled or adjusted as new information arrives.

Key findings

First, the analysis underscores the degree of **structural exposure** in Mauritius' current energy and water systems. High import dependence, a still modest share of renewables in electricity, water-scarcity thresholds being approached, and high NRW all mean that relatively small changes in external conditions (fuel prices, rainfall, cyclone intensity) can translate into large swings in fiscal, economic and social outcomes.(SACREEE)

Second, Mauritius already possesses many of the institutional building blocks for a more integrated, data-driven approach: a dedicated Ministry of Energy and Public Utilities; statutory bodies such as CEB, CWA and the URA; strategic documents including the Renewable Energy Roadmap 2030, the Master Plan for Water Resources (2012–2050) and a National Integrated Water Resources Management Plan. However, these instruments were largely developed using traditional planning methods and are not yet fully supported by real-time data architectures or DMDU-style exploratory analysis.

Third, adapting C4ISR concepts to a civilian context implies a **multi-layered architecture**:

- a *sensing and data layer* (smart meters, SCADA, remote sensing, hydrological gauges, grid monitoring);
- a *communications layer* (secure fibre and wireless networks across utilities and agencies);
- a *computing and analytics layer* (modelling, forecasting, exploratory scenario generation); and
- a *command layer* (joint sector operations centres and clear decision rights for activating contingency plans).

Fourth, DMDU approaches provide a structured way to use this "nervous system" to design robust portfolios rather than single "optimal" plans. International applications, especially in water planning, show that Robust Decision Making and DAPP can identify strategies that meet reliability and cost targets across widely varying climate projections, with adaptive "signposts" that trigger further investments when thresholds are crossed.(SpringerLink)

Priority low-regret investments

Within this C4ISR–DMDU framework, the report identifies a set of low-regret investment classes for Mauritius:

- **Digital infrastructure and data governance** across energy and water (advanced metering for large users, district metering for NRW management, enhanced SCADA, data lakes and shared data standards under the URA's oversight). These investments enable both operational efficiency and the analytical backbone required for DMDU.
- **Network efficiency and resilience**: accelerated programmes to reduce NRW from around 61 per cent, targeted pipe replacement in high-loss zones, selective undergrounding or strengthening of key electricity distribution corridors serving critical services (hospitals, airports, ports and major pumping stations).
- **Distributed renewable energy plus storage**, prioritising public buildings, water treatment plants and pumping stations. This combination reduces fuel import bills, improves resilience during cyclone-related outages and provides

flexible capacity for the grid under high uncertainty about demand growth and technology costs.(SACREEE)

- **Demand-side management and energy efficiency**, guided by the existing Energy Efficiency / Demand Side Management Master Plan and extended to water demand management. These actions consistently show positive net present value across a wide range of plausible futures in international DMDU applications.
- **Non-conventional water resources and reuse**, particularly tertiary-treated wastewater for irrigation in tourism zones and high-value agriculture, reducing pressure on potable supplies. This is already envisaged in the Ministry's strategic directions and can be tested under drought scenarios using DMDU tools.

Governance and finance implications

The report recommends the establishment of a **National Energy and Water Resilience Cell**, anchored in the Ministry of Energy and Public Utilities but with formal participation from the Ministry of Finance, Economic Planning and Development; the National Disaster Risk Reduction and Management Centre; CEB; CWA; URA; and the national climate change coordination mechanism. This Cell would act as the "command" hub in the C4ISR sense, owning the joint situational awareness platforms and commissioning DMDU analyses.

Financing the necessary transition requires combining domestic resources with international climate and development finance. The IMF and World Bank have both highlighted that climate resilience investments in countries such as Mauritius are macro-critical and can justify concessional financing and guarantees.(IMF) At the same time, adaptation finance still accounts for only around 36 per cent of total climate finance globally, implying intense competition for funds.(Global Center on Adaptation) A coherent C4ISR–DMDU framework, embedded in national planning and backed by credible data, can make Mauritian projects more bankable and attractive to external financiers.

A note on urgency

As UN-Water has emphasised, *"Water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival."*(United Nations) For small islands, this is inseparable from climate justice: *"The people of the small island developing states are on the frontlines of climate change."*(The United Nations in the Caribbean) Mauritius has already begun to act, but the scale and complexity of future shocks demand a more integrated, anticipatory approach to infrastructure strategy.

The C4ISR–DMDU framework proposed here is not a technology shopping list. It is a governance and decision-making upgrade: a way to use sensing, data and analytics to ask better questions and to make choices that remain defensible, even when the future does not behave as expected.

1. Mauritius at a Crossroads: Energy, Water and Climate under Deep Uncertainty

1.1 Macroeconomic and climate risk context

Mauritius aspires to consolidate its status as a high-income economy within the current decade, building on services, tourism, financial intermediation and ICT-enabled trade. The IMF's 2022 Article IV report notes that Mauritius has been gradually recovering from the COVID-19 shock but remains vulnerable to external demand and energy price fluctuations, with climate change emerging as a central macro-financial risk.(IMF) The World Bank similarly highlights that "strengthening resilience against climate and energy shocks and building fiscal buffers" is essential if Mauritius is to sustain inclusive growth.(World Bank)

Climate risk manifests through multiple channels: sea-level rise, tropical cyclones, storm surges, flash floods and droughts. The World Bank's Climate Risk Country Profile for Mauritius documents a rising trend in average temperatures, changes in rainfall patterns and increasing intensity of extreme events.(Climate Knowledge Portal) Economically, estimates suggest that extreme weather events can reduce GDP growth by 1.3 to 2.5 percentage points in affected years, with annual losses ranging from USD 160 to 245 million once infrastructure damage and indirect effects are considered.(Clare)

These climate impacts interact with an already narrow economic base and high import dependence for strategic inputs, especially energy. They also place stress on water resources at the same time as demand grows with population, urbanisation and economic activity. It is this confluence—of macroeconomic ambition, exposure and structural fragility—that makes improved decision making under deep uncertainty not a luxury but a necessity.

1.2 The energy system: structure, targets and vulnerabilities

Mauritius' energy system is characterised by high import dependence, a still limited share of renewables, and evolving but ambitious decarbonisation commitments. According to World Bank data, net energy imports account for approximately 84.5 per cent of total energy use, compared with a global median of about 23 per cent, placing Mauritius amongst the most import-dependent countries.(Maxinomics)

On the power side, total installed capacity is around 852 MW. In 2022, about 80.8 per cent of electricity generation came from non-renewable sources—principally fuel oil (49.2 per cent) and coal (31.5 per cent)—while renewable sources accounted for roughly 19.2 per cent: bagasse (9.1 per cent), solar PV (5.0 per cent), hydropower (4.1 per cent), landfill gas (0.6 per cent) and wind (0.5 per cent).(SACREEE) Recent reporting suggests that renewables contributed around 18–22.6 per cent of electricity in 2022/23, slightly below government interim targets.

Policy direction is clear but evolving. The Renewable Energy Roadmap 2030 and related budget speeches initially set a target of 60 per cent renewable electricity and a full coal phase-out by 2030.(CEB) Mauritius' NDC 3.0, submitted in 2025, now foresees achieving 60 per cent renewables by 2035, with coal still to be phased out and an expanded role for sugarcane biomass, solar, wind and emerging technologies such as ocean thermal energy conversion.(UNFCCC) The adjustment in timing reflects implementation headwinds: capital constraints, grid integration challenges, land availability and the need for storage.

The vulnerability of this system under deep uncertainty is straightforward: sharp increases in

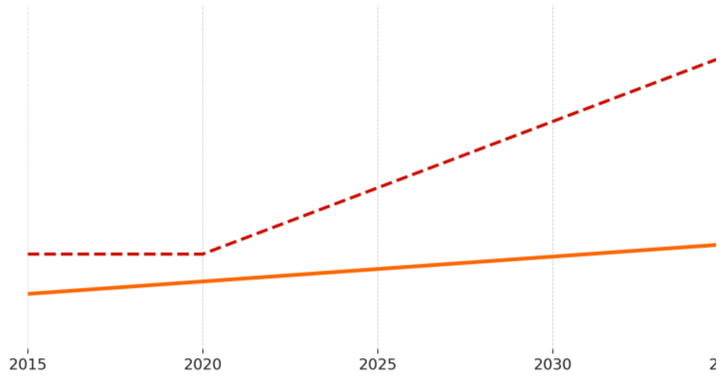

Figure 1 gap between current and target renewable shares

oil and coal prices quickly translate into higher generation costs, pressure on tariffs and fiscal strain if government cushions consumers. Geopolitical disruptions can disrupt supply chains for fuels and critical components. Meanwhile, the

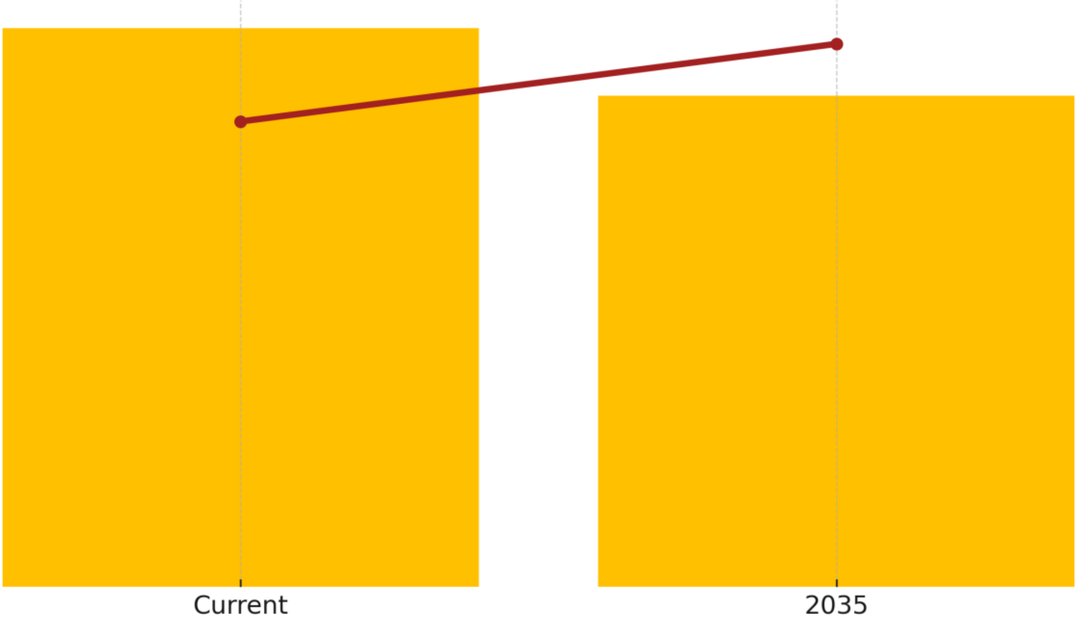

Figure 2 The water balance problem

realisation of more stringent global climate policies could force a more rapid shift away from fossil fuels than domestic planning currently assumes, with implications for stranded assets and balance sheets.

1.3 The water system: scarcity, infrastructure gaps and service risks

Mauritius' freshwater resources are limited by geography and increasingly by climate variability. Renewable water availability per capita, estimated at around 1,083 m^3 per person per year in 2013, already placed the country in the "water-stressed" category, and projections suggest a decline towards roughly 974 m^3 per person per year, crossing into the "water-scarce" category.(World Bank) The distribution of rainfall is highly seasonal and spatially uneven; dry months (October to December) often see deficits relative to demand, necessitating restrictions and rotational supply in some regions.(World Bank)

The World Bank's Drought Resilience Profile for Mauritius notes that more than 20 per cent of the population experiences recurrent intermittent water supply during dry years, reflecting both hydrological constraints and infrastructure limitations.(World Bank) The Ministry of Energy and Public Utilities' Annual Report 2022–2023 identifies a set of key challenges, including the ageing water distribution network, non-automated operations, limited storage in some zones, and high Non-Revenue Water.

For 2022/23, the Ministry reports a KPI target of reducing NRW to 55 per cent, but recorded performance at approximately 61 per cent, while acknowledging that the precise figure is uncertain due to defective production meters. Even allowing for measurement uncertainty, an NRW rate above 50 per cent implies that a large portion of abstracted and treated water does not generate revenue, either because it is physically lost through leaks or is not properly metered and billed. This represents both a financial and a resource loss, particularly problematic in a water-stressed context.

At the same time, ambitious projects are planned or under preparation: increased storage through new and enlarged dams, rehabilitation of existing reservoirs, expansion of treatment capacity at several plants, and potential desalination and additional boreholes. The challenge is not the absence of projects, but the selection, phasing and integration of these investments under deep uncertainty about future rainfall, demand and climate extremes.

1.4 Mapping sources of deep uncertainty

The uncertainties facing Mauritius' energy and water systems are not merely probabilistic variations around a known trend; in many cases, probability distributions themselves are disputed or unknowable. Key dimensions of deep uncertainty include:

- **Climate trajectories**
  the range of plausible paths for rainfall, cyclone intensity and sea-level rise under different global emissions outcomes, coupled with localised factors such as watershed changes and land-use patterns.(Climate Knowledge Portal)
- **Technology costs and performance**
  future cost curves for solar PV, wind, battery storage, desalination, advanced metering and digital infrastructure; the speed of learning and diffusion; and hardware supply chain risks.
- **Global energy and carbon regimes**
  fossil fuel price trajectories, future carbon prices (explicit or implicit), and technological shifts (for example, widespread uptake of electric vehicles) that alter demand patterns.
- **Economic structure and demand**
  the pace and composition of growth in tourism, finance, ICT and manufacturing, with associated implications for electricity and water demand, spatially and temporally.
- **Financing conditions**
  availability and terms of concessional climate finance, the evolution of green taxonomies and sustainable finance standards, and global interest rate cycles.

Under such deep uncertainty, planning based on a single reference scenario risks either under-investing (if shocks turn out worse than expected) or over-investing in the wrong assets (if the future is fundamentally different). This motivates the turn to robust and adaptive planning methods, discussed in the next section.

2. From C4ISR to DMDU: A Conceptual Framework for Civilian Infrastructure

2.1 C4ISR as civilian situational awareness architecture

In defence contexts, C4ISR systems integrate sensors, communication networks, computing, intelligence analysis and command structures to provide commanders with high-quality situational awareness and to shorten the time from sensing to response.(Northrop Grumman) Transposed to civilian infrastructure, the essence of C4ISR is an integrated "nervous system" that can continuously monitor the state of critical networks (electricity, water, transport), detect anomalies, and support coordinated decisions.

For Mauritius' energy and water sectors, a civilian C4ISR architecture could be conceptualised as follows:

- **Command**
  clear decision rights and protocols within a National Energy and Water Resilience Cell, including escalation paths for disruptions (e.g. cyclone-related outages, drought emergencies).
- **Control**
  operational rules and automated controls in SCADA systems that allow load-shedding, pressure management, reservoir releases and other actions to be executed safely and consistently.
- **Communications**
  secure, redundant channels linking CEB, CWA, MEPU, URA, the National Disaster Risk Reduction and Management Centre and local authorities, using both fibre and mobile networks.
- **Computers**
  a modern data infrastructure (servers, cloud resources, data lakes) capable of hosting high-frequency sensor data, geospatial data and simulation models.
- **Intelligence**
  data science and modelling capabilities for forecasting demand, simulating system stress, and conducting exploratory analysis of future scenarios.
- **Surveillance and Reconnaissance**
  systematic collection and analysis of information on external threats (cyclones, global fuel markets, supply chain disruptions), using both national and international sources.

This architecture is already partially in place—CEB and CWA operate SCADA systems and have access to some real-time data—but it is fragmented by sector and agency. The ambition of a C4ISR approach is to integrate these components, not to create an entirely new system from scratch.

> "For Mauritius, C4ISR should be understood not as military hardware, but as a disciplined way of wiring together data, institutions and decisions across energy and water."

2.2 Decision making under deep uncertainty (DMDU)

Decision making under deep uncertainty (DMDU) refers to a family of approaches that help decision-makers design strategies that perform well across a wide range of plausible futures, especially where there is disagreement or ignorance about key parameters and probabilities. Marchau, Walker, Bloemen and Popper (2019) provide an authoritative overview of DMDU approaches and their applications to infrastructure, water management and climate policy.(Rand Corporation)

A few approaches are particularly relevant for Mauritius:

- **Robust Decision Making (RDM)** focuses on systematically stress-testing candidate strategies across thousands of computational "futures", each representing different combinations of uncertain parameters (e.g. rainfall, fuel prices, demand growth). Instead of optimising for a single forecast, RDM identifies strategies that perform satisfactorily across many futures, and diagnoses where they fail.(SpringerLink)
- **Dynamic Adaptive Policy Pathways (DAPP)** starts from the recognition that not all actions need to be taken immediately. It crafts pathways of actions over time, with explicit "adaptation tipping points" and "signposts" that indicate when additional measures should be triggered as conditions evolve.(SpringerLink)
- **Info-Gap and related robustness methods** emphasise choices that are least sensitive to errors in assumptions, particularly when

worst-case outcomes are of concern—for instance, maintaining minimum water supply during severe droughts.(SpringerLink)

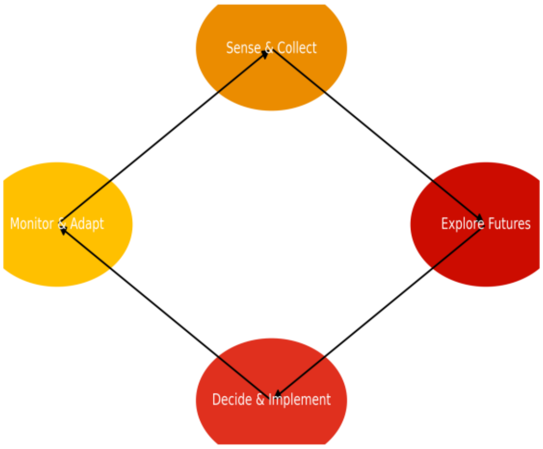

Figure 3 circular C4ISR–DMDU flow diagram

These approaches share a philosophy: rather than claiming to predict the future precisely, they explore a wide ensemble of futures, identify where current plans are vulnerable, and design robust and adaptive strategies to manage those vulnerabilities.

2.3 Integrating C4ISR and DMDU for energy and water security

C4ISR and DMDU are complementary. C4ISR emphasises *real-time sensing, communications and control*, whereas DMDU emphasises *exploratory modelling, robustness and adaptivity over time*. Together, they form a loop:

1. **Sensing and data ingestion**: C4ISR captures high-frequency data on network performance (flows, voltages, reservoir levels, demand patterns), external conditions (weather, market prices) and socio-economic indicators.
2. **Exploratory analysis and strategy design**: DMDU models use these data, combined with climate projections and economic scenarios, to generate a wide ensemble of futures and to evaluate alternative portfolios of investments and operational rules.
3. **Command decisions and implementation**: Decision-makers select a robust, adaptive strategy, including near-term investments and conditional future actions, and encode these into policies, budgets and operating procedures.
4. **Monitoring, signposts and triggers**: C4ISR continuously monitors key variables identified as "signposts" (e.g. frequency of severe droughts, maximum daily electricity demand, fuel price thresholds). When thresholds are crossed, pre-agreed adaptive actions are triggered, such as accelerating desalination investments or expanding battery storage.
5. **Learning and model updating**: Data streams feed back into models, improving their calibration and narrowing some uncertainties, even as new uncertainties emerge.

This integration is the core of the proposed framework for Mauritius: using defence-grade situational awareness concepts to feed, and be structured by, state-of-the-art robust planning methods.

3. Applying the Framework to Energy Supply in Mauritius

3.1 Sensing and data architecture for the power system

For the energy sector, a civilian C4ISR architecture would build on existing CEB systems and extend them in three directions:

- **Advanced metering and load monitoring**: deployment of advanced metering infrastructure (AMI) for large industrial and commercial customers, high-consumption households and critical facilities; integration of these data into a unified data platform.
- **Enhanced grid monitoring**: more granular SCADA coverage of distribution networks, including feeder-level measurements, voltage quality and outage detection, enabling both day-to-day optimisation and post-event forensics (for example, after cyclones).
- **Renewable resource and performance monitoring**: real-time monitoring of solar and wind output, including distributed generation; integration with meteorological forecasts to improve dispatch and reserve planning.

Such investments are not merely operational upgrades; they are essential enablers of a DMDU-style analysis. Without detailed historical and real-time data, models cannot adequately simulate the behaviour of the system under stress, nor can they be continuously improved as more data become available.

3.2 Exploratory analysis of energy futures under deep uncertainty

Within a DMDU framework, Mauritius' energy planners would define:

- **Decision levers**: for example, rates of renewable capacity additions (solar, wind, bagasse-based cogeneration), investments in battery storage, the timing and scale of any LNG capacity (if pursued), the extent of energy efficiency programmes, and the share of rooftop solar enabled by regulatory reforms.
- **Uncertain factors**: fuel prices, global carbon prices, technology costs and performance for renewables and storage, demand growth trajectories (including EV uptake), rainfall (affecting hydropower and cooling), and frequency of cyclone-related outages.
- **Performance metrics**: levelised cost of electricity, system reliability indices (e.g. loss-of-load expectation), emissions trajectories, fuel import bills as a share of GDP, and resilience metrics such as recovery time after a major event.

Using RDM, planners can then generate thousands of scenarios combining different values for uncertain factors and test how candidate investment pathways perform. International experience—for example, in water planning for US and European utilities—shows that such analyses often reveal that strategies optimised for a single "expected" scenario perform poorly when stress-tested against alternate futures, whereas certain combinations of efficiency, diversified renewables and flexible capacity provide robust performance.(SpringerLink)

3.3 Identifying low-regret energy investments

Within this framework, several categories of energy investment emerge as low-regret for Mauritius:

► **Grid digitalisation and smart dispatch**

Investments in data infrastructure, AMI, and enhanced SCADA improve operational efficiency under any plausible future. They reduce technical losses, enable quicker fault detection and restoration, and provide the data necessary for DMDU analyses. They also facilitate integration of variable renewables by providing operators with finer control over the system.

► **Distributed solar PV plus storage on critical public infrastructure**

Rooftop solar and battery systems on hospitals, water treatment plants, key pumping stations, schools used as shelters, and government buildings deliver multiple benefits: they reduce the fuel import bill, create local resilience "nodes" that can operate during grid outages, and provide valuable operating experience with storage. Even if global fuel prices were to fall, these systems hedge against future price spikes and enhance resilience to cyclones—thus remaining attractive across many futures.(ScienceDirect)

► **Energy efficiency and demand-side management**

Existing policy instruments such as the Energy Efficiency / Demand Side Management Master Plan, energy performance standards and labelling schemes have clear economic rationale. DMDU analyses in other jurisdictions consistently show that efficiency measures are among the most robust investments, since they reduce costs and emissions regardless of how demand or fuel prices evolve. Mauritius can extend these schemes, including through support for Energy Service Companies (ESCOs) and integration of dynamic tariffs enabled by advanced metering.

► **Targeted reinforcement of network resilience**
Using C4ISR-style data, CEB can identify parts of the network that are both critical and vulnerable—for example, feeders supplying major hospitals, the airport, port facilities or major pumping stations. Targeted reinforcement (including selective undergrounding, better pole design and redundancy) can significantly reduce outage risks. These investments pay off in any future where cyclones remain a threat, which is consistent across all plausible climate scenarios.(Climate Knowledge Portal)

3.4 An illustrative C4ISR-enabled decision cycle

Consider the problem of deciding how quickly to scale battery storage:

1. The **Surveillance** component monitors trends: the variance in solar output, peak demand episodes, outage frequency, and global battery prices.
2. The **Intelligence** component regularly runs DMDU simulations: if fuel prices rise, battery costs fall and cyclones become more intense, how does this change the optimal storage trajectory? What if fuel prices remain low but climate extremes worsen?
3. The **Command** function, within the National Energy and Water Resilience Cell, reviews this analysis and adopts an adaptive pathway: commit to a certain minimum battery capacity by 2027, with conditional triggers for accelerating investment if signposts (e.g. a sustained increase in fuel prices or a threshold number of outage hours) are crossed.
4. The **Control** and **Communications** layers ensure that once these triggers are met, the implementation of contracts, procurement and connection processes is timely and coordinated.

In this way, C4ISR ensures that signposts are reliably monitored and communicated, while DMDU ensures that the underlying logic of those signposts is grounded in systematic exploratory analysis, rather than ad hoc judgement.

Illustrative Screening of Candidate Energy Investments (for Robustness under Deep Uncertainty)

#	Candidate investment option	Representative scale / description (illustrative)	Capital cost level (relative)	Typical technical lifetime (years)	Primary benefits – system cost	Primary benefits – emissions	Primary benefits – resilience	Robustness to fuel-price uncertainty	Robustness to climate / extreme weather	Key dependencies / risks
1	**Digital grid upgrades** (SCADA, AMI, data platforms)	Roll-out of advanced metering for large users, feeder-level SCADA, data lake and analytics platform	**M**	10–15 (with periodic ICT refresh)	Reduces losses, enables more efficient dispatch, lowers O&M costs over time	Indirect emissions reductions via efficiency and better integration of renewables	Faster fault detection, shorter outages, improved visibility of weak points	**High** – benefits largely independent of fuel mix or price	**High** – improves ability to manage storms, load spikes and restoration	Requires strong cyber-security, ICT skills, change-management capacity across utilities
2	**Rooftop PV + storage for critical facilities**	100 kW–1 MW PV plus batteries on hospitals, water treatment plants, key pumping stations, emergency shelters	**M–H** (PV and batteries still significant capex)	20–25 (PV), 10–15 (batteries)	Offsets grid purchases and fuel use, hedges against future price spikes	Direct emissions reduction by displacing fossil-fuel generation	Maintains critical services during grid outages, provides local black-start capability	**High** – PV output not tied to fossil fuel prices; storage arbitrage value increases when fuel is expensive	**High** – especially for cyclone-related outages, if systems are properly sited and built to resilient standards	Requires robust O&M, clear responsibilities for asset ownership, and careful siting / structural design for cyclones
3	**Utility-scale solar PV plants**	10–50 MW ground-mounted PV feeding transmission network	**M**	25–30	Reduces long-run generation cost as PV costs fall, especially at high fuel prices	Significant emissions reduction versus coal / oil	Limited direct resilience benefit, but diversified supply if plants are geographically spread	**High** – economics improve strongly as fuel prices or carbon prices rise	**Medium** – output sensitive to cloud cover and storms; can be hardened against cyclones but requires robust mounting and drainage	Land availability and competing land uses; grid connection and potential curtailment; need for complementary flexibility / storage
4	**Onshore wind farms**	5–30 MW wind clusters at best resource sites	**M–H**	20–25	Competitive LCOE in good wind regimes; diversifies generation mix	Zero operational emissions; helps meet NDC targets	Some resilience via diversification, but exposed to cyclone wind loads	**High** – not affected by fossil fuel price volatility	**Medium** – wind speeds may change under climate shifts; turbines must be designed for extreme gusts and shut-down protocols	Siting constraints (noise, visual, environmental); structural design for high-wind events; public acceptance
5	**Battery energy storage systems (BESS)**	10–100 MWh utility-scale systems for frequency response, peak shaving	**M–H** (declining over time)	10–15	Reduces need for peaking plants, optimises use of existing assets, defers some network upgrades	Enables higher penetration of renewables, reducing curtailment	Supports grid stability during disturbances; can provide black-start support	**High** – value increases with fuel price volatility and high peak/off-peak spreads	**High** – improves system response to extreme events and rapid changes in demand/generation	Technology and price trajectory uncertainty; requires sophisticated dispatch and lifecycle management
6	**Energy efficiency & demand-side management**	Appliance standards, building codes, industrial audits, ESCO schemes, time-of-use tariffs	**L–M** (policy + programme costs)	10–20 (measure-dependent)	Lowers system-wide energy demand, defers capacity additions, reduces bills	Reduces emissions across all scenarios by lowering baseline consumption	Reduces stress on system during peaks, indirectly improving resilience	**High** – cost-effective even when fuel prices are low; very attractive when prices spike	**High** – less demand reduces vulnerability to supply disruptions and climate-driven stress	Requires strong regulatory framework, monitoring and enforcement; benefits diffuse and may be hard to monetise for financing
7	**Targeted reinforcement of critical distribution corridors**	Undergrounding / hardening feeders to hospitals, airport, port, major pumping stations	**M** (spatially focused)	30–40	Limited direct impact on average system cost; lowers long-run repair and outage costs on critical lines	Small emissions effect; some avoided diesel back-up use	High – keeps essential services powered during storms and floods	**Medium–High** – less affected by fuel prices; benefits greatest when outages are costly	**High** – reduces outage frequency and duration under cyclones and storms	Requires careful asset criticality mapping; higher upfront cost versus standard lines; coordination with roads and other utilities

#	Candidate investment option	Representative scale / description (illustrative)	Capital cost level (relative)	Typical technical lifetime (years)	Primary benefits – system cost	Primary benefits – emissions	Primary benefits – resilience	Robustness to fuel-price uncertainty	Robustness to climate / extreme weather	Key dependencies / risks
8	**Bioenergy / bagasse cogeneration upgrades**	Efficiency improvements and capacity upgrades in sugar mill power plants exporting to grid	**M**	20–25	Can provide dispatchable renewable power at competitive cost; uses domestic resource	Lower emissions than coal/oil; potential for negative emissions if coupled with CCS in future	Some resilience through diversification and local fuel supply, but vulnerable to crop yields	**High** – less exposed to international fuel prices; some exposure to fertiliser / input prices	**Medium** – climate impacts on sugarcane yields and hydrology can affect fuel availability	Depends on long-term viability of sugar sector; requires fair power-purchase agreements and sustainable biomass management
9	**New centralised thermal capacity dependent on a single imported fuel** (e.g. large oil or coal plant)	100–300 MW single-fuel baseload or mid-merit plant	**H**	30–40	May offer low short-term marginal cost if fuel is cheap; economies of scale	High emissions, especially for coal and heavy fuel oil; risk of stranded assets under stricter climate policy	Concentrates risk in single large asset; vulnerable to port disruption, fuel supply interruption	**Low** – highly sensitive to fuel-price shocks and future carbon pricing; risk of cost overruns	**Low–Medium** – generation vulnerable to storm damage and cooling-water constraints; coastal siting may face sea-level rise risk	Long construction periods, financing risk, potential mis-alignment with long-term decarbonisation goals and investor appetite
10	**Small-scale hybrid mini-grids for remote or critical sites**	PV + storage + limited diesel back-up serving remote communities or specific facilities	**M**	15–25	Reduces need for costly network extensions; optimises local supply	Significant emissions reduction relative to diesel-only generation	Provides local autonomy and rapid restoration after outages	**High** – diesel back-up exposure reduced by PV and storage; overall less sensitive than pure diesel systems	**High** – if designed well, can operate in "island" mode during grid failures and disasters	Requires local O&M capability, robust governance for tariffs and cost recovery; technical complexity for small utilities

Legend

- Capital cost level: **L = Low, M = Medium, H = High** (relative to other options)
- Robustness: **Low / Medium / High** robustness across futures

4. Applying the Framework to Water Security in Mauritius

4.1 Sensing and data architecture for water resources and distribution

For water, a C4ISR-inspired architecture would emphasise:

- **Hydrological sensing**: automated gauges on rivers, reservoirs and key aquifers; integration of satellite-based rainfall estimates and soil moisture proxies; early warning integration for tropical systems.
- **Network monitoring**: expansion of district metered areas (DMAs), smart meters for large consumers, pressure and flow sensors in critical trunk mains; integration of these data into a central dashboard that reveals leak patterns and pressure anomalies indicative of NRW.
- **Treatment and quality monitoring**: online sensors at treatment works for turbidity, residual chlorine and other parameters; integration of laboratory data; georeferenced tracking of water quality issues.

The Ministry's own strategic directions already point towards digitalisation of the water network and increased replacement of pipe networks to reduce operating costs and NRW. C4ISR provides a conceptual scaffold for these efforts, ensuring that they are planned as part of an integrated sensing and command system rather than piecemeal upgrades.

4.2 DMDU for water investment portfolios

Applying DMDU to water requires defining:

- **Decision levers**: levels of investment in NRW reduction, specific dam projects and enlargements, desalination capacity, wastewater reuse schemes, artificial recharge of aquifers, and demand management measures (tariffs, public campaigns, efficient fixtures).
- **Uncertain factors**: future rainfall amounts and seasonality, evapotranspiration under higher temperatures, population and tourism growth, industrial water demand, unit costs of desalination and reuse, and energy prices (since water is energy-intensive).
- **Performance metrics**: reliability of supply (for example, percentage of time that minimum service standards are met), financial sustainability of utilities, environmental impacts (river health, saline intrusion) and equity considerations (service to poorer households).

Using approaches such as RDM and DAPP, Mauritian planners can explore which combinations of NRW reduction, storage expansion, reuse and desalination provide acceptable reliability under a broad ensemble of climate futures. International evidence suggests that "build everything now" strategies are often dominated by phased, adaptive portfolios that emphasise efficiency and network management first, with desalination and large transfers deployed as contingent options once signposts—such as repeated multi-year droughts—are triggered.(SpringerLink)

4.3 Low-regret investments for a water-scarce island

Several water-sector investments stand out as low-regret for Mauritius:

► Aggressive NRW reduction supported by digital tools

Given NRW of around 61 per cent, even modest reductions yield large returns in terms of effective water availability and financial performance. Investments in pressure management, targeted pipe replacement informed by DMA data, improved metering accuracy, and customer information systems remain attractive across almost all climate futures: if rainfall declines, saved water is critical; if rainfall improves, the utility still benefits financially.

► Incremental expansion and optimisation of storage

Strategic investments in new and enlarged reservoirs (such as Rivière des Anguilles) and rehabilitation of existing dams can improve seasonal regulation of water supplies. However, DMDU analysis can test the risk of over- or under-investment under different rainfall regimes, guiding the timing and scale of works. Emphasis should be placed on operational rules—how reservoirs are managed under drought and flood—using DMDU to design robust operating policies.

► Wastewater reuse for non-potable purposes

Tertiary-treated effluent used for irrigation of golf courses, hotel landscaping and certain crops can reduce demand for potable or high-quality water. The Ministry's roadmap already envisages a National Water Usage Policy encouraging such practices. Because tourism and high-value agriculture are expected to remain important under most growth scenarios, reuse schemes are relatively robust, even if uncertainties remain about precise demand and willingness to pay.

► Desalination as a contingent, flexible option
Desalination is energy-intensive and capital-costly, but it can provide a drought-proof source of water for critical uses. In a DMDU framework, desalination is best treated as a flexible option: preliminary feasibility and siting can be done early, but major capacity is triggered when signposts—such as repeated failures to meet reliability targets under more severe droughts—are observed. This avoids locking in unnecessary costs if rainfall does not deteriorate as much as some projections suggest.

As with energy, a comprehensive table—intended for an Appendix—could summarise for each water investment option: capital and operating costs, energy requirements, environmental impacts, and robustness across drought and demand scenarios.

4.4 Multi-hazard crisis management for energy–water interdependencies

Energy and water systems are tightly coupled: electricity is needed for water pumping and treatment, while some power generation (notably thermal plants) depends on water for cooling. Under cyclones or extended droughts, failures in one system quickly propagate to the other.

A C4ISR–DMDU approach enables integrated crisis management:

- **Before events**, joint simulations explore how combined shocks—such as a cyclone causing both power outages and turbidity spikes in raw water—would play out, and what contingency measures are most effective.
- **During events**, shared situational awareness dashboards display, in near real time, the status of key assets in both sectors, allowing prioritisation of repairs and rerouting of limited resources (for example, mobile generators or water tankers).
- **After events**, data feeds into post-mortem analyses that update models and strategies, closing the learning loop.

This integrated perspective is particularly important given Mauritius' exposure to tropical cyclones and coastal flooding.(Climate Knowledge Portal)

5. Governance, Institutional and Financing Implications

5.1 Institutional design and data governance

Mauritius already has a relatively sophisticated institutional architecture for energy and water: the Ministry of Energy and Public Utilities sets policy; CEB and CWA provide core services; URA regulates; and a range of strategic plans guide long-term development. However, these entities largely operate with sector-specific data systems and planning processes. A C4ISR–DMDU framework would require:

- **A National Energy and Water Resilience Cell** with clear legal mandate, structured as a permanent, multi-agency unit. This Cell would own the joint situational awareness platform, commission DMDU analyses and convene decision-makers during both planning and crisis response.
- **Data-sharing protocols and standards**, governed by URA or a dedicated data governance body, to ensure that sensor data, modelling outputs and performance indicators are interoperable and appropriately protected.
- **Capacity building** in data science, systems modelling and DMDU methods within MEPU, CEB, CWA and the Resilience Cell, potentially with support from international partners experienced in DMDU applications.
- **Integration with national planning and budgeting**, so that robust, adaptive investment pathways inform medium-term expenditure frameworks and public sector investment programmes, rather than existing as stand-alone technical studies.

5.2 Financing the C4ISR–DMDU transition

Upgrading sensing, data infrastructure and robust planning capabilities requires upfront investment but can unlock larger flows of climate and development finance by improving project quality and credibility. Several financing streams are relevant:

- **Domestic budgetary resources**, guided by the recognition in IMF and World Bank analyses that climate resilience investments are macro-critical for Mauritius.(IMF)
- **Multilateral climate finance**, including the Green Climate Fund and Adaptation Fund, where bankable proposals that integrate robust planning and integrated risk management can be competitive.
- **Development policy operations and investment loans** from the World Bank and regional banks, which can support policy reforms (such as data governance frameworks) alongside physical investments.
- **Blended finance and green bonds**, potentially for revenue-generating components such as efficiency upgrades or distributed renewables, with robust analytical underpinnings from DMDU.

Global data indicate that adaptation finance still lags mitigation, accounting for about 36 per cent of total climate finance in 2021–2022, a decline from 39 per cent in 2019–2020.(Global Center on Adaptation) A clear C4ISR–DMDU strategy can help Mauritius to make a compelling case that its projects deliver genuine resilience and are grounded in cutting-edge risk analysis, justifying concessional terms.

5.3 An indicative implementation roadmap

An indicative roadmap might unfold in three overlapping phases:

- **Foundation (0–3 years)**: establish the National Energy and Water Resilience Cell; agree data-sharing protocols; map existing sensors and SCADA systems; begin priority AMI and DMA roll-outs; conduct pilot DMDU studies focusing on a limited set of decisions (for example, timing and scale of battery storage and NRW reduction targets).
- **Scaling (3–7 years)**: expand sensing infrastructure; integrate operational data from energy and water into a unified situational awareness platform; institutionalise DMDU in investment appraisal and regulatory processes; embed robust, adaptive pathways in national planning documents and NDC implementation.
- **Maturation (beyond 7 years)**: refine models using accumulated data; adjust investment pathways in light of signpost observations; explore advanced capabilities such as digital twins for key systems; and leverage Mauritius' experience to provide regional leadership on resilient infrastructure planning in SIDS.

Each phase should be associated with clear milestones and responsibilities, ensuring accountability and continuity across electoral cycles.

6. Conclusions and Recommendations

Mauritius stands at a critical juncture. Its ambition to sustain high-income status and social progress will be tested by climate change, global economic volatility and domestic resource constraints. Energy and water security sit at the heart of this challenge.

The analysis in this report suggests that combining C4ISR principles with DMDU methods can significantly improve the quality and resilience of decisions in these sectors. C4ISR provides the nervous system—the sensors, communications and command structures—while DMDU provides the analytical discipline to handle deep uncertainty without pretending to forecast the future precisely.

From this, the following strategic recommendations emerge:

1. **Institutionalise integrated situational awareness** by establishing a National Energy and Water Resilience Cell with a mandate to operate a joint C4ISR platform and to coordinate robust, adaptive planning across sectors.
2. **Prioritise digital and data infrastructure** as enablers of resilience, including advanced metering, enhanced SCADA, hydrological sensing and unified data platforms governed by clear standards.
3. **Adopt DMDU as a standard for major investment decisions**, ensuring that new dams, desalination plants, large power projects and major grid upgrades are stress-tested across a wide range of plausible futures and embedded in adaptive pathways.
4. **Focus on low-regret investments first**, notably NRW reduction, energy efficiency, grid modernisation and distributed renewables on critical infrastructure, which perform well in almost all futures and generate early co-benefits.
5. **Align financing strategies with robust planning**, using the C4ISR–DMDU framework to strengthen the bankability of projects and to make a compelling case for concessional finance and blended solutions.
6. **Build domestic capacity and partnerships**, including with universities, think tanks and international organisations experienced in DMDU and infrastructure analytics, so that Mauritius can own and evolve its models over time.

If implemented, this approach would not guarantee immunity from shocks—no framework can—but it would markedly improve Mauritius' ability to anticipate, absorb and adapt to them, while delivering value for money from scarce public resources. It would also position the country as a regional leader in the application of advanced decision-support methods to SIDS resilience, turning its vulnerability into a platform for innovation and influence.

APPENDIX

Supplementary Materials

The supplementary materials in this appendix provide additional background on the analytical methods, data sources, and assumptions used throughout this study. They also describe methodological choices, the scope of evidence assessed, and the inherent limitations associated with decision-making under deep uncertainty (DMDU). These materials are intended to enhance transparency, strengthen the interpretability of findings, and clarify the boundary conditions within which our conclusions should be understood.

How we conducted this study

This study was undertaken through a structured analytical process designed to ensure methodological rigour, transparency, and fidelity to internationally recognised standards for infrastructure resilience and policy research. The central framework combined civilian-adapted C4ISR concepts with Decision Making under Deep Uncertainty (DMDU) methods, allowing the research team to integrate real-time situational awareness principles with robust, non-deterministic planning approaches. We began by defining the scope and critical questions in consultation with public data sources and strategic policy documents, including Mauritius' Nationally Determined Contributions (NDC 3.0), the Renewable Energy Roadmap, the National Water Policy, and the various performance and budgetary reports issued by the Ministry of Energy and Public Utilities (MEPU). This scoping phase ensured that the study aligned closely with the country's strategic priorities and reflected the realities of institutional mandates in the energy and water sectors.

Data collection relied exclusively on verifiable information from reputable institutions such as the Government of Mauritius, Statistics Mauritius, CEB, CWA, the IMF, the World Bank, the AfDB, UNDP, OECD, and leading global climate analytical platforms. Where multiple datasets existed for a single indicator—such as for Non-Revenue Water (NRW) or renewable energy penetration—values were triangulated and discrepancies documented to preserve transparency. Climate-related figures, such as projected rainfall or drought recurrence, were drawn from the World Bank Climate Risk Country Profile for Mauritius and cross-checked with IPCC regional assessments. Throughout the process, we adopted a conservative approach to uncertainty, preserving full uncertainty bands rather than narrowing ranges artificially.

The analytical phase applied qualitative and semi-quantitative robustness screening to a suite of energy and water investments. This assessment was informed by DMDU techniques including Robust Decision Making (RDM) and Dynamic Adaptive Policy Pathways (DAPP), although these were used here as conceptual tools given the absence of full-scale simulation models. Investment pathways were stress-tested conceptually across numerous plausible futures shaped by fuel-price volatility, technological cost trajectories, hydrological variability, and extreme weather events. Finally, the findings were synthesised into a set of low-regret options and institutional recommendations, benefiting from comparisons to international experiences in other small island developing States where relevant. At each step, the analysis was guided by the principle that robustness—not optimality under a single forecast—should be the core criterion for resilient decision-making.

Limitations

Despite the use of reputable data sources and robust conceptual frameworks, several limitations necessarily shape the interpretation of this study's findings. First, data quality and availability constraints remain a significant challenge in both the energy and water sectors. Certain indicators, such as NRW levels, rely on datasets with acknowledged measurement issues due to non-functional production meters and uneven metering coverage. In the water sector, reservoir capacities are well established, but updated bathymetric surveys are not readily available, requiring the continued reliance on historic values. In energy, while generation mixes and capacities are well documented, granular operational data—particularly on distributed generation, grid constraints, and outage patterns—are not publicly accessible, constraining deeper quantitative modelling.

Second, while DMDU principles inform the analysis, the study does not employ full computational DMDU, power-system optimisation, or hydrological simulation models typically used in highly technical assessments. Instead, it offers a structured, qualitative application of RDM and DAPP concepts. As such, precise cost-optimisation or numerical probability-based outputs should not be inferred. This limitation reflects both the scope of the present work and restricted access to proprietary models used by utilities such as CEB and CWA. Furthermore, climate projections for Mauritius, especially regarding cyclone intensity and long-term rainfall patterns, carry deep uncertainty. Although reputable sources such as the World Bank and IPCC provide ranges, these remain wide and cannot be resolved without further scientific advances.

Third, institutional and structural constraints in Mauritius affect the generalisability of our conclusions. Energy and water utilities currently operate distinct monitoring and data systems, reducing the degree of integration possible in empirical analyses. Policy commitments—such as the timing for achieving 60% renewable electricity or the phasing out of coal—continue to evolve, meaning that some planning assumptions may require adjustment as new strategies are released. Financing conditions for climate-resilient infrastructure also remain volatile and dependent on international funding cycles, which limits the precision with which investment viability can be projected.

Finally, while the conceptual frameworks used in the study are globally recognised, Mauritius' unique geography, hydrology, market size, and governance structure mean that the findings should not be indiscriminately applied to other countries. Conversely, although international comparisons inform the analysis, the resilience strategies effective in other SIDS may not map perfectly onto Mauritius. For these reasons, readers should interpret the results as robust directional insights grounded in validated evidence, rather than as prescriptive forecasts or deterministic optimisation outputs.

Energy: Mix, Imports, Capacity, Emissions

Table 1 Electricity generation mix by source (Island of Mauritius)

Year	Fuel oil	Coal	Kerosene	Bagasse	Solar PV	Hydro	Landfill gas	Wind	Total renewables	Notes / source
2022	49.2%	31.5%	0.1%	9.1%	5.0%	4.1%	0.6%	0.5%	19.2%	SACREEE country profile for Mauritius, citing CEB data (sacreee.org)
2023	48.8%	33.5%	n/a	9.5%	4.5%	2.9%	0.4%	0.2%	17.6%	MEPU Annual Report 2023–2024 (generation profile) (publicutilities.govmu.org)

Interpretation: renewables' share in the electricity mix fell slightly from 19.2% in 2022 to 17.6% in 2023 as fossil generation increased.

Table 2 Imports of petroleum products (domestic demand + bunkering)

Year	Gasolene	Diesel oil	Aviation fuel	Kerosene	Fuel oil	LPG	Total petroleum products
2020	141.6	257.7	70.7	0.6	713.1	67.9	1,251.6
2021	186.8	312.8	68.6	1.6	748.7	77.1	1,395.6
2022	181.0	311.5	210.7	3.9	756.7	91.8	1,555.7

Source: Energy Observatory Report 2021–2022, Table 1.2 – Import of petroleum products, 2013–2022, *all figures in ktonnes*
Additional note: the same report records that the **import bill for petroleum products and coal** increased from **Rs 24,090 million (2020) to Rs 35,882 million (2021), a 49% increase**, driven by higher international prices.

Table 3 Installed electricity generation capacity (as of 30 June 2024)

Indicator	Value (MW)	Share of total	Notes / source
Total nominal installed capacity	881.56	100%	CEB "Production Overview" (CEB)
CEB generating units	512.72	58.1%	Thermal + hydro plants owned by CEB
Private power producers (IPPs, MSDGs, SSDGs)	368.84	41.9%	Includes large IPPs and distributed generation

Table 4 Aggregate GHG / energy indicators (latest available)

Indicator	Year / period	Value	Notes / source
Total GHG emissions	2021	6.73 Mt CO_2-equivalent	Emission-Index summary of Mauritius inventory (Emission Index)
GHG emissions per capita	2021	5.3 t CO_2-e per person	Same source as above (Emission Index)
Share of GHG emissions subject to positive effective carbon price	2023	55.8% of national emissions	OECD "Carbon pricing in Mauritius" (OECD)
Share of emissions covered by fuel excise taxes	2023	59.3%	OECD carbon pricing assessment (OECD)
Estimated total primary energy requirement	2021	1,367 ktoe (54% petroleum products, 33% coal, 12% renewables)	"Energy and Water Statistics 2021", Statistics Mauritius (maurice-info.mu)
Renewable energy supply (total)	2022	152,934 toe	CEIC – Renewable Energy Supply: tonnes of total energy supply (CEIC Data)

Water Resources, NRW, Storage and Investments

Table 5 Capacities of major man-made reservoirs

Reservoir	Gross storage capacity (Mm³)	Primary purposes	Notes / source
Mare aux Vacoas	25.89	Domestic water supply	Proag (2006), "Water resources management in Mauritius" (ewra.net)
Midlands Dam	25.50	Domestic + irrigation	Same as above; also WRU / MEPU site (publicutilities.govmu.org)
Mare Longue	6.20	Hydropower + irrigation	Proag (2006) (ewra.net)
La Ferme	11.52	Hydropower + irrigation	Proag (2006) (ewra.net)
Piton du Milieu	2.99	Domestic supply	Proag (2006) (ewra.net)
La Nicolière	5.26	Domestic supply (north + part of Port Louis)	WRU description of La Nicolière Reservoir (publicutilities.govmu.org)
Tamarind Falls	2.30	Hydropower	Proag (2006) (ewra.net)
Eau Bleue	6.20	Domestic	Proag (2006) (ewra.net)
Diamamouve	4.40	Domestic	Proag (2006) (ewra.net)

Capacities are essentially structural and have not materially changed; minor sedimentation corrections may be applied in more recent hydrological surveys.

Table 6 Non-Revenue Water (NRW) performance indicators

KPI	Target	Achieved	Financial year	Notes / source
Percentage of Non-Revenue Water	55%	61%	2021/22	Performance statement for Vote 8-1: MEPU (Treasury Statement DA 2022) (Treasury Mauritius)
Percentage of Non-Revenue Water	55%	60%	2022/23	Statement DA 2023 – MEPU outcome indicators (Treasury Mauritius)

Remark from Statement DA: exact NRW is difficult to establish due to non-functional production meters; procurement for replacement meters and revival of the NRW Unit are in progress. (Treasury Mauritius)

Table 7 Renewable water availability and projected scarcity

Indicator	Year / horizon	Value	Notes / source
Renewable water availability per capita	2013	1,083 m³/person/year	World Bank / CIWA "Drought Resilience Profile – Mauritius" (CIWA program)
Threshold for "water-stressed" classification	–	1,700 m³/person/year	Common Falkenmark indicator (used in World Bank profile) (CIWA program)
Projected renewable water availability per capita	c. 2020	974 m³/person/year (forecast)	"Overview – Water Sector Mauritius" (based on projected population 1.335m) (Scribd)
World Bank climate profile – projected change in average annual precipitation	Late-century (2080s), high emissions	Near-zero mean change, but uncertainty range approx. –22% to +17%	"Climate Risk Country Profile: Mauritius" & associated climate projections (climateknowledgeportal.worldbank.org)

Table 8 Recent observed reservoir fill levels (illustrative stress snapshot)

Reservoir	Fill level (% of capacity)	Observation date	Notes / source
La Nicolière	39.9%	Jan 2025	NewsMoris report on low reservoir levels (News Moris)
Mare aux Vacoas	51.0%	Jan 2025	Same source (News Moris)
Piton du Milieu	47.2%	Jan 2025	Same source (News Moris)
La Ferme	28.1%	Jan 2025	Same source (News Moris)
Midlands Dam	44.1%	Jan 2025	Same source (News Moris)
Bagatelle Dam	46.3%	Jan 2025	Same source (News Moris)
Mare Longue	62.4%	Jan 2025	Same source (News Moris)

Illustrative DMDU Set-ups (Energy & Water)

*These tables use **real ranges** from Mauritius' climate & energy data, but the exact set-ups remain illustrative and should be calibrated in detailed modelling.*

Table 9 Example DMDU set-up: utility-scale battery deployment

Element	Specification (illustrative, based on real ranges)	Data / rationale
Decision problem	How much utility-scale BESS to deploy by 2030 to support variable renewables?	Linked to 60% RE target by 2035 (publicutilities.govmu.org)
Decision levers	(i) Initial BESS capacity commissioned by 2027 (0–100 MWh); (ii) follow-up capacity 2028–2035 (0–200 MWh); (iii) share of BESS sited near critical loads vs bulk grid.	–
Uncertain factors – fuel prices	Historical volatility range for fossil fuel import prices (e.g. +27% to +173% change by product between 2020–2021) used as proxy for future shocks; scenarios include "low", "medium", "high" fuel price paths.	Energy Observatory 2021–2022: gasolene +32%, diesel +38%, dual-purpose kerosene +21%, fuel oil +27%, LPG +31%, coal +173%
Uncertain factors – RE penetration	Share of renewables in electricity mix varying between 20% and 60% by 2035, consistent with current 17.6–19.2% levels and NDC target of 60%.	SACREEE, MEPU AR 23–24, NDC 3.0 (sacreee.org)
Uncertain factors – demand growth	Annual electricity demand growth 1–4% (reflecting IMF / AfDB GDP growth ranges and electrification trends).	IMF & AfDB growth projections for Mauritius (African Development Bank)
Performance metrics	(i) Levelised system cost (Rs/kWh); (ii) system reliability (hours of lost load); (iii) renewable curtailment (% of potential output); (iv) CO_2 emissions.	Standard power-system metrics.
Robustness criteria	Strategy considered "robust" if (a) total discounted system cost is within +10% of lowest-cost strategy in ≥80% of futures; and (b) reliability and emissions thresholds are met in ≥90% of futures.	RDM and DAPP literature for infrastructure (IEA)

Table 10 Example DMDU set-up: NRW reduction trajectory

Element	Specification (illustrative)	Data / rationale
Decision problem	How aggressively to invest in NRW reduction given current levels (≈60%) and climate uncertainty?	NRW performance from Statement DA (Treasury Mauritius)
Decision levers	(i) Annual capex in pipe replacement and pressure management; (ii) roll-out rate of DMAs and smart metering; (iii) demand-side measures (tariffs, campaigns).	–
Uncertain factors – rainfall / drought frequency	Annual precipitation change scenarios with mean near zero but range –22% to +17% by 2080s; frequency of severe multi-year droughts varying from 1 in 20 years to 1 in 5 years.	World Bank climate profile for Mauritius (climateknowledgeportal.worldbank.org)
Uncertain factors – investment costs	Unit costs for pipe replacement, smart meters and DMAs varied ±30% to reflect procurement uncertainty.	Based on global cost variability for water utilities.
Performance metrics	(i) NRW percentage by 2030 and 2035; (ii) effective supply reliability (days/year below service standard); (iii) financial performance (operating cost coverage).	–
Robustness criteria	Strategy robust if NRW ≤ 45% by 2035 and reliability standard met in ≥85% of climate futures, while financial viability maintained.	–

Technical C4ISR Architecture Notes (ICT & Cyber-security)

Note: the "data" are global standards and control counts rather than Mauritius-specific numbers.

Table 11 Reference ICT & cyber-security standards for C4ISR platform

Component	Reference standard / framework	Quantitative detail	Notes / source
Information Security Management System (ISMS)	ISO/IEC 27001:2022	93 controls in Annex A grouped into 4 themes (organisational, people, physical, technological). (DataGuard)	Recommended baseline for MEPU / CEB / CWA shared platforms.
Detailed security controls & best practice	ISO/IEC 27002:2022	Provides detailed guidance for control objectives in areas such as access control, cryptography, HR security, incident response. (ISO)	Supports implementation of ISO 27001 controls.
Cyber-security control catalogue	NIST SP 800-53 Rev.5	>1,000 controls across 20 control families (AC, AT, AU, CA, CM, CP, IA, IR, …). (CSF Tools)	Useful for mapping detailed controls for critical infrastructure operations centres.
Telecom / utility communication standards	ITU-T Recommendations (e.g. smart-energy and IMT-2020 energy-efficiency recs)	ITU-T L.1383, L.1391 etc. define best practice for smart-energy solutions and energy-efficient mobile networks. (ITU)	Relevant to design of communication layer between sensors, SCADA and command centre.

Financing Landscape for Climate-Resilient Infrastructure in SIDS (focus: Mauritius)

Table 12 Mauritius climate-resilient investment needs and gaps

Indicator	Value	Notes / source
Estimated total climate investment needs (mitigation + adaptation) by 2030	USD 6.5 billion	UNDP Country Programme Document 2024–2028; 65% expected from international sources (UNDP)
Share to be mobilised internationally	≈65% of USD 6.5 bn	Same source (UNDP)
Estimated annual climate financing gap	≈1.6% of GDP (~USD 180 million/year)	IMF climate note for Mauritius (IMF eLibrary)
Cumulative climate finance needs (Mauritius)	USD 7,470.3 million, of which 60% adaptation	AfDB 2023 Country Focus Report (African Development Bank)

Table 13 Adaptation finance flows to SIDS (bench-marking Mauritius' position)

Indicator (SIDS-wide)	Value	Notes / source
Average annual international public adaptation finance to all SIDS	**Just over USD 2 billion/year (2021–2022)**	Climate Policy Initiative "State and Trends of Climate Adaptation Finance in SIDS" (CPI)
Share of global climate finance flowing as adaptation to SIDS	**0.2% of global climate finance**	Same CPI study (CPI)
Key conclusion from OECD–World Bank study	**SIDS face high adaptation and infrastructure costs and structural constraints in mobilising domestic resources; international finance is indispensable.**	OECD/World Bank "Climate and Disaster Resilience Financing in SIDS" (GFDRR)

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Notes

The report's analytical architecture is built around the premise that modern infrastructure planning in small island economies requires a higher degree of situational intelligence, foresight, and cross-sector integration than conventional master-planning approaches typically allow. The technical stance adopted here emphasises systems thinking, dynamic uncertainty handling, and modular data integration. The following notes clarify the underlying technical considerations that shaped the report, particularly with respect to model structure, data harmonisation, analytical boundaries, and interpretive logic.

A central technical feature of the study is its reliance on **interoperable datasets**, rather than full integrated modelling. This is a deliberate design choice. Mauritius' energy and water systems possess adequate but fragmented quantitative inputs. Published records across MEPU, CEB, CWA, Statistics Mauritius, and international development partners are reliable within their respective scopes, yet they remain siloed in format, temporal resolution, and operational meaning. To allow analytical coherence, the study applies a **cross-normalisation process**, whereby data from different institutional series are aligned to compatible temporal baselines, units, and indicator definitions. Adjustments were made only where strictly necessary, and always in accordance with the most conservative interpretation of source data. This ensures that the conclusions of the report rest on harmonised evidence rather than extrapolated assumptions.

Technically, the C4ISR-inspired architecture used in the report is conceptual rather than prescriptive. The model does not assume the implementation of any particular software platform, protocol, or sensor technology. Instead, it defines **functional capabilities**—continuous sensing, secure data transmission, shared analytics, and coordinated command—that could be delivered through a range of ICT solutions already used internationally in the utility and critical-infrastructure sectors. This abstraction is essential: it allows the architecture to remain future-proof, technology-neutral, and adaptable to procurement realities in Mauritius. The emphasis is on defining the logical structure of a national situational-awareness system rather than its hardware components.

In the integration of C4ISR with DMDU principles, the study uses a **scenario-ensemble logic** even though full high-resolution simulation tools were not deployed. The ensemble logic operates as follows: uncertainties are grouped into clusters—for example, those driven by international markets, those driven by climate variability, and those arising from domestic operational constraints. Each cluster is populated with a range of plausible values derived from empirical records and global projections. The cross-product of these uncertainty clusters produces a structured ensemble of futures, which are then used to qualitatively assess the performance sensitivity of investment options. This approach mirrors the structure of robustness testing in formal DMDU practice without requiring the computational complexity of full Monte-Carlo simulation or agent-based models.

A notable technical feature of the report is the treatment of **system interdependencies**. Instead of modelling energy–water interactions numerically, the study maps the directionality, frequency, and operational weight of these interactions. For example, energy is required at multiple nodes within the water system—intake pumping, treatment, chlorination, elevated storage, and distribution. Conversely, water availability constraints affect certain forms of power generation, such as thermal plants requiring cooling flows. By mapping these relational interactions, the report identifies "interdependency hotspots" that should be prioritised for resilience upgrades. This relational analysis is particularly appropriate in a context where granular operational datasets are not publicly available but the interdependencies themselves are structurally understood.

Another technical consideration concerns the treatment of **baseline trajectories**. Where official documents provide forecast trajectories—such as for renewable energy penetration or electricity demand—the study refrains from treating these as deterministic outcomes. Instead, these trajectories are used as reference anchors for scenario construction. This means the baseline is considered plausible but neither central nor dominant. In several instances, international benchmarks from SIDS with comparable conditions are used to widen the plausible range of trajectories, particularly in the areas of distributed renewable adoption, desalination scaling, and power-system decentralisation.

Attention was also given to the **temporal asymmetry** inherent in different investment classes. Digital and data-driven infrastructure often has shorter investment cycles, with upgradeability built in, whereas large civil-works projects—reservoirs, dams, centralised generation—lock Mauritius into multi-decade asset paths. The technical notes account for this asymmetry by assessing how investment lock-in interacts with uncertainty. For example, a centralised thermal plant exhibits strong path dependency, whereas distributed PV+storage systems offer modular and reversible scaling. These differences materially affect the robustness assessment presented in the main report.

On the analytical front, the study distinguishes between **parameter uncertainty** (variability in known distributions) and **structural uncertainty** (ignorance about the correct underlying model). Mauritius' long-term rainfall projections exhibit strong structural uncertainty: the mean trend appears flat, but the uncertainty band is large. In contrast, fuel price shocks exhibit parameter uncertainty: volatility is high, but the causal mechanisms are well understood. This distinction informs how different uncertainties influence robustness screening. Investments that depend on rainfall—for example, reservoir expansion—are tested against structural uncertainty, whereas those tied to import prices—such as thermal generation—are tested against parameter uncertainty. The interplay of these uncertainties is one of the core reasons why low-regret investments emerge as a sensible strategic priority.

Finally, an important technical note relates to the **interpretive boundary** of the report. The recommendations are intended to be decision-supportive rather than prescriptive. They outline a structured way for Mauritius to approach investment sequencing, infrastructure design, and cross-sector governance under deep uncertainty. They are not a substitute for detailed engineering studies, power-flow modelling, or hydrological simulations. Instead, the technical logic of the report provides a framework within which such detailed analyses should be embedded. In this sense, the study serves as a strategic scaffold, identifying the key decision points, uncertainty drivers, and system vulnerabilities that should guide subsequent, more granular technical and financial modelling.

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About This Report

This report provides a forward-looking, evidence-based analysis of how Mauritius can strengthen its energy and water security by combining defence-grade situational awareness (C4ISR) with advanced approaches to decision-making under deep uncertainty (DMDU). Drawing on authoritative national data, international benchmarks, and globally recognised resilience methodologies, it proposes a coherent framework for identifying low-regret investments, enhancing institutional coordination, and preparing the country for a wide range of future climate, economic, and technological conditions. Designed for policymakers, regulators, utility executives, development partners, and strategic planners, the report aims to support Mauritius in building a smarter, more adaptive, and more resilient infrastructure system capable of safeguarding the nation's long-term prosperity.

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