Project Delivery Risk Assessment: Lake Lyell Pumped Hydro Energy Storage

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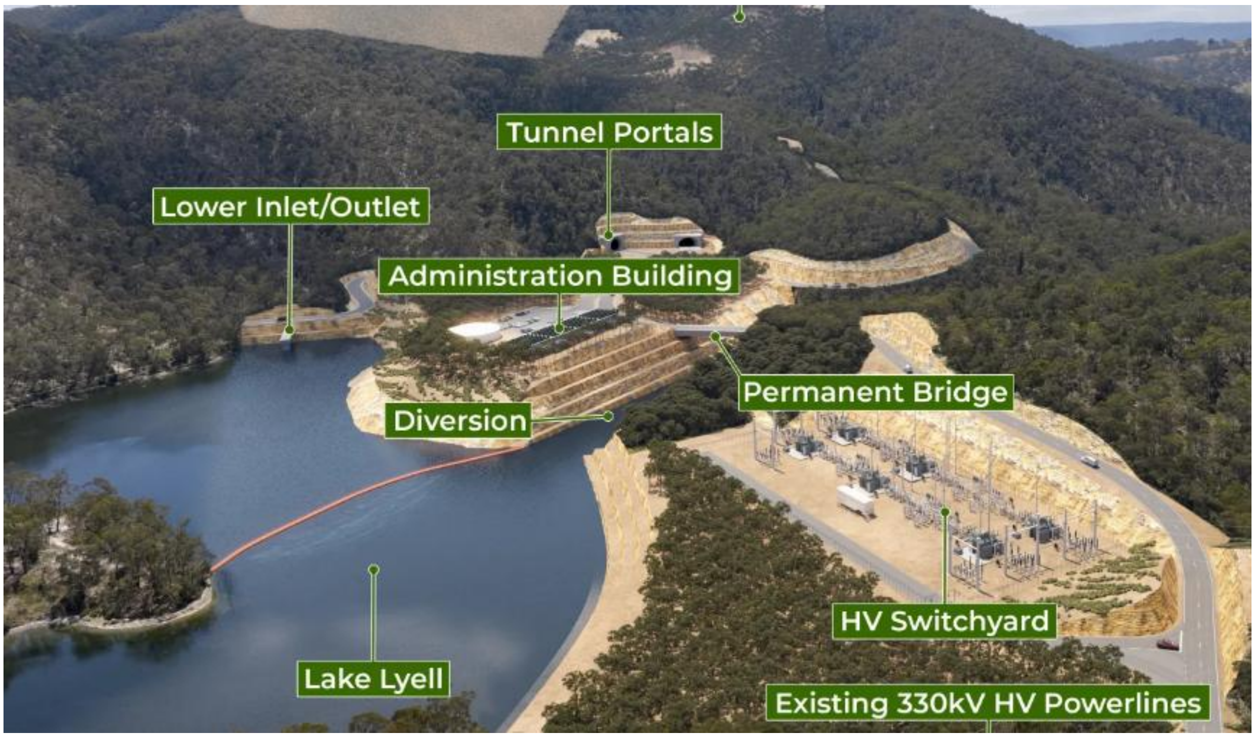

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1. Purpose and Scope

1.1 Purpose

This document presents an evidence-based assessment of **project delivery risk** for the proposed Lake Lyell Pumped Hydro Energy Storage (LLPHES) project. It applies reference class forecasting methodology developed by Professor Bent Flyvbjerg at Oxford University's Saïd Business School to assess the probability of cost and schedule overruns.

1.2 Scope

This analysis is limited to **project delivery outcomes** — specifically, the likelihood of cost overruns and schedule delays. It does not assess:

- Environmental impacts
- Cultural heritage considerations
- Economic merit or energy market value
- Technical feasibility

These matters are addressed through other assessment processes.

1.3 Methodology

This assessment applies **reference class forecasting**, which predicts project outcomes by examining the statistical distribution of comparable completed projects rather than relying on project-specific estimates. This method was developed specifically to counter the systematic optimism bias documented in megaproject planning.

1.4 Limitations

This analysis is based on publicly available sources. The author has not had access to:

- LLPHES feasibility studies or internal cost estimates
- Draft Environmental Impact Statement
- EnergyAustralia or EDF proprietary documentation
- Detailed geotechnical survey results

Where claims depend on specific sources, these are noted. Quantified scenarios are illustrative and should not be interpreted as precise predictions.

1.5 Author Declaration

Roger White is aligned with the Lake Lyell Community Group, which has expressed concerns about the proposed project. This analysis has been conducted independently using publicly available sources and academic research. The author has no financial interest in battery storage or competing energy projects.

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2. Analytical Framework: Why Megaproject Outcomes Are Predictable

2.1 The Evidence Base

Professor Bent Flyvbjerg's research at Oxford University has assembled the largest database of megaproject performance in existence, comprising over 16,000 projects across multiple sectors and geographies. This work, summarised in his 2023 book *How Big Things Get Done* (co-authored with Dan Gardner), represents decades of systematic data collection and analysis.

The central finding is striking: **cost and schedule overruns are not random — they cluster by project type in predictable patterns.**

This challenges the conventional assumption that each project is unique and that overruns result from project-specific failures of planning, management, or execution. Instead, the data reveals that certain types of projects systematically produce poor outcomes regardless of who builds them, where they are built, or how carefully they are planned.

2.2 The Iron Law of Megaprojects

Flyvbjerg identifies an "Iron Law" governing megaproject performance:

> **"Over budget, over time, under benefits, over and over again."**

Across his database:

- **Over 90%** of megaprojects exceed their initial budgets
- Average cost overrun across all project types is approximately **62%**
- Schedule delays are similarly prevalent
- Benefit shortfalls compound the problem further

These patterns persist across decades, continents, and political systems. They are not explained by incompetence, corruption, or bad luck — they reflect systematic behavioural and structural factors.

Source: Flyvbjerg, B. & Gardner, D. (2023). How Big Things Get Done. Macmillan.

2.3 Behavioural Causes: Optimism Bias and Strategic Misrepresentation

Flyvbjerg identifies two primary behavioural mechanisms driving cost and schedule overruns:

Optimism Bias

Project planners systematically underestimate costs, durations, and risks while overestimating benefits. This is not intentional deception but a documented cognitive bias. People genuinely believe their project will go better than history suggests, discounting base rates in favour of project-specific reasoning.

Strategic Misrepresentation

In competitive environments, project proponents have incentives to understate costs and overstate benefits to secure approval and funding. Once projects are approved and construction begins, the true costs emerge — but by then, sunk costs and political commitment make cancellation difficult.

Political Lock-in

Once projects receive public announcements, government funding, or regulatory designations, they become politically difficult to cancel even when costs escalate. This creates a “too big to fail” dynamic where projects proceed despite evidence they will not deliver value.

2.4 What Determines the Risk Distribution

Critically, Flyvbjerg’s research demonstrates that **project outcomes are predictable by project class** — and the risk profile is determined by structural characteristics of the project type, not by the quality of planning or execution.

Projects can be located along a spectrum from “thin-tail” (low and predictable risk) to “fat-tail” (high risk with potential for catastrophic overruns). The structural characteristics that predict where a project falls include:

Characteristic	Thin-Tail (Lower Risk)	Fat-Tail (Higher Risk)
Modularity	Divisible into independent units; can stop/adjust mid-build	Monolithic; all-or-nothing commitment
Reversibility	Decisions can be undone; incremental commitment	Irreversible after early stages
Technological novelty	Proven, repeated designs	First-of-kind or bespoke engineering
Interface complexity	Few interdependencies	Many systems must integrate perfectly
Ground/site risk	Above-ground or known conditions	Subsurface, geology-dependent
Scalability of learning	Each unit teaches the next	Lessons learned too late to apply
Construction duration	Short (months)	Long (years to decades)
Political dynamics	Easy to cancel if problems emerge	“Lock-in” makes cancellation difficult

The crucial insight is this: **The shape of the risk distribution is largely determined before the first shovel hits the ground.** Excellent management can move a project toward the better end of its class distribution, but it cannot fundamentally change which distribution applies.

2.5 Reference Class Forecasting

The practical application of this research is **reference class forecasting**. Rather than building up cost estimates from project-specific details (which are subject to optimism bias), this method:

1. Identifies the appropriate reference class (e.g., “pumped hydro projects”)
2. Examines the statistical distribution of outcomes for that class
3. Uses the distribution as the baseline forecast
4. Adjusts for project-specific factors that might push toward better or worse outcomes

This approach has been formally recommended by government planning agencies, including the UK Treasury Green Book guidance for infrastructure appraisal.

Source: HM Treasury (2022). The Green Book: Central Government Guidance on Appraisal and Evaluation.

3. Locating Project Types in the Risk Distribution

3.1 Global Evidence by Project Class

Flyvbjerg's database enables comparison of delivery risk across project types. The following table summarises mean cost overruns and the probability of experiencing severe overruns (defined as >50% above budget):

Project Class	Mean Cost Overrun	Probability of >50% Overrun	Primary Structural Drivers
Solar farms	~1%	<1%	Modular, no ground risk, factory-built components, repeatable
Battery storage (BESS)*	~5-10%	<5%	Factory-built modules, no geology risk, short build times
Wind farms	~10%	~5%	Modular with some site variation
Roads	~20%	~18%	Linear construction, but ground conditions vary
Bridges	~25%	~24%	Site-specific engineering, interface complexity
Rail/metro	~45%	~33%	Urban disruption, many interfaces, long duration
Tunnels	~40-80%	~35%	Geology unknowable until excavated
Dams and hydroelectric	~96%	~41%	Combines tunnelling, geology risk, water management, bespoke design
Nuclear power	~120%	~55%	Regulatory complexity, first-of-kind, very long duration
IT projects and Olympics	~150-200%	~50%+	Fixed deadlines, scope creep, political capture

Note: BESS-specific data is limited in Flyvbjerg's database as the technology is relatively new at utility scale. The estimate is based on modular technology analogues and Australian deployment evidence. CSIRO GenCost data shows on-time delivery is typical for Australian BESS projects.

Source: Flyvbjerg, B. (2017). "Introduction: The Iron Law of Megaproject Management." In *The Oxford Handbook of Megaproject Management*. Oxford University Press. Supplemented by sector-specific studies cited in Flyvbjerg & Gardner (2023).

3.2 Why Pumped Hydro Sits in the Fat-Tail Zone

Pumped hydro energy storage projects combine multiple structural characteristics that produce fat-tail risk distributions:

Subsurface Uncertainty

Pumped hydro requires extensive underground construction: tunnels, shafts, caverns, and foundations. Geology cannot be fully known until excavation occurs. Even extensive geotechnical surveys sample only a fraction of the ground that will be encountered. Unexpected conditions — hard rock where soft was expected, soft ground where hard was expected, water ingress, fault lines — are common and expensive.

Monolithic Commitment

Unlike modular projects where construction can be paused or adjusted, tunnelling operations cannot be meaningfully stopped once begun. Tunnel boring machines must continue forward; the sunk costs mount daily. This creates a “point of no return” early in construction.

Bespoke Engineering

Every pumped hydro site is unique. The topography, geology, hydrology, and connection to existing infrastructure require custom design. There is no “standard pumped hydro unit” that can be replicated. Each project is, in effect, a prototype.

Long Construction Duration

Pumped hydro projects typically require 5-10 years from ground-breaking to operation. This extended timeframe exposes projects to:

- Inflation and materials cost escalation
- Labour market changes
- Contractor financial difficulties
- Political changes and policy shifts
- Regulatory changes
- Compounding schedule delays

Interface Complexity

Pumped hydro involves multiple complex systems that must integrate precisely: tunnels must meet caverns, caverns must house turbines, turbines must connect to generators, generators must connect to transmission. A failure at any interface cascades through the project.

Irreversibility

After the Final Investment Decision (FID), there is no graceful exit from a pumped hydro project. You either complete construction at whatever cost is required, or you write off billions in sunk costs. This asymmetry gives contractors leverage and makes cost escalation difficult to resist.

Political Lock-in

Public announcements, government grants, regulatory designations, and community commitments create political pressure to proceed even when costs escalate. The political cost of cancellation often exceeds the financial cost of continuation — at least in the short term.

3.3 Why BESS Sits in the Thin-Tail Zone

Battery Energy Storage Systems (BESS) exhibit the opposite structural characteristics:

Modularity

A 500 MWh battery project is effectively 500 × 1 MWh containers, each manufactured and tested independently. Units can be installed sequentially. Problems with one unit do not affect others.

Factory-Built

Battery modules are manufactured in controlled factory conditions with consistent quality. Site work is primarily civil (concrete pads, fencing) and electrical (cabling, grid connection). The risk-intensive manufacturing occurs off-site.

No Geology Risk

BESS installations sit on surface foundations. Ground conditions are readily assessable and easily addressed. There is no subsurface excavation.

Short Duration

Utility-scale BESS projects typically achieve operation within 12-24 months of ground-breaking. This short timeframe limits exposure to external shocks.

Reversible Commitment

Construction can be paused at any stage with usable partial capacity. If economics change or problems emerge, you stop building additional modules — and what you have already built still works.

Scalable Learning

Each BESS installation provides lessons that can be applied to the next. Unlike one-off megaprojects, there is a learning curve: costs fall approximately 15-20% with each doubling of global installed capacity.

Easy to Cancel

BESS projects can be cancelled or scaled back without catastrophic sunk costs. There is no "point of no return" that creates lock-in dynamics.

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4. Australian Reference Class: Snowy 2.0

4.1 Why Snowy 2.0 Is the Relevant Reference

While global data establishes the risk profile for pumped hydro as a class, the most directly relevant reference for LLPHES is **Snowy 2.0** — the pumped hydro project currently under construction in NSW.

Snowy 2.0 shares critical characteristics with LLPHES:

- Same jurisdiction (NSW/Federal)
- Same project class (pumped hydro with tunnelling)
- Same era (2017-present)
- Same contractor environment (Australian civil construction market)
- Similar political dynamics (government-backed, energy transition rationale)

Snowy 2.0 is now sufficiently advanced to provide real-world Australian data on how pumped hydro projects perform in current conditions.

4.2 Cost Trajectory

The following table documents the evolution of Snowy 2.0 cost estimates:

Date	Source	Estimate	Multiple of Original
March 2017	Turnbull Government announcement	$2.0 billion	1.0x
December 2018	Final Investment Decision	$5.1 billion	2.6x
August 2023	Project reset announcement	$12.0 billion	6.0x
October 2025	Current (reassessment underway)	$20.0+ billion (expert estimates)	10.0x+

Sources: - 2017: Prime Minister Malcolm Turnbull, public announcement - 2018: Snowy Hydro Ltd, FID documentation - 2023: Federal Minister Chris Bowen, public statement; Snowy Hydro corporate plan - 2025: RenewEconomy analysis; Professor Bruce Mountain, Victoria Energy Policy Centre

The Snowy 2.0 cost trajectory represents a **ten-fold increase** from the original announcement to current estimates — and a further cost reassessment is underway that is expected to take nine months to complete.

4.3 Schedule Trajectory

Milestone	Original Target	Current Estimate	Delay
Construction start	2019	2019 (achieved)	—
First power	2024	2027	+3 years
Full operation	2024	December 2028+	+4-5+ years

The project is now projected to achieve full operation **7-8 years after the original target**, assuming no further delays. Industry experts have expressed scepticism that the December 2028 date will be achieved.

Source: RenewEconomy reporting; Snowy Hydro statements to Senate Estimates (October 2023, October 2025).

4.4 Documented Causes

Federal Energy Minister Chris Bowen, in confirming the 2023 cost reset, attributed the overruns to:

- **"Design immaturity"** at the time of the Final Investment Decision
- **"Site conditions and geology"** — specifically, encountering "soft ground" that should not have been a surprise but halted the tunnel boring machine (TBM) Florence for an extended period
- **Contractor disputes** — more than $2.2 billion in variation claims lodged by the Future Generation Joint Venture
- **Supply chain cost increases** — particularly for bespoke underground power station components

The Minister stated explicitly that the geological conditions that caused the TBM stoppage **"should have been known at the time"** of the investment decision.

Source: Federal Government statement, 31 August 2023; Senate Estimates testimony, October 2023.

4.5 Key Insight

Snowy 2.0 is not an aberration or the result of unusually poor management. It is the **expected outcome for a project in the fat-tail risk class**.

The pattern matches Flyvbjerg's documented causes precisely:

- Optimism bias in initial estimates ($2 billion announcement figure)
- Strategic understatement to secure approval
- Lock-in after political commitment
- Geology surprises despite extensive surveys
- Contractor leverage once project is committed
- Escalating sunk costs making cancellation unthinkable

The key lesson for LLPHES assessment: **these patterns are structural, not circumstantial**. They emerge from the characteristics of the project class, not from failures specific to Snowy Hydro or its contractors.

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5. What Success Looks Like: Contrasting Cases

Not all pumped hydro projects experience catastrophic overruns. Examining successful projects reveals the conditions that enable better outcomes.

5.1 Dinorwig (Wales, United Kingdom)

Dinorwig Power Station, known locally as "Electric Mountain," is one of the most successful large-scale pumped hydro installations in the world.

Key specifications: - Capacity: 1,728 MW - Head: 500+ metres (natural topography) - Storage: 9.1 GWh - Opened: 1984 - Still operating: Currently undergoing £1 billion refurbishment to extend life 25+ years

Why it worked:

- **Natural topography**: Two existing lakes (Marchlyn Mawr upper, Llyn Peris lower) at significantly different elevations, requiring no manufactured reservoirs
- **Known geology**: Built inside Elidir Fawr mountain, which had been extensively mined for slate over centuries — the cavern structure and rock quality were well understood
- **High head**: 500+ metres of natural elevation difference, reducing water volume requirements and civil works
- **Pre-existing excavation**: The slate mining had already created substantial underground cavities

Source: First Hydro Company; NS Energy; UK National Grid documentation.

5.2 Bath County (Virginia, United States)

Bath County Pumped Storage Station is the largest pumped hydro facility in North America.

Key specifications: - Capacity: 3,003 MW - Head: 335 metres (natural topography) - Opened: 1985 - Cited as "one of the nation's most outstanding engineering achievements of 1985"

Why it worked:

- **Natural topography**: Favourable valley configuration in the Allegheny Mountains
- **Known geology**: Appalachian rock formations with well-understood characteristics
- **Appropriate site selection**: Site chosen specifically for pumped hydro suitability, not retrofitted to existing infrastructure

Source: Dominion Energy; American Society of Civil Engineers.

5.3 Common Features of Successful Pumped Hydro

Successful pumped hydro projects share several characteristics:

Feature	Dinorwig	Bath County
Natural head (elevation difference)	500+ m	335 m
Pre-existing reservoirs or natural lakes	Yes (two lakes)	Partially (favourable valleys)
Known geology	Yes (centuries of mining)	Yes (established formations)

Feature	Dinorwig	Bath County
Manufactured upper reservoir required	No	Partial
Deep underground powerhouse excavation	Yes, but in known rock	Surface powerhouse

5.4 Contrast with LLPHES

LLPHES lacks several of the characteristics associated with successful pumped hydro:

Feature	Successful Projects	LLPHES
Natural head	335-500+ m	255 m
Pre-existing upper reservoir	Yes (natural lakes or favourable valleys)	No (must be manufactured)
Known geology at powerhouse depth	Yes (mining history or established formations)	Limited (drilling conducted but results not public)
Upper reservoir construction	Minimal	40m embankment walls required
Site selection basis	Pumped hydro optimality	Transmission proximity

The 255-metre head at LLPHES is **less than half** that of Dinorwig and significantly below the 600+ metre head typical of Class A sites identified in the ANU Pumped Hydro Atlas.

Source: EnergyAustralia project documentation; ANU RE100 Atlas.

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6. LLPHES Project-Specific Assessment

This section examines the specific characteristics of LLPHES to assess where within the pumped hydro risk distribution this project is likely to fall.

6.1 Site Selection

ANU Pumped Hydro Atlas Classification

The Australian National University (ANU) RE100 Group maintains a comprehensive atlas of potential pumped hydro sites in Australia, ranking sites from Class AAA (best) through Classes AA, A, B, C, D, and E (progressively more costly).

Lake Lyell does not appear as a Class A site in the atlas. The Concerned Lithgow Community Group has stated that the site is "not even listed in the top 4,000 potential sites identified in Australia."

Class A sites are characterised by: - High head (typically 600+ metres) - Favourable water-to-rock ratio (minimal excavation per unit of storage) - Short distance between reservoirs - Low-cost configurations

Source: ANU RE100 Pumped Hydro Atlas (re100.eng.anu.edu.au); Lithgow Mercury, September 2022.

Head Comparison

Professor Andrew Blakers, lead researcher on the ANU atlas, has noted:

> "It is striking how many pumped hydro proposals in Australia utilise heads below 300m, when much larger heads are readily available."

A sample of 150 Australian Class AA sites shows a typical head of **600 metres**. LLPHES, with a head of 255 metres, operates at less than half this optimal level.

Source: Blakers, A. (2024). "Pumped Hydro Energy Storage." Engineers Australia presentation.

Why the Site Was Selected

EnergyAustralia documentation indicates the site was selected for: - Proximity to existing Lake Lyell (lower reservoir) - Proximity to Mt Piper power station infrastructure - Access to existing 330 kV transmission lines - EnergyAustralia land ownership

These are valid commercial considerations. However, they prioritise **transmission proximity over pumped hydro optimality**. The site is being made to work through engineering, rather than being naturally suited to pumped hydro.

Source: EnergyAustralia project documentation; NS Energy Business.

6.2 Engineering Configuration

LLPHES requires substantial civil engineering to compensate for site limitations:

Underground Powerhouse - Excavated approximately **170 metres below ground level** - Houses two reversible pump-turbine units, generators, and transformers - Requires access tunnels, ventilation, and emergency egress

Tunnel Network - Headrace tunnel connecting upper reservoir to powerhouse - Tailrace tunnel: approximately 500 metres long, 7 metres internal diameter - Main Access Tunnel (MAT): approximately 600 metres long, 7.5m × 8.2m - Emergency, Cable and Ventilation Tunnel (ECVT): approximately 500 metres long, 7m × 8.2m - Vertical penstock shaft connecting reservoirs to powerhouse

Upper Reservoir - "Turkey nest" design with **40-metre high embankment walls** - Storage capacity of approximately 5.3 gigalitres - Located behind the southeastern ridge of Mount Walker - Constructed from rock excavated on-site

Lower Reservoir Works - Lake Lyell serves as lower reservoir (existing) - Intake/outtake structures to be constructed - Dredged channel required - Farmers Creek diversion required (open channel) - Permanent bridge required

Source: EnergyAustralia "Project Elements" documentation; NS Energy Business.

6.3 Compensatory Engineering

The relatively low head (255 metres) creates engineering consequences:

More Water Required

Power generation is proportional to head × flow rate. A lower head requires moving more water to generate equivalent power. This means: - Larger tunnel diameters - More powerful pumps - Greater civil works volume

Underground Powerhouse Necessity

The underground powerhouse, while reducing visual impact, adds significant complexity and cost compared to surface installation. Excavating a cavern at 170 metres depth in unproven rock conditions is inherently uncertain.

Design Already Revised

In 2023, EnergyAustralia announced significant design changes following community feedback: - Upper reservoir location moved to reduce visual impact - Powerhouse moved underground (was previously surface) - Reservoir wall construction changed from concrete to rock-fill

While responsive to community concerns, design changes during feasibility indicate the project configuration is still evolving — consistent with the "design immaturity" cited as a cause of Snowy 2.0 overruns.

Source: RenewEconomy, August 2023; EnergyAustralia announcements.

6.4 Geology Risk

What Is Known

EnergyAustralia conducted geotechnical drilling during 2023-2024. The results of this drilling have not been made public.

What Is Not Known

Without access to the geotechnical reports, the following remain uncertain:

- Rock quality at powerhouse cavern depth (170m)

- Groundwater conditions
- Fault lines or fracture zones
- Variability across the tunnel alignments

The Snowy 2.0 Precedent

Snowy 2.0 conducted extensive geotechnical surveys before construction. Despite this, the tunnel boring machine Florence encountered “soft ground” that halted progress for months and contributed to billions in cost overruns. Federal Minister Bowen stated this condition “should have been known at the time” but was not adequately characterised.

The lesson: **geotechnical surveys sample a fraction of the ground that will be excavated**. Surprises are common in tunnelling, and the consequences are expensive.

Source: Federal Government statement, August 2023; Senate Estimates testimony.

6.5 Behavioural Risk Indicators

Applying Flyvbjerg’s framework, several behavioural patterns associated with cost overruns are observable:

Indicator	Evidence	Interpretation
Static cost estimate	$1 billion figure unchanged since 2022 despite scope changes	Suggests optimism bias; credible estimates evolve as understanding improves
Hedged language	“Approximately $1 billion, subject to adjustments during the design phase”	Acknowledges uncertainty but does not quantify it
No published contingency range	Only a point estimate in the public domain	Conceals the range of possible outcomes
CSSI designation	Critical State Significant Infrastructure status granted June 2024	Restricts merit appeals; creates political lock-in
Government grants received	$11 million under Pumped Hydro Recoverable Grants Program (September 2022)	Creates commitment before FID; sunk cost psychology
Equity transaction	EDF acquired 75% stake mid-2024	Creates commercial lock-in; third-party commitments make cancellation harder
Accelerated timeline	FID targeted for late 2025	Pressure to commit before full understanding of risks

None of these indicators proves that LLPHES will experience overruns. However, collectively they match the pattern Flyvbjerg documents in projects that subsequently experienced significant cost escalation.

Source: NSW Government announcements; EnergyAustralia media releases; NSW Major Projects Portal.

6.6 Locating LLPHES in the Distribution

Based on the analysis above:

Base Case: Pumped Hydro Class - Mean cost overrun: 96% - Probability of >50% overrun: 41%

Project-Specific Factors Pushing Toward Worse Outcomes:

Factor	Direction	Rationale
Suboptimal site selection	Worse	Not Class A; head significantly below optimal
Low head requiring compensatory engineering	Worse	Larger tunnels, more civil works
Uncharacterised geology at depth	Uncertain	No public disclosure; Snowy 2.0 precedent suggests surprises likely
Design still evolving	Worse	2023 relocation suggests “design immaturity”
Behavioural indicators present	Worse	Static estimates, lock-in dynamics observable
Australian civil construction cost environment	Worse	Current market experiencing significant inflation

Project-Specific Factors That Might Push Toward Better Outcomes:

Factor	Direction	Rationale
Experienced JV partner (EDF)	Potentially better	EDF has global pumped hydro experience
Existing lower reservoir	Better	Lake Lyell exists; no new dam required
Existing transmission access	Better	Reduces one interface risk
Relatively small scale (335 MW vs 2,000 MW)	Uncertain	Smaller projects may be more manageable, but also lack economies of scale

Conclusion:

LLPHES is likely to fall in the **upper quartile** of the pumped hydro risk distribution — worse than the class average of 96% overrun. The project-specific factors that might improve outcomes (experienced partner, existing lake) are modest, while the factors pushing toward worse outcomes (suboptimal site, compensatory engineering, design changes, behavioural indicators) are substantial.

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7. Quantified Risk Scenarios

7.1 Methodology

The following scenarios apply reference class data to the stated $1.0 billion estimate, adjusted for project-specific factors identified in Section 6. These are illustrative scenarios based on the statistical distribution for the project class, not engineering cost estimates.

7.2 Cost Scenarios

Scenario	Overrun	Final Cost	Probability	Basis
Best case	+25%	$1.25 billion	~10%	All geology favourable; no contractor disputes; design stable
Lower quartile	+50%	$1.50 billion	~20%	Minor issues only; project executes at better end of class
Reference class median	+96%	$1.96 billion	~30%	Mean outcome for hydro/dam class
Upper quartile	+150%	$2.50 billion	~25%	Project-specific factors materialise as expected
Fat-tail outcome	+200-400%	$3.0-5.0 billion	~15%	Follows Snowy 2.0 trajectory; major geology or contractor issues
Snowy 2.0 case outcome	+900%	$10.0 billion	—	Snowy 2.0 actual trajectory ($2B → $20B+, 10× original) applied to LLPHES stated estimate

7.3 Schedule Scenarios

Scenario	Completion	Delay	Probability
On time	2029	None	~15%
Minor delay	2030	+1 year	~25%
Reference class typical	2031	+2 years	~30%
Upper quartile	2033	+4 years	~20%
Fat-tail	2035+	+6+ years	~10%
Snowy 2.0 case outcome	2033-2034+	+4-5+ years	— (observed)

7.4 Expected Value Calculation

Using probability-weighted averaging:

Expected Final Cost: - (0.10 × $1.25B) + (0.20 × $1.50B) + (0.30 × $1.96B) + (0.25 × $2.50B) + (0.15 × $4.0B) - = $0.125B + $0.30B + $0.59B + $0.625B + $0.60B - = **~$2.2-2.4 billion**

Expected Completion: - Probability-weighted: **~2031-2032**

7.5 Implications

Planning based on the stated $1.0 billion estimate and 2029 completion reflects **best-case thinking**, not expected outcomes.

A decision-maker applying reference class forecasting would plan for: - Cost of approximately **$2.0-2.5 billion** (2-2.5× stated estimate) - Completion around **2031-2032** (2-3 years later than stated) - Meaningful probability (~15-20%) of outcomes significantly worse than this

These are not pessimistic projections — they are the **statistical expectation** for projects in this class.

7.6 Caveats

These scenarios are illustrative. They are based on: - Global reference class data for dams and hydroelectric projects - Australian evidence from Snowy 2.0 - Project-specific factors observable in public documentation

They do not incorporate: - Internal cost estimates from EnergyAustralia or EDF - Detailed geotechnical data - Contractor pricing or risk allocation

Actual outcomes depend on factors not visible in the public domain. However, reference class forecasting is specifically designed to provide more accurate forecasts than project-specific estimates, which are systematically subject to optimism bias.

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8. Cost Estimate Provenance Analysis

The quantified risk scenarios in Section 7 take the stated $1.0 billion estimate as their starting point and apply reference class overrun distributions. This section examines whether that starting point is itself credible. The evidence indicates it is not — the $1 billion figure lacks formal provenance, has not been revised despite material changes in scope and market conditions, and is inconsistent with current Australian benchmarks.

8.1 The $1 Billion Figure Has No Primary Source

The $1 billion estimate does not appear in any EnergyAustralia press release, investor briefing, or official project document. A review of key public milestones confirms this:

Date	Event	Cost Figure Published
September 2022	NSW Government grant ($11M)	None
December 2023	Concept design release	None
June 2024	CSSI declaration	None
June 2025	EDF joint venture (75% equity)	None

The $1 billion figure appears only in secondary industry databases (NS Energy Business, Power Technology, Infrastructure Pipeline), always with the qualifier *“subject to adjustments during the design phase”* and attributed vaguely to “project estimates” without citation.

The use of hedging language in all secondary citations suggests the proponent does not wish to be held to the figure.

8.2 Inconsistency with CSIRO GenCost Benchmarks

The CSIRO GenCost 2024-25 Final Report provides the authoritative Australian cost benchmarks for electricity generation and storage technologies. For pumped hydro at 335 MW:

Storage Duration	Capital Cost ($/kW)	335 MW Project Cost
8-hour	~$4,500–5,500	$1.5–1.8 billion
10-hour	~$5,200–6,200	$1.7–2.1 billion
24-hour	~$7,000–8,500	$2.3–2.8 billion
48-hour	~$7,800–9,500	$2.6–3.2 billion

The $1.0 billion estimate implies approximately **$2,985/kW** — significantly below the bottom of the GenCost range for 8-hour pumped hydro ($4,500/kW).

GHD’s parametric cost modelling for AEMO (July 2025) shows pumped hydro power costs ranging from **$4,000–$8,000/kW** depending on site characteristics, with costs at the higher end for sites with lower head and underground construction — both of which apply to LLPHES.

Source: CSIRO GenCost 2024-25 Final Report, Appendix Table B.7; GHD, “Pumped Hydro Energy Storage Parameter Review” for AEMO (July 2025).

8.3 Australian Reference Project Comparison

Project	Capacity	Cost	$/kW	Notes
Kidston (Genex)	250 MW / 2,000	$777M	$3,108	Brownfield; existing

Project	Capacity	Cost	$/kW	Notes
	MWh			mine void
Snowy 2.0 (2017 announcement)	2,000 MW	$2B	$1,000	Original estimate
Snowy 2.0 (2019 FID)	2,000 MW	$5.1B	$2,550	At investment decision
Snowy 2.0 (2023 reset)	2,000 MW	$12B	$6,000	Revised mid-construction
Snowy 2.0 (2025 estimate)	2,000 MW	$20B+	$10,000+	Current trajectory
Borumba (Qld)	2,000 MW / 48,000 MWh	$18.4B	$9,200	2025 estimate

No Australian pumped hydro project has been delivered at the implied LLPHES cost of ~$3,000/kW. The only project approaching this figure (Kidston) is a brownfield site using an existing mine void — fundamentally different from LLPHES's greenfield underground construction.

8.4 Construction Cost Escalation Since 2022

If the $1 billion estimate dates from 2022 feasibility studies, it has not been adjusted for construction cost escalation. The GenCost 2024-25 report notes *"sustained long-term increases in Australian construction costs"* as a key driver of upward revisions.

Year	Escalation Factor	Adjusted Cost
2022 (base)	1.00	$1.0 billion
2023	1.06	$1.06 billion
2024	1.13	$1.13 billion
2025	1.20	$1.20 billion
2026 (current)	1.27	$1.27 billion

Even with no design changes, simple cost escalation would bring the figure to approximately **$1.3 billion** by 2026. The addition of an underground powerhouse (adopted in 2023 after the estimate was established) and other design revisions would increase this further.

8.5 Timeline Slippage Without Cost Revision

Project milestones have slipped without any corresponding cost update:

Milestone	Original Target	Current Target	Slippage
EIS submission	Mid-2024	Late 2025	~18 months
Final Investment Decision	H2 2025	Late 2026	~12 months
Commercial operation	2029	2030+	~12+ months

Timeline slippage without cost revision is a characteristic pattern of projects experiencing scope or cost challenges during development. Credible cost estimates evolve as project understanding improves; static estimates in the face of material changes suggest the figure is not being actively maintained.

8.6 Revised Defensible Estimate Range

Applying GenCost benchmarks, GHD/AEMO locational cost factors, site-specific adjustments for sub-optimal head and underground construction, and cost escalation to 2026:

Scenario	Basis	Estimated Cost
Optimistic	GenCost low-end, no site premium	$1.5 billion
Central	GenCost mid-range, moderate site premium	$2.0–2.2 billion
Realistic	GenCost high-end, underground premium	$2.5–3.0 billion

8.7 Implications for Section 7 Scenarios

This analysis does not alter the quantified risk scenarios in Section 7, which correctly apply reference class overrun percentages to the stated estimate. However, it adds a critical dimension: **the starting point itself appears to be significantly understated**.

If the defensible baseline is $1.5–2.5 billion rather than $1.0 billion, then applying the same reference class overrun distribution produces substantially worse expected outcomes:

Scenario	Overrun	At $1.0B Base	At $2.0B Base (central estimate)
Reference class median	+96%	$1.96 billion	$3.9 billion
Upper quartile	+150%	$2.50 billion	$5.0 billion
Fat-tail	+200-400%	$3.0-5.0 billion	$6.0-10.0 billion

The Section 7 scenarios should therefore be understood as **conservative**. They measure overruns against an estimate that is itself already optimistic relative to current benchmarks.

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9. The Alternative: Battery Energy Storage Systems

9.1 Applying the Framework to BESS

The same structural characteristics that predict fat-tail outcomes for pumped hydro predict thin-tail outcomes for battery storage:

Structural Characteristic	BESS	LLPHES
Modularity	High — containerised independent units	Nil — monolithic commitment
Reversibility	High — can stop at any stage with usable capacity	Nil — committed once tunnelling begins
Geology risk	Nil — surface installation on concrete pad	High — 170m underground excavation
Construction duration	12-24 months	48+ months (stated); likely longer
Interface complexity	Low — electrical connections only	High — tunnels, caverns, water, power, transmission
Learning scalability	High — each installation improves next	Nil — one-off bespoke project
Cost trajectory	Falling 15-20% per capacity doubling	Flat to rising
Political lock-in risk	Low — easy to cancel or scale back	High — CSSI designation, grants, equity commitments

Conclusion: BESS sits in the thin-tail risk distribution; LLPHES sits in the fat-tail distribution. This is structural, not a reflection of project quality.

9.2 Australian Market Evidence

NSW Long-Duration Storage Tenders

In early 2026, the NSW Government awarded contracts to six new battery projects, including the largest in Australia to date. The winning projects include:

- **Great Western Battery** (Neoen): 300 MW / 3,500 MWh at the former Wallerawang coal station site — in the same Lithgow region as Lake Lyell
- Multiple other 8-hour duration projects

These contracts demonstrate that 8-hour battery storage is commercially viable and contracting in the same geographic area as LLPHES.

Source: RenewEconomy, February 2026; NSW Auctioneer for Long-term Energy Service Agreements.

Cost Trajectories

CSIRO GenCost 2024-25 data shows diverging cost trends:

- **BESS costs:** Fell 11-16% in 2024-25 (continuation of multi-year trend)

- **Pumped hydro costs:** Rose 12-15% (reassessment of actual project costs)

Global battery storage costs continue to fall with scale. BloombergNEF's 2025 survey found global average turnkey BESS costs of US$117/kWh — a 31% decline from the prior year.

Source: CSIRO GenCost 2024-25; BloombergNEF Energy Storage Systems Cost Survey 2025.

Global Capacity Shift

Battery storage global installed capacity is projected to overtake pumped hydro in 2025 — a milestone reflecting the exponential growth of the technology:

- 2020: 17.6 GW BESS vs 159.5 GW pumped hydro (10% BESS)
- 2024: 156.6 GW BESS vs 196.6 GW pumped hydro (44% BESS)
- 2025: BESS expected to exceed pumped hydro (>50% BESS)

Source: RenewEconomy analysis of IEA and BloombergNEF data.

9.3 Comparative Delivery Risk

Factor	LLPHES	400 MW 8-Hour BESS
Reference class overrun	96% mean (hydro class)	<15% estimated (modular tech)
Australian precedent	Snowy 2.0: 10× original cost	Multiple on-time projects
Time to operation	2029-2033 (4-8 years)	18-24 months
Reversibility of commitment	Nil after FID	High — can stop any time
Geology risk	High (unknown at depth)	Nil
Cost trajectory	Rising (+12-15%/year)	Falling (-15-20%/year)
Probability of >50% blowout	~41%	<5% estimated
Learning curve benefit	None (one-off)	Ongoing cost reductions

9.4 Functional Comparison

Both technologies can deliver 8-hour energy storage. Key functional differences:

Function	LLPHES	BESS
Storage duration	8 hours (expandable to longer at lower power)	8 hours (as contracted)
Dispatchable capacity	Yes	Yes
Frequency response	Slower (seconds)	Faster (milliseconds)
Synchronous inertia	Yes (rotating mass)	No (but grid-forming inverters can provide synthetic inertia)
Asset life	80+ years (stated)	15-20 years (but replacement aligns with cost curve improvements)
Round-trip efficiency	~75-80%	~85-90%
Water	5.3 GL upper reservoir;	Nil

Function	LLPHES	BESS
requirements	evaporation replacement	

The primary functional advantage of pumped hydro is asset longevity and synchronous inertia. However, the BESS replacement cycle (every 15-20 years) aligns with continued cost reductions, meaning the lifetime cost comparison may favour BESS despite shorter unit life.

9.5 Implications

A decision-maker choosing between LLPHES and BESS is choosing between:

- **LLPHES:** Fat-tail risk distribution; high probability of significant overruns; long construction; irreversible commitment; rising costs
- **BESS:** Thin-tail risk distribution; low probability of significant overruns; short construction; reversible commitment; falling costs

Both deliver the grid function required (8-hour dispatchable storage). The risk profiles are fundamentally different.

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10. Conclusions

10.1 Summary of Findings

1. **Pumped hydro sits in the fat-tail zone of the megaproject risk distribution.** This is a structural characteristic of the project class, not a reflection of management quality, contractor experience, or planning rigour. The mean cost overrun for dams and hydroelectric projects is 96%, with a 41% probability of exceeding budget by more than 50%.

2. **Snowy 2.0 confirms Australian projects follow the global pattern.** The trajectory from $2 billion to over $20 billion (10×+) and from 2024 to 2028+ completion (7+ years delay) matches the statistical expectation for projects in this class. The causes documented — design immaturity, geology surprises, contractor disputes — are the predictable consequences of fat-tail project characteristics.

3. **LLPHES has project-specific factors that place it toward the worse end of the pumped hydro distribution.** The site is not Class A (low head, not in top 4,000 sites); engineering must compensate for natural limitations (underground powerhouse, manufactured upper reservoir); design has already changed significantly; and behavioural indicators of optimism bias and lock-in are present.

4. **The $1.0 billion estimate has no formal provenance and is inconsistent with current benchmarks.** The figure does not appear in any primary EnergyAustralia document. At ~$3,000/kW, it sits below the bottom of CSIRO GenCost ranges for 8-hour pumped hydro ($4,500–5,500/kW) and below any delivered Australian pumped hydro project cost. A defensible current estimate range, before applying any reference class overrun adjustment, is $1.5–2.5 billion (Section 8).

5. **The risk scenarios in Section 7 are therefore conservative.** They apply reference class overrun percentages to a starting figure that is itself already optimistic. If the baseline is $2.0 billion rather than $1.0 billion, the expected outcome approximately doubles — from $2.2–2.4 billion to $3.9–4.8 billion. The true expected cost of LLPHES, accounting for both the understated baseline and the reference class overrun distribution, is likely in the range of **$3–5 billion**.

6. **A thin-tail alternative exists.** Battery energy storage systems sit in a fundamentally different risk class. BESS is modular, reversible, has no geology risk, short construction duration, and falling costs. NSW has just contracted 8-hour BESS projects in the same region, proving the alternative is commercially viable.

10.2 Implications for Decision-Makers

Approval of LLPHES based on stated costs and schedule would **systematically underweight delivery risk**.

The appropriate question is not “will this project experience overruns?” but “given the structural characteristics of pumped hydro and the project-specific factors identified, what outcomes should we expect?”

Reference class forecasting provides the answer: **expect approximately double the stated cost and 2-3 years of delay as the baseline, with meaningful probability of significantly worse outcomes.** The cost estimate provenance analysis in Section 8 compounds this further: the $1 billion starting point is itself inconsistent with current benchmarks, meaning the overrun scenarios are measured against an already-optimistic base. In the Snowy 2.0 case — the most directly comparable Australian project — costs escalated to ten times the original estimate.

The evidence does not support a decision to proceed:

- The stated $1 billion cost estimate has no formal provenance and falls below the bottom of CSIRO GenCost benchmark ranges
- The project sits in the fat-tail risk class with a 41% probability of exceeding budget by more than 50% — applied to a baseline that is itself understated
- Project-specific factors place LLPHES toward the worse end of that already unfavourable distribution
- A lower-risk, lower-cost alternative delivering equivalent grid function is commercially proven and contracting in the same region
- NSW faces real political and fiscal exposure from another pumped hydro cost escalation following Snowy 2.0
- It remains unclear whether cost overruns — which the evidence indicates are highly likely — would be borne by the project proponents or by Australian and NSW taxpayers and electricity consumers

10.3 Recommendation

This analysis recommends that LLPHES **should not be approved**. The evidence base supports the following position:

1. **Do not approve LLPHES** — The combination of fat-tail project class risk, suboptimal site characteristics, an unsourced and benchmark-inconsistent cost estimate, and the availability of a proven lower-risk alternative means this project cannot be justified on delivery risk grounds. Approval would knowingly commit NSW to a project class where cost overruns averaging 96% are the statistical norm, where the starting estimate itself appears understated by 50–150%, and where the most relevant Australian precedent has seen a ten-fold cost escalation.

2. **Pursue BESS alternatives** — Battery energy storage systems deliver equivalent grid function (8-hour dispatchable storage) with fundamentally lower delivery risk. BESS projects are modular, reversible, have no geology risk, and are already contracting in the Lithgow region. NSW policy objectives for long-duration storage are better served by directing investment toward BESS.

3. **Apply the lessons of Snowy 2.0** — The Snowy 2.0 experience demonstrates what happens when governments approve pumped hydro projects based on optimistic estimates. The responsible course is to avoid repeating that outcome, not to attempt to manage it through improved governance of a project that carries the same structural risks.

4. **If approved, ensure fat-tail risk is borne by the proponents, not the public** — Should the project proceed despite the evidence presented in this analysis, decision-makers must ensure that the cost overruns which the reference class data indicates are highly likely to occur are borne entirely by EnergyAustralia, EDF, and their investors — not by Australian or NSW taxpayers or electricity consumers. The Snowy 2.0 experience, in which cost escalation from $2 billion to over $20 billion has been absorbed by Snowy Hydro (a Commonwealth-owned entity and therefore ultimately by taxpayers), must not be repeated. Any approval should include binding contractual

protections that prevent the socialisation of private project risk through government grants, consumer price mechanisms, or regulated asset base recovery of cost overruns.

This recommendation does not oppose renewable energy storage — which is essential for the energy transition. It opposes committing public trust and consumer funds to a high-risk delivery model when a lower-risk alternative delivering the same function is available.

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11. Sources and Limitations

11.1 Primary Sources

Academic and Research - Flyvbjerg, B. & Gardner, D. (2023). *How Big Things Get Done*. Macmillan. - Flyvbjerg, B. (2017). “Introduction: The Iron Law of Megaproject Management.” In *The Oxford Handbook of Megaproject Management*. Oxford University Press. - Flyvbjerg, B. (2014). “What You Should Know About Megaprojects and Why.” *Project Management Journal*, 45(2), 6-19. - ANU RE100 Group. Pumped Hydro Energy Storage Atlas. re100.eng.anu.edu.au - Blakers, A. (2024). “Pumped Hydro Energy Storage.” Engineers Australia presentation.

Australian Government and Regulatory - CSIRO & AEMO. GenCost 2024-25 Final Report (July 2025). - GHD. “Pumped Hydro Energy Storage Parameter Review” for AEMO (July 2025). - Aurecon. “2024 Energy Technology Cost and Technical Parameter Review” for AEMO (May 2025). - AEMO. Integrated System Plan 2024. - NSW Department of Planning. Major Projects Portal. - Federal Government statements on Snowy 2.0 (Minister Bowen, August 2023). - Australian National Audit Office. Snowy 2.0 reports. - HM Treasury. The Green Book (2022). [For reference class forecasting methodology]

Project Documentation - EnergyAustralia. Lake Lyell Pumped Hydro project website and documentation. - EnergyAustralia. Media releases (2022-2025). - NSW Government. Pumped Hydro Recoverable Grants Program announcements.

Industry and Media - RenewEconomy. Snowy 2.0 coverage (2017-2025). - NS Energy Business. Project profiles. - BloombergNEF. Energy Storage Systems Cost Survey 2025. - Lithgow Mercury. Local reporting on Lake Lyell project.

11.2 Limitations

Access Limitations

The author has not had access to: - LLPHES feasibility study or detailed cost estimates - Geotechnical survey results - EnergyAustralia or EDF internal documentation - Draft Environmental Impact Statement

Data Limitations

- BESS reference class data is less robust than hydro data (technology is newer)
- Quantified scenarios are illustrative, based on class distributions
- Snowy 2.0 is a single Australian reference point; larger sample would increase confidence

Methodological Limitations

- Reference class forecasting provides probability distributions, not point predictions
- Project-specific factors may shift outcomes in either direction
- The analysis cannot account for unknown factors not visible in public documentation

11.3 Author Declaration

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Declaration: - Anthropic Opus 4.5 was used in drafting and research of this document; the conclusions are those of the author - This analysis was conducted independently using publicly available sources - The author has no financial interest in BESS, competing energy projects, or energy market participants - The Concerned Lithgow Community Group has expressed concerns about the LLPHES project; this analysis was prepared to inform those concerns with evidence-based methodology

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