SEAWATER PUMPED HYDRO

A Potential New Business for Wales

1. Introduction

Seawater pumped hydro represents an innovative and sustainable solution to the challenge of renewable energy storage. This technology relies on the gravitational potential energy of water, pumped from a lower reservoir to an elevated upper reservoir, to store energy during periods of low demand and release it during peak demand. By utilizing seawater, the system can be deployed in coastal regions, reducing dependency on freshwater resources. The concept has been successfully demonstrated in Okinawa Yambaru, Japan, where a seawater-based pumped hydro system operated for several years, showcasing its feasibility and reliability.

The United Kingdom, with its growing renewable energy portfolio, faces the critical challenge of balancing intermittent energy supply with demand. Repurposing disused or decommissioned quarries in the Western UK—such as Wales, Cornwall, Cumbria, and Scotland—offers a unique opportunity to establish upper reservoirs for seawater pumped hydro systems. These sites, often characterized by steep walls and significant elevation, provide ideal conditions for such projects. By combining innovative energy storage solutions with sustainable land use practices, the UK can take a significant step toward achieving its net-zero carbon goals.

2. Background and Context

Pumped hydro energy storage is the oldest and most widely adopted large-scale energy storage technology. It involves two reservoirs at different elevations, where water is pumped to the upper reservoir using surplus electricity and released back to generate electricity during periods of high demand. The efficiency, scalability, and long operational life of pumped hydro make it a cornerstone of energy storage infrastructure worldwide.

In the UK, the transition to renewable energy sources such as wind and solar has accelerated, but these sources are inherently variable. Energy storage solutions are therefore critical to ensure grid stability and resilience. Disused quarries in the Western UK offer an untapped resource for developing seawater pumped hydro systems. Many of these quarries are located near the coast, have natural elevation differences, and are no longer economically viable for their original purposes. Their conversion into energy storage facilities aligns with principles of circular economy and sustainable development.

The Okinawa Yambaru project serves as a valuable precedent. Operating between 1999 and 2016, it demonstrated the technical feasibility of using seawater for pumped hydro. Key lessons from this project—such as the importance of corrosion-resistant materials and environmental safeguards—provide a roadmap for adapting this technology to the UK's unique geographic and regulatory conditions.

3. Technical Feasibility

Implementing seawater pumped hydro systems in the Western UK requires careful consideration of site-specific factors:

- **Site Selection**: Quarries must be assessed for their proximity to the coast, elevation differences, and geological stability. Sites with minimal environmental sensitivity and existing access infrastructure are preferred.
- **Engineering Requirements**: Seawater systems require corrosion-resistant pumps, pipes, and reservoir linings to prevent degradation. Modifications to the quarry walls and base may be necessary to ensure structural integrity and prevent seawater leakage.
- **Energy Storage Potential**: The capacity of each site depends on the volume of water that can be stored and the height differential. Preliminary studies are essential to determine the energy storage potential and economic viability of each quarry.

By leveraging advances in materials science and engineering, these challenges can be addressed effectively, paving the way for successful project implementation.

4. Environmental and Regulatory Considerations

Seawater pumped hydro projects must navigate a complex landscape of environmental and regulatory concerns. Key considerations include:

- **Environmental Impacts**: Potential risks such as saltwater leakage, changes to local ecosystems, and visual impact on the landscape must be assessed and mitigated. Linings and monitoring systems can minimize leakage, while careful planning can reduce disruption to marine and terrestrial habitats.
- **Regulatory Compliance**: Projects must adhere to UK regulations governing coastal developments, water usage, and energy infrastructure. Collaboration with local councils, environmental agencies, and community stakeholders is essential to secure necessary permits and approvals.
- **Community Engagement**: Transparent communication and active engagement with local communities can build support for these projects, highlighting their benefits in terms of renewable energy and job creation.

5. Economic Viability

Seawater pumped hydro offers a cost-effective solution for large-scale energy storage, but initial investment costs can be substantial. Key economic considerations include:

- **Cost Estimates**: Retrofitting quarries involves capital expenditure on infrastructure, equipment, and regulatory compliance. However, the use of existing sites reduces land acquisition costs and construction timelines. Additionally, having the sea as an essentially infinite lower reservoir eliminates the need for constructing a secondary reservoir, resulting in significant capital savings.

- **Funding and Financing**: Potential sources of funding include government grants, private investments, and green bonds. Public-private partnerships may also play a role in de-risking investments.
- **Revenue Streams**: These systems can generate income through energy arbitrage, grid stabilization services, and capacity payments. A detailed financial model is required to assess profitability over the project lifecycle.

6. Case Studies

The Okinawa Yambaru project is a cornerstone case study for seawater pumped hydro. Operating with a 30 MW capacity, it demonstrated the viability of seawater systems under real-world conditions. Lessons from this project include:

- The importance of anti-corrosion technologies.
- Effective strategies for environmental monitoring and mitigation.
- Operational data that can inform the design and optimization of future projects.

The UK's existing pumped hydro facilities, such as Dinorwig in Wales, also provide valuable insights into operational and economic dynamics.

7. Implementation Plan

Developing a seawater pumped hydro system involves multiple stages:

1. **Feasibility Study**: Conduct technical, environmental, and economic assessments for shortlisted quarry sites.
2. **Pilot Project**: Select one quarry for a demonstration project to validate the concept and address technical challenges.
3. **Scaling Up**: Use lessons from the pilot project to guide the development of additional sites.
4. **Operational Management**: Establish frameworks for monitoring, maintenance, and stakeholder engagement.

A detailed timeline and milestone chart should accompany this implementation plan, ensuring accountability and progress tracking.

8. Tidal Optimization Strategy

The west coast of the UK experiences significant tidal variations, with amplitudes ranging from 3 to 7 meters. Incorporating these natural fluctuations into the operational strategy of seawater pumped hydro systems can enhance their efficiency and energy yield.

- **Pumping During High Tide**: When pumping water from the sea to the upper reservoir, operations should coincide with high tide. The reduced vertical height difference (head) between the sea and the reservoir minimizes the energy required for pumping.

- **Generating During Low Tide**: To maximize energy recovery, water should be released to the sea during low tide. The increased height difference at this stage maximizes the potential energy converted to electricity.

By aligning pumping and generating cycles with tidal fluctuations, the system can reduce operational costs and increase overall energy efficiency. This strategy leverages the natural ebb and flow of tides, making seawater pumped hydro an even more sustainable and cost-effective solution.

9. Conclusion and Recommendations

Seawater pumped hydro represents a transformative opportunity for the UK to enhance its renewable energy infrastructure. By repurposing disused quarries in coastal regions, the UK can address energy storage challenges while promoting sustainable land use. Drawing on lessons from the Okinawa Yambaru project and leveraging advances in technology, these systems can deliver long-term benefits for the environment, economy, and energy security.

To move forward, stakeholders must prioritize feasibility studies, secure funding, and foster collaboration between government, industry, and local communities. With the right approach, seawater pumped hydro can become a cornerstone of the UK's clean energy future.

Next Pages: Example sites

Candidate Quarry Site # 1

Distance from Sea:	700 m
Width:	390 m
Length:	620 m
Floor Elevation:	308 m
Upper Wall Elevation (average):	350 m

Estimated Volume: ~200,000 x 40 = 8,000,000 m^3

Maximum Storage Capacity = 8,000,000,000 kg x 9.81 m/s x 300 m
= 2.3544×10^{13} Joules
= 6.54 GWh

Candidate Quarry Site # 2

Distance from Sea:	6000 m
Base Width:	670 m
Triangular Height:	500 m
Floor Elevation:	126 m
Upper Wall Elevation (average):	230 m

Estimated Volume: ~ 168,000 x 104 = 17,472,000 m^3

Maximum Storage Capacity = 17,472,000,000 kg x 9.81 m/s x 126 m

= 2.16×10^{13} Joules

= 6.00 GWh

Candidate Quarry Site # 3

Distance from Sea:	9000 m
Width:	500 m
Length:	900 m
Floor Elevation:	262 m
Upper Wall Elevation (average):	350 m

Estimated Volume: ~ 450,000 x 80 = 36,000,000 m^3

Maximum Storage Capacity = 36,000,000,000 kg x 9.81 m/s x 262 m
= 9.25×10^{13} Joules
<u>= 26 GWh</u>

Candidate Quarry Site # 4

Distance from Sea:	4000 m
Diameter 1:	400 m
Diameter 2:	260 m
Floor Elevation:	112 m
Upper Wall Elevation (average):	160 m

Estimated Volume: ~ 86,000 x 45 = 4,000,000 m^3

Maximum Storage Capacity = 4,000,000,000 kg x 9.81 m/s x 112 m
= 4.4×10^{12} Joules
= 1.2 GW hours