Industry Pumped Storage Hydro project

MDES 2024 conference – Medium Duration Energy Storage 2024

By: Jonathan Cox, Principal Hydropower Engineer,
Energy Team,
AECOM

Scope of presentation

1. Introduction
2. ‘First generation’ PSH schemes; a UK perspective
3. ‘Second generation’ PSH schemes; technical developments
4. The status of new PSH development in the UK
5. Amfilochia PSH scheme

Introduction

Definition of MDS

The purpose of this presentation

Scheme operation; the big picture

Definition of MDS and the objective of the presentation

- Medium duration storage; a definition for the purposes of this conference is:
- Storage for between 4 hours and 200 hours
- This covers what others define as:
  - Medium duration storage; 4 hours to 10 hours
  - Long duration storage; 10 hours and 164 hours (one week)
  - Ultra-long duration storage; 1 week and more
- Summary of intention of presentation

"…addressing recent advances in thinking around the technologies, the policies and the commercial realities of Medium Duration Energy Storage (MDES). It will address:

- *……*
- *Specific technology and project updates within pumped hydro energy storage"*

Pumped storage; main principles

- Storage resource –the usable volume of raw water storage (m^3). Normally dictated by the shape and size of the upper Reservoir

- Static pressure resource (head) –the static water pressure corresponding to the difference in water levels (m), in the upper and lower reservoirs (or lakes).

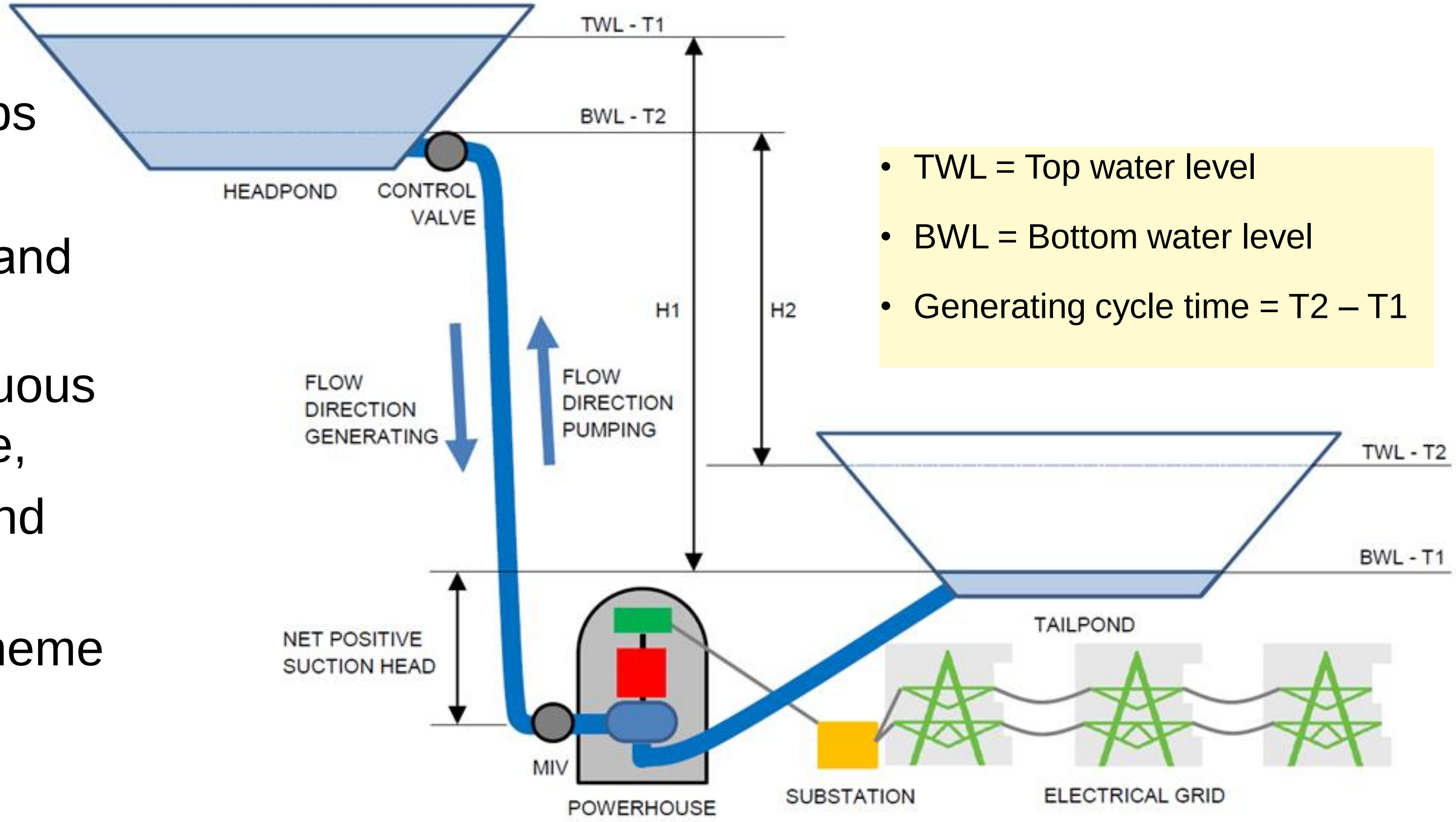
- During generation cycle the head drops from H1 to H2

- The design ('rated') flow for pumping and generating define the:

  a) minimum times for a single, continuous pumping cycle and generating cycle,

  b) station power capacity (pumping and generating)

  c) electrical energy storage of the scheme in MWh



- TWL = Top water level
- BWL = Bottom water level
- Generating cycle time = T2 – T1

First generation PSH schemes; a UK perspective

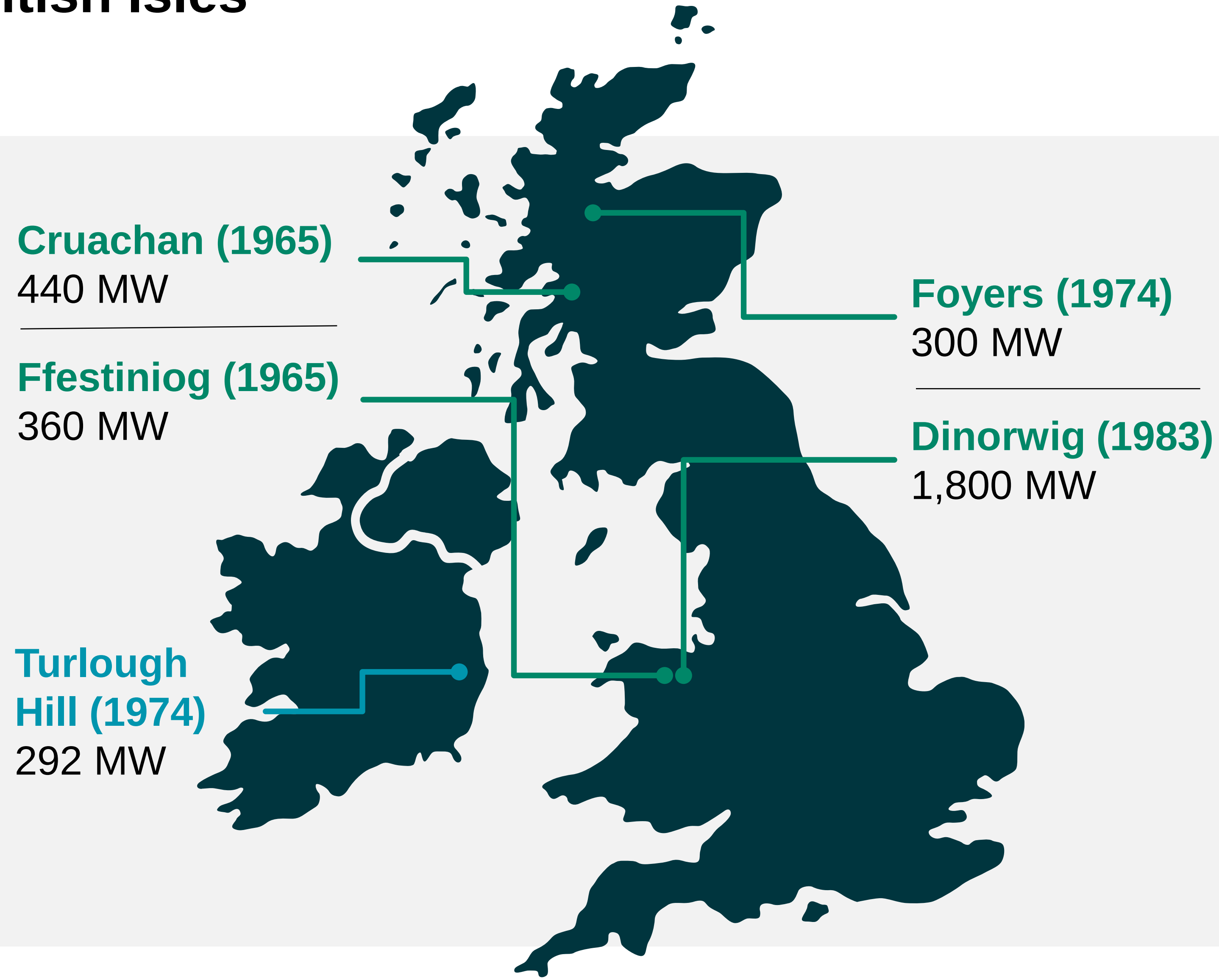
- PSH development in the 20th century, post 2nd world war
- The role of pumped-storage hydro
- Key features of Dinorwig Pumped-storage hydro scheme
- The importance of longevity and durability

AECOM

Pumped-storage hydro in the British Isles

Principal features:

- Cruachan; Cruachan Reservoir and Loch Awe, 4 x 110MW sets, 350m average head
- Foyers; Loch Ness and Loch Mhor, 175m average head
- Ffestiniog; Llyn Stwlan and Llyn Ystradau, 308m average head
- Dinorwig; Marchlyn Mawr and Llyn Peris, 518m average head
- Turlough Hill; Lough Nahanagan and Turlough Hill reservoir, 4 x 73MW sets, 286m head
- Providing a capacity of 2.9GW of storage in the UK



Purpose and uses of pumped storage hydro – “First generation” schemes

Schemes commissioned in the 20th century

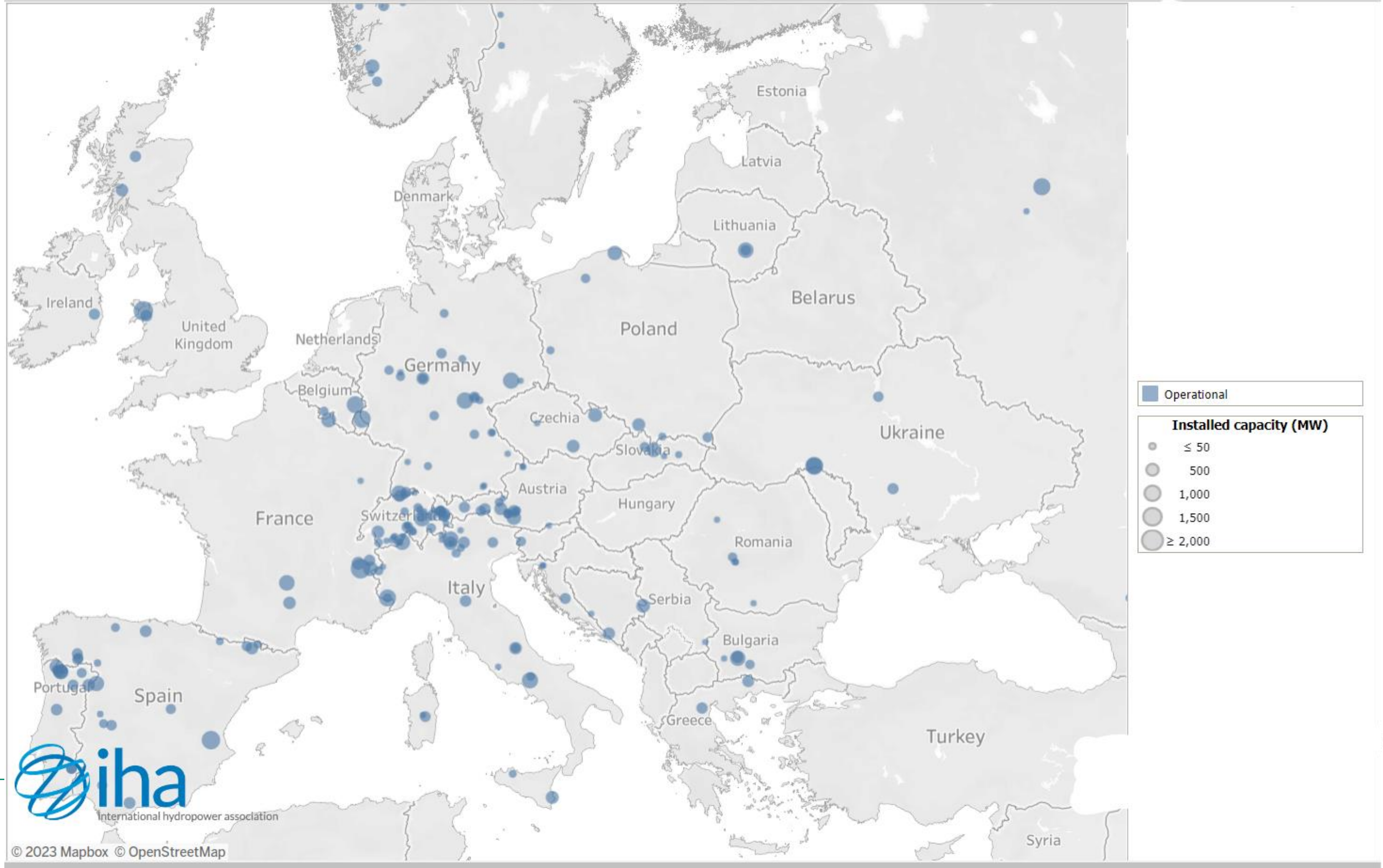
Electricity grids; centralised generating systems with traditional coal, gas fired and nuclear power plant

Context; little wind and PV power, some large-scale hydro-electric plant

PSH role; to supply peak loads and specialist grid services to maintain grid stability

UK & Ireland –schemes commissioned between 1965 and 1983

USA – schemes commissioned between 1950 and 1985



AECOM

Dinorwig - ‘state of the art’ at the time; some key features

- Very high head site using existing reservoirs; 494m to 542m (amongst the highest head schemes at the time)
- Upper surge shaft with surge pond
- Use of ‘construction steel’ for tunnel steel lining not high strength); fracture mechanics-based design approach
- Largest underground man-made cavern in Europe (at the time); main hall 180m long, 24m wide and 51m tall
- Pump-turbine units not separate (ternary layout)
- 6 x 300MW units; 1,800MW capacity pumping, 1,700MW generating, 9,100 MWh storage capacity
- Very fast response time (6s to 10s in some modes) with turbine ‘blow-down’ to facilitate ‘spinning reserve’
- Gas insulated switchgear (SF_6 gas)
- Power evacuation; 2,500mm copper conductors, oil cooled double-circuit, 400kV
- Developed by the Central Electricity Generation Board (CEGB)

Durability of PSH; the example of Cruachan PSH scheme

- 1965; original commissioning with:
  - 2 units supplied by English Electric, 600rpm (Units 1 & 2)
  - 2 units supplied by Boving (now Andritz Hydro), 500rpm (Units 3 & 4)
- 1979; Unit 3 generator converted to water cooled (stator and rotor windings)
- 1986 - 1989; all turbine units over-hauled, some generators rewound
- 1994 – 1996; Unit 3 generator converted to air cooled
- 2002 – 2004; Units 1&2 generators re-planted (120MW) and new turbine runners
- 2023 – ongoing; replanting Units 3&4…

Second generation PSH schemes; technical developments

PSH developments in the 21st Century; advances and development trends

AECOM

Purpose and uses of pumped storage hydro – "Second generation" schemes

Schemes commissioned in the 21st century

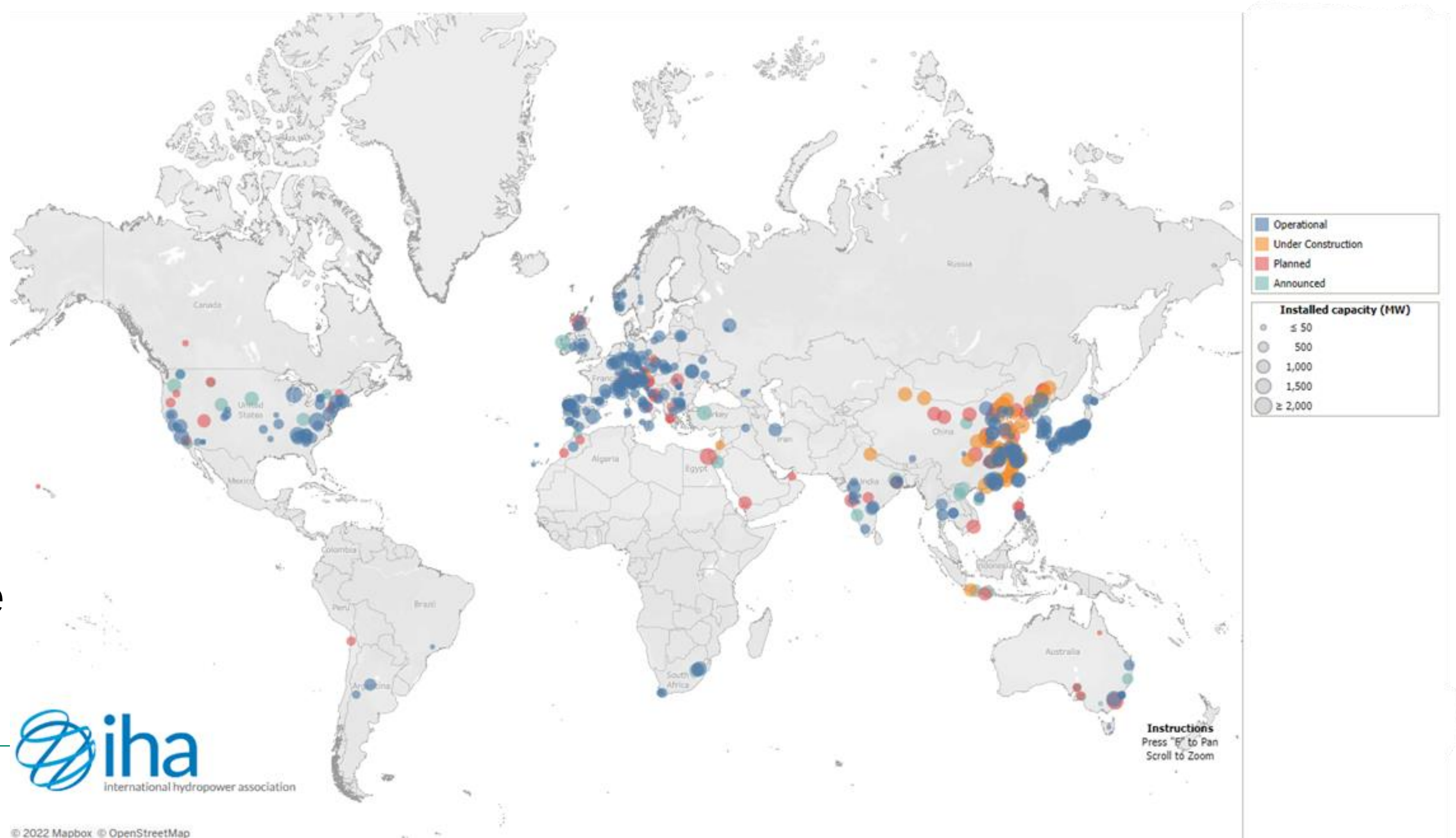
Electricity grids; more decentralised nuclear power, diminishing coal and gas fired plant

Context; rapidly increasing wind and solar PV farm generation. Significant 'embedded generation' and some small-scale storage

PSH Role; specialist grid services including 'inertia' but increasingly for 'long-duration storage' (LDES) to prevent curtailment of wind and PV generation

UK and Ireland – 2 schemes due for construction by 2030, other developments underway

Worldwide – many schemes recently build, in construction or planned; China is building more than 50 schemes each with a capacity of 1GW or more



Areas of technical development

- Computer based modelling and simulation routinely used for design optimisation:
  - Flood and river flow simulation (e.g. HEC-RAS)
  - Transient analysis of hydraulic systems for ‘water hammer’ (e.g. SIMSEN) fluid flow (Ansys-CFX)
  - Electrical interaction between station and grid (e.g. DigSILENT PowerFactory)
  - Fire life safety smoke modelling (e.g. SMARTFIRE)
  - Structural design (Ansys, NASTRAN)
  - Design (BIM, Internet Of Things)
- Use of environmentally friendly technology:
  - SF_6 free gas-insulated switch gear (even at 400kV)
  - Food grade hydraulic oil instead of mineral oil
  - Diesel / petrol free back-up generation systems
- Development by utilities not just public power corporations
- Much large energy storage capacities proposed (Coire Glas 30GWh, Dinorwig 9.1GWh)
- Use of hydraulic ‘short circuit’ operation (with ternary sets) or variable speed drives for pump mode operation

Areas of technology

- Pump-turbine unit maximum size; now up to 500MW
- Improved pump-turbine hydraulic efficiency (93% plus in generating and 94% plus pumping guaranteed)
- Improved generator efficiency (98% plus guaranteed)
- Use of double surge shaft arrangements to mitigate surge
- Use of high strength steels for tunnel lining (not ‘construction steel’) to reduce thickness and weight whilst maintaining weldment fatigue life
- Using ‘shaft’ style powerhouse arrangements rather than traditional cavern complexes
- Using variable speed drive systems to permit variable rate (and power) pumping. Use power electronic modules (DFIM, VSI)
- Power evacuation:
  - Cross-linked, polyethylene cables (XLPE) the norm (not oil cooled cables)
  - 400kV and even 500kV transmission voltage used
  - Evacuation by tunnel (air cooled) rather than in cable shaft
- Fire life safety systems improve; dedicated emergency egress tunnels, dealing with underground fires and smoke
- Dam embankment design; use of ‘concrete faced, rock filled design

The status of new PSH developments in the UK

Coire Glas, Cruachan Expansion project, Red John and others

Obtaining planning consent under Section 36 of the Electricity Act

Pumped Storage hydro developments in Scotland applying for or with planning consent

Coire Glas - SSE
1,500 MW
30,000 MWh

Cruachan Expansion - Drax
600 MW
10,000 MWh

Red John - Statkraft
450 MW
2,850 MWh

Lock Kemp - Statera
600 MW
9,000 MWh

Glenmuckloch - Foresight Energy
34 MW
1,600 MWh

KEY:

- PSH schemes with planning consent
- Applying for Planning consent

Hydropower and Dams

Red John Pumped Storage Hydropower

450 MW, Scotland, UK

Client: Statkraft

Date: 2018 – Ongoing

Status:

- Full planning approval
- Scheme recently procured by Statkraft
- Scheme originally developed by I.L.I
- Red John pumped-storage hydro scheme will utilise Loch Ness as a lower reservoir and a new reservoir to be constructed as part of the development.

Tailpond Inlet/Outlet
Looking South

Hydropower and Dams

Glyn Rhonwy Pumped Storage Hydropower

100 MW, UK

Client: Quarry Battery

Date: 2012 – Ongoing

Status:

- Pre-planning

Glyn Rhonwy Pumped-storage hydro proposal

Amfilochia PSH scheme

Case study of a European PSH scheme currently in the ‘design and build’ phase

Scheme development in outline

- A new development in Amfilochia, Greece
- The largest investment in energy storage in Greece
- Designated as a European “Project of Common Interest (PCI 3.24)” in October 2013
- A Strategic Investment, since 2014
- Technical studies (during project development), co-financed by the “Connecting Europe Facility Program”
- EU grant of € 250m for capital costs of the project financed through the “Recovery and Resilience Fund”
- An investment that exceeds € 600 million
- In July 2022, a ‘single purpose company was established to design, construction and operate the scheme; “Terna Energy S.A.
- In October 2022, installation permits were obtained
- In January 2023, the Independent Engineer for Cost certification was appointed (representing the EU and Greek government

Scheme features

- Total installed capacity of 680 MW (generating) and 730 MW (pumping) with an annual energy generation expected to be 816.00 GWh
- Two independent upper reservoirs (Aghios Georgios and Pyrgos) and a common lower reservoir, Kastraki Reservoir, built in 1960.
- The Project’s objective is the energy storage and the maximization of renewable energy (RES) penetration in the energy production mix

Project current status

- Detailed design started January 2023
- Tender for M&E (plant) completed. Contractor appointed and model testing due start
- Transient analysis studies completed by Power Vision Engineering, Switzerland and waterway layout finalised
- Structural design of waterway tunnel lining in progress (concrete lined sections and steel lined sections)
- O&M contract tender in progress
- Construction works at site started