MOTT MACDONALD

From water to wire

Delivering hydropower and pumped-hydro storage around the world

Our energy systems are evolving,
and the pace of change is accelerating.

Keeping the lights on

Electricity from wind and solar PV is expected to provide almost 20% of global power generation in 2027.

Hydroelectric facilities can quickly ramp up and down, and smoothly stop and start, to meet shifts in demand as well as to compensate for fluctuations in supply from intermittent sources, such as wind and solar. Pumped-hydrostorage (PHS), meanwhile, acts like a giant battery, where water from an upper reservoir generates power, when the sun doesn't shine, or the wind doesn't blow.

Turning a concept into reality

Global experience, local delivery.

From feasibility and environmental impact studies and geotechnical and hydrological investigations to outline and detailed design, cost estimating, contract documentation, project management, construction supervision, commissioning and maintenance, we are with you from start to finish – and beyond, to future refurbishment and upgrade.

Our global experience is combined with local delivery and our unique skillset covers every aspect of a hydro or pumped storage project:

- electro-mechanical
- water resources
- geological and geotechnical
- dam, barrage and underground engineering
- civil, structural and building services
- environment, health and social
- transmission and distribution
- asset management

Our services

- project identification
- feasibility and pre-investment studies
- engineering design
- procurement services
- construction supervision
- project management
- contract administration
- environmental and social studies
- due diligence and appraisals
- economic and financial analysis

11GW

pumped storage

35GW+

hydro

Delivering hydropower around the world:
Kidston (Australia), Song Bung 4 (Vietnam), Cruachan (UK),

Key to our ability to successfully deliver hydro projects is the integration of our expertise across multiple disciplines, such as geotechnical investigations, dams, tunnels, powerhouses, electro-mechanical engineering, power transmission and distribution, and environmental and social. It enables us to combine strategic analysis with total technical capability, so we can begin adding value from the outset.

100+

years' experience in hydropower

Delivering hydropower around the world: Suki Kinari (Pakistan), Tarbela (Pakistan), Chaglla (Peru)

60+

years working in pumped-hydro storage

Tunnels and dams for hydropower and pumped storage are in our DNA.

Our founders worked on the London Underground network's first deep tunnels in the 1890s, and we continue to design all types of tunnels – bored, segmentally lined, cut-and-cover, immersed tube and sequential excavation method – in every kind of ground, from the hardest rock to the softest clay, including structures under seismic conditions.

We are also at the forefront of developing new tunnelling techniques and methods. Whether it is small incremental improvements, or the occasional paradigm shifts – such as geotechnical baseline reports detailing ground conditions and 3D geological modelling – we can boast a collective corporate experience that is unmatched in its breadth, depth, and longevity.

Another founder was closely associated with the development and first heightening of the Aswan Dam in his capacity as advisor to Egypt's Ministry of Public Works, which began our 100+ years of involvement in hydro.

Our PHS heritage stretches back more than 60 years, to the 360MW storage project at Ffestiniog, Wales, where we broke new ground in hydraulic design with the use of a uni-directional ternary unit, a buttress dam to reduce concrete use, and underground test galleries to model the performance of steel liners for the power tunnels, enabling them to be streamlined for efficiency. Since then, our engineers have worked on PHS projects across five continents, passing their knowledge on from generation to generation.

Listen to our experts discuss all things hydro – past, present and future

Concrete lining for Song Bung 4 headrace tunnel, Vietnam

Advancing hydro in a changing world

Climate resilience

Climate change affects water in complex ways.

Extreme weather events such as floods and droughts are more likely and will be more severe. Both will put hydropower and PHS facilities at risk and potentially exacerbate the impacts of climate change on local communities and the environment if projects are not designed and managed with resilience in mind.

We understand the need to mitigate climate risks to maintain water supplies for people and secure the long-term sustainability of hydro projects.

Our experts authored technical **guidelines** on climate change and natural disasters resilience for the World Bank to ensure hydropower projects can withstand the risks of variable climatic conditions. Adopted by the International Hydropower Association, the guidelines provide engineers, operators, lenders and project owners with a practical approach to identify, assess and manage climate risks and enhance the resilience of new and existing hydro projects.

Climate change will cause more floods and droughts requiring more resilient hydro projects

Our design increased the capacity of Tarbela 4 from 960MW to 1410MW

Adding value, reducing costs

The lifespan of hydropower projects is at least 80 years, so they promise stable returns over time.

Large projects require significant upfront capital, however, so there is an ongoing drive to reduce costs and ensure projects are financially successful. Recent examples showcase our focus on design optimisation to add value and generate savings:

Optimising design

By optimising the initial designs, we increased the capacity of the Suki Kinari run-of-the-river hydropower plant in the Kaghan valley from 655MW to 884MW. Tarbela is a dam and reservoir hydro plant located on the Indus River and is currently undergoing its fifth extension. Our optimisation raised the capacity of Tarbela 4 from 960MW to 1410MW, and Tarbela 5 from 1230MW to 1530MW.

Tackling sediment

Sediment was also a threat to Tarbela 4, potentially blocking the water intakes by 2030. We proposed new intakes at a higher level, which required connecting a 13m diameter shaft into the existing tunnel. Both the design and construction were complex, and work took place in large rock and concrete. By adjusting the construction schedule and introducing horizontal stoplogs, we reduced the planned shutdown of the existing powerhouse from 15 to six months. Investment in the stoplogs totalled US$3M but the time saved was worth more than US$200M in revenue.

Raising capacity

Ngonye Falls hydropower project in Zambia was planned originally as a 45MW facility. At this scale, it was not economically viable. We identified an innovative way to raise capacity to 180MW that involves installing a low overtopping weir across the whole river to abstract the full flow – ensuring project viability.

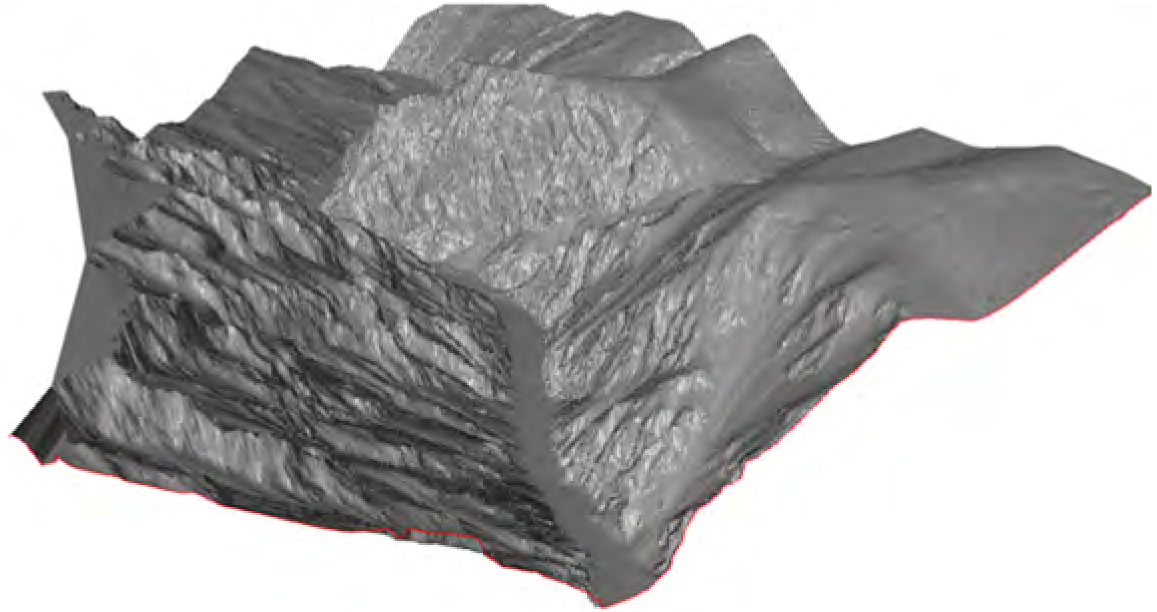
Financial viability

On Kidston, a 250MW PHS project in North Queensland, we found ways to adjust the client's strategy to reduce capital outlay while increasing the project's efficiency. Our review and optimisation study proposed changes to the original concept, including revising the upper dam arrangement, that were crucial to the financial viability of the project. The plan consists of installing two smaller water conveyance tunnels rather than one larger structure, potentially saving our client AUS$21M and cutting six months from the build programme.

Digital delivery

Advanced computer modelling – including bespoke systems – is helping us to deliver projects faster.

3D models of the steep-sided gorge help identify best dam location for the Skavica hydropower plant in Albania



Ground investigation

Our detailed design for the Kidston PHS was delivered by linking BIM 360 and Leapfrog software. The main underground structures were developed using Leapfrog geological software, with data from ground investigations added to enhance the geotechnical model. This was updated with real-time conditions as tunnelling work progressed, to both identify and verify potential changes.

Mapping potential

In Malaysia's Sabah state, we have employed geographic information systems (GIS) and our own **Moata digital solutions platform** to investigate hydropower potential. Automated GIS over a 36,000km^2 area containing many rivers enabled us to identify the best sites in the east coast area of Sabah for hydropower projects of more than 10MW with no large dams. Hydrological monitoring – rain gauging, constant water-level monitoring and flow measurement, for example – was via Moata. This produced better data accuracy, improved flow measurement planning and worker safety, and enabled real time data logging, remote monitoring and equipment status/issues diagnostics.

Modelling workflow

We also piloted an innovative automated 3D excavation modeler for our pre-feasibility study of the 25.4MW Liwagu hydropower project in Sabah. Named EXC3D, the modeler completely changes the workflow of dam excavation design from manual 2D drawings to an automated 3D excavation model. Section drawings and excavation calculations that previously took hours can be produced in minutes. The automated 3D also enables engineers to experiment to produce a more holistic design, and provides insights that were never captured in 2D, such as clash potentials and volume estimates.

Reducing uncertainty

The proposed 200MW hydropower plant at Skavica in Albania involves damming the narrow, steep-sided gorge of the Drin River, which features heavily vegetated and fissured slopes at angles greater than 75 degrees in places. Drones were used to photograph the landscape and build a 3D model of the gorge at the dam's proposed locations. The technology reduced workforce exposure to safety hazards and provided a more complete overview of the karst features and rock mass structure at inaccessible gorge sides, which will help reduce uncertainty during the design process.

Decarbonising infrastructure

With the global building stock expected to double in size by 2050, reducing embodied or capital carbon – the carbon impact of building new infrastructure – is crucial to tackling climate change.

Reducing the amount of concrete used to build hydropower projects will help meet climate goals

Our carbon tools can reduce embodied and capital carbon

Calculating carbon

Our **Moata Carbon Portal** tool is an infrastructure carbon calculator with PAS 2080 certification that enables all those working on a project to identify capital and operational carbon 'hot spots' in infrastructure projects and design carbon-saving solutions.

Carbon Twin

We have also developed a tool to analyse complex operational and embodied carbon issues and visualise in detail an infrastructure project's carbon intensity over the whole life of an asset. Called the **Carbon Twin** (left), the tool leverages BIM models and government carbon emission factors specific to the locality to automatically calculate embodied carbon, completing work in days that would otherwise take months.

Monitoring ESG metrics

For owners and operators, our tool enables them to track their assets against critical environmental, social and governance (ESG) metrics, from design and construction to operation and eventual decommissioning. Carbon Twin was trialled on the Kidston PHS project in Australia and tested with our client to ensure it provided value for them.

Renewable hubs

Given their relatively large scale and connection to the grid, hydro facilities are an opportunity to combine energy assets to generate additional revenue and reduce operating costs.

Installing floating solar PV (FPV) panels on reservoirs has both practical and economic benefits. The surface is largely free of obstructions that can shade panels and water can provide cooling to boost conversion efficiency and increase output, while the presence of the panels can reduce evaporation and algae growth. As assets, reservoirs tend to have little commercial value and installing floating solar is more cost effective than covering large tracts of land.

Floating solar

Tarbela 5 will be the first hydropower facility in Pakistan to have floating solar, with 325MW being installed across the reservoir and the head ponds of the downstream Ghazi Barotha hydropower project. Our solar team is using an innovative solution to cope with the reservoir's depth and variable height, which presents a challenge for anchoring FPV. The initial 25MW pilot installation will use PV modules mounted on unanchored rafts with small motors that self-locate using GPS co-ordinates.

Hydro can also be combined with other technologies, while the remote locations of hydro projects make them attractive places to install wind turbines and land-based solar farms to establish renewable energy hubs.

Combining hydro and battery storage

Čierny Váh PHS plant is Slovakia's largest, generating 200GWh of electricity on average a year. It was commissioned in 1982 and we have recently assessed modernisation proposals to increase capacity and operational flexibility. These include converting two existing turbines to variable speed 115MW turbines and adding a 70MW battery energy storage system. This hybrid model will provide much needed flexibility in form of ancillary services, such as frequency regulation, voltage control and black start capability.

Kidston will combine pumped storage with solar and wind power

Supporting solar and wind

In addition to the 250MW PHS facility, the Kidston 'energy hub' will generate solar and wind power, and these technologies will complement each other to maximise reliability and minimise risk. On cloudy days that provide less solar energy, the breeze is often stronger meaning wind power can compensate; days with little wind, on the other hand, tend to be sunnier. When both sun and wind are weak, the stored energy in the hydro comes into play.

People and planet

Hydropower projects must meet widely accepted sustainability standards and provide net benefits to local communities and the environment.

During the environmental and social impact assessment (ESIA) process, our environment and social specialists work together with our technical teams to help clients identify optimal solutions that maximise innovation with minimum impact on natural and human environments.

Nachtigal sand miners on the Sanaga River, Cameroon, site of a 420MW hydropower plant

Skills for local people

The 456MW Chaglla hydropower project in Peru has delivered positive social impacts to the area. A training programme called 'CREER' was established to develop local skills capacity for the project and more than 1500 local people acquired masonry, carpentry and driving skills. Overall, the project created 2500 direct jobs and 10,000 indirect jobs in the local town.

The Chaglla access road has also been a major benefit, improving access to health services, education and trade for local residents. Travelling to the nearest main town previously took six hours on a substandard road, with no reliable public transport available. Now the journey takes one hour, and two local transport companies provide a public service on the new road.

Addressing stakeholder concerns

Karot is a 720MW run-of-river hydropower scheme in the foothills of the Himalayas consisting of a 95m high dam, surface powerhouse, spillway, transmission equipment, new bridges and roads, and various safety and control features.

To reach financial close, the client needed a ESIA to meet International Finance Corporation (IFC) performance standards. We worked closely with the IFC to ensure stakeholder concerns were successfully addressed. International ESIAs for similar projects typically take between 12 and 18 months. Our team was able to complete the ESIA and develop a full suite of supplementary documents for this project within six months to facilitate financial close.

Power when rivers run low

Some years, New Zealand's hydropower catchments do not get enough rainfall or snowmelt, and the level of the storage lakes runs low and requires backup from fossil fuel power plants, hindering government efforts to meet its 100% renewable electricity generation target by 2030.

To tackle what is known as the 'dry year problem', we are leading the 'Te Rōpū Matatau' consortium to investigate the feasibility of pumped hydro storage at Lake Onslow on New Zealand's South Island. The proposed PHS project includes a significant upper storage reservoir, headrace and tailrace tunnels, and a 1500MW powerhouse containing 250MW reversible turbines.

Discover more about our projects:

Hydropower

Chaglla

One of the world's largest concrete-faced rockfill dams has been constructed at Chaglla, Peru, and provides 6% of the country's total electricity – and much more.

Read the full case study here

456MW
installed capacity

375Mm³
reservoir capacity

Tarbela

Extending Pakistan's biggest hydropower facility to 6418MW and adding floating photovoltaics will help meet peak demand and increase access to renewable energy.

Read the full case study here >

6418MW
total capacity after 5th extension

325MW
floating solar PV

60km²
reservoir area

Ngonye Falls

The 180MW Ngonye Falls hydropower project on the Zambezi River in the western province of Zambia will generate an average of 830GWh of electricity a year – enough for 200,000 Zambian households.

Read the full case study here >

884MW
installed capacity

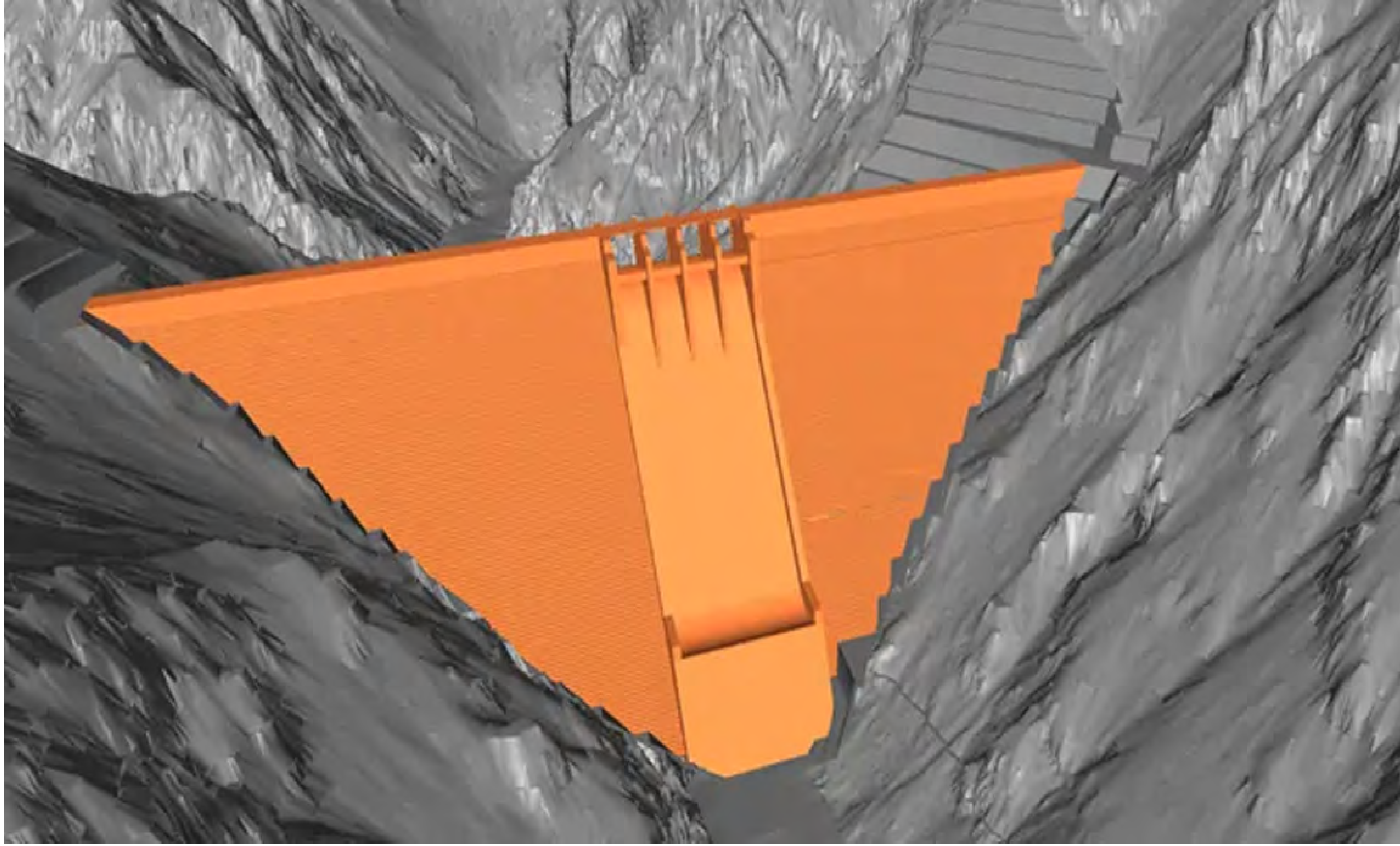
830GWh
average power a year

100km
transmission line

Skavica

At a height of 162m, the Skavica dam would be one of the tallest of its type in the world and become the controlling dam to an existing three-plant cascade system in Albania.

Read the full case study here >



200MW
installed capacity

162m
dam height

Suki Kinari

Located high in the Karakoram Mountains, Suki Kinari generates enough electricity to power 1.3M homes in Pakistan.

884MW

installed capacity

54.5m

dam height

9Mm³

reservoir capacity

Discover more about our projects:

Pumped-storage hydro

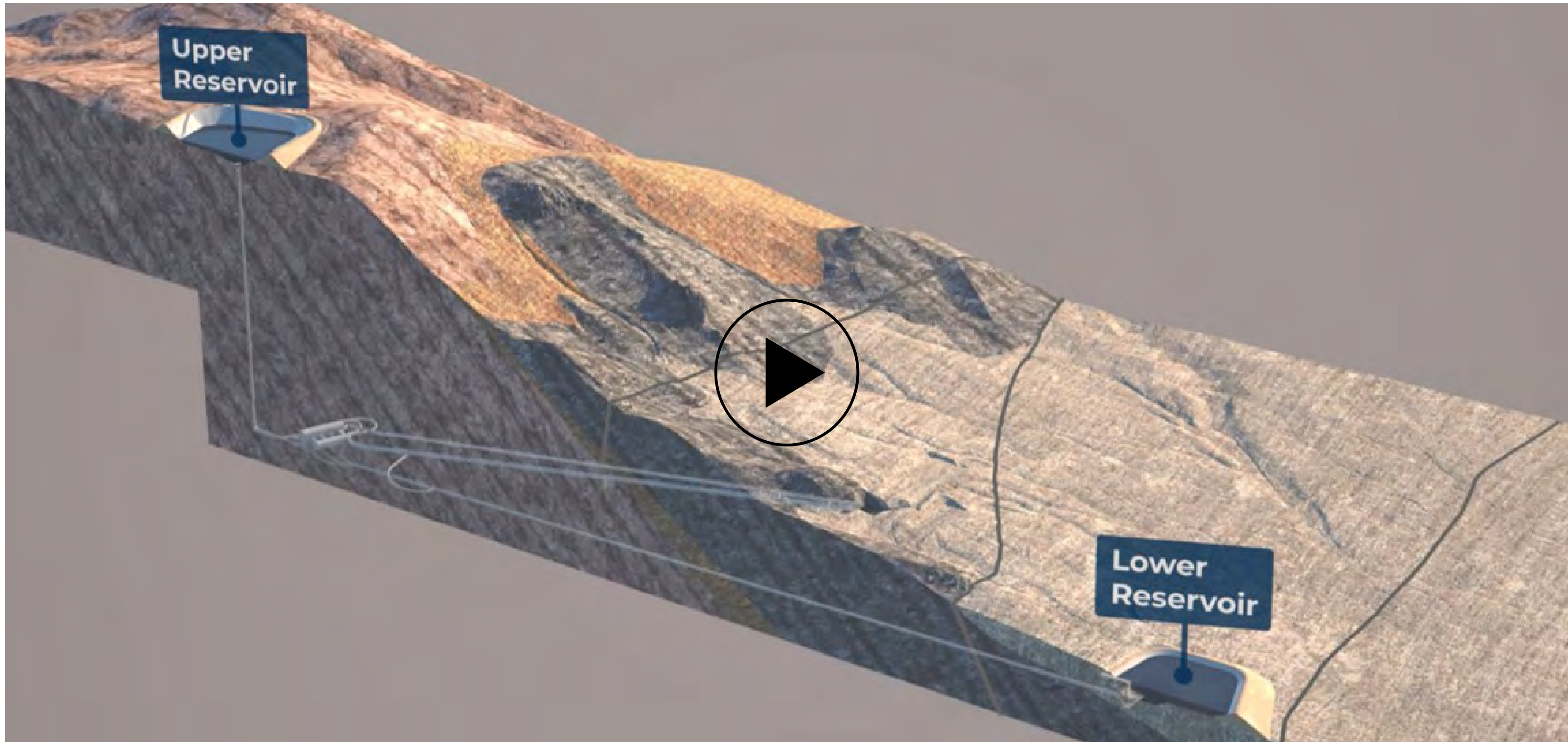
White Pine

The 1000MW White Pine pumped-hydro storage project under development in Ely, Nevada, USA, will provide 8000MWh of energy storage to generate up to eight hours of electricity.

Read the full case study here

8GWh
energy storage

40km
transmission line



Čierny Váh

Modernisation plans for the 40-year-old 730MW Čierny Váh pumped storage power plant in Slovakia include converting two of its six turbines from fixed to variable speed and incorporating a 70MW lithium-ion LFP battery energy storage system.

Read the full case study here >

2

new variable speed generating units

70MW

battery storage system

Kidston

The former gold mining settlement of Kidston in North Queensland, Australia, is being transformed into a renewable energy hub with a 250MW pumped-storage plant at its core.

Read the full case study here

140k
households with electricity

250MW
installed capacity

2000MWh
dispatchable power

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