KIDSTON PUMPED STORAGE HYDRO PROJECT (K2H)

Knowledge Sharing - ARENA

December 2018

1. Description and analysis of progress on the Measure

In December 2015, Genex Power Limited (**Genex**) secured up to $4M in Federal Government funding from the Australian Renewable Energy Agency (**ARENA**). This funding was provided to assist with the progress and development of the detailed feasibility works associated with the 250MW Kidston Pumped Storage Hydro Project (**K2-Hydro**).

In November 2016, Genex announced the successful completion of the Technical Feasibility Study (**TFS**) for K2-Hydro, completed by engineering consultancy firm Entura. Following this, in October 2017, Genex announced the completion of a TFS Optimisation by water-engineering specialist Mott MacDonald. As a result of these works, Genex was able to successfully meet the objectives of the Measure, by providing a bankable engineering solution that was also financially viable.

Final Project Design Parameters and Specifications:

Nameplate capacity:	250MW
Generation duration/storage capacity:	Up to 8 hours
Configuration design:	Two-pit solution (Upper reservoir – Wises, Lower reservoir – Eldridge)
Number of turbines:	2 x 125MW
Type of turbines:	Fixed-speed reversible francis
Turbine supplier:	ANDRITZ
Transmission connection:	275kV (Kidston – Mt Fox)
Maximum gross water head:	218m

Start-up time:	<30secs
EPC contractor:	McConnell Dowell & John Holland
Engineering consultant:	Entura

Project need & market benefits:

The Project offers a large-scale, low-cost and flexible solution to Queensland's growing peaking power requirements. The Project is well positioned to take advantage of the combined effects of an oversupply of baseload generation capacity and escalating peak power prices being driven by increasing gas turbine fuel costs. As renewable power gains momentum in Queensland, especially the prevalence of rooftop solar but increasingly supplemented by the deployment of large-scale solar projects, the need for energy storage and energy management will play a far more important role in the electricity network. Large-scale storage projects such as K2-Hydro will provide stability in supply to the grid which will become even more important because of intermittent generation issues associated with renewable energy. Therefore, the Project will significantly contribute towards alleviating the growing pressure on peaking power demand and peak power prices in Northern Queensland and in Queensland generally.

Besides delivering rapid response, flexible and renewable peaking power into the NEM network in Northern Queensland, the combined K2 project will also create more than 500 jobs in the construction phase as well as numerous indirect jobs and demand generally for services in the greater Etheridge Shire Region.

Peaking power deficit and rising prices

The Northern Queensland region is currently a net importer of electricity from the Central Queensland region, with a forecast growing peaking power deficit. Once operational, K2-Hydro will significantly alleviate this emerging issue.

The Queensland electricity market is currently experiencing high peak prices during hot summer days and cold winter days, and frequent power price spikes compared with other Australian States. Furthermore, the Mt Stuart peaking power generation station is scheduled for decommissioning in 2023. K2-Hydro currently represents an aggregate of between 15 - 20% of Queensland's total peaking power generation capacity. This issue is further compounded by the ramp up of LNG export which is making existing gas generators (for peaking and shoulder generation) highly costly to run.

At 250MW, K2-Hydro will add significantly to the State's peaking and shoulder power generation capacity. Aside from the capacity issues, the Project will also mitigate price increases forecast as a direct consequence of open cycle gas turbine peaking generators operating in an environment of escalating gas prices (due to the export of domestic gas from Gladstone).

Blackstart capability

90% of Queensland's power needs are met through the operation of coal fired power stations (59%) and gas turbines (31%). These generators have a restricted ability to self-start in the event of a power grid failure. Hydroelectric power plants are renowned for their ability to offer rapid response grid "Blackstart" capabilities, that is, the ability to restart other generators and the electricity grid within seconds in the event of network shutdown. With potential cyclone events and bushfire threats, the Project will provide Queensland with a more reliable insurance policy against these potential events.

K2-Hydro will be able to provide a full range of ancillary services to the grid, including frequency and voltage control, load levelling, synchronous generation capacity and capacity deferral. In addition, it has the potential to support grid stability through inertial spinning reserve and very fast ramp rates, which is particularly important in the context of growing deployment on the network of intermittent renewable energy.

Economic stimulus and employment within the Etheridge Shire Area

The Project will contribute significantly to the economic wellbeing of the Etheridge Shire area in which it is located. The Project will require extensive use of local building materials, construction services, and human resources during both the build and operating phases, drawing from an area needing economic and social uplift.

KS1 is already providing economic activity and employment opportunities to Kidston and the Etheridge Shire, and more than 160 jobs were created during the construction period. It is anticipated that K2 will generate a total of more than 500 jobs during construction, which Genex anticipates will be filled primarily from within the immediate local government area (Etheridge Shire) and other nearby locations (Townsville, Cairns, etc).

The success of the Project will ensure the longevity of a significant revenue source for the council and will be a significant contributor to the Etheridge Shire Region.

Genex currently supplies water on a voluntary basis, at no cost, to the local township of Kidston and to the surrounding cattle stations. The Copperfield Dam which is the source of the water for Kidston also serves an important role in regulating the river flow down to Einasleigh. The dam is currently maintained by the State with KGML (100% owned by Genex) providing 100% of private sector funding via its water services agreement with the State. The success of the Project will ensure the continuation of the various social benefits to residents in and around the Kidston area as a result of being able to use the Copperfield Dam.

A global first for Queensland in innovation and clean energy leadership

Once completed, the Project will be the first in the world to utilise a disused mine site for hydroelectric power generation, and the first hybrid large-scale solar photovoltaic and pumped hydro storage plant. The Project has already found interest internationally, and Queensland, as the host State, will receive recognition as an enabling partner in this innovative and ground-breaking use of a redundant mining asset for a clean energy power solution of significant scale.

Moreover, Queensland currently has over 11,000 abandoned/closed mines of various scale, most of which are in locations with excellent solar resource. The maintenance of abandoned mines and their environmental footprint currently poses a very significant financial drain

on the State. If the Project is successful, it is possible for the scheme to be duplicated across a number of sites within Queensland. This would not only substantially alleviate environmental costs and liability to the State but also signify a revolutionary way on how many mining projects can be utilised beyond the end of its mine life.

2. Lessons learned

Based on the works completed to date, Genex was able to reach the following conclusions:

1. **What are the practical impediments to building large-scale pumped storage energy schemes at disused mine sites across Australia?**

   - Typically, there is a lack of existing infrastructure associated with mine sites given they are usually located in isolated areas away from urban centres and resources (difficult for accommodation resources, electrical and water infrastructure, etc.). This issue was one of the reasons the Kidston Mine was selected as there was a significant amount of existing infrastructure left from the abandoned mine.
   - Significant financial liability associated with the purchase and ongoing monitoring and maintenance of abandoned mine sites in order to achieve environmental objectives. The financial liability is presented in the form of an environmental bond, required by the operating owner. The significance of the environmental bond differs between mining sites depending on a number of factors (e.g. amount of rehabilitation that has been completed). It is important to consider the degree of financial liability and environmental considerations when acquiring decommissioned mining sites.

2. **What scale of installed generation capacity is required to justify the high capital construction costs associated with pumped storage schemes, taking into account the ability to utilise existing assets and infrastructure associated with disused mine sites?**

   - Based on a market analysis completed in 2016 and the revised Optimisation Study in 2017, it was concluded that K2-Hydro should have a nameplate capacity of 250MW and have up to 8 hours of storage. Anything of greater capacity results in market inefficiencies.

3. **What is the ideal layout, configuration and sizing to achieve the optimal cost per MW of installed generation capacity?**

   - K2-Hydro has been sized at 250MW with up to 8 hours of storage capacity. In terms of design, there were a number of potential layouts and configurations explored, from the utilisation of the existing two pits, to the construction of an additional third reservoir known as a turkey's

nest. It was concluded that the utilisation of the existing two pits (i.e. a two-pit solution) was the most optimal design to achieve the lowest construction cost per MW of installed generation capacity.

- In terms of the most optimal configuration, the turkey's nest/3-pit solution was the most viable option when the project was initially sized at 330MW. However, following market studies that concluded 250MW was the most optimal size from a financial/market perspective, the scheme no longer required the additional capacity associated with building a third reservoir/turkey's nest. Genex was able to revert to a two-pit solution given this was adequate to achieve a 250MW nameplate capacity and more cost effective than constructing a third artificial reservoir.

4. **What geological factors should be considered when planning the building of a large-scale pumped storage scheme at a disused mine site and how critical are these in the planning process?**

   - Understanding the geotechnical integrity of the rock walls is crucial, given the amount of dynamic pressure that results from the fluctuating water levels during operation. Rock type (composition, integrity, porosity, etc.) and the chemical interaction of the rock with the water is crucial to finalise a technically viable design.

5. **What hydrological factors should be considered when planning the building of a large-scale pumped storage scheme at a disused mine site and how critical are these in the planning process?**

   - Ensuring adequate water resources are available by understanding long-term weather patterns and potential reserve water resources via pipeline systems and water access agreements.
   - Understanding the difficulties associated with the dewatering process during the construction period and the processes and timelines associated with moving large volumes of water around.

6. **What electrical losses can be expected throughout a full pumping/generation cycle, including transmission, transformation and cyclical losses.**

   - K2-Hydro has a roundtrip efficiency of 80%. Pumped storage hydro schemes typically have roundtrip efficiencies of between 70-85%, depending on a number of factors and constraints (e.g. distance between the two reservoirs/amount of resistance).

- Preliminary estimates indicate a 3-4% loss for the pumped hydro generation between the exported electricity at the site meter and the meter at Mt. Fox.
- During generation mode of K2-Hydro, transmission losses are anticipated to be 1.2-1.6% (3-4MW).

7. What factors should be considered in choosing between fixed speed vs. variable speed turbines and what are the relative advantages between the two alternatives?

- 2 x 125MW fixed-speed reversible turbines have been selected for K2-Hydro. This was selected due to the lower cost (compared to variable speed), greater operational simplicity and the ability to provide 'real inertia' (rather than 'synthetic inertia') into the grid.
- A variable speed turbine can offer greater operational flexibility, with the ability to ramp up and down during both the generation and pumping cycle. Variable speed turbines also have faster response times from both a cold-start and from the transition between generation and pumping mode. Therefore, variable speed turbines have a higher purchase cost compared to fixed-speed turbines.

Timelines & Key Steps

Since the formation of the original concept to the present day, the entire timeline has exceeded 5 years. This lengthy development period was the result of this novel, innovative concept that required detailed technical exploration and understanding prior to the analysis of the operational and financial components. However, this period was exacerbated by the company's development of a large-scale solar project, with the majority of resources allocated toward this development for 18 months.

Thus, to replicate this concept and development, it would likely take a minimum of 3 years before reaching the final development stage (detailed design and EPC contract execution) and another year to secure financing and initiate construction.

As a result of this development and the technical knowledge gained, in addition to the precedent created from the financial products associated with the project, future developments will become expedited, potentially requiring less than 3 years from concept to financial close.

In terms of cost ranges to complete feasibility works, it was found that the most significant costs are weighted towards the start and finish of this workstream.

3. Success in achieving the knowledge sharing objectives

As a result of the completed technical studies and the funding provided by ARENA, Genex has been able to successfully provide publicly available information on the challenges and benefits of building a pumped storage hydro scheme using an abandoned mine. This project marks the first project in the world to utilise the existing infrastructure left from an abandoned mine to create a pumped storage hydro scheme. Because of the knowledge shared from this project, other potential closed mine sites around the country are now being explored to replicate this successful concept.

Knowledge sharing activities:

Activity	Organiser/location	Date
Presented at the large-scale solar conference	Reneweconomy/Informa, Sydney	3-4 April 2017
Presented at the WA power & gas conference	Informa, Perth	27-28 March 2017
Presented at major project conference	Projectory, Sydney	30 March 2017
Presented at Townsville Industry Breakfast	Townsville Industry, Townsville	7 March 2017
ARENA Livewire Podcast – Episode 1	ARENA, Kidston	10 April 2017
Presented at North Qld mining & resources industry forum	NQ Industry, Townsville	7 June 2017
Presented at Australia energy policy forum	Clariden, Sydney	14-16 June 2017
Presented at Noosa mining conference	Noosa Mining, Noosa	19– 21 July 2017
Interview for CEFC Case Study	CEFC, Sydney	28 August 2017

Presented at Pumped hydro energy storage conference	Informa, Sydney	29 August 2017
Presented at Power grid resilience	Power Grid Resilience, Sydney	22 August 2017
Presented at Northern regional forum	Engineers Australia, Townsville	24 August 2017
Presented at powering north Queensland summit	Australia Solar Council, Townsville	31 August 2017
Climate Council Case Study video	Climate Council, Kidston	11 November 2017
Presented at Australia solar + energy storage	LeaderAssociates, Brisbane	5-6 December 2017
Presented at Australian energy & battery minerals conference	Australian Energy Conference, Brisbane	14-15 March 2018
Presented at pumped hydro energy conference	Informa, Brisbane	20 March 2018
ARENA workshop attendance	ARENA, Brisbane	16 May 2018
Presented at large scale solar + storage conference	Informa/Reneweconomy, Sydney	27 – 28 June 2018

For more information: https://www.genexpower.com.au/asx-announcements.html