Bright prospects for pumped storage in Chile

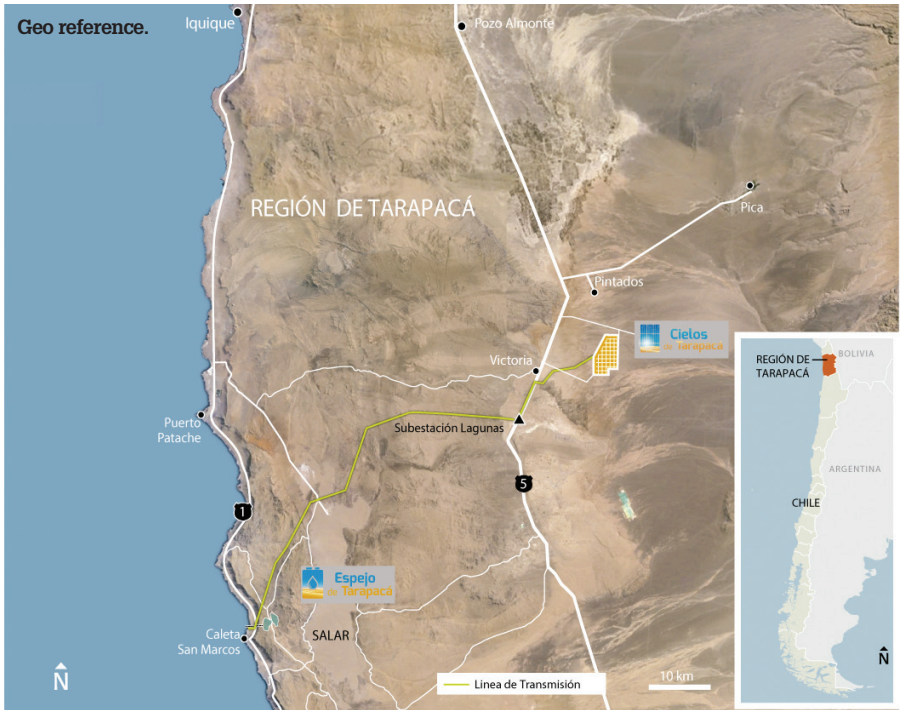
The distinctive geological characteristics of the Atacama Desert in northern Chile are providing ideal conditions for the construction and operation of an innovative pumped storage seawater plant, alongside a solar photovoltaic project.

Co founders Juan Camus and Francisco Torrealba.

Caleta San Marcos.

The Espejo de Tarapacá project (EDT) is an innovative power project located in northern Chile which combines natural solar and hydroelectric resources with proven generation technology. The project is comprised of two commercially integrated power plants:

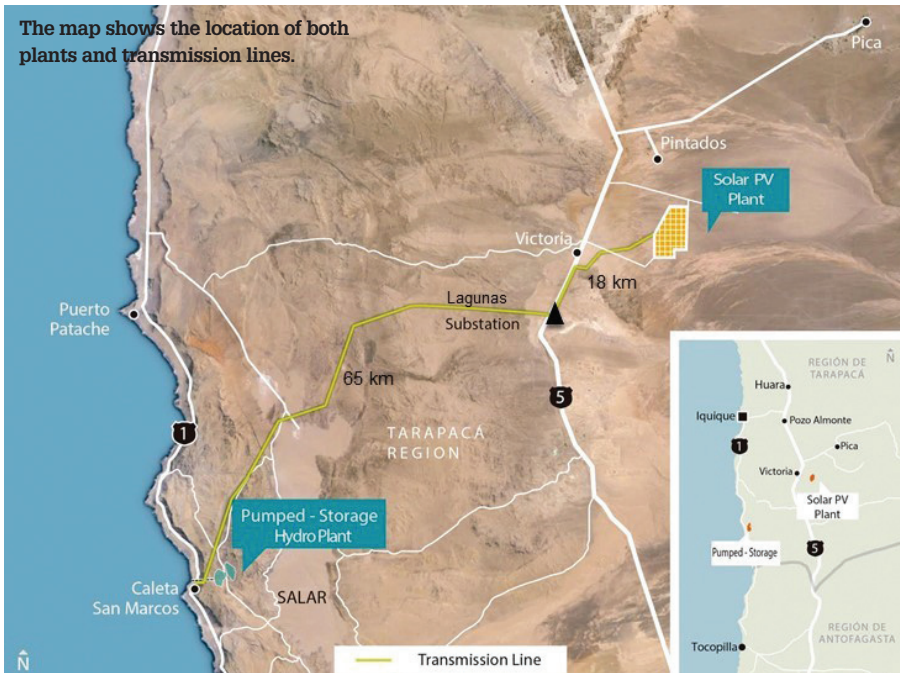
- A 300MW hydroelectric seawater pumped storage plant (the PSH plant) using the Pacific Ocean as its lower reservoir and an existing natural concavity as its upper reservoir.
- An up to 600MW-AC solar photovoltaic plant (the PV plant) with single axis tracking.



The plants will be commercially integrated to provide competitive, reliable and sustainable electricity 24 hours a day, seven days a week.

EDT is one of the most innovative large-scale infrastructure projects in the world, based on its unique integration of proven generation technologies with renewable natural resources to supply electricity 24/7. By combining Chile's natural resource characteristics with recent reductions in the cost of photovoltaic solar generation, EDT is able to provide a competitive, reliable and sustainable alternative to traditional electric generation. These natural characteristics include: (i) the best solar irradiation in the world, (ii) a coastal site with a steep cliff and a natural surface concavity within a short distance, and (iii) direct access to the Pacific Ocean, which provides continuous water supply with no hydrological volatility.

The project's unique combination of solar energy and pumped storage in Chile will resolve the intermittency or limited availability problem inherent to solar and wind technologies by effectively combining the country's abundant sunlight and seawater resources to ensure electricity availability 24/7, says the developers. EDT's pumped storage hydro plant is effectively equivalent to a large renewable energy battery – storing solar energy in the form of water which is pumped into the reservoir to be stored until required by the system.



The map shows the location of both plants and transmission lines.

Founded in Stanford

The project's founders, Juan Andres Camus and Francisco Torrealba, came up with the conceptual idea while completing post-graduate degrees at Stanford University. Their ambition was to design a storage system for their native Chile's infinitely abundant renewable energy resources. Torrealba, who grew up in the Atacama Desert in northern Chile, was familiar with the area's exceptional geographical characteristics, which include an extensive coastline along the Pacific Ocean, a lofty coastal mountain range containing deep surface concavities within kilometres of the ocean, and an arid, nearly cloudless inland climate, home to the best irradiation conditions in the world. These distinctive characteristics, together with recent technological advancements in photovoltaic solar generation which have yielded significant cost reductions, allow the project to provide reliable and sustainable renewable energy, which at the same time is competitive with coal-fired generation.

Hydro in the world's driest desert

Both the PSH and PV plants will be located south of the closest major city of Iquique in the Tarapacá Region of northern Chile. The PSH plant will be located on the coast approximately 100km south of Iquique on a site that includes a 600m coastal cliff with a large natural concavity on the surface. The PSH plant will connect to the Lagunas substation in the northern interconnected system known as SING, by means of a new 65km transmission line.

The site geography presents ideal conditions for the construction and operation of a PSH plant. The Pacific Ocean serves as the lower reservoir, providing an abundant and non-volatile water supply. A natural concavity located on the surface of a steep coastal cliff, only 3km from the seawater intake point, serves as the upper (storage) reservoir. Additionally, the natural elevation of the cliff, 600m above sea level, provides the significant height differential required for efficient hydroelectric generation.

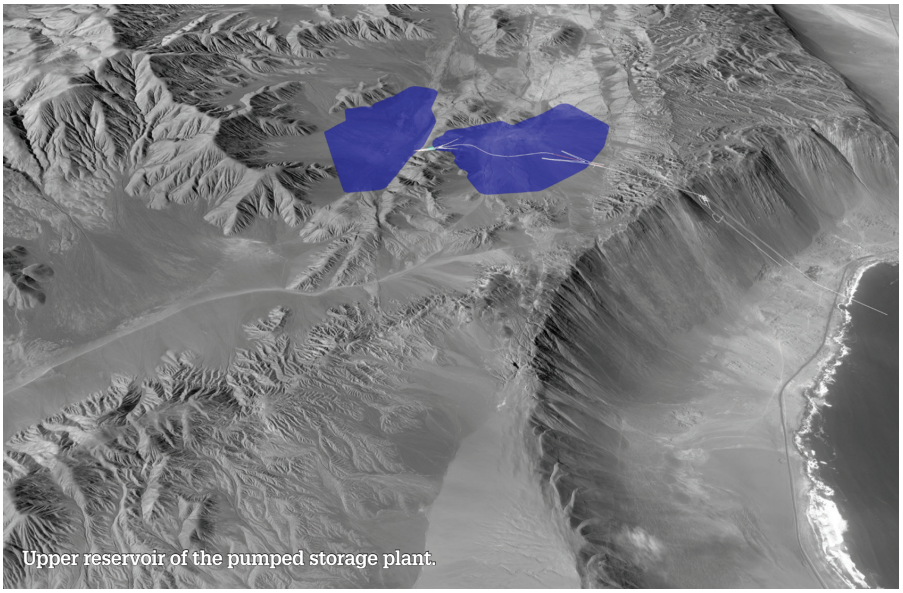
The project's upper reservoir, which is comprised of the natural concavity located on the top of the cliff, encompasses a total land area of 375 hectares and energy storage capacity of 83GWh, respectively. When the reservoir is at full capacity, the PSH plant can generate electricity at nominal capacity continuously for 11 days

The shaded area in the photograph below shows the location of the upper reservoir, which is comprised of two bodies of water, an eastern and western reservoir which will be interconnected via a canal with a distance of 275m. The white line indicates the PSH plant's waterways including the seawater intake and associated tunnels to the reservoir. Both the eastern and western reservoirs will be surrounded by a dike with an average height of 3m and completely lined with an impervious membrane made of a highly resistant bituminous material to prevent filtration. A separation dike will also be constructed in the western reservoir to enhance operating flexibility, allowing the project to store reserves or perform maintenance in one half of the reservoir while continuing to operate.

The PSH plant installations include reversible pumping equipment located in an underground powerhouse. As noted above, when the project is dispatched on a relatively continuous basis, during sun-hours, this equipment pumps water from the ocean to the upper reservoir on top of the coastal cliff, and during dark-hours, the equipment generates electricity with the water stored in the reservoir, which is released and returned to the ocean. There will be a single underground bi-directional water conduction system comprised of the ocean intake and tunnels, which will be used for the water flow in both pumping and generating modes.

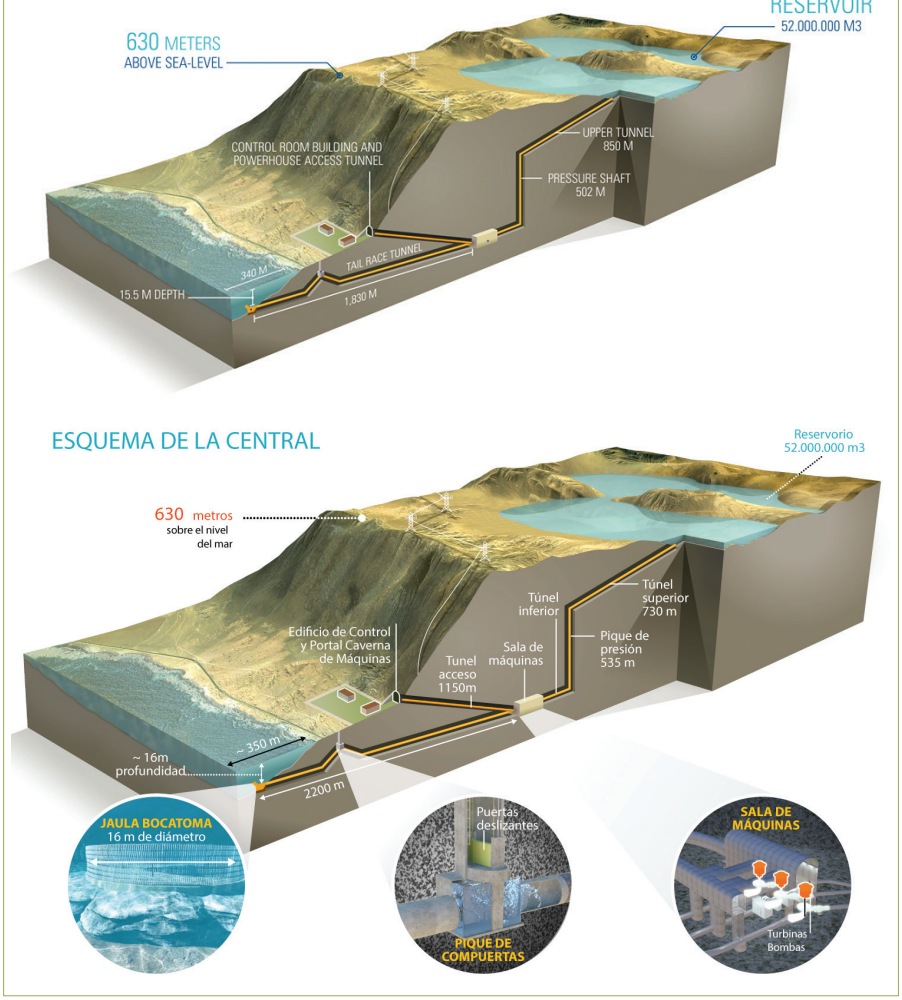
The principal components of the PSH plant include: (i) three 100MW Francis-type reversible turbines, along with 115 MVA transformers, (ii) a 350m subsea tunnel that ends in a sea piercing system with an intake point depth of approximately 16m, (iii) a 2200m underground water discharge tunnel, (iv) a 1150m access tunnel, (v) a 730m headrace tunnel, (vi) a vertical steel lined pressure shaft with a height of 535m, (vii) a 110m surge shaft at the top of the pressure shaft, (viii) a 150m surge chamber located downstream of the power cavern, (ix) a 220kV GIS substation, and (x) above-ground buildings including a control room, plant office, warehouse and desalinization plant (to provide water for PSH plant construction and operations and to the local community). The combined length of all tunnelling is approximately 5.5km.

The PSH plant installations also include the



Upper reservoir of the pumped storage plant.

Layout of the pumped storage plant.



Reinvigorating clean energy

EDT is 100% owned by Valhalla, a Chilean independent power company. The company is focused on the development, ownership and operation of renewable power projects which utilise Chile's natural resources and strategically diversify the country's energy matrix away from an overdependence on imported fossil fuels. Valhalla is currently in the process of inviting strategic investors to participate as partners in the ownership of the project.

Valhalla's innovative project is compatible with Chile's energy goals. Since March 2014, under the administration of Minister of Energy, Maximo Pacheco, Chile has focused on enhancing competition, boosting the development of non-conventional renewable energy, reducing carbon emissions and improving local development benefits provided by energy projects to the local communities. The government's Energy Agenda and Long Term Energy Policy has established a target of 70% of power generation from renewable sources by 2050.

Chile also became a founding member in the group of visionary countries that jointly launched the Mission Innovation initiative announced at the United Nations Conference on Climate Change in Paris in November 2015. This advocates the common goal "to reinvigorate and accelerate public and private global clean energy innovation with the objective to make clean energy widely affordable."

www.valhalla.cl

65km transmission line from the PSH plant to the Lagunas substation.

The PV plant site is a flat tract of land, approximately 1000m above sea level comprised of 1568 hectares in the middle of the Tarapacá Region of the Atacama Desert. The PV plant is comprised of a 600MW-AC PV solar park which will be constructed in phases and will utilise a single-axis tracking system in order to maximize energy output by tilting the panels to follow the sun throughout the day from east to west.

Project Status

Since 2011, Valhalla has focused on critical development activities including engineering and design, permitting, and community engagement. The project is currently at an advanced stage of development having achieved several important milestones such as approval of the PSH and PV plant and transmission line environmental permits, execution of collaboration agreements with community organisations, and pre-selection of certain construction contractors, among others.

Engineering

EDT has performed extensive engineering work and studies for the PSH plant, including feasibility site studies and engineering design. The engineering design was performed by Poch Engineering and Skava Consulting under the leadership and management supervision of EDT's Project Director. Several external experts were also engaged to analyse specific project components.

International consultants Norconsult and Multiconsult were engaged to review and assess the underground works and PSH equipment, respectively, and detailed engineering for design of the ocean intake was performed by specialised consulting firm, PRDW Consulting Port and Coastal Engineers. The results of the engineering studies were used to prepare the EIA permit request and the tender documents to request contractor proposals for the PSH construction contracts.

Permitting

The project has completed the environmental permitting process. The Environmental Impact Approval (EIA) for the PSH plant and the corresponding transmission line was unanimously approved by the authorities in December 2015 and the EIA for the PV plant and associated transmission line was unanimously approved by the authorities in January 2016.

Transparent and inclusive relationship

The project has prioritised the establishment of an early, transparent and inclusive relationship with the local community. The PSH plant is adjacent to a fishing village with a population of around 300 inhabitants. Interaction with the community was initiated in 2012 in order to address community concerns in early development. A formal work methodology was implemented to assist the community with analysis of the project, which included numerous working sessions, creation of a special commission and hiring of community advisors.

In March 2015, collaboration agreements which govern the interaction with the community during development, construction and operation of the project were executed with two community organisations.

The estimated project investment is approximately US$1.3B. Plans are afoot to launch the financing process in the next few months in order to commence construction prior to the end of the year. Total construction for the entire project, including the PSH and PV plants and transmission lines, will be approximately 3.5 years. The PV plant will initiate operations in phases, starting in 2019. The PSH plant and all PV plant installations are expected to be completed in 2020. ■