

PUCAMARCA FOREVER: PLAN FOR SOLAR-GEOTHERMAL DEVELOPMENT AS AN ALTERNATIVE FOR SUSTAINABLE CLOSURE OF THE PUCAMARCA MINE, PERU

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Overview

Ten years after the beginning of gold extraction at Pucamarca, this mine is on the eve of closing its activities. The closure of the Pucamarca gold project, characterized by its standards of respect for environmental resources, the reduction of operating costs, the incorporation of innovation processes, and the social inclusion of surrounding communities, means the culmination of more than one decade of strategic relationships for the development of the Tacna's communities. At the same time, the wealth of the Tacna region not only lies in the presence of minerals and its historical legacy but also, this location benefits from a solar potential greater than 7 kWh/m² in almost all months of the year, becoming the largest focus of solar energy wealth in Peru. Furthermore, within the area concessioned by the Pucamarca mine resides the sixth largest geothermal deposit on the planet known as the Valley of the Candarave Geysers, of which studies were carried out for its exploitation until 2018, but they were stopped due to the absence of an energy policy that promotes sustainable electricity and heating generation from geothermal sources, as well as the limited public-private partnership that accelerates technological development in this region of the country. The presence of the mining corporation MINSUR, as the majority shareholder of the Pucamarca mine, and its need to maintain alliances and sustainable practices with the community of Tacna, together with the current sources of green financing to which Peru has access, can lead to the resumption of geothermal studies for future exploitation for the benefit of the southern regions of Peru and the assurance of electrical resources in the National Interconnection Electrical System (SEIN) of the country.

Methods

The development of this research required approaching it from a mixed methodology. On the one hand, a qualitative analysis was carried out on the data from the Pucamarca mine (evolution of mining activity, closure of the mine, relations with the communities, site plans) provided by the mining corporation MINSUR, as well as the active green financing alternatives in Peru, such as the UK Government's Green Bond Program and the Green Climate Fund (GCF). On the other hand, this research is based on a quantitative methodology that processes solar resource data through NASA and the Global Solar Atlas platforms. Furthermore, the exploration of the current mining cadastre of Peru and the areas of geothermal potential were subjected to a comparative analysis through the GEOCATMIN software provided by the Peruvian entity INGEMMET. Subsequently, the solar and geothermal technical feasibility and the Carbon Footprint projection were found through mathematical modeling and equation resolution, while the economic feasibility was addressed from a statistical and cash flow analysis.

Results

The Pucamarca mining project is located in the district of Palca, Tacna, Peru, at 4,250 meters above sea level, and less than 1 km from the Peru-Chile border. Currently, Pucamarca has properties that total 1,155.50 hectares of land that reaches the Candarave Geysers Valley, and that, additionally, gives it the capacity to install up to 1,000 MWp (1 GWp) of solar energy.

Solar development

A 100 MWp solar photovoltaic powerplant was sized with a lifetime of 25 years. In this case, the use of solar batteries will not be considered, since the energy will be injected directly into SEIN through the Peruvian "Los Héroes" Substation, allowing the injected energy to be interconnected with the Chilean substation "Parinacota" (Arica) to contribute with the electrical supply intended for the Peru-Chile Regional Electrical Interconnection. Likewise, the installation requirement of 250,000 panels of 400W on almost 50 Ha of land was found. Additionally, this part of the project will generate approximately 221'529,000 kWh/year, of which 456,400 kWh will be subsidized to the communities of Palca.

On the other hand, this solar project is an ideal candidate for the issuance of Green Bonds granted by the United Kingdom government and the Lima Stock Exchange with the facility of an interest rate between 4% and 7%. This benefit would allow the

CAPEX of 85'000,000 USD to have an NPV of 371'256,960 USD at the end of the plant's life and an IRR of 36%. Considering also that in the third year of investment, the return of capital will be obtained.

Geothermal development

According to the GEOCATMIN tools and the geothermal bulletins provided by INGEMMET, an area of 20 km in the Paucarani sector, with a depth of 1 km, was preselected for the sizing of a single flash geothermal power plant with a 25-year lifespan. This sector has a geothermal potential of 77.12 MWe, a reservoir temperature of 180°, an enthalpy of 2000 kJ/kg, a pressure of 10 bar-a, and a mass flow of 30 kg/s. According to the results of the Rankine Cycle, a turbine efficiency of 85% is assumed with a power of 31.49 MWt and 30.86 MWe that will require around 7 drilled wells (3 extraction wells, 2 reinjection, and 2 additional contingency). This geothermal plant will generate approximately 240'000,000 kWh annually with a CAPEX of 139'000,000 USD that will recover the capital in year 7 after its installation. In addition, an annual OPEX was estimated at 1.5 million USD with additional costs for drilling maintenance of 35 million USD every 4 years.

Rankine Cycle	Enthalpy (kJ/kg)	Pressure (bar-a)	Mass flow (kg/s)	Fluid state
Point1	2,000	10	90	liquid
Point 2	2,000			62% steam
Point 3	721	8	33.76	liquid
Point 4	2,768	8	56.23	steam
Point 5s	2,108.94			steam
Point 6	191.8	0.1		liquid
Point 7	2,584.3	0.1		steam

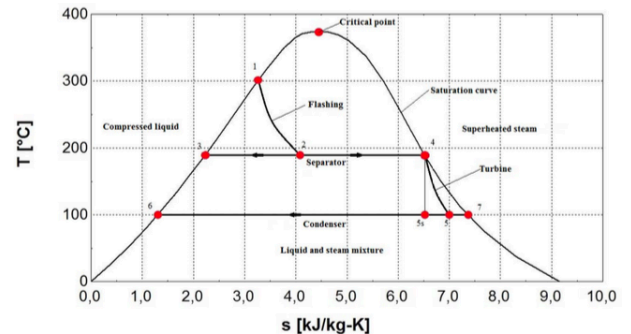


Table 1. Summary of enthalpy, pressure, mass flow and fluid state values according to the Rankine Cycle (own elaboration).

Carbon Footprint

Annually, GHG emissions from the Pucamarca mine amounted to 19,650 tons of CO₂eq, which, in 10 years of mining activity, is equivalent to 196,500 tons of CO₂eq. Therefore, by injecting electricity through the 100 MW solar power plant, 45,058 tons of CO₂eq/year will be offset. Meanwhile, the 30 MW geothermal powerplant will offset 48,815 tons of CO₂eq/year, allowing 100% of the GHG emissions generated during the 10 years of mining activity to be offset in the first 5 years of renewable electricity generation.

Conclusions

Pucamarca has a solar potential of approximately 7.1 kWh/m² and more than 1,000 hectares of land that allow the installation of up to 1 GWp of solar energy. Added to the fact that the Paucarani sector, part of Pucamarca, has a geothermal potential of ~77 MW suitable for exploitation through technologies such as solar pumps, Wellhead extraction or conventional single flash plants that will require 8 years of studies and construction for commissioning. To make this proposal viable, the solar plant will be installed through the issuance of green bonds that reduce the interest rate and allow a return of capital after 3 years of investment. With these profits, the drilling and study expenses required by the geothermal plant will be partially covered, and, starting in year 8, Pucamarca will have a hybrid solar-geothermal plant that will offset the GHG emissions generated during the 10 years of mining activity and will allow strengthen 11 Sustainable Development Goals aimed at reducing gender gaps, accessing affordable and sustainable electricity, and increasing climate action in the region of Tacna, Peru.

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