A combined photovoltaic and novel renewable energy system: An optimized techno-economic analysis for mining industry applications

Eduardo Vyheimister a, Cristina Aleixendri Muñoz b, José Miguel Bermúdez Miquel b, Javier Pina Moya b, Carlos Fúnez Guerra c, Lourdes Rodríguez Mayor d, Alex Godoy-Faúndez e, Pablo Higuera s, Carmen Clemente-Jul g, Héctor Valdés-González b, Lorenzo Reyes-Bozo b,.

a Departamento de Energía y Mecánica, Universidad de las Fuerzas Armadas, ESPE, extensión Latacunga, Ecuador
b Departamento de Ingeniería y Desarrollo, Bound4blue S.L., Espa

c Centro Nacional del Hidrógeno, Puertollano, España
d Centro de Excelencia en Investigación en Arquitectura, Ingeniería y Diseño, Universidad Europea de Madrid, Madrid, España
e Centro de Investigación en Sustentabilidad y Gestión Estratégica de Recursos, Facultad de Ingeniería, Universidad del Desarrollo, Santiago, Chile
f Departamento de Ingeniería Geológica y Minera, Universidad de Castilla-La Mancha, Almáden, Ciudad Real, España

g Departamento de Energía y Combustibles, Universidad Politécnica de Madrid (UPM), Madrid, España
h Universidad Central de Chile, Santiago, Chile

A R T I C L E I N F O

Article history:
Received 2 October 2016
Received in revised form 18 February 2017
Accepted 18 February 2017
Available online 22 February 2017

Keywords:
Copper mining industry
Renewable energy
Photovoltaic energy
Economic analysis
Optimization system

A B S T R A C T

The productivity of the mining industry in Chile, currently the main driver of Chilean economy, is closely tied to foreign demand for ores. Ore-processing is known for involving energy-intensive processes, such as comminution, concentrating and cathodic processes. As mining activities take place in the arid north of Chile, they are affected by water scarcity. Water shortage has forced the industry to pump desalinated seawater up to mining sites over 2000 m above sea level, further increasing electricity consumption. Given these energy needs, and the fact that electrical energy supply in the north of Chile is based on fossil fuels, it is important to consider the use of renewable energies as environment-friendly and economic alternatives. The aim of this work is to evaluate, by an optimized techno-economic analysis, the use of photovoltaic and a novel wind-based technology to supply at least 10% of the current and the predicted electrical energy requirements of the mining industry in the Antofagasta region. A combination of an optimization problem and technical evaluation was performed using Matlab to obtain the optimal number of solar and wind-based technology units in a case study. Total energy generation from a novel wind-based technology unit is 67,616 MWh/y, corresponding to 14.45 $/Nm^3 (1298 t) of hydrogen and 7.41 × 10^6 $/Nm^3 (10,323 t) of oxygen after electrolytical transformation. Considering a 65% efficiency of the combined cycle fed with hydrogen and oxygen, 28,133 MWh/y of electrical energy would be obtained. For the cases studied the cost of energy from the combined system was estimated to be between 0.255 US$/kWh and 0.273 US$/kWh, slightly higher than the average energy regional cost. According to the analysis, the renewable energy system could be a sustainable alternative to supply economic green energy to the mining industry in Chile.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Chile is one of the most economically competitive countries in Latin America, a new Organization for Economic, Cooperation, and Development (OECD) member, and considered a high-income country due to high Gross Domestic Product (over US$22,000 per capita; The World Bank, 2016). Agriculture and mining activities, together with services, are the principal drivers of Chilean economic growth (Rehner et al., 2014). The mining industry is mainly located in the north of the country, in the mountainous region of the Atacama Desert, with the Antofagasta region producing almost half of the copper (33% in 2014, as estimated by Cochilco, 2016).

http://dx.doi.org/10.1016/j.jclepro.2017.02.136
0959-6526/© 2017 Elsevier Ltd. All rights reserved.