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Mining experts' perspectives on the determinants of solar technologies adoption in the Chilean mining industry

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ABSTRACT

The energy demand in Chile arises mostly from mining, its largest industry that accounts for about 35% of total electricity consumption. Energy generation to satisfy this demand depends completely on imported fossil fuels. As a result, the mining industry faces several energy related challenges. In particular, the cost and environmental impact of fuel sources are threatening the competitiveness of the industry and urge for new developments. In that regard, the importance of using clean and cost-competitive renewable energy sources has increased significantly in Chile and several government policies helped to increase the investment in them. The impact has been particularly large in the development of solar energy in the northern part of the country, where almost all mines are located. In fact, the country has become one of the largest solar markets in Latin America thanks to its abundant solar resources, favorable market conditions, and successful policy reforms. Solar energy then, could play a significant role as an alternative to satisfy the mining industry's energy demand offering a broad range of technological solutions. This study examines the key issues -barriers and drivers- influencing the adoption of solar technologies in the Chilean mining industry from the perspective of mining actors. As a result of the analysis the paper also provides a scope for appropriate policy interventions.

1. Introduction

Over the last decades, Chile has experienced a remarkable economic performance with high growth rates, low unemployment, low inflation, and a significant reduction in poverty [1]. Chile's economic development has been mostly based on the exploitation of natural resources, which accounts for 75% of overall exports [2]. Historically, the mining industry has been a fundamental productive pillar in the Chilean economy. The world's largest reserves of copper and lithium are located in Chile. In fact, Chile is the leading copper-producer in the world as it supplies a third of the global copper output.

Since the early 1990s, the mining industry has represented, on average, 8.5% of the country's total gross domestic product (GDP) and 47% of its exports. In 2016, the mining industry accounted for 51% of total exports and was 8.1% of the GDP [2]. The current projections from international and local experts show that the mining sector in the Chilean economy will continue playing an important role [3]. However, the industry faces important challenges that needs to overcome to be able to keep a significant role in the long-term. Some of them are energy related and are also significant enough to threat the profitability and competitiveness of the industry. The role of energy is certainly an important factor given the fact that the cost of energy represents between 20% and 40% of the total cost of mining operations. A number of successive energy crises over the last decade in Chile has resulted in a serious threat to the local economy, dragging the mining sector into a critical situation due to high costs and even availability of energy.

In this regard, addressing the energy challenges is an important matter if Chile wants to keep being a relevant player in the global mining industry in the future. A first step in the right direction was taken by the government when setting the policy goal of fostering a reliable, affordable, and environmentally clean energy to sustain the economy. In this context, renewables were considered an important contribution to the country's energy diversification strategy. Having a great potential in terms of natural resources and a promising business climate made the country an ideal marketplace for renewable energy project developers. As a result, over the last few years Chile experienced a remarkable energy transformation towards renewable energy. As of January 2011, installed renewable capacity was 591 MW representing just 3.8 per cent of the energy mix (15,268 MW). In May 2017, only five years later, it reached 3793 MW, representing 17 per cent of the total capacity (22,846 MW) (CNE, 2017) [4]. It is not surprising then, that Chile has grown into the largest producer of solar energy in Latin

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America.

The Atacama Desert, which has one of the highest rates of solar radiation in the world, is located in the north of Chile, precisely where the world's largest copper reserves are located [5]. Given that the expansion of solar technologies in the energy mix has progressed at a pace faster than expected due to their significant reduction in costs, the mining industry has the opportunity to use solar technologies in its mining operations and overcome some of the energy challenges they face.

In this context, we examine the key issues influencing the adoption of solar technologies in the Chilean mining industry from the perspective of mining actors. The analysis allows a better understanding of barriers and drivers and also provides information for appropriate policy interventions. The research findings are a valuable contribution for the industry and for researchers as they improve the knowledge about the major issues affecting the diffusion of solar technologies in the mining sector in general, and not only in Chile. They are also a valuable input for policymakers aiming at promoting the use of solar technologies in the industry and developing suitable policies for that purpose.

There are several studies in the literature addressing the barriers and motivators for the adoption of solar technologies. The specific focus in this literature is limited on the power generation sector and residential consumers in the context of various countries [6–8]. Given the fact that the mining industry accounts globally for 11% of the total final energy consumption and 38% of industrial final energy consumption [9] examining the determinants of the solar technology adoption in the mining industry represents an important contribution to the literature. In general, there is lack of comprehensive academic research in terms of examining the barriers preventing the adoption of solar technologies in the mining industry and this study contributes to fill that gap, especially in terms of considering the view of mining experts.

The paper continues as follows: Section 2 gives an overview of the key energy challenges the Chilean mining industry faces; Section 3 provides a literature review to examine the issues influencing solar technology implementations in the mining industry; Section 4 describes the research methodology; Section 5 presents and discusses the results; and finally, Section 6 concludes.

2. Energy challenges of the mining industry in Chile

The mining industry has historically used only imported fossil-based fuel sources – diesel, oil, coal, and natural gas – to meet its energy demand. While facing volatile commodity prices, even though prices were quite low for several years, the continued reliance on imported fossil fuels created serious challenges for the industry. These challenges can be classified under five broad topics: growing energy demand and costs, increasing energy dependency from external sources, increasing opposition from communities to new investments in conventional energy sources, growing environmental and social unrests, and rising energy demand for desalinization water plants.

2.1. Energy demand and costs

The rapid economic expansion over the past decades in Chile created a significant boost in energy consumption. As of 1990, energy consumption was 11.099 (ktoe[1]) and reached 25.145 (ktoe) in 2015, a 130 per cent increase in 15 years [10]. Industry and mining are the two largest economic sectors consuming energy in the country. In 2015, industry represented 23% of final consumption and mining represented 17%, the latter mostly copper [4]. The mining sector energy consumption is mainly electricity (35%), diesel (26%), and biomass (20%). In this context, the electricity consumption of the copper industry increased from 14.985 GWh in 2003 to 23.128 GWh in 2014, around 63% in a decade. The projection of the Chilean Copper Commission is that the demand will grow even faster, reaching 41.100 GWh in 2025 [11].

The increasing dependence on imported sources and a steady growing energy demand have resulted in both high and unstable electricity costs for the mining industry. After labor, energy constitutes the largest fraction of total operating cost in mining. Furthermore, the share of energy expenses has been continuously growing over the last 20 years, as the cost of energy in Chile increased significantly and became one of the most expensive among mining countries. According to COCHILCO, the cash-cost of producing copper in Chile was US$0.63 per pound in 2004 and reached US$2.50 in 2013, a 350% rise [12]. A significant fraction of that increase is due to higher energy costs. The cost factor is especially serious at off- grid remote locations, where mining companies often have to use expensive diesel generation. The cost of diesel in remote zones not only depends on the oil price but also on other factors such as transport and theft, which affect the final cost significantly. For these reasons, the cost of electricity can reach up to 300 USD/Mwh at off-grid mines in remote locations [13]. A sharp escalation in costs has exacerbated productivity issues in the mining sector, generating a large disadvantage with respect to its competitors in the rest of the world. In fact, today the cost of energy in Chile's mines is twice as much as their peers in neighboring Peru, another top mining country. Growing energy costs together with energy demand remain an important matter then, threatening the competitiveness of Chile's largest industry and posing a major challenge for new developments.

2.2. Energy dependency

Historically, the generation of electricity in the Great North Interconnected System of Chile (SING) – where most of the mining operations are located – has relied almost 90% on fossil fuel sources. As of 2017, 67% of the total installed power generation capacity in Chile was based on fossil fuel sources, mostly coal and diesel [4]. Since Chile has almost no reserves of fossil fuels, all resources are imported [14]. In addition, its neighboring country Bolivia –which is very rich in natural gas- refuses to sell it to Chile for political reasons. Therefore, natural gas needs are met with expensive Liquefied Natural Gas (LNG), averaging two- to three- times the price of natural gas in North America. The heavy dependence on energy imports generates high vulnerability to external shocks, not only in terms of price but also on supply availability. The clearest example occurred in 2004, when the gas crisis in Argentina took place and exports to Chile were unilaterally curtailed [10]. In addition, the external dependence amplifies the volatility of energy prices, which makes it more difficult to predict energy costs when evaluating projects.

2.3. Opposition from communities

Over the last couple of decades, the country has experienced several consecutive energy crises due to negative shocks in both energy prices and energy supply. For example, in 1999 and 2011, the shortage of energy supply implied rationing electricity for several months. This situation urged the government to seek rapid investment in the sector with the objective of fostering a more reliable supply and diversifying the country's energy matrix. Despite an overall attractive investment climate and encouraging market conditions, investments in new projects have been difficult to materialize. The main reason is the opposition of local communities to large conventional projects because of their expected environmental and social impacts [15]. As a result, several energy projects—especially the large ones like Pangue/Ralco, HidroAysén, Barrancones, and Castilla —have provoked intense public debates that delayed their approval processes and, in most cases, ended up in the rejection of the project.

[1] In thousands tonnes of oil equivalent (ktoe).