Energy Demand Analysis and Policy Instruments Assessment for Mining Industry in Chile

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Abstract

Northern Chile has the best worldwide solar energy potential to produce energy. Chile can consider this huge potential and meet the demand of energy-intensive industry sector, especially mining, due to having important mining activities in the north of the country. This paper aims to analyze the energy and electricity demand forecasting of mining industry and asses the related policy instruments to stimulate renewable energy in the mining sector. Key findings of the research are as follows: the expected total energy demand value for the mining sector is obtained as 405.12 PJ, which means the demand will almost double in 20 years. The main energy demand share in mining sector belongs to the copper sector with 78.9%. The forecasting results show that this share will increase gradually and reach 81.6% in 2035. The demand for electricity and diesel in the copper sector will double in 20 years and reach 171.38 PJ and 138.20 PJ, respectively. Electricity has the most significant share with 51.9% in copper energy demand between all fuels, and it is followed by diesel (41.8%), natural gas (3.6%), and oil (2.3%), accordingly. When energy policy instruments used in the world and Chile are compared to promote renewable energy, Chile has implemented some of them successfully, particularly renewable electricity production without fiscal incentives or FITs. However, Chile should also consider the following obligatory regulations in the mining industry: priority or guaranteed access to networks, priority dispatch, tax credits, production-based incentives and soft loans.

Keywords: Energy Planning, Scenario Development, Industry Sector, Solar Energy.

1. Introduction

Chile ratified the Paris Agreement in 2017 and committed to develop policies to face climate change and to transition to a more sustainable energy system. Besides international promises on the environment, Chile has ambitious targets for the development of renewable energy (RE) technologies, which are described in the latest long-term energy planning report of the government (Comité Consultivo de Energía 2050, 2015; Ministerio de Energía, 2018). The current national goal is for at least 70% of the electricity in Chile to be generated from renewable energy sources by 2050. The share of RE in electricity generation is expected to grow from 15% in 2015 to 65% in 2035 (Ministry of Energy, 2015). To meet these national and international goals, Chile has considered its significant renewable energy potential. The north of Chile has the best worldwide solar energy potential for energy generation, on account of dryness and clear sky (Escobar et al., 2015, 2014). Also, the industry in the north of Chile is based on highly energy-intensive mining activities (Del Sol and Sauma, 2013).

Promoting renewable energy and energy efficiency became an essential strategy for Chile to reduce emissions and reach its energy and environmental goals, which are addressed in various governmental studies (Ministerio de Energía, 2018). Also, the significant solar potential of the northern region can be the solution to meet high energy-intensive industry activities in Chile.

Additionally, the industry sector has an essential share in Chile's gross domestic product (GDP) as listed the historical shares in Table1. Between the years 2007 and 2016, industry sector contribution of GDP changed from 39.94% to 28.93%, respectively. Moreover, mining as a sub-sector of the industry has also an important contribution to GDP, as shown in the table with a 14.9% average contribution in the last ten years.

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Tab. 1: The share of the industry sector in Chile's gross domestic product (GDP) ("The share of economic sectors in GDP Chile," n.d.)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
All industry GDP Share	39.94%	34.24 %	34.44 %	35.70 %	34.70 %	32.54 %	31.19 %	30.85 %	29.67 %	28.93 %
Mining GDP Share	14.50%	20.70 %	20.50 %	14.00 %	13.10 %	16.00 %	14.90 %	12.80 %	11.30 %	11.20 %
Other Industry GDP Share (except mining sector)	25.44%	13.54 %	13.94 %	21.70 %	21.60 %	16.54 %	16.29 %	18.05 %	18.37 %	17.73 %

Chilean industry sector includes several subsectors such as paper and cellulose, agroindustry, fishing, cement, construction, iron and steel, sugar, petrochemistry etc. Figure 1 shows energy demand share based on sub-classes of industry sector. Mining has the highest share in this sub-sector by including copper, iron, saltpetre and other mining activities. Between the mining sub-sectors, copper is the most energy demanding sector, which requires 34.65% of the total energy demand of the mining sector. In addition to mining, paper and cellulose industry consumes a large amount of energy, which is 20.73 % of total industry demand as shown in the figure.

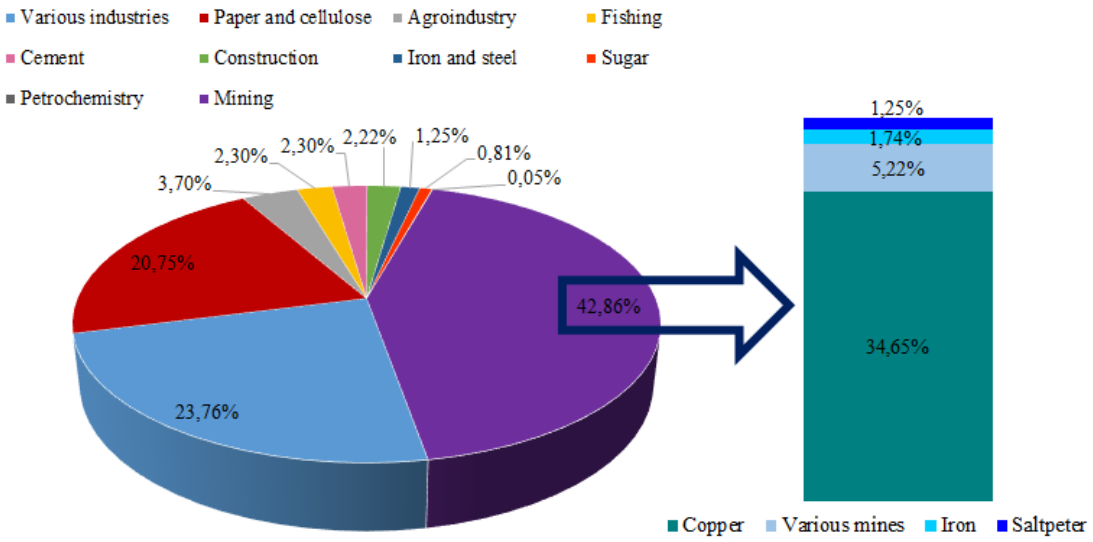

Fig. 1: Industry sector energy demand share based on sub-sectors (Ministerio de Energía, 2015a)

Besides sub-sectors, the industry sector energy demand by fuels should also be analyzed. Figure 2 presents the historical share of the industry sector (except mining) demand based on fuels. It can be seen from the figure that the majority of sources come from fossil fuels. Diesel, natural gas and LPG have an important share in the demand as presented in the figure. Only biomass has significant share between approximately 30% of total demand between the years 2010 and 2017.

Also, the electricity demand has a significant share in the energy demand of the industry sector, with an average share of 24.3% in the last seven years. It can be slightly seen that solar energy contribution appears in the years 2012 and 2013. However, due to the huge overall demand, this share is almost negligible.

Besides, copper is the main industry in Chile. Thus, energy demand plays an essential role in the national energy balance. Cooper sector requires mostly electricity and diesel to meet the demand. On the other hand, the contribution of biomass can be seen slightly when no solar energy exists in the energy balance (Ministerio de Energía, 2015a).

In order to reach short- and long-term energy/electricity targets in Chile, current and future energy demand analysis is required in sectoral bases. Also, the assessment of essential policy instruments by comparing the

worldwide used policies and Chile will help to promote renewable energy in the industry sector. Therefore, this paper aims to analyze energy and electricity demand of the mining sector by 2035 and define the required renewable energy promotion instruments to achieve targets.

This article is organized as follows. Section 1 contains the introduction section and the objectives of the research. Section 2 presents the methodological approach followed in the research. Section 3 includes analysis results and discussion for Chile. Finally, section 4 concludes the paper and includes suggestions for future research.

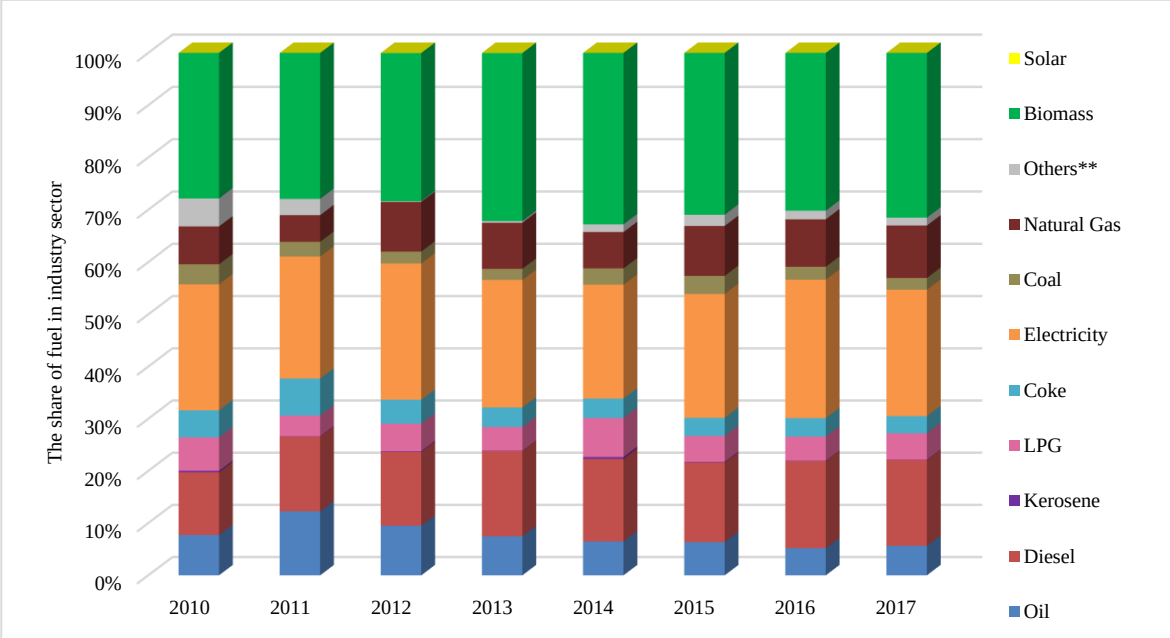

Fig. 2: Historical share of Industry sector (except mining) demand based on fuels (Ministerio de Energía, 2015a)

2. Methodology

The first step of the methodology is to search the database of National Energy Balance of Chile. The detailed energy balance data for Chile is obtained between 2008 and 2017 from the national databases (Comision Nacional de Energia, n.d.). After obtaining available datasets, the compound annual growth rate (CAGR) is calculated from equation (1) to see the growth between the years 2008 and 2017:

$$CAGR_{(calculated)} = \left(\frac{I\_value_{\_ending\ at\ T2}}{I\_value_{\_beginning\ at\ T1}}\right)^{\frac{1}{(T2-T1)}} - 1 \qquad (1)$$

$I\_value_{\_beginning\ at\ T1}$= The value for year T1

$I\_value_{\_ending\ at\ T2}$= The value for year T2

T1: the year for the beginning value

T2: the year for ending value

After obtaining the growth rate from equation (1), the expected energy and electricity demands for 2035 are calculated as presented in equation (2):

$$I\_value_{\_2035} = I\_value_{\_ending\ at\ T2} * \left(1 + CAGR_{(calculated)}\right)^{2035-T2} \qquad (2)$$

$I\_value_{\_2035}$= The calculated value for 2035 based on growth rate.

These calculations are applied to total energy demand of mining, total copper energy demand by fuel and total electricity demand for the mining sector until 2035. The results and discussions are presented in the following section.

3. Results and Discussion

In the first part of this section, the result of the Chilean mining industry demand analysis is presented. After that, the results of total copper energy demand by fuel, electricity demand of the mining sector by 2035, and the comparative analysis of energy policy instruments to promote renewable energy are given, respectively.

3.1. Energy Demand of Mining Industry by 2035

In Figure 4, total energy demand forecasting for the mining sector is presented for every five years until 2035. The demand was 199.63 PJ in 2015, and when the forecasting is realized for 2035, the expected energy demand value for the mining sector is obtained as 405.12 PJ, which means the demand will almost double in 20 years.

As it can be seen in 2015, the main energy demand share in mining sector belongs to the copper sector with 78.9%. The forecasting results show that this share will increase gradually and reach 81.6% in 2035. Besides copper, iron sector energy demand share is also expected to increase from 4.0% to 6.7% between 2015 and 2035. On the other hand, based on the forecasting results, saltpeter and other mining sectors energy demand share will decrease in the mining sector.

Finally, energy demand is expected to reach 330.46 PJ for copper, 8.06 PJ for saltpeter, 26.95 PJ for iron and 39.67 PJ for other mining sectors by 2035.

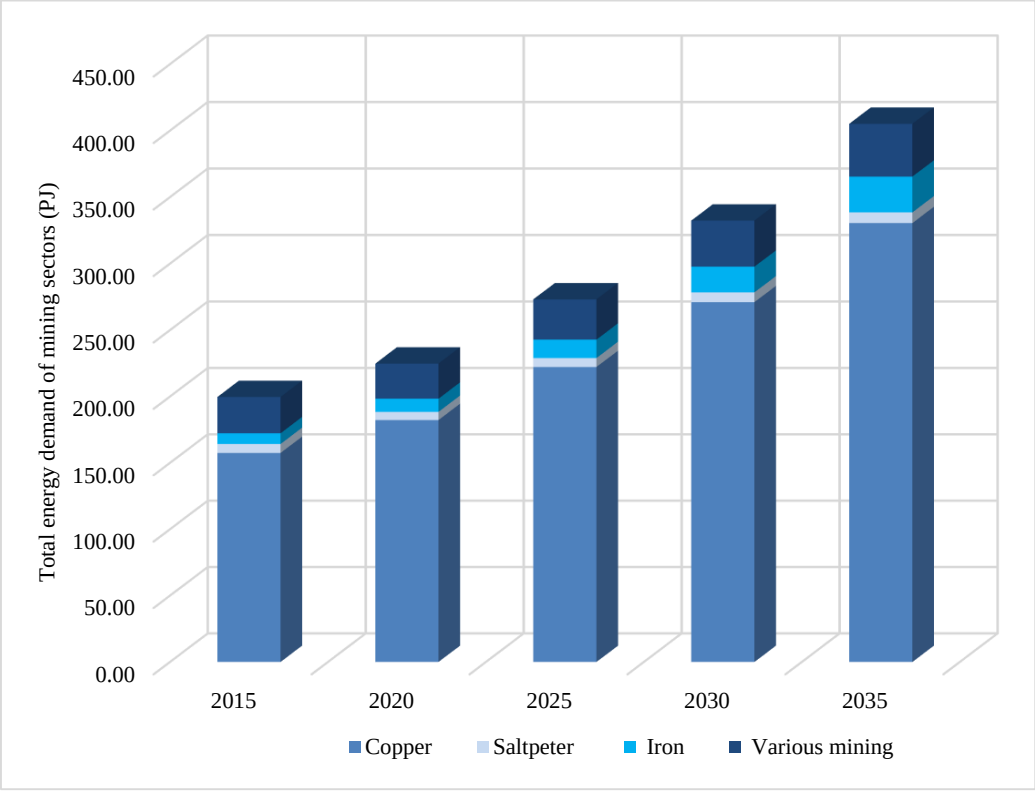

Fig. 4: Total energy demand forecasting for mining sector until 2035

3.2. Total Copper Energy Demand by Fuel by 2035

In addition to total demand forecasting for each mining sub-sectors, it is necessary to analyse the demand by fuels. Figure 5 presents the total copper energy demand by fuel in 2015 and 2035. In 2015, it can be seen that electricity demand has the most significant share between all fuels, with 51.9% share value. It was followed

by diesel with a 41.8% share in the demand profile by fuels in 2015. The rest of the demand which is 6.3% of total demand is met by natural gas (3.6%), oil (2.3%) and biomass, coke, LPG, kerosene (total 0.5%).

When it is assumed that the same shares of fuels are expected to be the same in the future, the demand of electricity and diesel will double in 20 years and reach 171.38 PJ and 138.20 PJ, respectively. This huge amount of energy demand in the copper industry should be supplied by more renewable energies. Especially, processes which require heat should be supplied by cleaner heat production technologies such as solar thermal and geothermal power plants instead of diesel generators. Also, electricity demand should be met by generation from renewables based on the renewable energy potential of the mine region.

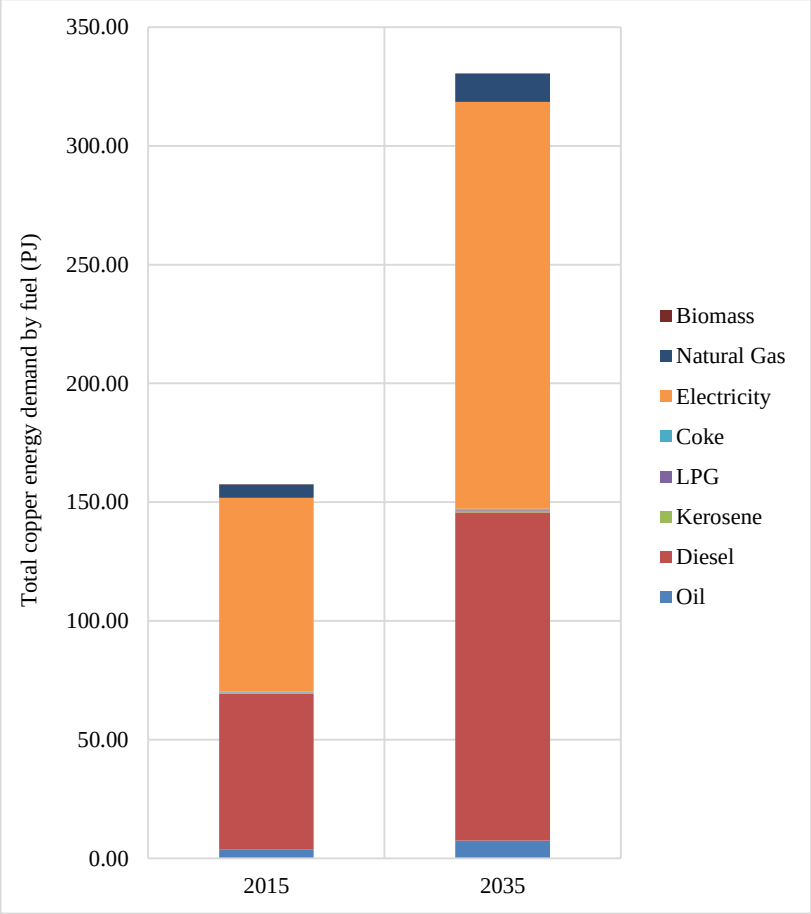

Fig. 5: Total copper energy demand by fuel in 2015 and 2035

3.3. Electricity Demand for Mining Sector by 2035

The total electricity demand forecasting in the mining sector is important due to two aspects: for the benefits of the mining company and electricity generators. Mining sector should have a continuous, sustainable and reliable energy source due to non-stop 7/24 hours activities, and most of them are depended on energy suppliers. Also, electricity planning is important for generators to understand their distribution by years.

Figure 6 shows the total electricity demand forecasting for the mining sector between 2015 and 2035. As presented in the figure, the total electricity demand was 24,507.52 GWh in 2015, and it is expected to reach 42,902.62 GWh for 2035 with a 75% increase in 20 years. When we look at the sub-sectoral level, although electricity demands of copper and iron show an increasing trend, saltpetre electricity demand is decreasing significantly. Copper electricity demand is expected to reach 39,751.03 GWh by 2035 when iron increases to 2,362.54 GWh. Otherwise, saltpetre electricity demand will decrease to 112.51 in 2035 GWh from 371.93 GWh in 2015.

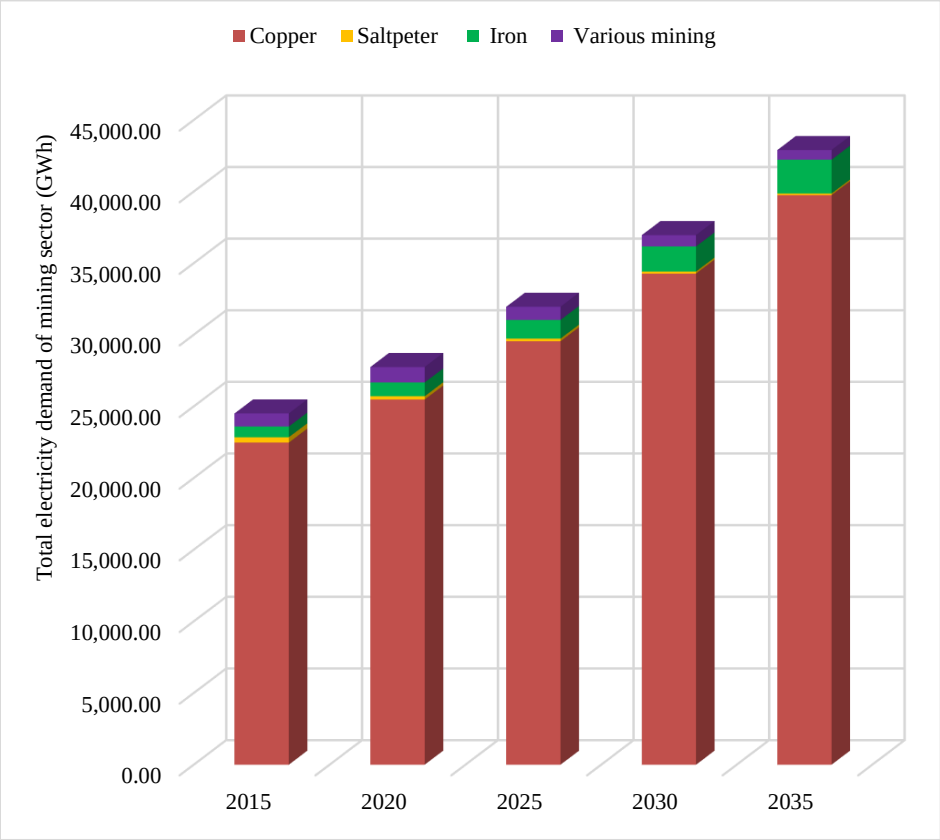

Fig. 6: Total electricity demand forecasting for mining sector until 2035

3.4. The Comparative Analysis of Energy Policy Instruments to Promote Renewable Energy

The energy demand of mining industry by 2035 will almost double in 20 years and is expected to reach 405.12 PJ. The major energy demand share in mining sector belongs to the copper sector with 78.9%, and it will reach 330.46 PJ. Electricity has the most significant share with 51.9% in copper energy demand between all fuels, and it is followed by diesel (41.8%), natural gas (3.6%), and oil (2.3%), accordingly.

When the business as usual scenario is considered for Chile, fossil fuel dependency will continue increasingly. Therefore, Chile should promote renewable energy to reduce the dependency of fossil fuels in the mining sector and to fight against climate change worldwide. Political and scientific committees agree that renewable energy has to perform an essential role in the pathway to a low-carbon economy (Löschel and Zew, 2012). Besides developed countries like Germany, Spain, and the United States, developing countries such as India and China have recently started to significantly support renewable energy (Thapar et al., 2016).

In different studies, various classifications can be found for energy policy instruments (Benitez, 2012; IRENA, 2012; Oikonomou and Jepma, 2008; Park, 2006; Perrels, 2001; Regulation Body of Knowledge, n.d.; Thapar et al., 2016; Warbroek, 2013). The key energy policy instruments used worldwide in support of the deployment of renewable power are these: fiscal incentives, public finance, and regulations as shown in Table 2 (Benitez, 2012; Elizondo Azuela and Barroso, 2011; IRENA, 2012; Thapar et al., 2016).

FITs, tax incentives, and tradable green certificates are support mechanisms commonly used by governments to promote renewable energy (Abolhosseini and Heshmati, 2014; Thapar et al., 2016). FITs, quotas, tendering, and tax measures are especially being utilized by European countries to increase the share of electricity produced from renewable energy sources (Löschel and Zew, 2012; Ragwitz et al., 2006). However, it has been shown that although FITs are more effective (Warbroek, 2013), they can be relatively expensive when compared to quota mechanisms (Elizondo Azuela and Barroso, 2011). Further, renewable energy deployment

has accelerated considerably in various Latin America countries such as Mexico, Chile, and Brazil (IRENA, 2015a).

In contrast to the EU countries, Chile is one of the countries that have been successful in the promotion of renewable electricity production without fiscal incentives or FITs. The development of renewable energy capacity in Chile without any incentives is remarkable. As presented in Table 2, Chile currently has a renewable energy target, quota obligation, auctions, net metering, certificate system, and grid access, as well as some fiscal incentives for rural areas in electricity production (IRENA, 2015a, 2015b). Chile has a new long-term target, which was set in Energy 2050 study (Ministerio de Energía, 2015b): at least 70% of the electricity generated in Chile will come from renewable energy sources by 2050. Based on its targets, Chile has a quota obligation as the main policy instrument. In the Chilean Renewable Energy Law signed in 2013 (Ministerio de Economía, 2013), renewable energy quotas were defined as 12% in 2020, 18% in 2024, and 20% in 2025 (excluding large hydro). Auctions for electricity production are another important support mechanism for Chile. They allow all types of renewable energy generators to have 10-year power purchase agreements with distribution companies. Also, Chile uses net metering, which permits consumers to produce their own electricity from renewable energy sources and inject extra generation into the grid. Additionally, the current law allows renewable energy generators under 9 MW to be exempt from grid access fees. Moreover, Chile provides technology-specific support and regulations especially for biomass, geothermal (exploration and exploitation of resources), concentrated solar power, solar roof application, and small hydro (IRENA, 2015b, 2015a).

Tab. 2. Energy policy instruments used in the world and in Chile to promote renewable energy

Energy policy instruments used in the world to promote renewable energy	Energy policy instruments status quo in Chile	Instruments to consider for energy sectors
Fiscal incentives • Grants • Energy production payments • Rebates • Tax credits • Tax concessions/exemptions	• Renewable energy target • Quota obligation • Auctions • Net metering • Certificate system • Priority grid access • Fiscal incentives for rural areas in electricity production • Carbon tax • Subsidies for disaster-affected regions • Tax-exempt fiscal incentives for biodiesel and bioethanol • Regulations for mixing bioethanol and biodiesel • Direct support for electricity access in rural and indigenous regions and agriculture	**Mining and Industry:** o Priority or guaranteed access to networks o Priority dispatch o Tax credits o Production-based incentives o Soft loans
Public finance • Investments • Guarantees • Loans • Public procurement		
Regulations • Renewable portfolio standards • Quota obligations or mandates • Auctions • Tendering, bidding • Feed-in-tariffs (FITs) • Premium payment FITs • Green energy purchasing • Green labelling, net metering • Priority or guaranteed access to networks • Priority dispatch		

As mentioned above, Table 2 summarizes the comparison of energy policy instruments used in the world and in Chile to promote renewable energy. In order to encourage renewable energy usage in mining and industry sector, Chile should consider priority or guaranteed access to networks, priority dispatch, tax credits, production-based incentives and soft loans.

4. Conclusion

Chile mostly depends on imports for its domestic energy supply, almost 65% in the most recent years, although it has noteworthy renewable energy potential for sources. Based on the latest targets, the share of RE in electricity generation is expected to grow from 15% in 2015 to 65% in 2035 (Ministry of Energy, 2015). In order to meet these national and international goals, Chile should analyze its energy and electricity demand in several sectors, especially for mining sector due to having a significant share in the GDP.

This study has investigated the energy and electricity demand for the mining sector by 2035 for Chile and required energy policy instruments to promote renewable energy to meet the increased demand in the mining industry. The main findings of the research are as follows: the energy demand of the mining industry by 2035 will almost double in 20 years and is expected to reach 405.12 PJ. The most important energy demand share in mining sector belongs to the copper sector with 78.9%, and it will reach 330.46 PJ. Electricity has the most significant share with 51.9% in copper energy demand between all fuels, and it is followed by diesel (41.8%), natural gas (3.6%), and oil (2.3%), accordingly. When energy policy instruments used in the world and Chile are compared to promote renewable energy, Chile has implemented some of them successfully, particularly renewable electricity production without fiscal incentives or FITs. However, Chile should also consider the following obligatory regulations in the future: priority or guaranteed access to networks, priority dispatch, tax credits, production-based incentives and soft loans.

Further studies are planned to investigate alternative scenarios to meet the calculated demands with renewable energy sources for the mining sector in Chile. Finally, the research in this paper can support the provision of particular recommendations and insights for energy researchers working on long term energy demand forecasting of developing countries.

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