Open Access

Advances in Environmental and Engineering Research

LIDSEN Publishing Inc.

Original Research

Impact of COVID-19 on Chile's Energy Transition Policies and Goals

José Nieto [1, †, *], Carmen Vasquez [1, †], Rubén Acevedo [1, †], Rodrigo Ramírez-Pisco [2, †], Luís Manuel-Navas [3, †], Mercedes Gaitan-Angulo [4], Melva Inés Gómez-Caicedo [5], Catalina Altamar-Cuervo [4]

1. Universidad Nacional Experimental Politécnica Antonio José de Sucre, Av. Corpahuaico con Av. La Salle, Parque Tecnológico, Barquisimeto, Venezuela; E-Mails: josemnietoc@gmail.com; cvasquez@unexpo.edu.ve; ruben.a.acevedo@gmail.com
2. Universitat Carlemany, Andorra, Andorra; E-Mail: rramirez@univertatcarlemany.com
3. University of Valladolid, Valladolid, Spain; E-Mail: luismanuel.navas@uva.es
4. Business School, Konrad Lorenz University Foundation, Bogotá, 110111, Colombia; E-Mails: mercedes.gaitana@konradlorenz.edu.co; catalina.altamarc@konradlorenz.edu.co
5. Fundación Universitaria Los Libertadores, Bogotá, 110111, Colombia; E-Mail: migomezc@libertadores.edu.co

† These authors contributed equally to this work.

* **Correspondence:** José Nieto; E-Mail: josemnietoc@gmail.com

Academic Editor: Zed Rengel

Special Issue: Energy – Urban Planning and Sustainable Development

Adv Environ Eng Res
2022, volume 3, issue 4
doi:10.21926/aeer.2204041

Received: June 16, 2022
Accepted: October 04, 2022
Published: October 13, 2022

Abstract

Because of climate change, greenhouse gas (GHG) emissions have increased, leading to the implementation of energy transition policies. Countries have adopted the Paris Agreement to curb the effects of climate change. The emergence of COVID-19 in 2020 led to the application of different measures to stop its transmission. This study evaluated the effects of COVID-19-related restrictions (such as quarantine and mobility restriction) in Chile during the first wave on compliance with the country's energy transition policies and the goals toward a decarbonized energy matrix by 2050. For this, the main GHG contributors were evaluated.

According to updated Chile's fourth biennial climate change report, the main GHG contributor is the energy sector (during the generation and transportation of electricity). In addition, the country's economic growth during the same period was evaluated by analyzing the quarterly GDP data presented by the Central Bank of Chile. The results indicated a decrease in GHG emissions compared with the same period of the previous 2 years. Because the energy sector contributes 77% of emissions, the fulfillment of the established goals is possible by targeting this sector. However, the COVID-19-related restrictions slowed down the country's economy, as indicated by the significant decreases in quarterly GDP during the study period.

Keywords

COVID-19; climate change; Paris Agreement; greenhouse gases; Chile's energy matrix; energy transition; Energy in 2050

1. Introduction

In recent decades, greenhouse gas (GHG) emissions have been the major cause of global warming and climate change due to anthropogenic activities. Therefore, to reduce these emissions and curb global warming, several countries have signed the recent Paris Agreement (2015), with Chile being one of its signatories. Various factors intervening in these goals have been analyzed, leading to the implementation of National Energy Policy 2050 Chile [1].

The emergence of the SARS-COV-2 pandemic, later known as COVID-19, in 2019 led to a series of social distancing measures to reduce the number of infections and deaths. Chile also implemented measures to limit the contagion, one of the most stringent ones being mandatory quarantine. These measures impacted energy consumption and, in turn, the energy sector, which is one of the main sources of GHG emissions.

The measures to limit the spread of COVID-19 continue even after 1 year of initiation. Similar phenomena can occur in the future, thereby giving rise to a new work dynamic, impacting the energy sector, and reducing GHG emissions worldwide [2]. Therefore, this study evaluated the impact and contribution of COVID-19 on the achievement of the objectives set by Chile. This would facilitate the analysis of COVID-19's impact at a global level and the achievement of sustainable development.

2. Description of the Research Site

2.1 Geographical Profile of Chile

The contextualization of this research requires describing the country in which it was performed; this would facilitate the extrapolation of the study results to other geographical locations. According to the 2017 census, Chile is a unitary Republic with a population of 17,574,003 people, distributed mostly (62.4%) in the Metropolitan Region (40.5%), Biobío (11.6%), and Valparaíso (11.6%) that has a total area of 2,006,096 km^2 [3].

Chile's economy is mostly dependent on mining; moreover, it is open (favors trade and investment) and stable. According to the 2019 statistics, a major part of the country's imports

(52.2%) are for the mining sector, followed by intermediate goods (49.6%). Moreover, in 2019, an increase in most economic activities was noted, with services and trade being the largest contributors to gross domestic product (GDP) [4].

2.2 Description of Chile's National Electric System

Chile has three independent sources of electric power. The National Electric System (SEN) is the major system and is constituted by the Central Interconnected System (SIC) and the Great North Interconnected System (SING). With an installed capacity of 25,817 MW as of August 2021, SEN represents 99.3% of the country's total installed capacity. The other smaller systems are the Aysen Electric System (SEA) and the Magallanes Electric System (SEM), with capacities of 67.43 MW and 107.39 MW, respectively. Moreover, SEA and SEM represent 0.3% and 0.4% of the total installed capacity [5, 6]. Figure 1 displays this distribution.

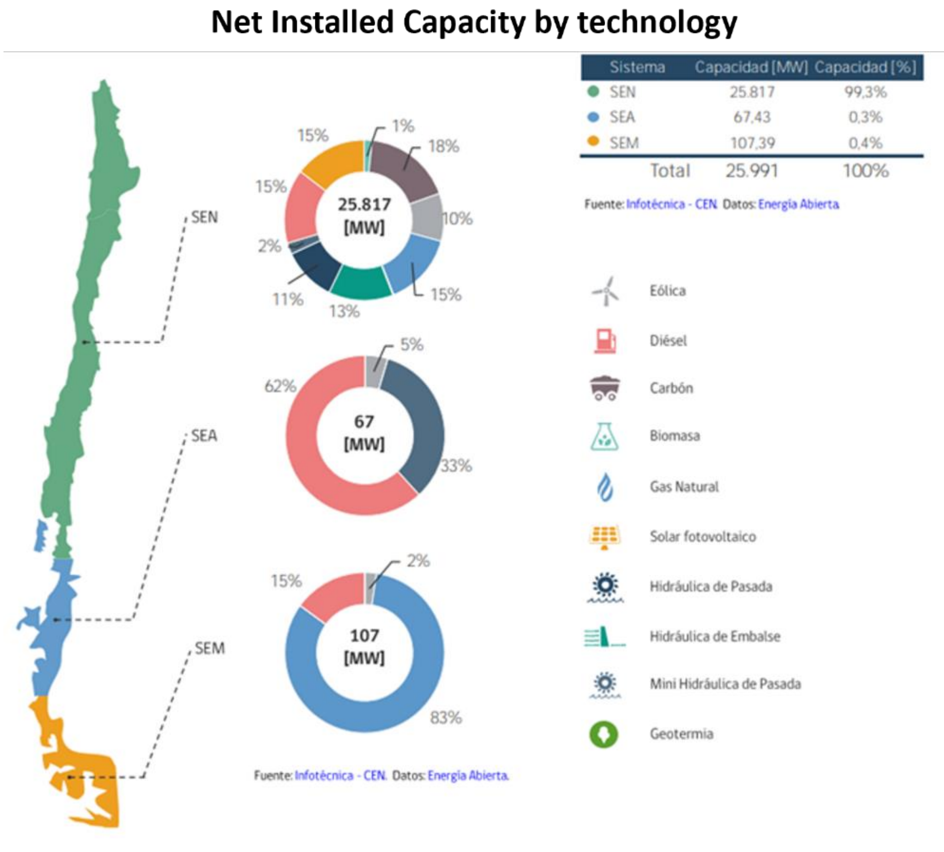

Figure 1 Net Installed Capacity by technology for 2021 [5].

2.3 COVID-19 and Its Impact on Chile's Energy Matrix

The first confirmed COVID-19 case in Chile was on March 03, 2020. Because of the high transmission rate, Chile adopted measures to stop or slow the transmission. These measures include social distancing; closure of schools, churches, shopping centers, and other institutions; isolation and confinement of suspected and confirmed cases; curfews; mandatory quarantine in communities with a high number of confirmed cases, and mandatory use of masks [7]. These measures affected various areas of daily life, with the energy sector being no exception. This is because the operation of cities in these conditions requires a reliable supply of electrical energy.

This COVID-19 scenario highlights the importance of analyzing the factors in each country. The economic, social, political, and geographical factors influence the implementation of policies to achieve the energy transition. In other words, the novel habits developed in the use of energy and available resources during the pandemic will continue after the pandemic subsides [8].

3. Results

3.1 Determination of the Study Period

The research focused on the impact of COVID-19 on Chile's energy transition politics and goals; therefore, the evaluation period was chosen as the stage exhibiting the most outstanding features of the pandemic and the measures implemented to control it, such as social isolation, mandatory quarantine, or measures that were implemented during the initial stage of the pandemic. The pandemic began in December 2019 in Wuhan, China, and was declared a global pandemic on March 11, 2020 [9].

Because the first confirmed case in Chile was on March 03, 2020, the study period began on March 2020. During this period, the cases began to increase, leading to the implementation of mandatory measures to restrict mobility in the government.

On July 19, 2020, the Chilean government presented the 5-phase plan to overcome the COVID-19 pandemic. The plan ranged from quarantine implementation to early opening, under which the measures were applied particularly in the regions and/or communes on the basis of epidemiological indicators, the capacity of the health-care network, testing, traceability, determination of the health authority, and the change of stage for each commune. The first vaccine arrived in Chile on December 24, 2020, and was mainly used to vaccinate health personnel. Subsequently, on December 31, 2020, a new shipment of vaccines arrived, and in January 2021, announcements were made, and the massive phase of the vaccination plan began. However, despite the advances in this vaccination process, the increase in the positivity rate of infection has not been eliminated. In many communities where the measures were relaxed, stringent measures were reinforced due to the continuous increase in cases. The new waves of infections are even higher than the initial ones, as displayed in Figure 2 [10].

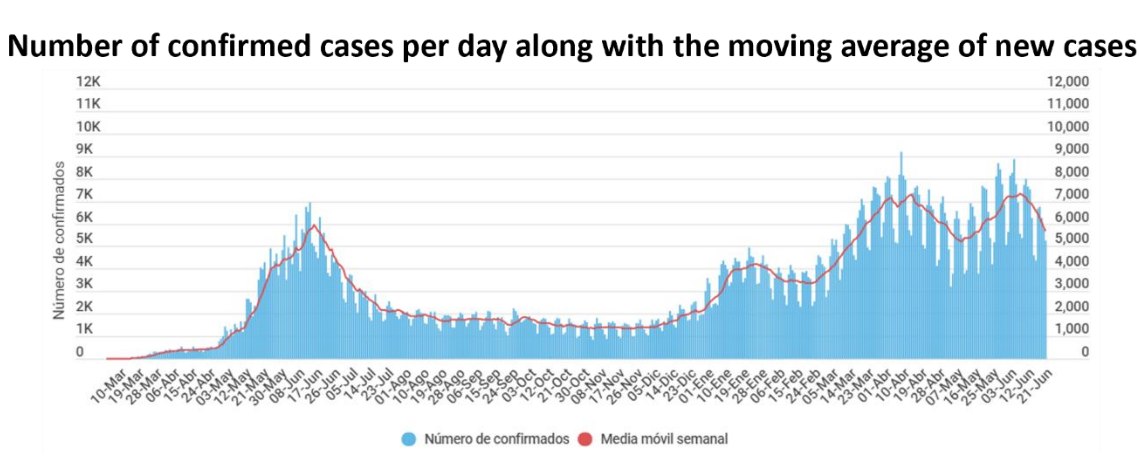

Figure 2 Number of confirmed cases per day from March 2020 to June 2021 [11].

The first maximum number of infections was reported between May and June; therefore, these months were considered in the analysis (Figure 2). The number of infections stabilized between mid-August and early September, indicating that the measures were effective. This marked the end of the study period.

The study period was between March 2020 and September 2021, with infections peaking in mid-June. To depict this behavior, a graph was constructed using data from official figures published by the Government of Chile (Figure 3) [10].

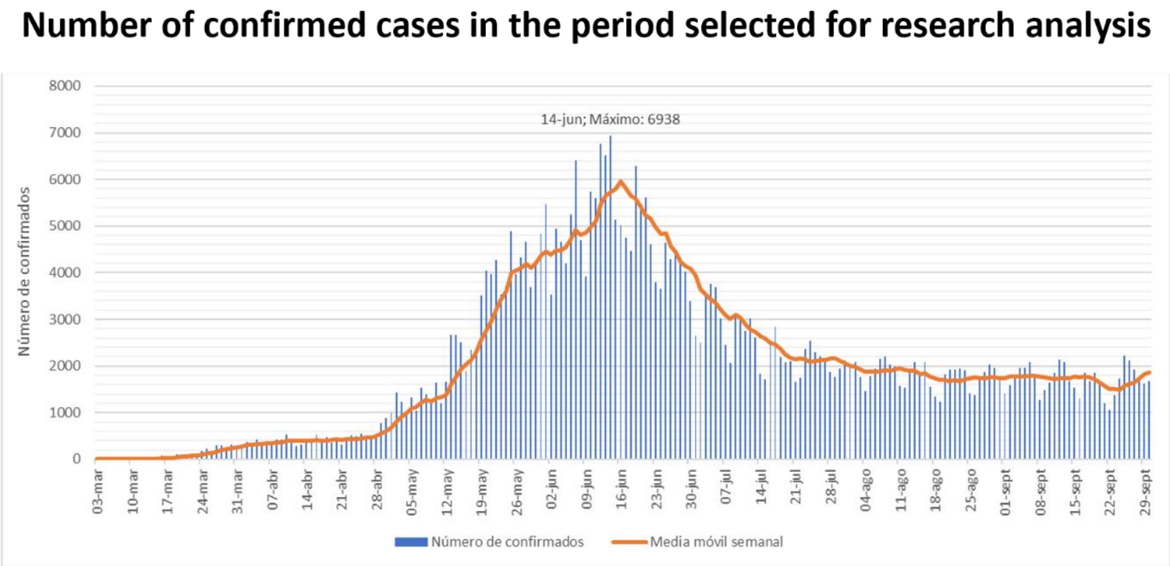

Figure 3 Number of confirmed cases between March 2020 and September 2021. Source: Prepared by the authors on the basis of data from the Government of Chile [11].

3.2 Selection of Indicators to Be Analyzed

To understand the past trends in the energy sector and GHG emission and relate it to the impact of COVID-19, it is necessary to evaluate energy generation and compare it with a similar period in the past years. This will enable the determination of variation in energy consumption expected for that period. To evaluate the changes in the transport sector, the number of annual circulation permits during the year was determined. Moreover, the types of vehicle engines during the study period were compared to that of previous years.

Data from the National Inventory of Greenhouse Gases (INGEI) [4] were evaluated to determine the contribution of the studied sectors (generation and transportation) to GHG emissions. To perform an objective evaluation of the impact, the country's GDP must be considered. This enabled determining whether Chile's development during the investigation period was in line with expectations or whether there were factors influencing the results.

3.3 Analysis of the Energy Matrix Before the Study Period

On the basis of the 2018 National Institute of Statistics (INE) report on the environment, the most recent energy matrix has been quantified in Figure 4.

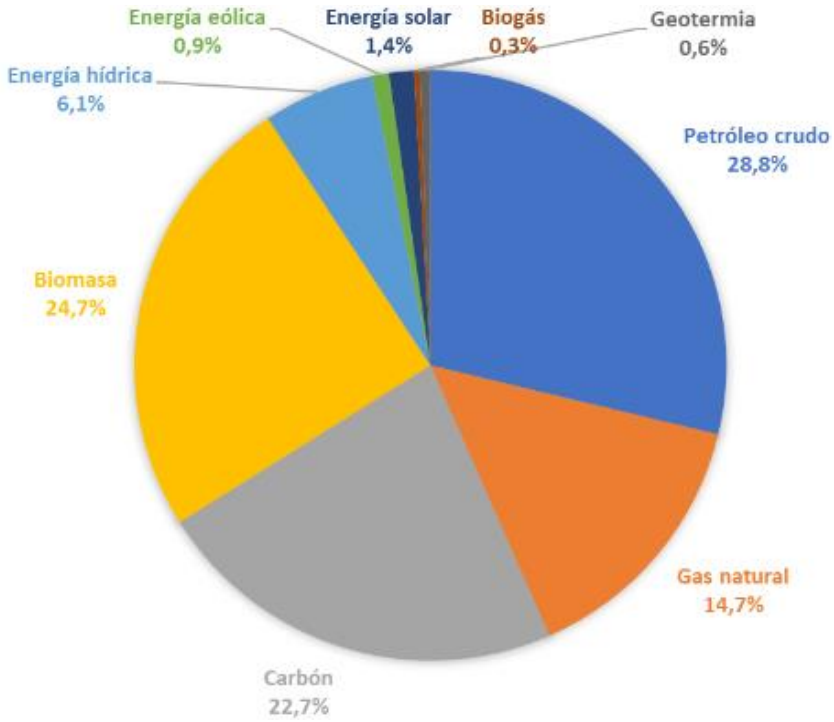

Figure 4 Primary energy matrix 2018 [12].

According to the energy matrix, fossil fuels are the major source of energy. Nonconventional renewable energies (NCRE) are a recent entry and have contributed to the decarbonization of this matrix. NCRE must continue to grow to achieve the goals proposed by Chile in its Energy 2050 program [1].

3.4 Changes in the Generation Sector due to the Impact of COVID-19

To evaluate the changes in the energy matrix, the monthly energy generation of the study year and the two previous years (during March–September) were compared. To evaluate whether the projections based on previous years are met or whether there is any significant variation, total energy during the previous years were compared with their respective projection (Table 1). Figure 5 displays data obtained from the CEN's monthly energy reports [13].

Table 1 Total energy and projection by study period. Source: Own elaboration based on CEN energy reports [13].

Total energy and projection for the period (GWh)							
2018	2019	2020 Projected	2020 Real	Delta Expected	Delta Real	Delta Diff.	Diff. Percentage of Delta (%)
44.799	45.261	45.723	45.066	462	-195	-657	-142%

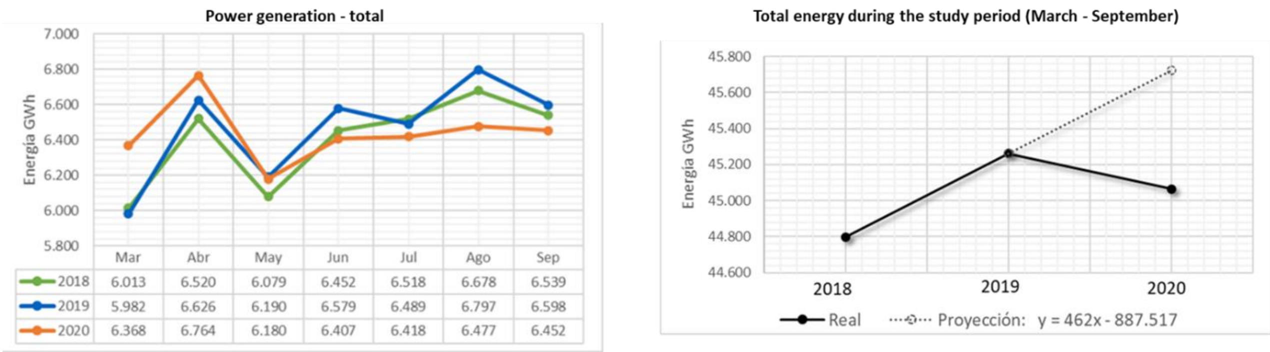

Figure 5 Total monthly (left) and total projected (right) power generation during the study period. Source: Own elaboration based on CEN energy reports [13].

At the beginning of the pandemic, energy generation increased. However, in May, it dropped to values below those of 2019, and from June onward, energy generation fell below even those obtained in 2018.

Table 1 and Figure 5 display the expected energy generation in the absence of the pandemic. A growth of 462 GWh was expected for the same period in 2020. However, energy generation decreased by 657 GWh, which represents a drop of 142% with respect to the expected growth. This indicates that energy consumption significantly reduced during the first COVID-19 wave. However, each energy source used in these periods must be thoroughly evaluated. Although consumption was affected by a decrease in the total energy, the energy generation sources must be evaluated. Table 2 displays the total energy consumption for the study period for each energy source and their respective projections. The trends can be verified in Figure 6 to Figure 13, reflecting a period from 2018 to 2020, during the study months. Both the monthly details and the expected projection are provided.

Table 2 Total energy and projection by study period. Source: Own elaboration based on CEN energy reports [13].

Total energy for the period		2018 (GWh)	2019 (GWh)	2020 Projected (GWh)	2020 Real (GWh)	Delta Expected (GWh)	Delta Real (GWh)	Delta Diff. (GWh)	Diff. Percentage of Delta (%)
Geothermal	G			130					144%
Solar	S	2.604	3.086	3.568	3.674	482	588	106	22%
Wind	E	2.044	2.591	3.138	2.912	547	321	-226	-41%
Diesel Oil	P	324	258	192	515	-66	257	323	489%
Natural Gas	GN	8.340	9.586	10.832	10.084	1.246	498	-748	-60%
Coal	C	18.288	17.097	15.906	16.689	-1.191	-408	783	66%
Other Thermal	OT	1.650	1.492	1.334	1.393	-158	-99	59	37%
Water	H	11.437	11.030	10.623	9.656	-407	-1.374	-967	-238%
Total		**44.799**	**45.261**	**45.723**	**45.066**	**462**	**-195**	**-657**	**-142%**

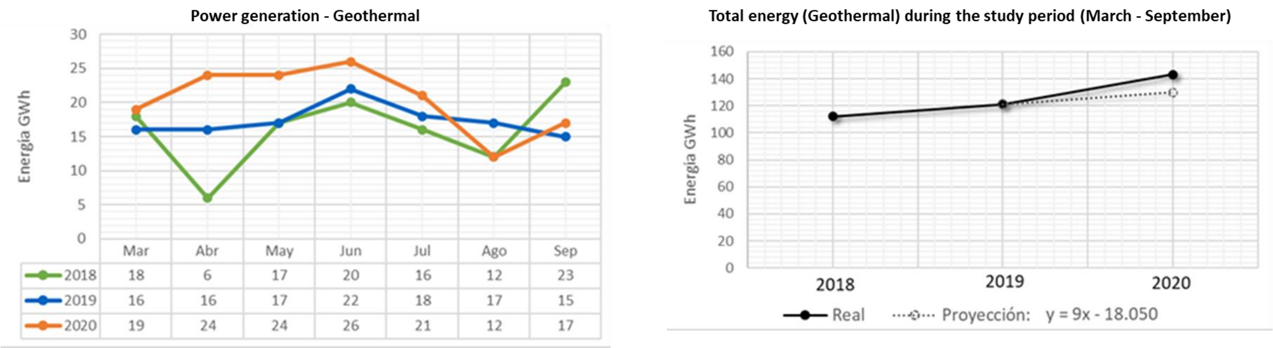

Figure 6 Monthly (left) and yearly projected (right) geothermal energy generation during the study period. Source: Own elaboration based on CEN energy reports [13].

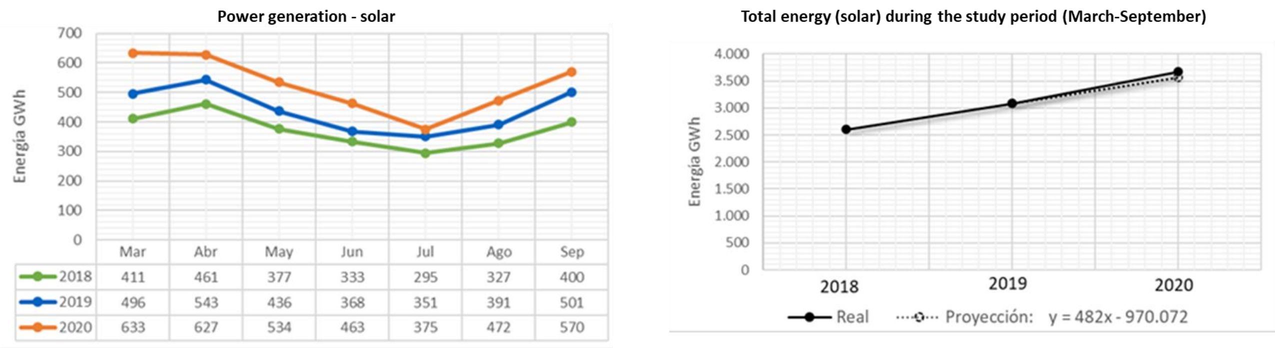

Figure 7 Monthly (left) and yearly projected (right) solar energy generated during the study period. Source: Own elaboration based on CEN energy reports [13].

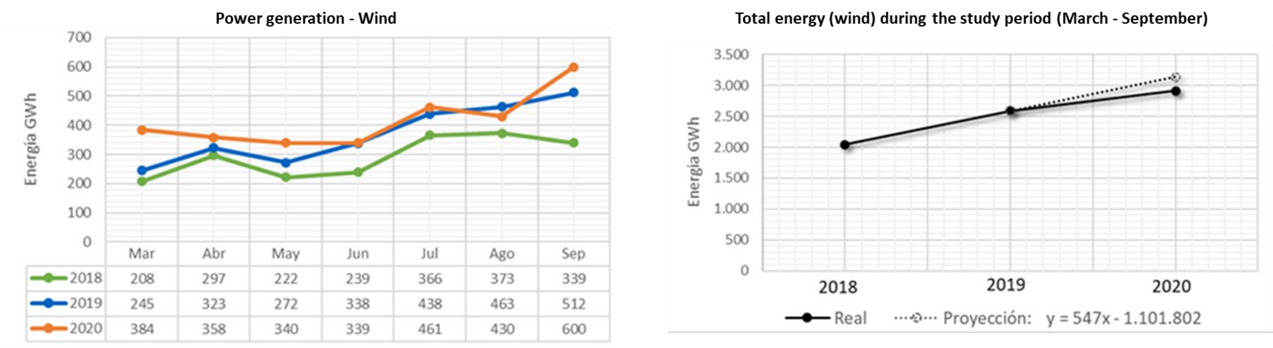

Figure 8 Monthly (left) and yearly projected (right) wind power generation during the study period. Source: Own elaboration based on CEN energy reports [13].

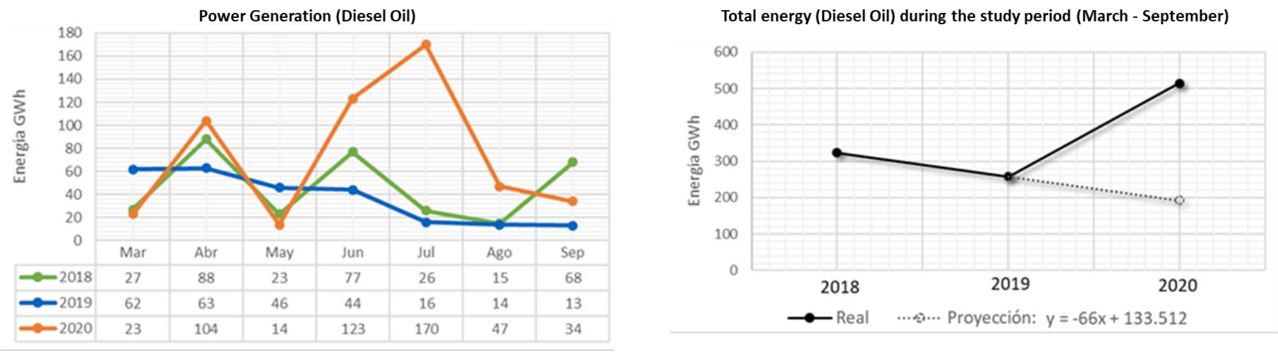

Figure 9 Monthly (left) and yearly (right) diesel power generation (right) during the study period. Source: Own elaboration based on CEN energy reports [13].

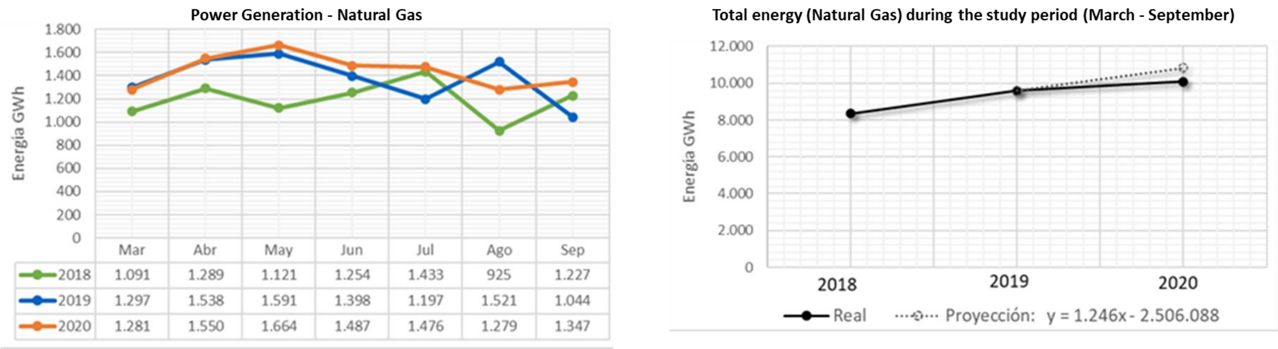

Figure 10 Monthly (left) and yearly (right) natural gas power generation during the study period. Source: Own elaboration based on CEN energy reports [13].

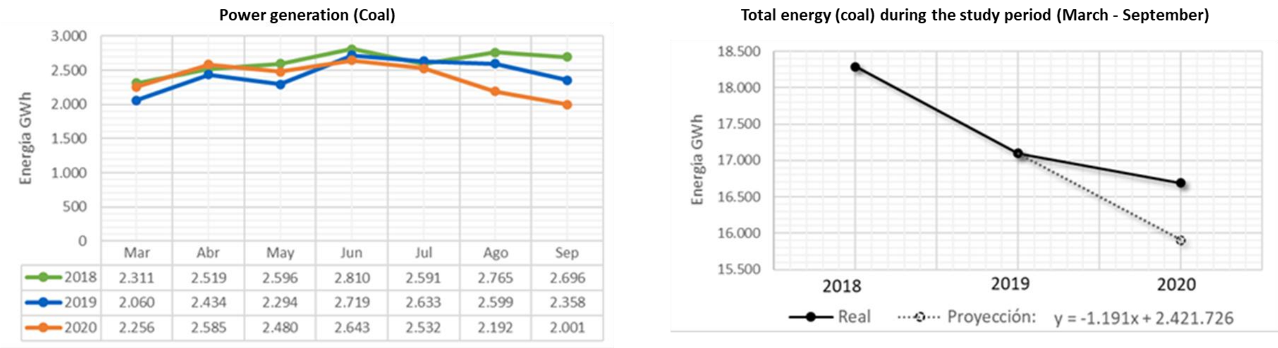

Figure 11 Monthly (left) and yearly (right) coal power generation during the study period. Source: Own elaboration based on CEN energy reports [13].

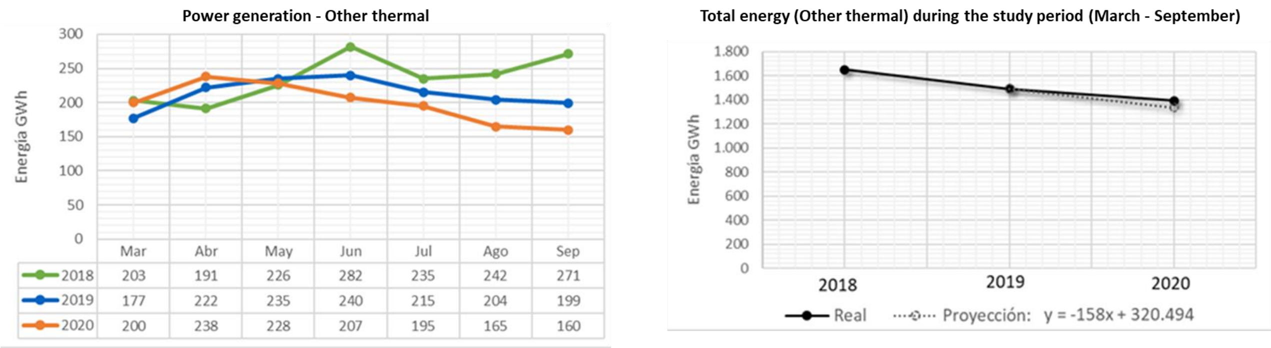

Figure 12 Monthly (left) and yearly (right) other than thermal power during the study period. Source: Own elaboration based on CEN energy reports [13].

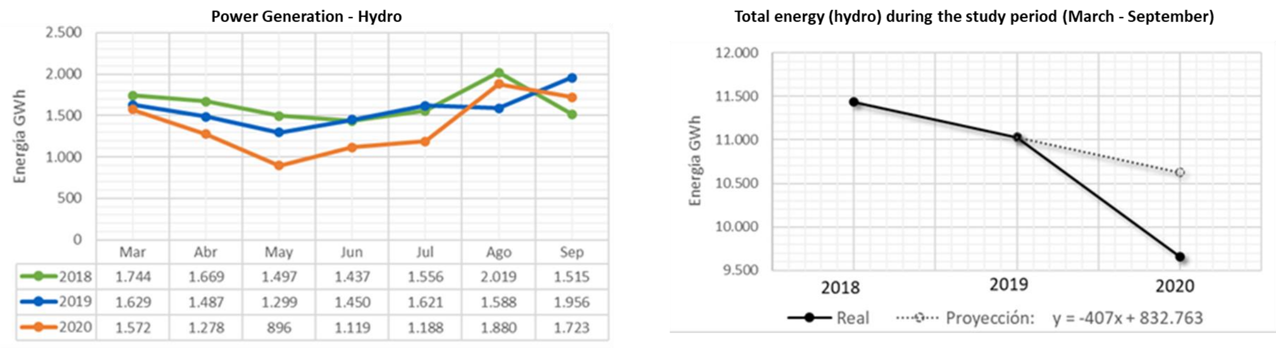

Figure 13 Monthly and yearly hydropower during the study period. Source: Own elaboration based on CEN energy reports [13].

The results presented in Table 2 and Figures 6 to 13 indicate different trends for the various energy sources, with geothermal energy exhibiting one of the largest percentage increases, i.e., 144% above the expected value. However, geothermal energy contributed the least to the system, with only 143 GWh in December 2020.

Increased contributions of nonconventional renewable energies, i.e., solar and wind energy, were observed in the same period of previous years; therefore, this sector was favored for energy contributions to the interconnected system. The analysis of total energy generated in the study period revealed that solar energy increased by 22% with respect to the expected projection for 2020. Wind energy maintained its growth; however, the growth fell short of the projected value by 41%.

Energy from diesel oil represented the highest percentage increase in 3 months (the study period); however, it was the second energy that contributed the least to the system, surpassing only geothermal energy. Therefore, compared with the remaining types of energy, these two energies contributed the least to the system.

Although natural gas is a source of GHG emissions, its efficiency is much higher than that of coal and plays an important role in the energy transition. As observed in the graph, it managed to maintain an increase, although lower by 60% than the projected value based on the values in 2018 and 2019. During the study period, it provided the second-largest energy contribution to the national electricity system.

Energy generation from coal exhibited a decrease throughout the study period, with the value being lower than that in 2018 and 2019. However, considering that there was a decrease between these two years, it was foreseeable that energy generation could decrease to the same extent. The actual value, however, remained 60% above the projected value. A similar trend was observed in energy generation from other thermal sources, which also fell below that in both years. However, the actual value was 37% above the projected value.

Hydro generation presented the most appreciable decrease in absolute energy values, with the decrease in the study period being lower than that in 2018. The actual value was lower by 238% than the expected value. However, Chile faced drought in recent years, which is directly reflected in the values. According to the annual report of the Meteorological Directorate of Chile, rainfall exhibited a decrease in most parts of the national territory and was characterized by accumulated precipitation deficits [14].

3.5 Changes in the Transport Sector

Data on the automotive sector for the selected period could not be obtained. However, to determine any substantial changes in the use of vehicles during the pandemic years (due to the mobility restrictions), the INE annual report will be evaluated from 2015 (which coincides with the date of the Paris Agreement) to 2020.

The data obtained from the INE database [15] are referenced to the circulation permits granted by the different municipalities of the country. It was divided into three main groups according to vehicle use (Table 3). The projected trend obtained based on the existing value in 2019 was compared with the existing trend. The graphs reflecting the trends in the use of each transport are displayed in Figures 14 to 17.

Table 3 Number of vehicles in circulation and the projected number of vehicles in circulation according to their use. Source: Own elaboration based on the INE database [15].

Use and Type of Transport	2019	2020 Project.	2020 Real	Delta Expected	Delta Real	Diff. Of Delta	Diff. % Delta (%) Delta (%)
Private, Others: Car, Station Wagon, and Off-Road, Van, Minibus, Pickup, Motorcycle and Similar, Others with Engine and without Engine (motor home (up to 1,750 kg), tow truck (up to 1,750 kg) and others).	5.186.521	5.421.626	5.082.296	235.105	-104.225	-339.330	-144%
Cargo: Single Truck, Tractor-Trailer, Agricultural Tractor, Other with Engine, Trailer, and Semi-Trailer.	315.448	323.556	308.104	8.108	-7.344	-15.452	-191%
Collective: Basic Taxi, Collective Taxi, Tourist Taxi, Minibus, Collective Transport, Collective Transport Bus.	216.440	221.384	200.745	4.944	-15.695	-20.639	-417%
TOTAL	**5.718.409**	**5.966.567**	**5.591.145**	**248.158**	**-127.264**	**-375.422**	**-151%**

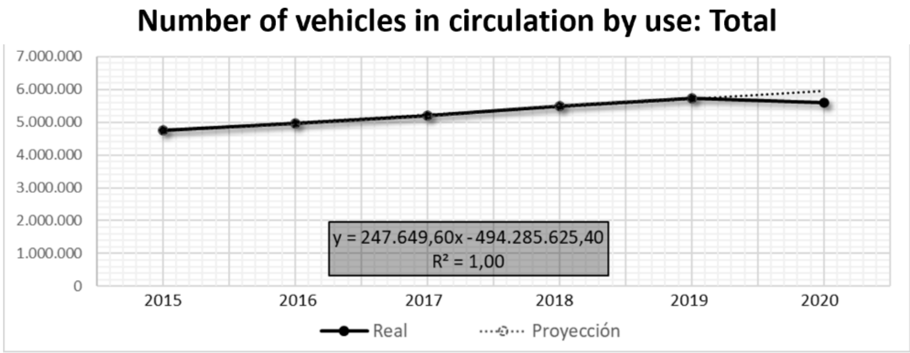

Figure 14 Number of vehicles (total, i.e., all types of vehicles) in circulation by use. Source: Own elaboration based on INE data [15].

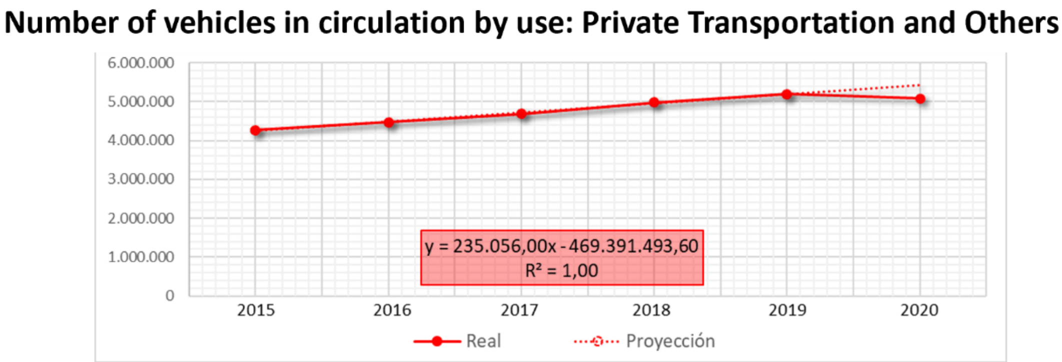

Figure 15 Number of vehicles (private transport and others) in circulation by use. Source: Own elaboration based on INE data [15].

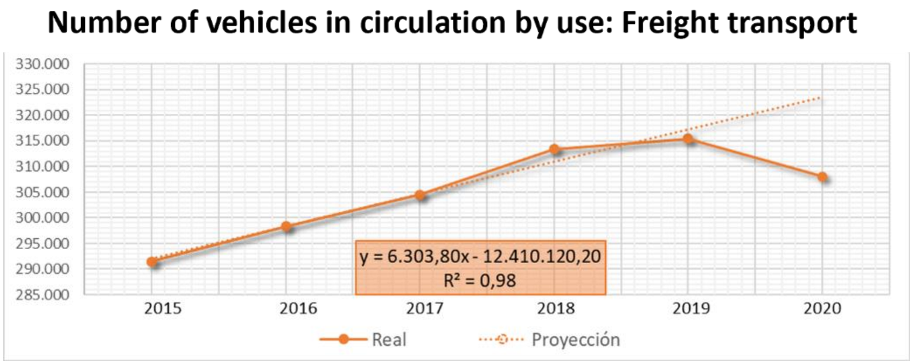

Figure 16 Number of vehicles (freight transport) in circulation by use. Source: Own elaboration based on INE data [15].

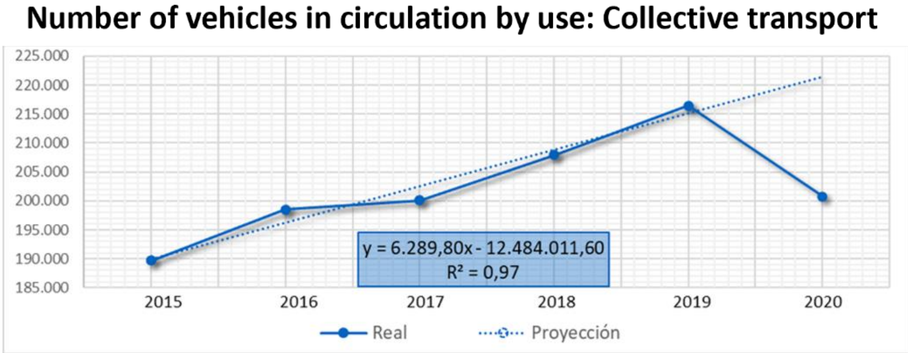

Figure 17 Number of vehicles (public transport) in circulation by use. Source: Own elaboration based on INE data [15].

According to the data in Table 3 and the graphs in Figures 14 to 17, in the years before the pandemic, all types of vehicles in circulation exhibited a progressive increase. In 2020, the number of vehicles in circulation was 151% less than the projected value, a coincident trend.

In 2020, the number of freight transport and collective transport vehicles in circulation was lower than the values in 2018, with a reduction of 191% and 41%, respectively, with respect to the estimated projection. Only the number of private and other transport vehicles was lower than those in 2019. However, in terms of the number of total vehicles, a decrease of 339,330 vehicles (141%) with respect to the projected value obtained based on the value in 2020 was observed.

Such declines (as in 2020) were not observed in any of the sectors before the pandemic. The private sector was the most affected in terms of quantity, whereas the freight sector had the highest percentage impact.

This behavior is attributable to the mobility restrictions implemented in 2020 due to COVID-19. These restrictions positively impacted GHG emissions because the number of vehicles with polluting engines in circulation exhibited a sharp decrease, as per the official figures obtained from the INE database [15].

According to the biennial report, by September 2020, 701 electric buses and 1,133 Euro VI buses were already in operation. These buses were partly financed by Chile's 2019 sovereign green bond that will finance an additional 212 electric buses in the last quarter of 2020 [4]. However, in 2020, the electric vehicle sector represented only 0.052% of the total number of vehicles in the country.

3.6 GHG Inventory and Indicator Comparison

The 2018 official report of the National Greenhouse Gas Inventory (INGEI) indicates that the country's total GHG emissions (excluding LULUCF) were 112,313 ktCO_2eq, an increase of 128% since 1990 and 2% since 2016.

The balance between GHG emissions and removals in the country (including the Land Use, Land Use Change, and Forestry sector [LULUCF]) amounted to 48,321 ktCO_2eq. The changes in these emissions over the years are presented in Table 4, and the respective graph is given as Figure 18.

Table 4 INGEI Chile: Balance data and total GHG emissions ($ktCO_2eq$) by sector, period 1990–2018 [4].

Sector	1990	2000	2010	2013	2016	2017	2018
1. Energy	33.631,40	51.746,40	66.607,70	79.901,30	86.191,00	86.896,10	86.954,30
2. IPPU	2.224,20	4.803,60	4.279,60	5.084,50	5.977,10	6.079,80	6.611,30
3. Agriculture	11.834,80	13.708,90	12.921,10	12.597,40	11.881,30	11.724,00	11.789,40
4. LULUCF	-60.152,60	-73.364,30	-76.966,40	-77.561,50	-74.697,90	-11.710,30	-63.991,90
5. Waste	1.519,00	2.742,60	4.133,60	5.095,10	6.106,60	6.515,70	6.957,60
Balance [1]	**-10.943,10**	**-362,9**	**10.975,60**	**25.116,90**	**35.458,20**	**99.505,30**	**48.320,70**
Total Emissions [2]	**49.209,50**	**73.001,40**	**87.942,10**	**102.678,40**	**110.156,00**	**111.215,60**	**112.312,60**

[1] Balance refers to the sum of GHG emissions and removals, expressed in CO_2 eq, including the LULUCF sector.

[2] Total Emissions refers only to the sum of GHG emissions, expressed in CO_2 eq, excluding emission sources and removals in the LULUCF sector.

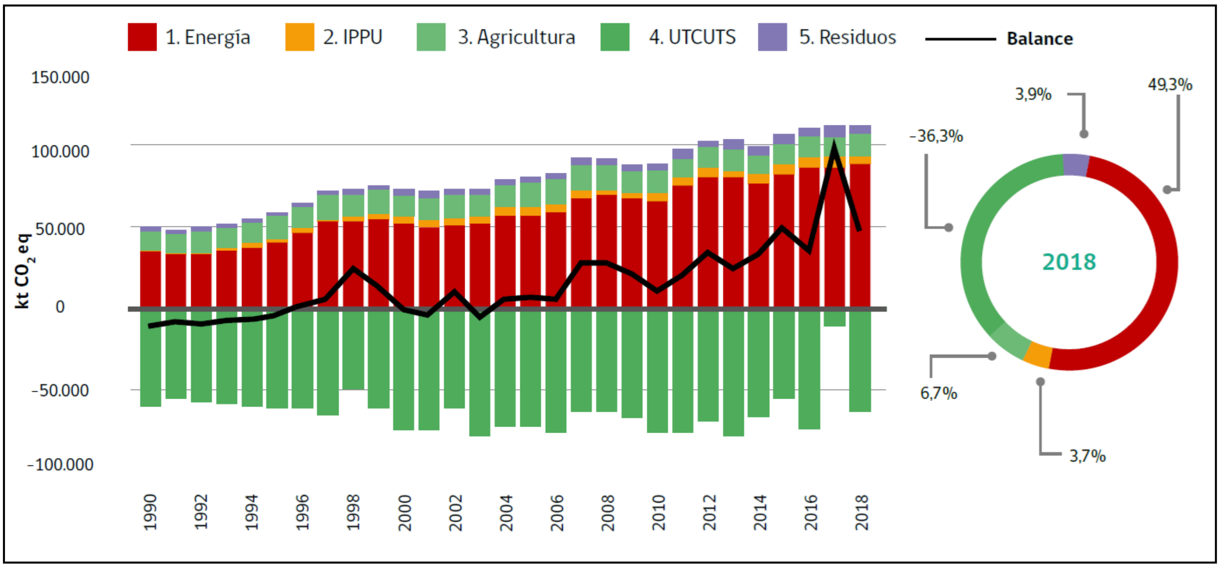

Figure 18 INGEI Chile: Behavior of total GHG balance and emissions (ktCO_2eq) by sector, period 1990–2018 [4].

As per Table 4 and Figure 18, the energy sector was the main GHG emitter, representing 77% of total emissions in 2018. The emissions were mainly contributed by the burning of coal and natural gas used for electricity generation and the use of liquid fuels for land transport.

According to the 2018 biennial report, the main subcategories of the energy sector are energy industries with a 39% share, transport with 33%, manufacturing and construction industries with 18%, and other sectors with 9%.

The LULUCF sector, which favors the environmental context due to GHG absorption, for 2018 accounted for –63,992 ktCO_2eq, mainly due to the use of biomass in native forest renewables and forest plantation. In 2017, a maximum emission of 570,000 ha was achieved due to forest fires, cultivation, and pastures [4].

The main contributor to GHG emissions, therefore, is the energy sector (77%), followed by the energy industry (39%) and transport (33%), respectively. The aforementioned sectors contributed to 72% of the GHG emissions, excluding only the subsectors of manufacturing and construction industries (18%) and others (9%). These can be intuited to have similar behavior to the one evaluated in the research because they depend directly on these two main contributors.

3.7 GDP as an Indicator for the Evaluation of the Country's Development

Trends in Chile's GDP during the study period must be determined to evaluate their linkage with the analyzed indicators. Table 5 below shows the GDP trends and their respective estimated projection. Figure 19 displays the annual GDP as per the data of the Central Bank of Chile [16].

Table 5 Chile's annual GDP and projection. Source: Prepared by the authors based on data from the Central Bank of Chile [16].

GDP projection (Billion pesos)						
2019	2020 Projected	2020 Real	Expected Delta	Delta Real	Delta Diff.	Diff. Percentage of Delta (%)
196.379	208.954	200.512	12.575	4.133	-8.442	-67%

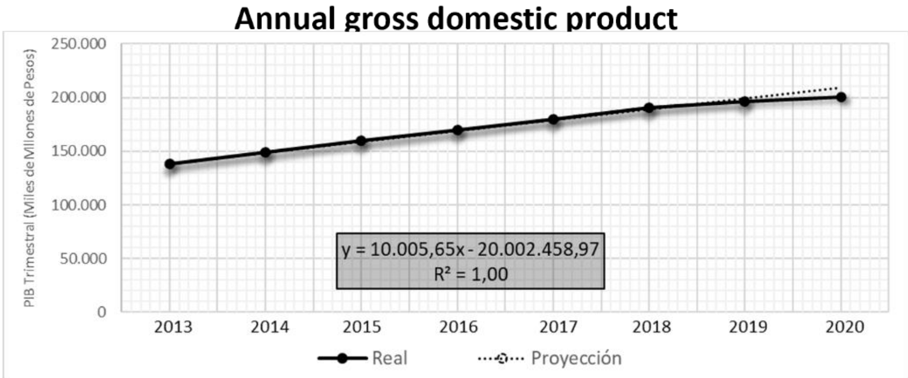

Figure 19 Annual GDP of Chile [16].

As per Figure 19, GDP growth is maintained throughout the entire period, with a deceleration of the slope in 2020 by 67% with respect to the projected value obtained based on previous years' data. However, the quarterly GDP, available in the database of the Central Bank of Chile, should be analyzed to determine the GDP trend during the study period. The data was framed in the two central quarters of the year and was compared with the indicator data of two previous years. Table 6 below shows the quarterly GDP since 2018, as well as the delta of the slopes between the quarters of each year. Figure 20 displays the graph according to the official figures of the Central Bank of Chile.

Table 6 Chile's quarterly GDP and quarterly growth delta. Source: Prepared by the authors based on data from the Central Bank of Chile [16].

Año	2018				2019				2020			
Trimestre	I	II	III	IV	I	II	III	IV	I	II	III	IV
PIB	47,124	47,287	45,635	50,781	48,688	48,772	47,677	51,261	51,062	45,941	47,546	55,963
Delta (MM peso/trimestre	163		5,146	-2,112	104	-1,095	3,584	-199	-5,121	1,605	8,416	

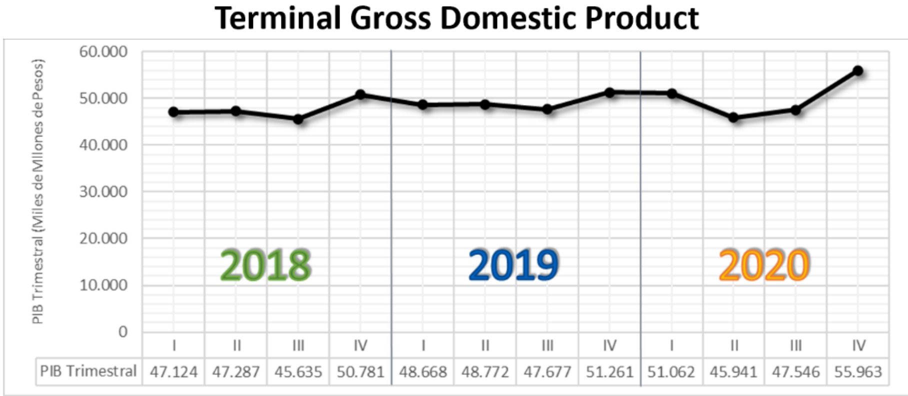

Figure 20 Chile quarterly GDP [16].

As a recall, the study period was defined as March 2020 to September 2021, which represents the entry and exit of the first wave of COVID-19 infections, with a peak in mid-June.

Considering the GDP as an indicator of the country's development, the initial period of the pandemic can be evaluated by analyzing the graph in Figure 20. The graph curve between the first and second quarter of each year indicates that both in 2018 and 2019, a positive trend in GDP, with 163 and 104 MM pesos, respectively, was observed. In 2020, an abrupt fall of 5,121 MM pesos was observed, which was close to the lowest index in the last 2 years.

Between the second and third quarters of 2018 and 2019, a decrease of 1,652 and 1,095 MM pesos, respectively, was observed. However, in 2020, an increase of 1,605 MM pesos with respect to the previous quarter was observed. The increase was below the year 2019; therefore, it does not represent normal growth but a slight recovery from the abrupt fall reflected between the first and second quarters.

The end of the first wave of COVID-19 was reflected in the change between the third and fourth quarters. During this period, the highest growth was forecast, with 5,146 MM pesos for 2018 and 3,584 MM pesos for 2019. The projected values were consistent with the actual value in 2020, with the highest slope compared to the previous 2 years and a value of 8.416 MM pesos. This compensated for the initial falls. A decelerated growth followed, which was directly linked to the beginning of the cessation of the quarantine-related restrictions due to the existing pandemic in the year.

This analysis indicated a direct relationship between the trends of the evaluated indicators and the quarterly GDP. These indicators revealed a decrease in GHG contributions in both energy generation and transport sectors; however, this, in turn, was correlated with the slow economic growth in that period.

4. Discussion

4.1 Impact of COVID-19 on the Country's Energy Policy Goals

The trends in the energy generation sector during the first wave of COVID-19 and the application of the corresponding measures revealed that energy consumption decreased 142% below the estimated projection based on the values in 2018 and 2019. Moreover, nonconventional renewable energy sources and gas-fired generation were prioritized, which will have a positive impact on the achievement of the GHG emission reduction targets.

In the transport sector, a decrease in the number of vehicles in circulation of up to 150% with respect to the estimated projection was observed. The decrease is mainly attributable to the measures adopted during the pandemic period, such as the mobility restriction. However, efforts in this sector should be increased because one of the analyses revealed a stagnation in the entry of electric cars into the vehicle fleet. Despite efforts such as those reflected in the biennial report of the National Electromobility Strategy and the entry of electric buses, these are insufficient for reducing GHG emissions in the country.

The remaining subsectors of the energy sector, i.e., manufacturing and construction industries, and others, will also have the same trend as the analyzed subsectors because of the direct dependence on the energy consumed and the requirement of transport to move the raw materials. Therefore, the 77% decrease in the energy sector will have a significant impact on the country's GHG inventory.

Finally, the analysis of quarterly GDP reflected a slowdown in economic growth during the study period. Thus, the measures to control the first wave of the pandemic led to a 61% decline in GDP. In future pandemics, the adoption of similar strict measures would decrease GHG emissions; however, there will be repercussions on the growth and development of the country.

4.2 Comparison of the Analyzed Situation of the Effect of the COVID-19 Pandemic with Projections of Meeting Energy Policy Targets Without Pandemic Considerations

The decarbonization plans set out in the Energy 2050 policy are in accordance with nationally determined contributions (NDCs), which is at the heart of the Paris Agreement. This, in turn, is validated by GHG reduction projection studies. For example, Loyola established the expected trends in electricity generation and transport by individually and jointly evaluating different scenarios. The graphs are presented in Figure 21 to Figure 23.

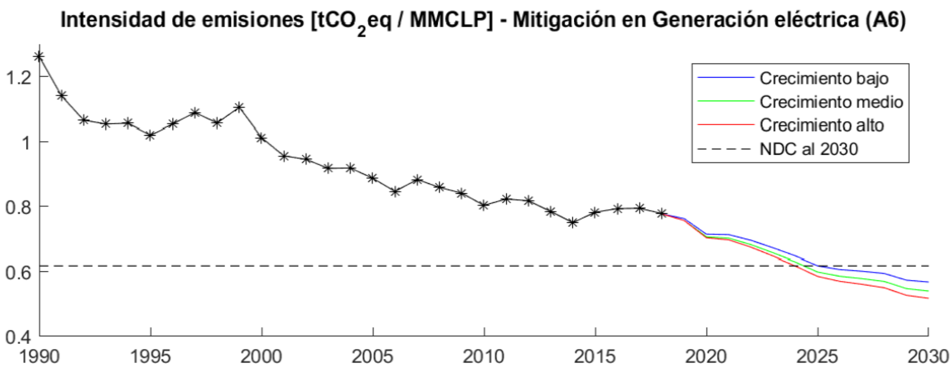

Figure 21 Assessment of the A6 mitigation scenario for electricity generation with respect to the NDC [17].

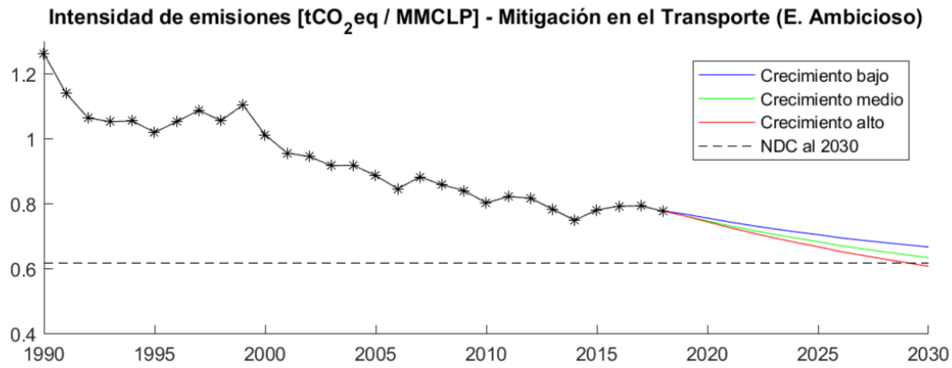

Figure 22 Assessment of the ambitious transport mitigation scenario with respect to the NDC [17].

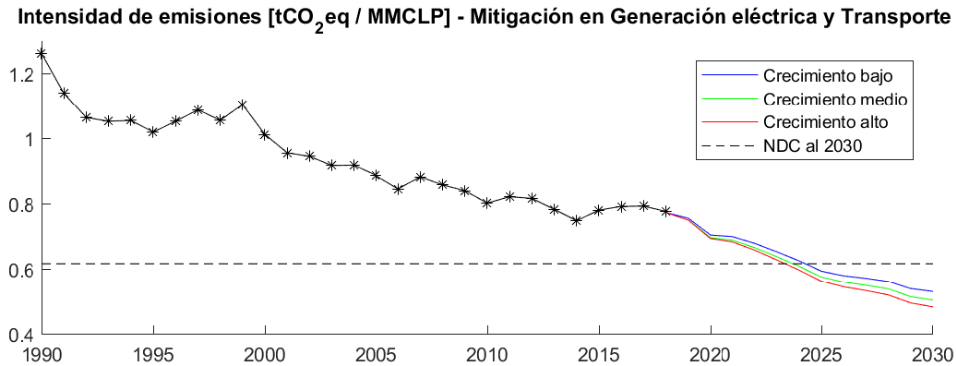

Figure 23 Assessment of the joint mitigation scenario in transport and power generation with respect to the NDC [17].

As per Figures 21 to 23, the projections were made under normal conditions, i.e., a non-pandemic scenario and the pandemic began in 2020. The results indicated the achievement of NDC targets. Regarding the electricity generation sector, target achievement is dependent on the fulfillment of the coal-fired power plant retirement program and does not depend on the country's GDP. Regarding the transport sector, the situation is slightly less favorable because only in a scenario of high growth would the targets be met by 2030. However, the combination of both cases produces a positive scenario that validates the achievement of the proposed objectives.

5. Conclusions

This study analyzed Chile's energy matrix and the main contributors to GHG emissions. Recently, Chile's biennial update report on climate change revealed that the energy sector was the highest contributor (77%).

The results observed in the study period indicated that trends in GDP, electricity generation, and transport could be extrapolated to the remaining energy sectors, i.e., manufacturing and construction. This is because of the direct relationship between the main sectors with these other subsectors. Therefore, a decrease in the major sectors would decrease GHG emissions.

If stringent measures, such as quarantine and mobility restriction, are implemented during the new waves of COVID-19, GHG emissions may reduce, as observed between March 2020 and September 2021; however, it will result in a slowdown in the country's economic growth.

Considering the update of the NDCs, the targets proposed in the Paris Agreement were expected to be met. According to scenarios presented in sector research, the impact of COVID-19 improved the projection. However, it is still critical to comply with the planned phaseout of coal plants by 2050. Moreover, a greater injection of resources is required to achieve the transition to electric vehicles.

Acknowledgments

The authors would like to thank the institutions Universidad Nacional Experimental Politécnica Antonio José de Sucre, Universitat Carlemany, Universidad de Valladolid, for their support in this research.

Author Contributions

Authors J. Nieto, C. Vásquez and R. Acevedo have contributions in all sections of the article. Authors R. Ramírez-Pisco, L. Navas have contributions in the discussion of the results and conclusions. Authors M. Gaitán, M. Gómez and C. Altamar.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Watari T, McLellan BC, Giurco D, Dominish E, Yamasue E, Nansai K. Total material requirement for the global energy transition to 2050: A focus on transport and electricity. Resour Conserv Recycl. 2019; 148: 91-103.
2. Koch CA, Sharda P, Patel J, Gubbi S, Bansal R, Bartel MJ. Climate change and obesity. Horm Metab Res. 2021; 53: 575-587.
3. Síntesis de resultados CENSO 2017. Santiago: National Institute of Statistics; 2018.
4. 4th Biennial Update Report of Chile on Climate Change. Santiago: Ministry of Environment; 2020. Available from: https://unfccc.int/sites/default/files/resource/Chile_4th%20BUR_2020.pdf.
5. Asumadu-Sarkodie S, Owusu PA. A review of Ghana's energy sector national energy statistics and policy framework. Cogent Engineering. 2016; 3: 1155274.
6. Educarchile. MINEN; [cited date 2020 August]. Available from: https://www.aprendeconenergia.cl/matriz-energetica-primaria-y-secundaria/.
7. Ochoa-Rosales C, González-Jaramillo N, Vera-Calzaretta A, Franco OH. Impact of mitigation measures on the COVID-19 pandemic in Chile: Preliminary data for the period April 14 to May 14. Rev Salud Públ. 2020; 22: 1-6.
8. Ayala-Chauvin MI, Riba G. COVID-19 and the energy transition. CienciAmérica. 2020; 9: 21-30. doi: 10.33210/ca.v9i2.280.
9. Ricardo CL. Coronavirus, a story in progress. Rev Méd Chile. 2020; 148: 143-144.
10. Caqueo-Urízar A, Urzúa A, Aragón-Caqueo D, Charles CH, El-Khatib Z, Otu A, et al. Mental health and the COVID-19 pandemic in Chile. Psychol Trauma. 2020; 12: 521.

11. Official COVID-19 figures [Internet]. Obtained from Ministry of Science database, based on Reporte Diario Coronavirus Ministerio de Salud. Santiago: Government of Chile; [cited date 2021 August]. Available from: https://www.gob.cl/coronavirus/cifrasoficiales/.
12. Dujisin PR. Environmental impact generated by sports, recreation, and tourism activities in high mountain. Analysis of the mountain range of the Metropolitan Region of Santiago, Chile. RETOS-Neuvas Tendencias en Educacion Fisica, Deporte y Recreacion. 2020: 62-69.
13. Gillingham KT, Knittel CR, Li J, Ovaere M, Reguant M. The short-run and long-run effects of Covid-19 on energy and the environment. Joule. 2020; 4: 1337-1341.
14. Climatic Report. Santiago: Meteorological Directorate of Chile; 2020. Available from: https://climatologia.meteochile.gob.cl/application/publicaciones/documentoPdf/reporteClimatologico/reporteClimatologico-2020.pdf.
15. Transport and communications [Internet]. Santiago: National Institute of Statistics; [cited date 2021 November 11]. Available from: https://www.ine.cl/estadisticas/economia/transporte-y-comunicaciones/permiso-de-circulacion.
16. Gross domestic product, quarterly, current prices [Internet]; Santiago: Central Bank of Chile; [cited date 2021 November 2]. Available from: https://si3.bcentral.cl/estadisticas/principal1/excel/ccnn/trimestrales/excel.html
17. Loyola, E. Evaluation of climate change mitigation scenarios in Chile with respect to the target set in the Paris agreement. Chile: Universidad de Chile; 2019.