TRANSrisk
TRANSITION PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE POLICIES

TRANSITIONS PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES

D3.2 Context of 15 case studies:

Chile: Renewable Energy

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1 COUNTRY CASE: RENEWABLE ENERGY

Chile is facing increasing demands on energy resources to respond to the expected social, environmental and economic welfare of the population; as well as to contribute to the global efforts to deal with climate change and improving the environment. For these purposes, the Chilean government is trying to improve the use of its resources by increasing the efficiency and quality of energy generation, and exploring different technological options that support its national and global ambitions to reduce greenhouse gases (GHGs) emissions.

This case study will seek to answer the overarching research question, "How can Chile move towards a more efficient use of energy resources to support sustainable growth?"

1.1 Research questions for the Chilean case study

Research Questions:

1. How can Chile move towards a more efficient use of energy resources to support sustainable (social/economic/environmental) growth?

2. How could we reduce the energy requirement of the economy?
    a. What areas should we primarily focus on? Mining? Transport? Industry?
    b. How can we incentivise energy-saving in transport (i.e. diesel)?
    c. What is the government perception about complementation/change policy of a carbon tax with cap and trade in electricity generation?

3. What changes are needed in industry and transport to reduce emissions?
    a. Using the city of Santiago as a case study of an urban area, what further steps could be taken to improve local air quality (i.e. the reduction of pollutant emissions)?

4. How could Chile produce energy from existing natural resources in a sustainable manner?
    a. What energy resource should Chilean government consider in the short, medium and long term? Renewables? Clean coal? Hydropower? Nuclear?
    b. Is it necessary to expand renewable energy targets to 70% by 2050 in order to promote more investment in this area?
        i. What are the socio-economic and environmental costs/benefits of expanding renewable energy targets to 70%?
        ii. What incentives are necessary to expand renewable energy targets to 70% and promote more investment in this area?

5. How does Chile perceive the possible regional integration of energy with Argentina, Peru, Colombia and Bolivia as partners?
    a. Is it feasible to assess the CAPEX and OPEX estimations of the recent connection with Argentina?
    b. What is the Chilean perception of a possible integration with a transmission line between Colombia-Peru and Chile?
    c. Specifically, what is the Chilean perception of a possible scenario of energy integration with Bolivia? Is this option desirable considering the current legal and political frictions?

1.2 Introduction to the general context

1.2.1 Policy overview

The Chilean energy sector has been seen as a potential source of economic growth and is a part of the energy agenda launched by the national government in 2014. The main objectives of the agenda are: 1) to facilitate the entrance of new competitors; b) to set up the interconnection between the two main electricity systems, the Central Interconnected System (Sistema Interconectado Central, SIC) and the Northern Interconnected System (Sistema Interconectado del Norte Grande, SING); and 3) to promote energy efficiency and clean technologies. The objectives and timeline of the agenda are shown in Table 1.

Table 1 Energy Agenda

Objective and Target	Timeline
Reduce marginal electricity costs in SIC by 30 percent	2017
Reduce bid prices for electricity supply by 25 percent	2025
Reduce energy use by 20 percent	2025
Achieve 20 percent share of renewables in the energy matrix	2025

Source: IMF Article 4 Consultation (2014)

The implementation of the agenda requires, however, a significant private investment in the sector, which is expected to trigger economic growth. Recently, the government invited tenders to provide 12.430 GWh per year, starting in 2021, in the SIC and SING systems. This call constituted an important step forward in the implementation of the energy agenda. A total of 84 companies participated in the tender process and the electricity supply was awarded to companies that offered to sell electric power to the market at US$ 47.6 per MWh. This price is much lower than those currently set in the market, as shown in Figure 3. Importantly, two thirds of the investment will be in solar and wind generation (Ministerio de Energía de Chile, 2016).

In addition to the Chilean economic efforts carried out in the last 40 years, the country has been also engaged in efforts to mitigate the negative effects of climate change. One of the important efforts was the approval of a law to provide incentives promoting Non-Conventional Energy Sources (NCES). The law states that by 2025, 20% of total energy would correspond to NCES (Ley No 20257, 2008).

The current energy public policy agenda stipulates that 45% of the increase in electricity supply in the 2014 to 2025 period should come from NCES. Chile is also including new policy instruments to mitigate GHGs emissions. In the 2014 tax reform, the government introduced a tax on CO_2 emissions and local air pollutants (SO_x, NO_x, and particulate matter) from fixed specific sources. The tax on CO_2 emissions was set at US$5 per ton. In addition, a car tax was imposed based on NO_x car emissions.

According to the International Energy Agency, IEA, in 2012 the average global CO_2 emissions per capita were 4.5 tons per year, with Chile having a similar figure. Those numbers are much lower than OECD average of 97.2 tons per person. In the Latin America region, Chile accounted for 4.7% of total emissions.

Chile, as a member of the UNFCCC, has committed to reducing GHG emissions by 30% by 2030 (Gobierno de Chile, 2015). The mitigation efforts should occur in different sectors that produce GHGs, focusing on:

- Energy, industry, mining and other sectors using fossil fuels;
- Processes in the industrial sector;
- Use of land; and
- Waste.

To achieve the reduction in GHGs by 2030, Chile has made the following commitments:

- Chile will reduce its greenhouse emissions by 30% vis-à-vis its 2007 levels, provided it is possible to keep its economic growth pace, and implement the required policies to achieve the objective.
- Chile will reduce its GHGs emissions by 35% to 45% vis-à-vis its 2007 levels, provided it is possible to keep economic growth pace and obtain international grants to finance the additional required measures to attain the objective.
- In the land management sector, Chile commits to the restoration of 100,000 hectares of forestry, which corresponds to the reduction of 600,000 tons of GHGs emissions per year.

1.2.2 Natural resources and environmental priorities

The primary Chilean energy mix depends on oil (32.9%), coal (24.4%), wood and biomass (23.7%) and hydroelectricity (6.4%) (Ministerio de Energía de Chile, 2014). It is important to notice that 95% of oil is imported, and thus the primary energy matrix is heavily dependent on international resources. During 2014, the primary energy supply reached 314,163 teracalories (TCal).

The final energy consumption matrix, which corresponds to the consumer behaviour in the country, reached a total value of 278.667 TCal in 2014, which can be broken down into crude oil derives (56%), electricity (22%), biomass (14%), natural gas (6%) and coal (2%).

Table 2 summarises the structure of consumption of primary energy. Mining and industry represents 49.9%. As expected transport is the main sector consuming petroleum oil derivatives, consuming around 59.0% of these. Electricity is mainly consumed by the mining and industry (60.4%) and residential (32.5%) sectors.

Table 2 Consumption by end users and type of energy

	Primary energy	Petroleum Oil Derives	Electricity
Energy (Auto consumption)	8.1%	3.8%	5.7%
Mining and industry	49.9%	28.3%	60.4%
Transport	0.6%	59.0%	1.5%
Commercial, public and residential	41.4%	8.8%	32.5%

Source: Ministerio de Energía de Chile, 2014

Consequently, as shown in Figure 1, the electricity generation sector will be one of the key sectors targeted for meeting energy demand for the next few years. Thus, reduction of GHGs emissions from electricity generation has to be considered when developing the strategy for climate change policies in Chile.

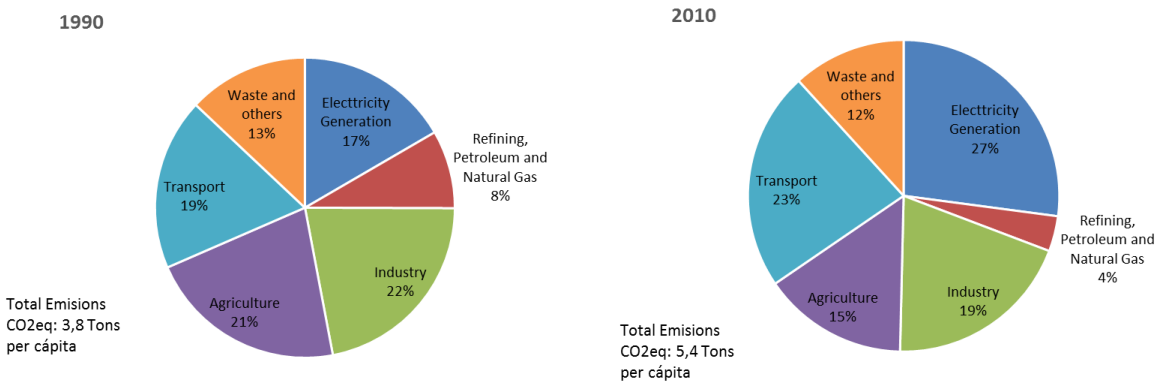

Figure 1 Chilean emissions by sector in 1990 and 2010

1.2.3 Electricity system

The share of electricity in final energy consumption increased from 19% in 2010 to 22% in 2014. The increase in the final consumption of electricity has provided incentives to increase the generation of electric power. In Chile, private companies provide electric power, and their functions comprises of generation, transmission and distribution activities. The economic authority (Ministry of energy) acts as a regulator and establishes criteria to incentivise economic expansion of the electric power system.

The main sources of electricity generation in Chile differ from the global average mainly in the use of hydroelectricity and natural gas. In Chile, hydroelectricity accounts for 34% while natural gas is just 11%. The opposite occurs in the global average, where hydroelectricity accounts for 16% of total electric power while natural gas accounts for 23%.

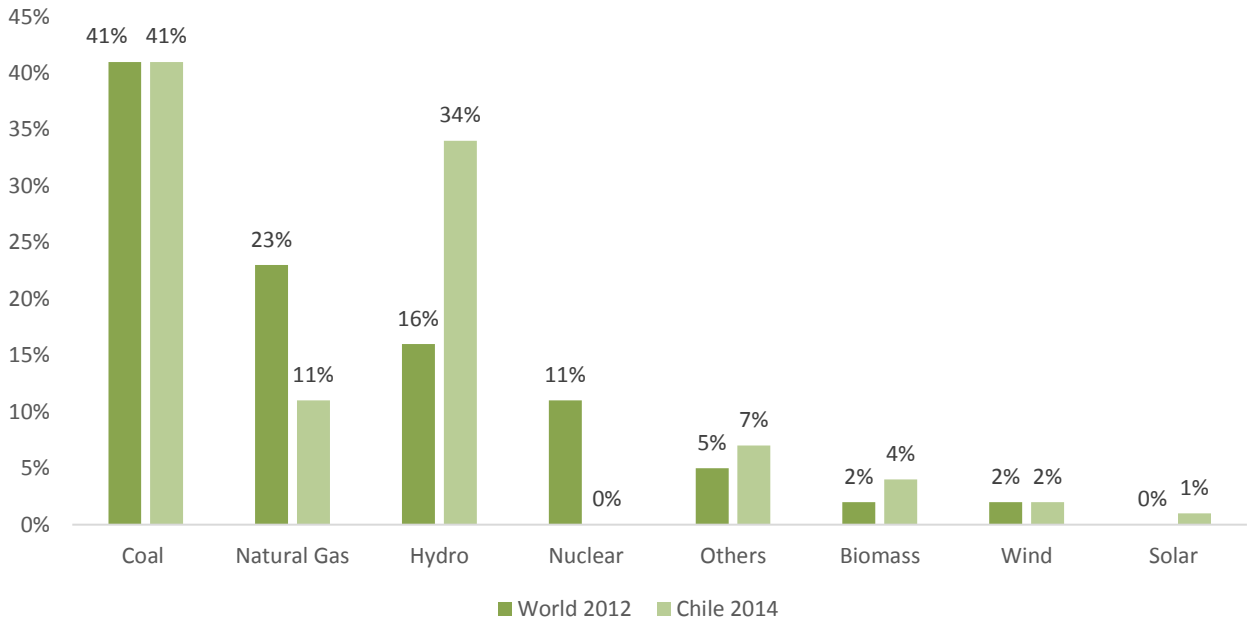

Figure 2: Electricity generation by source 2012 and 2014

Source: Ministerio de Energía de Chile, 2016

The Chilean electricity generation system has a capacity of 20,375 MW. Chile has two main electricity systems, the SIC, the Central Interconnected System, which generates 77.7%; and the SING, the Northern Interconnected System, which generates 21.5%. In addition, there are two other electricity generators in the south of the country in Aysén and Magallanes. Generators must coordinate their operations with the corresponding Economic Dispatch Load Center (CDEC-SIC and CDEC-SING). SIC electricity generation comes from hydropower; and SING uses hydro thermal power based on coal, natural gas and oil.

Chile use to import most of its natural gas from Argentina. However, a supply shortage in Argentina led Chile to substitute natural gas with oil. As the world faced an increase in the oil price since mid-2000s, the marginal cost of generation of electricity also increased considerably in Chile. Figure 3 plots the evolution of marginal cost both at SING (Crucero 220 kV) and SIC (Alto Jahuel 220 kV), which multiplied by five between 2006 and 2009.

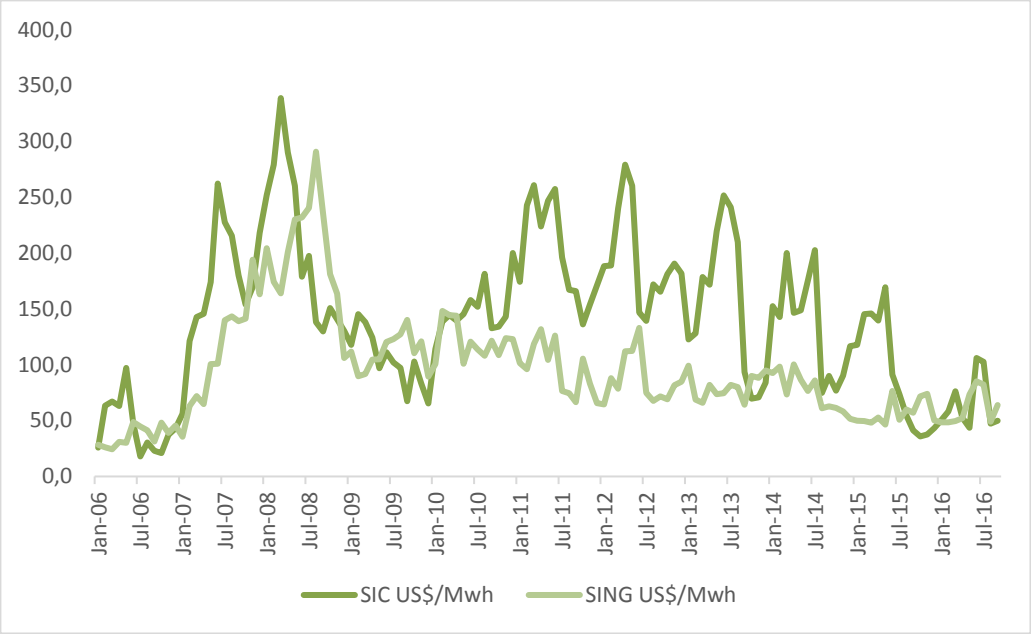

Figure 3: Marginal Cost of Production of Mwh, SIC and SING

Source: Authors' elaboration with data published by Systep.[1]

While the figure suggests that one of the challenges faced by the energy system is to decrease those marginal costs, note that average prices in Chile do not differ significantly from the rest of the world (see

4).

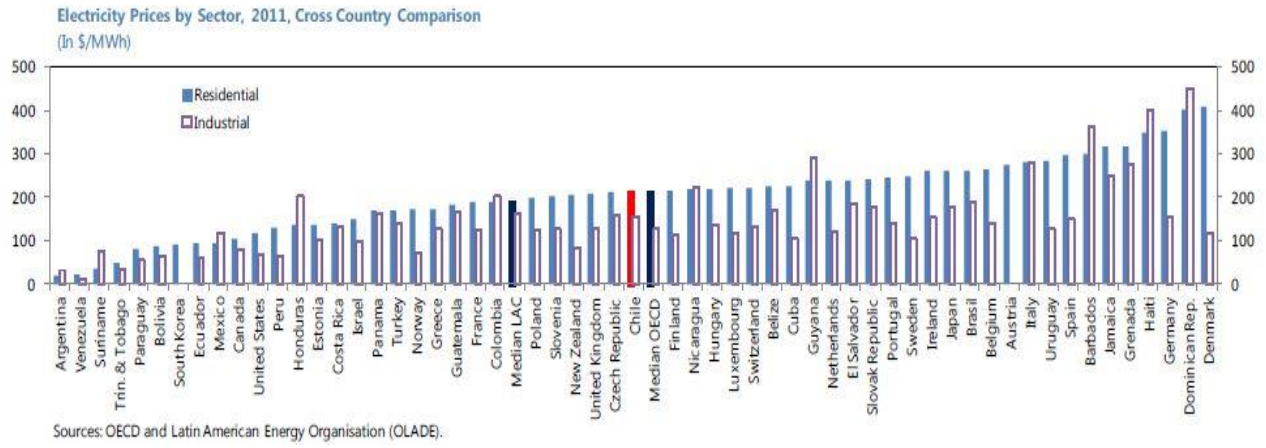

Figure 4: Electricity prices, cross country comparisons

[1] Systep Chile: http://www.systep.cl/[Accessed 9 November 2016].

1.2.4 Economic priorities

Chile is a small, open economy in South America with an estimated GDP of 258.682 billion US dollars in 2014, equivalent to 0.37% of world GDP (IMF, 2016). Its population was near 18 million people in 2014, and GDP per capita as purchasing power parity (PPP), was $22,995 USD, similar to some European countries, e.g. Hungary, Poland and Portugal. In 2013, Chile was the economic leader in the region, followed by Argentina and Uruguay (see Figure 5). However, in the past Chile was just average with the region, as depicted in Figure 6 which shows data from 1980.

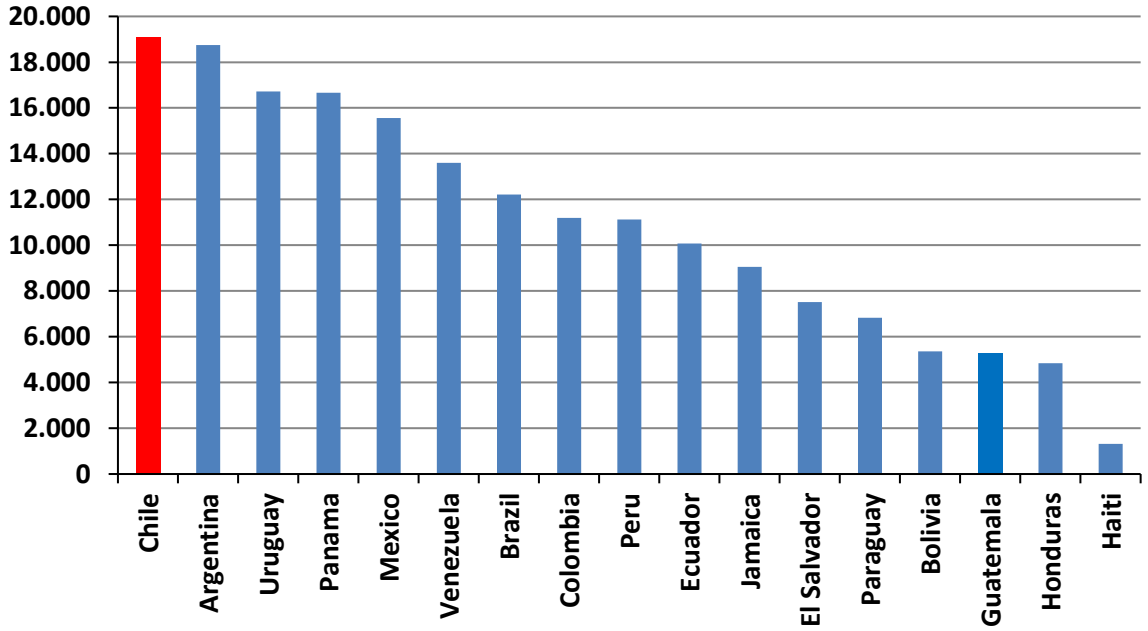

Figure 5: GDP per capita, PPP, 2013: South America and other selected Latin American Countries

Source: IMF, 2016.

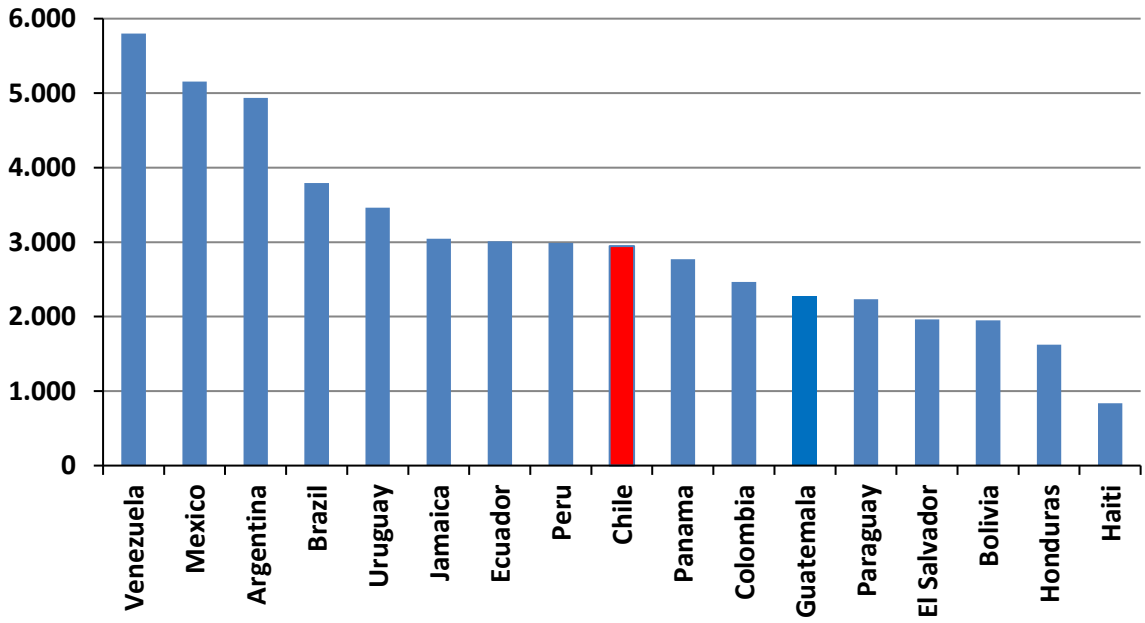

Figure 6: GDP per capita, PPP, 1980: South America and other selected Latin American countries

Source: IMF, 2016

Chile's GDP per capita has increased at a fastest pace when compared to its Latin American neighbours. For example, Chile experienced average per capita GDP growth of 3% between 1980 and 2013, a higher rate than other countries such as Uruguay (2%), Colombia (1.9%), Argentina (1.4%), Brazil (0.9%), Venezuela (-0.1%) and Haiti (-1.2%), among others.

Population growth between 1980 and 2013 was 1.4% per year, and thus Chile's over GDP grew in that period at an average of 4.5% per year. That number contrasts with the Chilean experience during the 1940s and 1950s, when it grew by about 3.0% per year. In the following decades there were episodes of economic boom and crisis, but on average, the economy kept its pace during the 60s, 70s and early 80s. However, since the mid-80s, the performance of the Chilean economy improved significantly, averaging a 7.2% GDP growth between 1986 and 1997 and 4.2% between 2000 and 2008. The period between 1986 and 1997 was called the "golden period" (Gallego and Loayza, 2002) due to the large economic growth rate, which allowed for significant changes in the Chilean standard of living. Between 1985 and 2013, life expectancy increased from 71.5 years to 79.3; the infant mortality rate decreased from 30 children per thousand to 8; average schooling years rose from 7.3 to 9.7; and poverty rates decreased from 38.6% to 7.8% (IMF, 2016; CEPAL, 2016; and PNUD, 2015).

The Chilean golden period, and its subsequent increase in per capita income, was by a large part due to a set of economic reforms introduced between the mid-70s and mid-90s (Larraín and Vergara, 1992). The reforms included: State-Owned Enterprise (SOE) privatisation; opening the economy to international trade; implementing a tax reform that reduced corporate taxation from 46% to 10% (CLAPES-UC, 2014); and fiscal consolidation and the use of concessions to increase investment in infrastructure (Larraín and Vergara, 1992).

A large part of Chile's GDP depends on international trade; in fact, the sum of exports and imports accounts for almost two thirds of GDP. Similar to other small open economies, Chile benefits from global economic expansion, but it also suffers when the world economy faces recessions. As a result, during the 1980s Latin American debt crisis, Chile suffered a recession, with GDP decreasing by 11% in 1982 and an unemployment rate that rose to 21%. Similarly, in 1999 due to the Asian crisis that affected emerging economies, Chile's GDP decreased by 0.5% while investment growth was -16.1%. Finally, during the 2008-2009 international recession, Chile's GDP dropped 1% (in 2009) while investment dropped 12.1%.

To overcome those external negative shocks Chile has developed a macroeconomic institutional framework (IMF, 2014) that includes two elements. Firstly, there is a fiscal structural rule that follows the idea that the Chilean public sector saves during booming years whilst expanding counter to the economic cycle, in other words, in the slowdown of the cycle savings are used to smooth the negative shock in the economy by promoting fiscal expenditure. Secondly, the Chilean Central Bank follows an inflation targeting-framework with a flexible exchange rate to respond to sudden large capital inflows and outflows.

Chile aims to increase its GDP per capita to converge with advance economies,[2] which represents an important economic challenge for the country. Firstly, this might require doubling its current level of GDP per capita. At current rates, and discounting population growth, Chile would require almost 70 years to double its actual per capita income. Thus, a main challenge is to increase its long-term GDP growth. In addition, Chile has a large income inequality. Its GINI index is around 0.5, and there are social and political pressures to expand fiscal expenditure and engage in social reforms to reduce income inequality. Thus, a second economic challenge is to implement economic policies that favours the poor and decrease income inequality, but without hurting the performance of the economy and avoiding the middle-income trap (Eichengreen, Park and Shin, 2014).

During 2014 and 2015, investment dropped by 2.5% on average per year and Total Factor Productivity has been negative in both years. In addition, the government has run a fiscal deficit of around 3 points of GDP since 2014. The Fiscal Budget Bill, about which discussions recently started in the Chilean Congress, has as a main objective closing the structural balance deficit a quarter point of GDP. To do so, fiscal expenditure should expand 2.7%, and budget increases should focus on education, health and pensions. Pension reform is currently an important social pressure and the government´s response in the fiscal budget is to increase by 10% pension payments to 1.3 million of poorer pensioners.

[2] The World Bank, Data. How does the World Bank classify countries?, [online] Available at https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries [Accessed 28 November 2016]

In addition to the fiscal budget, the government has approved laws aiming to improve productivity through tax cuts for export service, and also providing new investment alternatives for the management of pension funds. A bill to set up a public guarantees to incentivise concessions in infrastructure has also been suggested (in discussion in the Congress). Thus, a current focus is to improve the long run growth prospects of the economy.

1.2.5 Societal priorities perspective on climate change

Chile, a country with 17.8 million inhabitants in 2015, represents 4% of the total population of South America, which has a total of population 416 million. This includes Brazil, that has 49.8% of the total population in the region (CEPAL, 2015). Chile is facing aging challenges with 16.0 % of its population above 65 years-old (INE, 2016). As shown in Figure 7, Chile's population in 1980 was distributed like a pyramid, indicating that people up to 20 years old represented 44.6% and the elderly population (age 65 or more) only represented 5.5% of the population. Forecasts suggest that in the next decades this shape will change in the opposite direction, where the population under 20 will represent 22.3% and people more than 65 years will represent 21.5% (see Figure 8). Therefore, population aging would be a major societal concern, as it is in European countries (Valdes, Gonzales y Kutchner, 2016).

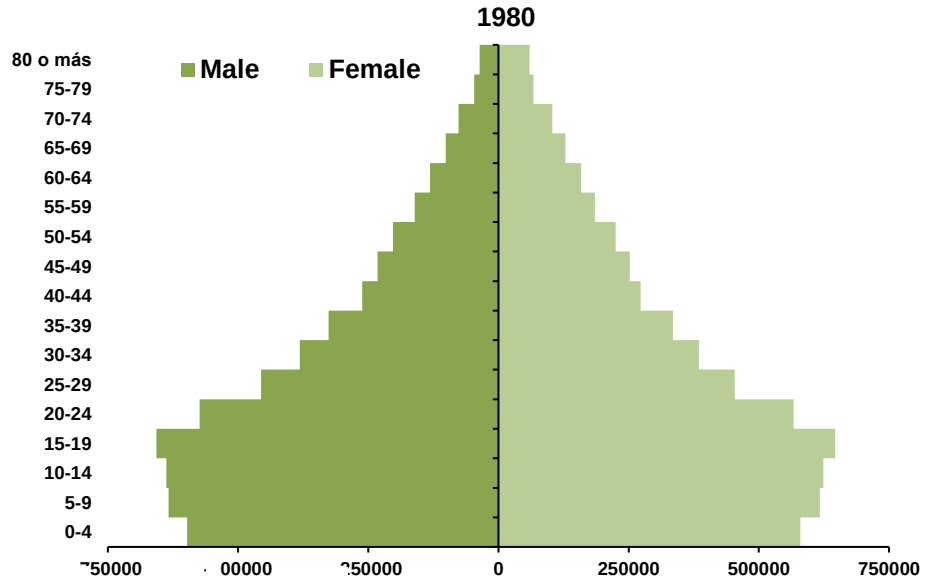

Figure 7: Chilean population structure 1980

Source: Valdes, Gonzales y Kutchner (2016).

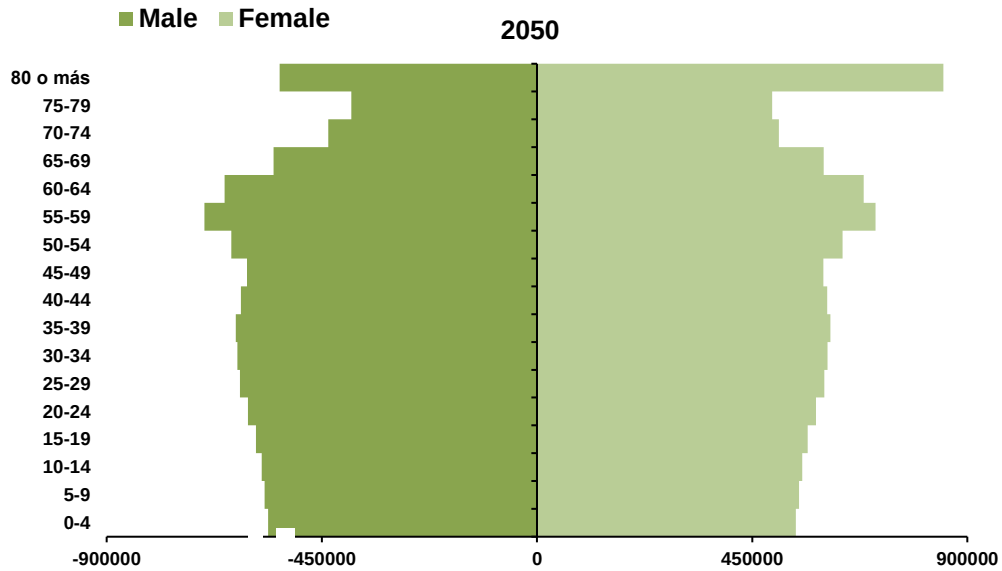

Figure 8: Chilean population structure 2050

Source: Valdes, Gonzales y Kutchner (2016).

The economic growth of Chile is expected to average 3.3% in 2021 (Ministerio de Hacienda, 2016). In this context, the average expected growth rate for electricity consumption until 2035 would be 2.4% between 2015-2035; divided into two periods: 1) in the first ten years it is expected to grow at 2.7%; and 2) from 2026 to 2035, it is expected to grow at 2.0% (CDEC SIC, 2015).

Climate change is not the principal driver to address GHGs reduction in Chile. People's perceptions of climate change are very important; what the population perceive as the most severe environmental challenges are shown in Figure 9 (MMA, 2016a). 65% of the citizens surveyed identified the top three most severe environmental challenges as air pollution, urban waste and noise. Only 1% of the surveyed citizens perceived that the climate change was a severe environmental challenge.

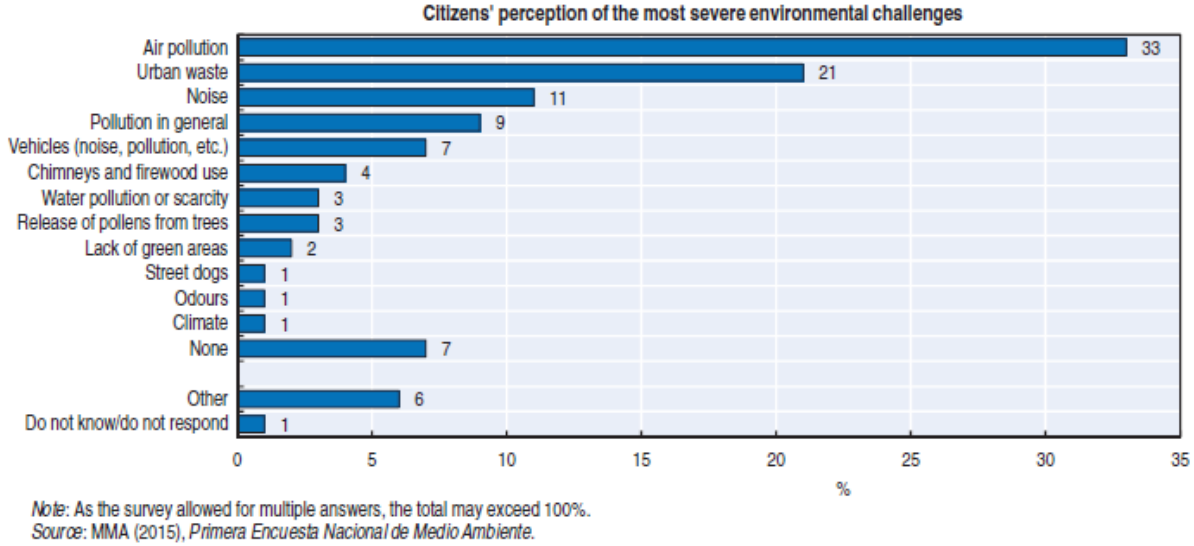

Figure 9 Citizens' perceptions of the most severe environmental challenges in Chile

1.2.6 Politics of energy development priorities

Energy policy is at the heart of public policies in Chile. Energy is seen as a potential driver of economic growth and productivity. In fact, energy issues may be one the reasons behind depressed total factor productivity over the past few years. As an example, the former Finance Minister Alberto Arenas[3] suggested that lower growth, at least since 2014, was due partially to the large marginal cost of energy. The current Minister of Energy, Maximo Pacheco, has a similar view.[4] Therefore, a decrease in marginal costs of energy could provide a fresh driver for economic growth.

The government had recently granted the construction of new energy facilities to private companies, seeking to lower marginal costs and support economic growth. However, the main challenge is in the implementation process. Disappointingly, there are examples in the past of energy projects that were not implemented due to opposing green groups. For instance, Hidroaysen was an approved megaproject that aimed to build hydroelectric power plants in the South of Chile. The project could have provided the equivalent of 21% of SIC demand by 2020. But in June 2014, the Chilean government rejected the Hidroaysen due to social pressures from environmentalists (see LyD, 2014).

[3] Electricidad. La revista energética de Chile: http://www.revistaei.cl/2014/03/12/ministro-de-hacienda-lamenta-altos-costos-de-energia-y-baja-productividad/[Accessed 09 November 2016].
[4] La Tercera newspaper: http://www.msn.com/es-xl/noticias/other/ministro-pacheco-sin-energ%c3%ada-no-es-posible-crecer-lo-que-la-econom%c3%ada-de-chile-puede-crecer/ar-AAPBvK [Accessed 09 November 2016].

1.2.7 Conflicts and synergies

In the previous sections we mainly described four issues that will generate both conflicts and synergies in the identification of future scenarios to mitigate climate change in Chile. First, as described in table 1, the contention existing between the implementation of the energy agenda and the commitments of the country to the Paris Agreement; second, the actual mix of electricity generation matrix, which depends on oil, gas and coal with high marginal costs; third, the necessity to get resources to increase the rate of investment, and eventually to increase electricity production, the rate of economic growth and improve productivity; and finally, the social context that faces inequality, aging population, and environmental problems. These issues demand energy policies aimed at solving these problems.

The interviews carried out for this stage of the research have shown that, firstly, Chile has potential to achieve the energy agenda and the NDC targets with the introduction of renewable energy mainly from solar and wind technologies (Interview 3 and 5, see Table 6 Stakeholder engagement for interview details), demonstrated by the results of the bid of energy for 2021 that obtained two thirds for renewable sources for the next decade (MEC, 2016). Secondly, following new investments, jobs opportunities would be generated following plans to reduce GHG emissions in forthcoming next years, especially in mining and power electric sectors (Interview 6). Finally, a better economic scenario with higher investments would improve profits in pension funds and consolidate the retirement system, releasing budgetary sources for other demands in the economy (Interview 9), thus easing pressures placed by an ageing population and the associated pension burden.

However, some conflicts are identified in the interactions of these policy targets. Acceptance and discussion of climate change in the Chilean economy is not at the top of the agenda in Chilean society (see Figure 9) (Interview 3). Low energy prices and the new potential of hydro power create some investment uncertainty in the mid-term for solar and wind technologies, even with the last result of the bid of 2016 (Interview 4). Finally, because of the aging society problem one of possible options that appears in the energy debate is to return to pay as you go system for pensions that require more fiscal resources from fiscal policy.

1.3 The Innovation System

1.3.1 The case study focus: solar energy

As an emerging economy, Chile faces the challenges of continuing its economic growth, improving social welfare and implementing its environmental actions. However, this requires the development of a broad vision, which completes the discussion previously stated about the air quality in the cities. In this regard Chile faces the challenge to change its energy mix, favouring renewables, and to develop scenarios for a future low carbon economy.

In this section we will describe the global vision of the increase renewable energy in Chile with particular attention to solar energy power. For this purpose, first we will review the universal vision of the energy sector in the past and the vision planned until 2050 as a benchmark. Secondly, we will examine the sectorial vision for energy and, finally, we will review some transversal criteria for the energy sector and its policy.

Chile's energy policy in the last decade has been continually trying to build a consensus between the social, economic and environmental approaches. One of the best examples of this was the approved laws providing the first road map for the intervention of renewable energy in the market. This first action included establishing a target of 20% of renewable energy by 2025; currently this goal will be achieved in 2018 (Interview 5).

The universal vision of the sector is founded around concepts of energy and its compatibility with the environment and community goals. This also requires the implementation of the concept of universal and balanced access to energy services, while at the same time providing competitive prices, opportunities for innovation, efficiency in production and consumption, and security of provision. With these attributes in place in the past and for the next decades, the universal vision of the energy sector in Chile is to increase renewable energy including solar power (Interview 4).

From the sectorial vision, these objectives are identified in electricity generation, oil production, consumption (end users like commercial, public and residential), transport and mining, in addition to industry. For our case study, the sectors of oil production and transport are omitted in this analysis. Solar electricity generation is the main focus, and the objective pursued in this sector includes having access to entire network coverage. This will allow for continued electricity provision and the possibility of distributed generation and micro-nets. In this sense, competitive prices in this sector help to provide the necessary conditions for key activities like production in mining.

A key fundamental characteristic of the electricity sector is the participation of the government and the private sector. In this sense, it is important to emphasise that public private partnership would be an option especially in the future of electricity technologies.

1.3.2 TIS life cycle value chain: a cradle to grave analysis

For the technological innovation system, we selected coal because given the current mix of electric generation system is the major source of energy in Chile representing 41% (see Figure 1).

The value chain of energy in Chile is presented in Figure 10, where primary energy is identified by 8 sources where the most representative of them are Crude Oil, Coal and Biomass.

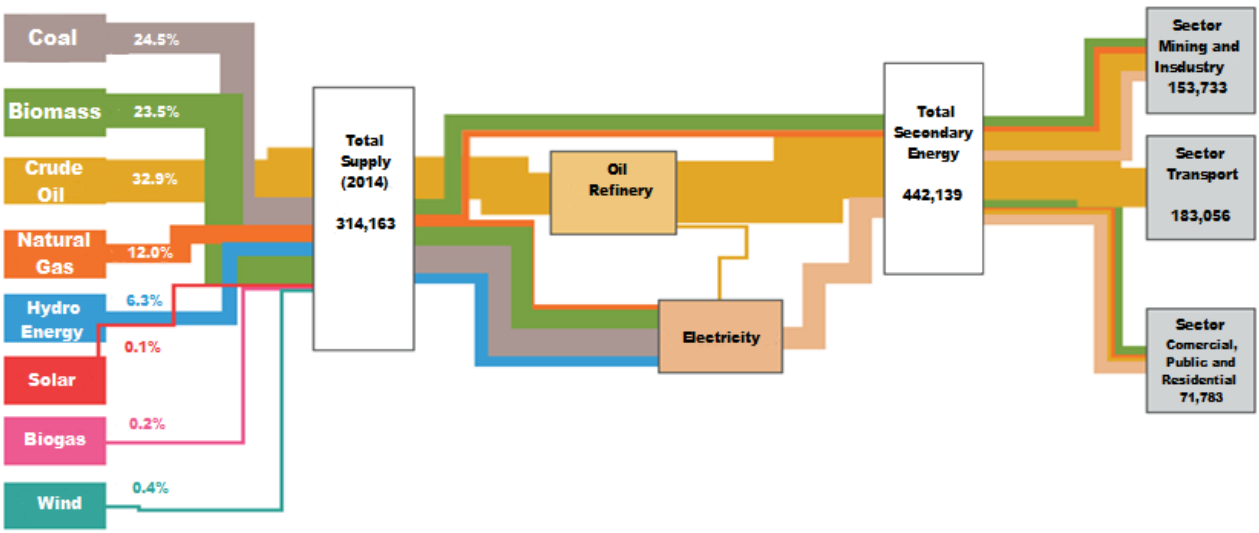

Figure 10 Value chain of energy in Chile, 2014

Source: Ministerio de Energia de Chile, 2016

Chile is mostly dependent on the imports of energy: 95.1% of crude oil is imported; and natural gas and coal imports represented 85.6% and 77.3% of domestic consumption respectively in 2014. National coal represents only 19.7% of the supply and 67.1% is also imported (see Table 3).

Table 3 Primary energy supply mix 2014 in Chile

	Local Production	Imports	Exports
Crude Oil	4.6%	95.1%	0.0%
Natural Gas	19.5%	85.6%	0.0%
Coal	19.7%	67.1%	13.2%
Hydro Electricity	100.0%	0.0%	0.0%
Wind	100.0%	0.0%	0.0%
Solar	100.0%	0.0%	0.0%
Biomass	99.8%	0.2%	0.0%
Biogas	96.4%	3.6%	0.0%

Source: Ministerio de Energía de Chile, 2014

Thermoelectric generation is mainly based in 75% coal and 25% natural gas. It is important to consider that informal biomass trade (i.e. black market of wood) represents a significate portion of use even in the residential sector, mining and industry.

1.3.3 Enabling environment: policy mixes in the socio-economic system

As signed in Paris on December 2015, the agreement on climate change aims to hold the increase in the global average temperature to well below 2°C above pre-industrial levels, and to enhance efforts to limit the temperature increase to 1.5°C above pre-industrial levels, mainly through the reduction of CO_2 emissions (UNFCCC, 2015).

One of the ways for Chile to achieve its Paris Agreement goals is by promoting conducive strategies to implement its NDC in the context of Chilean priorities, which include resources and capabilities converted in collective actions towards a low carbon strategy. However, NDC implementation implies economic challenges, especially for Chile, a middle income country, which is attempting to achieve its NDC goals through a reduction of GHGs emissions and simultaneously its economy grow on a sustainable basis.

Chile has established three environmental priorities (see table 4) that would have a direct impact on the renewable energy sector. First, the role of renewable energy in preventing climate change or, in the case of Chile, 'cleaning up' the energy mix and shifting to a low carbon based economy. Second, the priorities have a role in protecting and maintaining biodiversity, essentially reducing the impact of energy technologies on nature. Finally, the priorities address the impact of less carbon intensive energy production on local air pollution, especially in Santiago which is the Chilean city with not only the highest concentration of CO_2 emissions but also with the majority of the population in the country (41%). Nevertheless, the traditional use of biomass in the south is also another challenges that need to be faced (Ministerio de Medio Ambiente, 2015).

Table 4 Chile environmental priorities and corresponding renewal sector

Chile environmental priorities	Chile National Policies	Chile Directive Reference
1. "Preventing climate change"	National Council on Climate Change (Formed by Ministries of Finance, Energy and Environment) Nationally Determined Contribution of Chile (NDC) National Mitigation and Adaptation Plan of Chile	- Sustainable Council - Private advisory council
2. "Maintain and restore biodiversity"	General Environmental Framework Law, modified by Law No. 20,417 Law on the Recovery of Native Forest and Forest Development Law on Recreational Fishing General Law on Fishing and Agriculture Hunting Law Forest Law Environmental Impact Assessment System Regulation Species Classification Regulation Hunting Law Regulation	Forestry, Fauna and Flora
3. "Plan nacional de descontaminación"	The Clean Air Act of Chile (CAA)	- Health Ministry

Source: Ministerio de Medio Ambiente, 2015

Table 5 presents a list of economic instruments available for the environmental policy in order to administrate and achieve the priorities. These instruments could also be classified as a command or control from the perspective of a regulation.

Table 5 Chile policy instruments that directly or indirectly impact the renewal sector

Policy themes	Chile National Policy Instruments			
Energy Climate	Research Subsidy for pre investment studies in advanced project of Renewal Energy	Specific Tax to oil combustibles Permit for exploration and exploitation geothermic power	Direct Electric consumption subsidy to household Pre investment program in energy efficiency	Carbon Tax USD$ 5 per ton, proximately introduce in 2018
Agriculture	Protection of Water Against Agricultural Nitrate Pollution	Single Payment Scheme for agricultural production		
Air	Compensation system for fixed sources Santiago			
Waste/ resource use	Glass and plastic bottles recycle program	Subnational Tax for the waste collectors		
Water	Tariff subsidy water for households	Solar credit for water solar heating		
Mining	*Mining Patents, Specific tax for Mining*			

Source: Authors' elaboration

1.3.4 Enabling environment: government institutions

In the last twenty years Chile has improved significantly the institutional framework for environmental issues. The Superintendencia del Medio Ambiente, set up in 1994, is the most important institution to enforce the environmental regulations, based principally in the Law 19300 of general bases of environmental issues in Chile. Furthermore, it interacts with the energy sector, allowing or restricting investments and operations of energy generations plants.

In the central government, the Council of Ministers for Sustainability is the institution in charge for horizontal coordination between economic, social and sectorial ministries. Accordingly, subnational authorities are delegated to control and execute the environmental actions decided by the central council.

An important feature of the institutional environmental framework of Chile is the absence of criminal sanctions for environmental offences (OECD/ECLAC, 2016). However, problems with past land and water contamination have been recognised in the recently Mine Closure Law (Ley No 20551, 2011).

Chile has also made remarkable progress in the promotion of environmental friendly business practices through diversity instruments like the Clean Production Agreement (APLs). This agreement promotes social responsibilities, with environmental focus, in production by companies in every sector of the economy

In terms of program evaluation, the Ministry of Environment has implemented an important procedure of ex ante and ex post evaluation that allows the reshape of both programs in execution and those that are in the design and planning phase. Specifically, Chile reinforced the regulatory framework for air and water pollution. The main institution for evaluating impacts is the System of Environmental Impact Assessment (SEIA) that constitute a milestone in Chilean environmental regulation.

1.3.4.1 Climate Change Institutional Framework

For climate change, the Office of Climate Change coordinates Climate Change policies. The Ministry of Energy influences climate change policy through the Office of Sustainable Development, that coordinate actions by introducing legal initiatives to the main institution, the Council of Ministers for Sustainability and Climate Change. The structure of the other institutions related to the climate policy is presented in Figure 11.

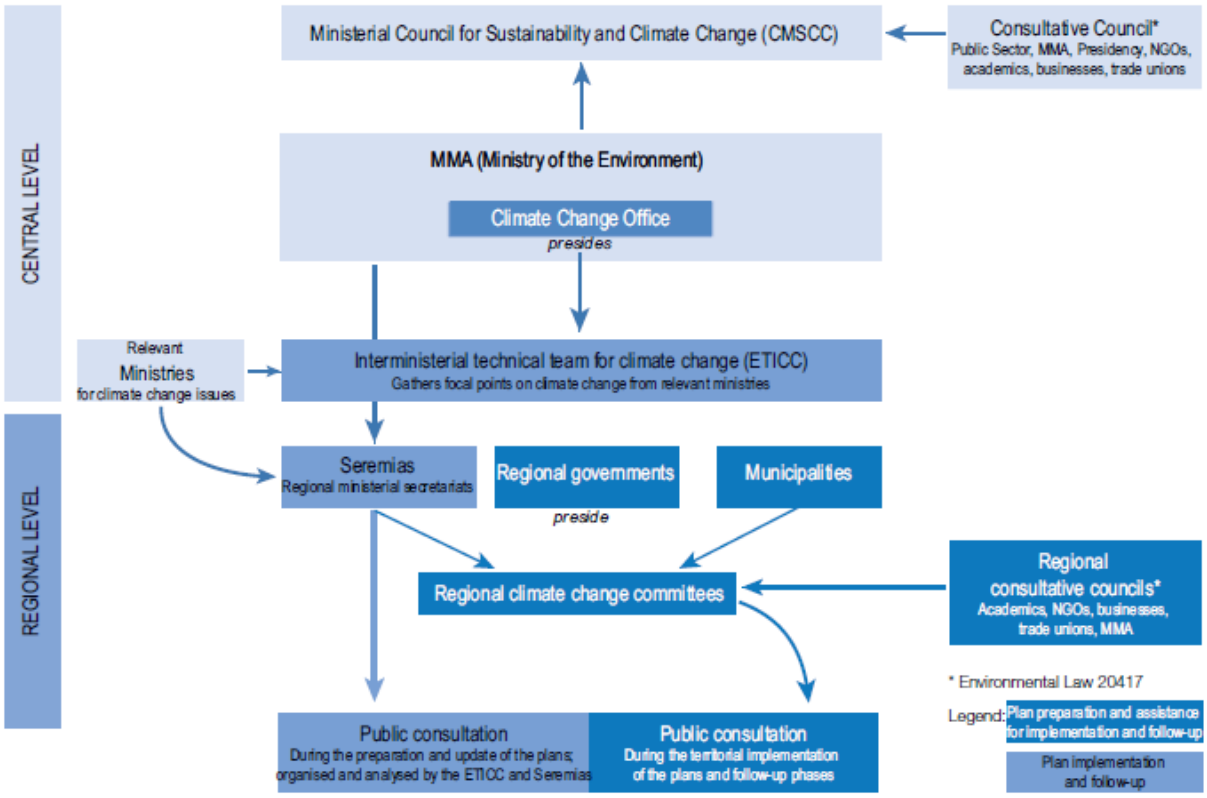

Figure 11 Chilean institutional framework for climate change

Source: OECD/ECLAC, 2016)

1.4 The Innovation System map

The innovation system map in figure 12 provides a top level view of the general energy system. This map was created early on in the case study process and will be revised to include more details of the TIS value chain as we carry on further research. The system map identifies the main government institutions, policy mix and facilitating services (e.g. banks and international organisations), and infrastructure (water desalination) that impact the mining industry as well as the energy sector.

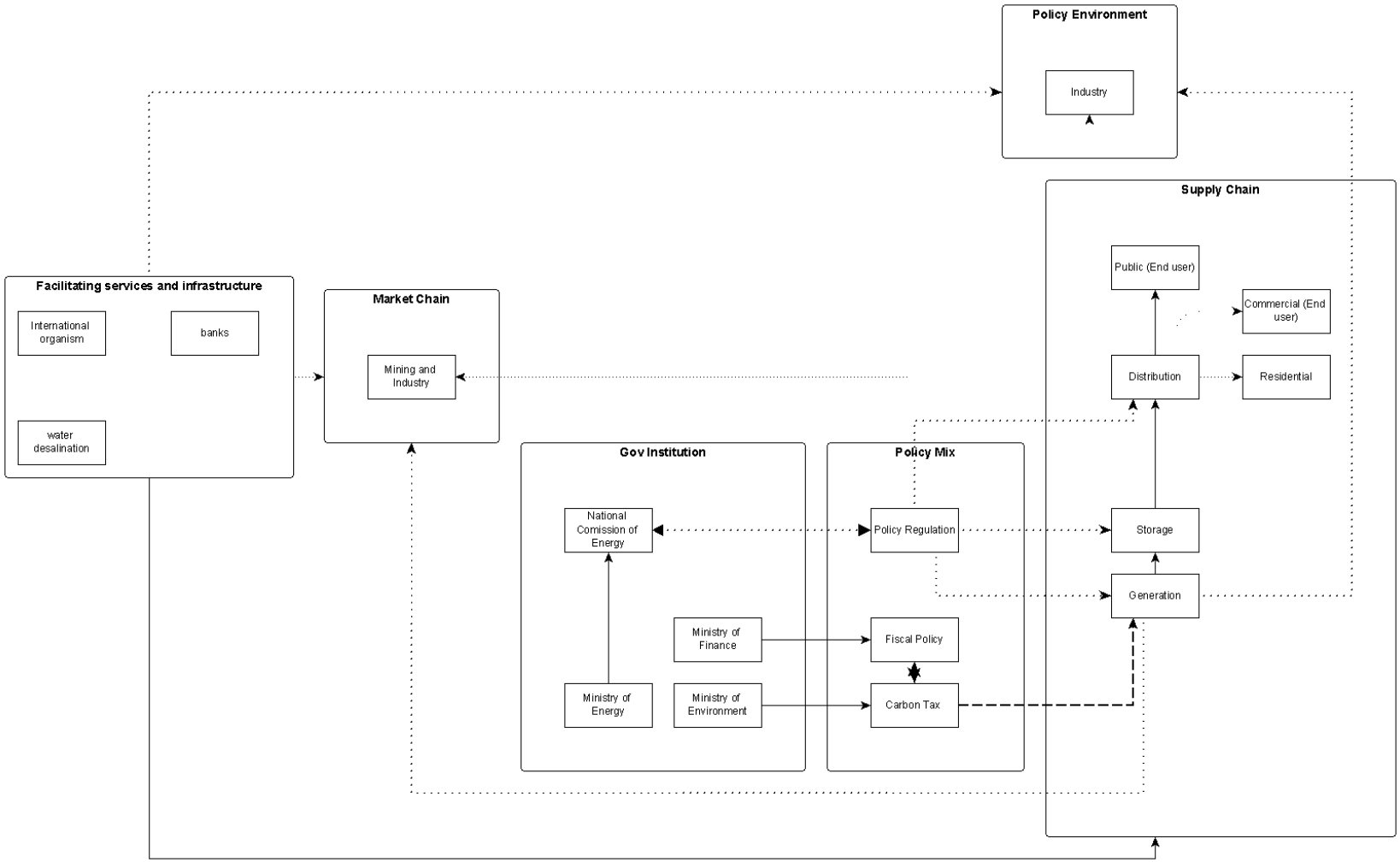

Figure 12 Innovation system map

1.5 Stakeholder engagement

Table 6 below gives some details of all stakeholders that were contacted for this stage of the research. The stakeholders were targeted due to their involvement in the areas of energy policy, electricity generation and society. All the interviewees were contacted by email, and interviews took place in the period of June-October 2016.

Stakeholders' opinions were included in the analysis for this case study. Also, we expect to invite them to participate in a workshop for the second part of this case study, for the constructions of scenarios and pathways based on changes for solar electricity generation.

Table 6 Chile stakeholders' engagement

Interview	Type of Organisation	Position in the organisation	Sector
1	Industry	Director	Mining
2	NGO	Director	Climate change and environment
3	Consultancy	Senior consultant	Climate change and air quality
4	Government agency	Senior officer	Energy
5	Industry	Director	Renewable energy
6	Consultancy	Senior consultant	Mining
7	Government agency	Senior officer	Agriculture
8	Government agency	Director	Climate change
9	Academic	Professor	Economics

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