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Is the Distributed Generation Law Effective?

The Case of the Chilean Residential Solar Energy

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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In Chile, the number of projects interconnected by solar photovoltaic (PV) systems under the Law No 20,571 regarding Distributed Generation has been increasing over the last years. However, it is not clear whether these improvements are desirable for a country with high irradiation for solar energy. The study aims to develop a better understanding of the deployment of residential solar energy in Chile, focusing on the Distributed Generation Law. The method chosen to pursue this objective comprises two different elements: First, a comparison of the Chilean deployment of residential solar energy with the success case of the State of California. Secondly, a SWOT analysis (strengths, weaknesses, opportunities and threats analysis) of the Distributed Generation Law.

Results show that external factors make the Law more effective than internal factors. External factors detected are: i. Decreasing cost of solar PV systems ii. International awareness about global warming and the promotion of green technologies. In contrast, an internal factor is the Net Billing scheme, because for owners of solar PV systems, the scheme is not economically attractive. Results also confirm that the development of residential solar energy in Chile is increasing, however, its spread is unequal socially and geographically. The recommendation is to transform the solar residential market in Chile in the same way as in the State of California.

Keywords: Distributed Generation Law, Law 20,571, Net Billing, Net Metering, Solar PV systems, Renewable Energy, Renewable Energy Policies.

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List of Abbreviations

BCN	Biblioteca del Congreso Nacional [Library of the National Congress of Chile]
CEC	California Energy Commission
CNE	Comisión Nacional de Energía [National Energy Commission]
CORFO	Chilean Economic Development Agency
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
DHI	Diffuse Horizontal Irradiation
DG	Distributed Generation
DNI	Direct Normal Irradiance received
GDP	Gross domestic product
GHI	Global Horizontal Irradiation
IEA	International Energy Agenda
IOU	Investor-owned utilities
IRENA	International Renewable Energy Agency
GW	Gigawatt
$kWh/m^2/day$	Kilowatt hour per meter square day
MMA	Ministerio del Medio Ambiente de Chile [Ministry of Environment of Chile]
MW	Megawatt
NCRE	Non-conventional renewable energy
NEM	Net energy metering
NREL	National Renewable Energy Laboratory
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
RES	Renewable Energy Systems
RM	Region Metropolitana [Metropolitan Region]
RPS	Renewable Portfolio Standards
SEC	Superintendencia de Electricidad y Combustible [Superintendence of Electricity and Fuel]
SWOT	Strengths, weaknesses, opportunities and threats
SWH	Solar water heating

1. Introduction

Since the Paris Agreement in December 2015 there is global agreement to limit global warming to an average of no more than 2 °C (IRENA 2015). Hence the importance of the energy sector because “energy accounts for two-thirds of total greenhouse gas emissions and 80% of CO2” (IEA 2018; IRENA 2015). Therefore, any effort to decrease emissions must include the energy sector. In other words, in the arena of energy planning, analysis and policy making is essential to promote sustainable development and solving climate change. To achieve this goal, governments started their energy transition toward low carbon energy, where renewables play an essential role together with energy efficiency, because both actions “can provide 90% of the CO2 emission reduction needed by 2050” (IRENA 2018). Therefore, clean energy is not only associated with the reduction of CO2 emissions but also energy quality and security of supply, as well as a driver of development (Ministry of Energy of Chile 2015).

This study focuses on Chile because currently, it is in the middle of its “Energy Revolution” (Pacheco M. 2018). It is experiencing its energy transition toward renewables motivated by energy security (Lyon and Yin in Muñoz *et al* 2017). The country has an impressive economic growth, according to the World Bank its GPD per capita is about US $13,792 in 2016, higher than its neighbour Argentina (US $12,440). However, unlike some other countries in Latin-American, Chile does not have oil or natural gas of its own. Thus, it is a country which depends highly on imports for domestic energy supplies (IEA 2018d; Ministry of Energy of Chile 2015; CNE 2018). For this reason it is interesting how the country meets the opportunity to deploy its renewable energy investment (IEA 2018d).

As a country with a large range of “solar climates” due to large latitude and altitude variation (Molina *et al.* 2017), how do Chilean citizens use the renewable energy system as a “free resource as well as democratically provided by nature”? (Rukus and Freely 1998). Some progress has been made in bringing the green energy closer to the citizens. In this sense, the government decided to take advantage of solar energy potential creating strong policies in order to avoid high electricity prices to consumers and the dependence on imported fossil fuels (Watts *et al.* 2015).

Law 20,571, known as the Distributed Generation, Net Metering Law or Net Billing Law, onwards - Distributed Generation Law – began after implementing regulations and technical standards on 23rd October 2014. It regulates the payment of electricity tariffs for residential generators. However, the problem detected is the implementation of the Law and its impact in the use of distributed energy. According to Barrett *et al.* (2016), there is a lack of growth (and potential future growth) of the residential solar PV industry in Chile, in like manner other sources of information state that "after two years of validity of this legislation there are very few households that have opted for self-generation” (Senate Chilean Republic 2018). Therefore, the PV solar projects under Distributed Generation Law is increasing but is not clear whether these improvements are those desired for a country with high potential for renewable energies.

The significant of the problem is due to the Chilean Congress having started the modification of the Law for self-generation. Therefore, a particular analysis about residential solar energy has become necessary, analysing inside the nation as well as comparing outside of the frontier with success cases.

The aim of this study is to develop a better understanding of the deployment of residential solar energy in Chile focusing on the Distributed Generation Law. The following research questions have been formulated with the objective of fulfilling the aim stated above: i. How does Distributed Generation Law differ between Chile and the State of California? ii. Which factors make the Distributed Generation law in Chile particularly effective or not?

The method chosen to pursue this objective comprises two different elements: First, a comparison of the Chilean deployment of residential solar energy focusing on policy instruments in Chile with a success case such as the State of California. The State is a leader in residential solar, with roughly 20 years of experience and five times the installed capacity of any other State in the U.S (Scott Madden 2017). The results will answer the first research question. Secondly, in order to analyse the Distributed Generation Law - the author chose the SWOT analysis (strengths, weaknesses, opportunities and threats analysis) because it provides a simple way to assess how a policy can be best implemented (Start and Hovland 2004). In addition, the methodology has been used in other studies in order to evaluate solar PV technology in Europe, Japan and the U.S (European Commission 2005). The results will answer the second research question.

The contribution of this study is to enrich the discussion through a variety of interviews conducted in different regions of Chile. To understand the deployment of residential solar energy in Chile focusing on Distributed Generation Law as well as comparing outside of the frontier with a success case of deployment of residential solar energy.

After the introduction, Chapter 2 of this thesis contains the literature review which provides a comprehensive description of state of the art concerning the deployment of residential solar energy in Chile focusing on the Distributed Generation Law. Chapter 3 contains the methods section, which describes the data collection methods (interviews, field notes and documentary research) and the method of data analysis and limitation of the research. Chapter 4 outlines the results of method via qualitative interviews and for data analysis under two components: i. Comparison of the Chilean deployment of residential solar energy with the success case of the State of California ii. The SWOT analysis regarding the Distributed Generation Law in Chile. Chapter 5 contains the discussion sections, it includes the answers to the two research questions and it gives an overview of the significant findings of the study as well as relation with existing studies, possible causes of the results and limitation of the research. Chapter 6 contains the conclusion, which answers the research questions, gives the main findings and recommendations and lays out opportunities for future studies.

2. Literature Review

2.1 Structure of Literature Review

This chapter provides a comprehensive description of the state of the art concerning the deployment of residential solar energy in Chile focusing on Distributed Generation Law. The literature review is divided into four major sections. In the first section, the literature review begins with an introduction of solar energy, thereby providing information about Chilean irradiation as well as technologies associated, focusing on PV systems. Then the review briefly describes the barriers to deployment non-conventional renewable energy (NCRE), starting with general and international peer-reviewed scientific literature and the experience of the PV system in Chile. This is followed by the analysis of renewable policies spotlighting the policies regarding the payment of electricity tariffs for residential generators from renewable energy. Then the review clarifies the concepts about Net Metering and Net Billing Law as well as analysis about the effect of the Law in the deployment of residential solar in Chile. The last part includes reasons why the author chose the State of California for comparing the current Chilean deployment of residential solar energy focusing on policy instruments.

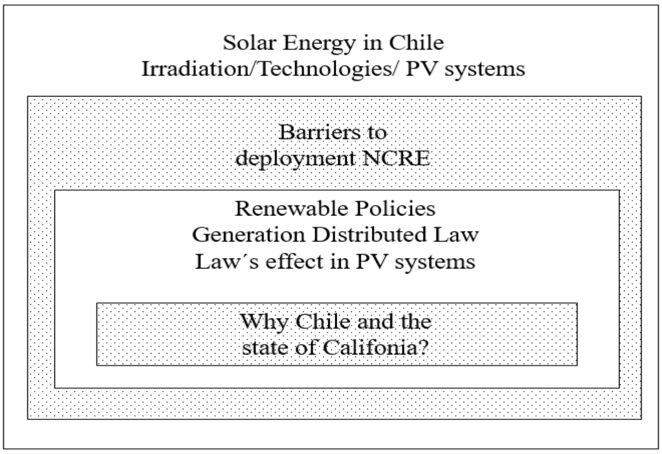

Figure 2-1: Structure of literature review.
Source: The author´s elaboration

2.2 Solar Energy in Chile

According to the Solar World Energy Council (2013), the irradiation is the input of solar energy system, and the amount of solar radiant energy received on a surface can be counted per unit area or per unit of time. The total solar irradiation is called Global Horizontal Irradiation (GHI) which is the sum of the Direct Normal Irradiance (DNI) received "the irradiance from a small solid angle of the sky, centred on the position of the sun" plus the Diffuse Horizontal Irradiation (DHI) "the radiation component that strikes a point from the sky, excluding circumsolar radiation" (NREL 2018). This energy is used for generating electricity or heating and desalinating water, and the population is widely using it. Worldwide the trend in solar energy installed capacity grew up from 9,158 MW in 2007 until 390,625 in 2017. It means that during ten years this energy increased by 43 times.

In Chile the installed capacity exponential of solar energy grew up from 2 MW in 2012 until 2,110 MW in 2017 (IRENA 2018b).The reason for the exponential growth deployment of solar energy is due to the excellent condition of irradiation in the country. As Figure 2-2 shows half of the territory presents a solar irradiance (GHI) above 5 kWh/m^2/day. For comparison, Oslo in Norway has very low average annual insolation (2,27 kWh/m^2/day) meanwhile Central Australia is very high (5,89 kWh/m^2/day) (Solarinsolation.org 2018). Therefore, northern Chilean region presents excellent solar radiant energy, with 7kWh/m^2/day and clear skies (Haas *et al*. 2018). The Central region, where the majority of the population is living presents solar irradiation levels above 5 kWh/m^2/day. The southern cities, present values above 3.5 kWh/m^2/day. The southern region, from Temuco to Punta Arena city (the extreme south of the country) present the lowest values of total solar irradiation.

The amount of solar energy varies in any part of the world according to these factors: Geographic condition; time of day; season; local geography; local weather (EERE 2018). Taking everything into account, in Latin America Chile has the lowest GHI in Southern Chile and the highest GHI in the Atacama region (World Energy Council 2016).

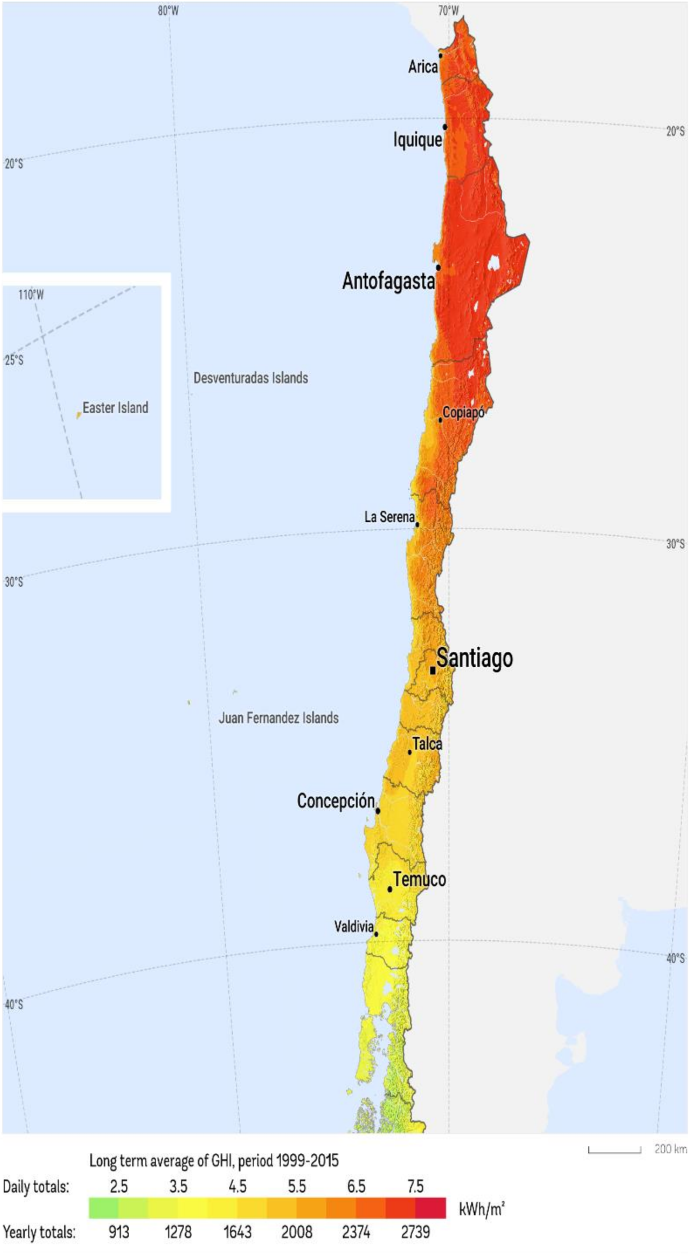

Figure 2-2: Global Horizontal Irradiance in Chile
Source: Solargis.com

Local studies regarding the amount of solar energy have been made in Chile. For instance, Alvarez *et al.* (2011) estimate monthly global solar radiation for the south-central parts of Chile; Rondanelli *et al.* (2014) present the maximum of annual-mean surface solar irradiance or GHI over the coastal Atacama Desert; Cornejo *et at.* (2017) analyse solar irradiation in the northern part of Chile in a region called Arica y Parinacota. The later state that the region of Arica-Parinacota[1] has the highest values of solar irradiation per year in the

[1]The region is located between 17° 30' and 21° 28' south latitude (BCN 2018)

World. However, according to the World Energy Council 2016, the highest GHI is in the Atacama region[2]. On the other hand, Watts *et al.* (2015) state that in 2010 Calama[3] had the highest total GHI, meanwhile the city of Puerto Montt had the lowest. Probably results vary according to the methodology used in each study.

There are other factors which determine the irradiation. EERE (2018) explain that solar radiation passes through the atmosphere, thereby some of it is absorbed, distributed, and reflected by air molecules, water vapour, clouds, dust, pollutants, forest fires, and volcanoes. All of these factors take part of the DHI. According to the American office, "Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloudy days". In this sense, Molina *et al.* (2017), who, provide a public database of solar irradiation in Chile, conclude that the primary factor that controls surface solar irradiance in Chile is cloudiness and there are some limitations, such as errors in cloud detection at sunset and sunrise. In addition, the authors state that GHI is widely validated in Chile, but the DNI and DHI should be used as a reference only because there are not enough validation data. Complementary Cornejo *et al*. (2017) add that altitude and proximity to the coast have substantial influences on the annual levels of solar energy. Additionally, Rondanelli *et al.* (2014) state that as the Atacama Desert presents a favourable scenario because it has shallow values of water vapour, cloud cover, ozone, and aerosols, as well as topography, stimulate solar radiation. Therefore, several factors influence the amount of irradiation in specific regions of the country.

[2] It is located between 26° and 29° 20' south latitude (BCN 2018).
[3] It is located in south latitude 22° 28′ 0″ (BCN 2018).

Regarding on-line information about solar energy potential, there are available different sources of information around the world. NREL shows a set of solar resource maps in the U.S including maps of DNI and GHI. Furthermore, it shows solar photovoltaic and concentrating solar power resource potential for the United States. On the other hand, Solargies prepared a variety of solar maps published by the World Bank Group under the Energy Sector Management Assistance Program (ESMAP) initiative helping companies to develop solar projects. Chile is not lagging behind concerning accessible information. A public database of solar irradiation is presented in Molina *et al.* (2017) and currently is part of the online tool of the Ministry of Energy website called "Explorador Solar" [solar explored][4]. It allows for a preliminary evaluation of the energy potential on any site defined by the user to be obtained. In addition, it is possible to estimate the generation of a PV system as well as allows to calculate the savings generated by the installation of a thermal solar system for domestic hot water. This demonstrates that Chile is taking advantage of information technologies incorporating free and accessible information to the citizen.

2.3 PV Solar Technologies

The solar market has three essential technologies: i) Solar Photovoltaic (PV) also known as Photovoltaics (PV) or cells convert sunlight to electricity directly ii) Concentrated solar power (CSP) generates electricity through mirrors which capture the rays and heat fluid, creating steam to drive a turbine. This technology is used to generate electricity in large-scale power plants iii) Solar Thermal Technologies convert sunlight to heat energy transferred by solar radiation. The heat could be used for cooling and heating applications,

[4] See information: http://www.minenergia.cl/exploradorsolar/

or the heat engine, work with a generator and produce electricity (World Energy Council 2016; SEIA 2014; IRENA 2018b). It is important to note that PV systems, directly convert the solar irradiation into electricity thereby it works just during the day unless it is integrated with battery system for storage. However, solar thermal technologies, with a medium for thermal storage, can operate through the day, making it attractive for large-scale energy production. Similarly, CSP also can store energy through molten salt allowing electricity to be generated after the sun has set (IRENA 2018b).

According to the trend, the cost of manufacturing PV has decreased drastically; prices declined by the end of 2009 and 2015 at around 80% (IRENA 2017). In the same direction, solar PV deployment has grown its installed capacity from 8679 MW in 2007 to 385,674 MW in 2017. Meanwhile, CSP has been increasing lower than PV its installed capacity from 479 MW in 2007 to 4,951 MW in 2017 (IRENA 2018b).

How do solar photovoltaics work? Photovoltaics are electronic devices, where the semiconductor material is used to convert sunlight into electricity directly. As Figure 2-3a shows daylight is comprised of photons, and when it hits the semi-channel metal of the PV board, electrons are discharged. Typical PV systems consist of: an array of solar PV panels, an inverter(s) and cables, display and switchgear. The output of the inverter provides the electricity for the house. It means that no

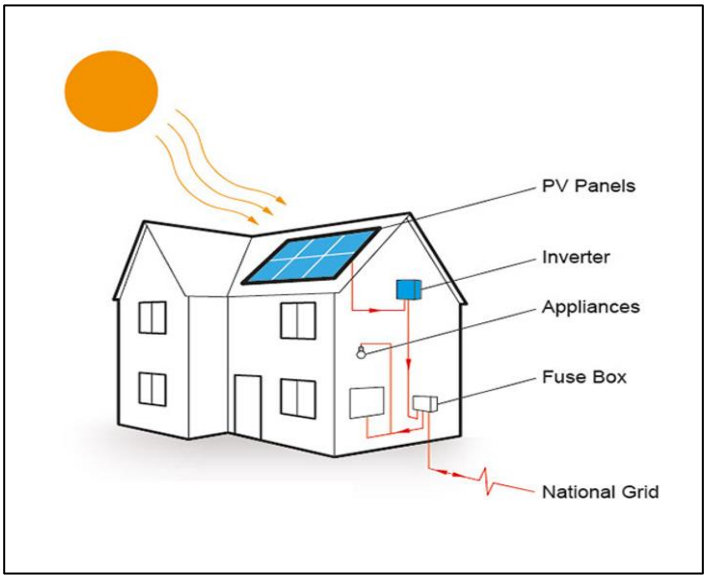

Figure 2-3a: Operation of solar PV
Source: Acorn Electrical Supply

electricity from the national grid is necessary when this system is working. The generated electricity is synchronized and depending on the demand can be used within a property or distributed to the main supply or national grid, when there are very sunny days or when not many loads are turned on thereby the system is generating more power than the consumption. Therefore, free energy from the sun and any surplus power will automatically transfer to the main grid where in some cases companies can buy this green electricity generated (Heatserve 2018).

Figure 2-3b shows the electricity generated by PV solar panel is produced during the day from 7 am to 6 pm approximately. That means that the grid consumption, is mainly during the night and the grid injection is during the day when there is less demand. In this sense, the best for energy producers is the sale for the retail price, because PV systems produce energy at the highest retail electricity price. However, there are other forms of payments where energy companies are favourable, due to they pay in prices lower than the retail price of the electricity (S.W.H group SE. 2018).

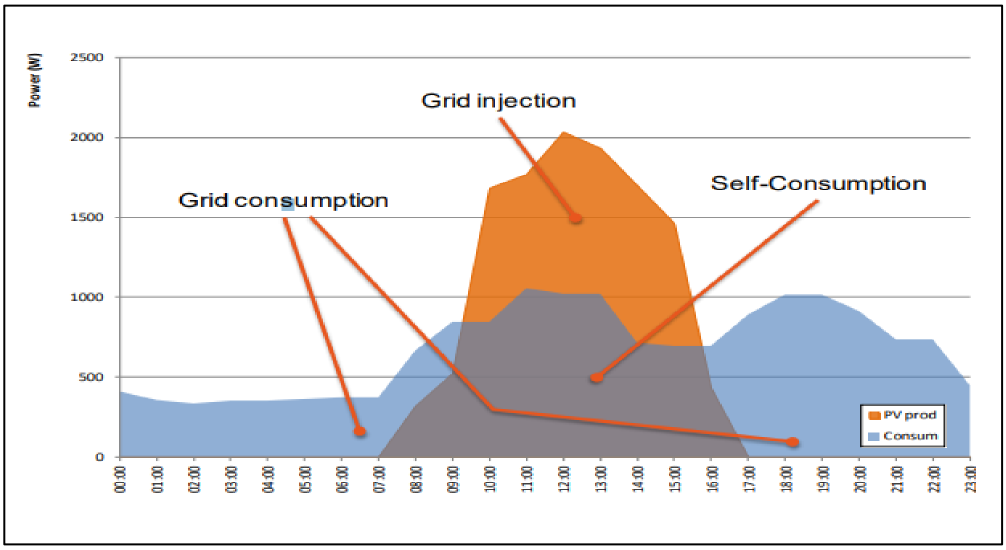

Figure 2-3b: Comparison of production and consumption profiles.
Source: IEA 2016

To sum up, there is an agreement among the authors that the country presents strong solar irradiance. Thereby, the country has a strong potential for the following technologies: photovoltaic (PV), concentrated solar power (CSP) and concentrated photovoltaic (CPV). Chile has a broad range of ‘climates solar' as Molina *et al.* (2017) identify in their study, where the Atacama Desert, is one of the driest deserts on Earth (McKay *et al.* 2003; IEA 2018). According to the authors, solar energy potential is influenced by; geographical and climate conditions, latitude and longitude, the season of the year, altitude and proximity to the coast, time of day, ozone, aerosols, and low cloud cover. In addition, there is a consensus that the primary factor that controls surface solar irradiance is cloudiness. Future research should be done to obtain better cloudiness measurements and validation of DNI and DHI measurements. Regarding solar technology, Chilean families can produce their own energy and sell to the grid. In this sense, it is important to note that PV solar panel generate energy during the day. Therefore, it is important to consider the payment mechanism for self-consumers as well as for electric power distribution companies.

2.4 Barriers to the Deployment of Renewables

Despite the excellent geographic and climatic conditions for renewables in the country, competitive prices and the development of technologies, “renewable energy has been tapped only to a small fraction of its potential" (Painuly 2001). Today in Chile, renewable energy represents 18% of the national total installed capacity and 16% of the electricity generation (CNE 2018) but still could be improved compared with other countries, such as Denmark or Germany, whose electricity production from renewable sources, excluding hydroelectric, in 2015 is 60% and 27,4% respectively (The World Bank 2015).

What are the barriers to renewables? According to Painuly (2001), several barriers prevent the penetration of renewables into the energy system, and these include: “cost-effectiveness, technical barriers, and market barriers such as inconsistent pricing structures, institutional, political and regulatory barriers, and social and environmental barriers". In her study, the author presents a framework to identify the barriers and suggest measures for mitigation.

Overcoming barriers to NCRE and achieve the transition toward renewable is the central challenge of the 21st century. In this sense three concepts have to be aligned; policies, the economy (cost and prices) and technological innovation (Verbruggen *et al*. 2010). Another challenge for the 21st century is "sustainable economic development and global climate change” (Foster *et al*. 2017). The authors state that if the cost of renewables is more competitive than fossil fuel, it is expected that renewable energy can continue without subsidies. In addition, the authors find that renewable energy transition will be slower or more costly than anticipated, because it is likely that the price of fossil fuel power generation will respond to the massive scale penetration of renewables and claim that future researches are necessary to quantify these effects.

Nasirov et al. (2015) is considered one of the few in Chile which identifies barriers to renewables' penetration in energy projects in the country. Through data collected, questionnaires, surveys, and interviews among developers of the renewable project, the study concludes that the main barriers include; lack of grid capacity, long time for renewable projects permits, land or water lease securement and limited access to financing. The results include policy recommendations and point out that further studies are necessary considering the nature of each renewable technology. Lastly, the author states that more studies are necessary about barriers considering the view of financial institutions and government.

The next step is to focus on national studies by technology or renewable energy. In this regards Sanchez *et al*. (2015) focus their research on geothermal energy in the Andes of Chile, where according to the authors this is "the largest undeveloped geothermal region in the world". In their study, the authors show an integrated analysis of geothermal barriers, policies, and economics in Chile. The methodology used includes a survey of critical participants from academia, the government, and industries. The result demonstrates that the main barriers to this kind of energy is the lack of public incentives for the private sector and clear medium-to-long term energy policies. To encourage the development of geothermal power generation in Chile as well as in the developing regions the authors present some guidelines for geothermal stakeholders.

Specifically about solar technology, Hass *et al*. (2018) express that there is a vast literature about barrier studies for solar technology, but no publication is found regarding the situation in Chile. It must be stated that the authors identify an immature solar market, where the deployment of residential photovoltaic (PV) and solar water heating (SWH) have no clear statistics yet. Hence critical barriers have not been reached. The study provides the status of solar energy in Chile, identifies the barriers of the mass deployment of solar energy technologies in Chile through interviews classifying barriers in six groups: "economic, market, system integration, technical, regulatory and information barriers". They also provide an overview of promotion policies and strategies for the detected barriers. Further research is necessary to evaluate their solution in quantitative terms, and the evaluation of the solutions including cost-benefit studies.

As can be seen, to promote renewables in the energy sector, actions will not be productive if authorities or policymakers do not consider barriers present in each country. International and national studies demonstrate that there are extended barriers to developing renewable energy. The most common barriers are cost and financial incentives. In addition, there are few studies regarding barriers in Chile (Sanchez *et al*. 2015; Nasirov *et al.* 2015; Haas *et al.* 2018) and only one specifically about solar technologies (Haas *et al.* 2018). The last pointed out the gap of information regarding the barriers to the deployment in residential photovoltaic (PV) and solar water heating (SWH), still an immature market.

2.5 Renewable Policies and Distributed Generation Law in Chile

2.5.1 Renewable Policies

One of the most widely used regulations for encouraging green energies is a renewable portfolio standard (RPS) (Muñoz *et al.* 2017). According to NREL 2018, RPS is a regulatory mandate which permits the production of energy from renewable and other alternatives of an electric generation different from fossil and nuclear energy. It is also known as a renewable electricity standard.

According to Lyonand Yin (2010) in Muñoz *et al.* (2017), countries or states adopt RPS policies for several reasons: i) decarbonisation energy matrix reducing greenhouse gases and air pollutant emissions ii) increasing energy security (case of Chile) iii) covering volatility of market prices iv again) and, with little evidence, stimulating local employment.

Other sources of information confirm that one of the main factors pushing renewables in Chile is the increasing energy insecurity due to demand growth and the lack of fossil resources. The country is depending highly on imports for domestic energy supply, about 90% of its fossil fuel requirements in 2014 were imported (Ministry of Energy 2015). For this reason, “the country is subject to the instability and volatility of international market prices and the supply restrictions owing to political, weather, or market phenomena” (Ministry of Energy, 2014).

Motivated by the reason stated above, the Chilean Energy policy states (among other targets) that the percentage of electricity from green energy should be 70% by 2050 (Ministry of Energy 2015). In this sense Muñoz *et al*. 2017 assess the cost of meeting the target by 2050, utilizing an Integrated Resource Planning model considering different scenarios such as; transmission system configuration, resource eligibility, for instance, large hydropower and demand expansion. The highlights demonstrate that the target will be met mostly thanks to the availability of renewable resources in the country and the continued reduction of costs in technology. Also, more transmission capacity could grow renewable sharing from 45% to 52%. The authors state that if hydropower[5] is considered as a renewable, the policy will not be needed.

Additionally, although Chile is only responsible for 0.25% of global emissions, it is highly exposed to climate change effects. Therefore, in the Paris Agreement Chile presented its Intended Nationally Determined Contribution to Mitigation (INDC) where renewables are one of the critical components in the Chilean energy sector (Chilean Government. 2015).

[5] Chilean Law 20.257 defines a small hydropower plant below 20 MW as Non-Conventional Renewable Energy.

Nowadays in Chile the national and international commitments go hand in hand with the electricity regulation. To place the ongoing electricity regulation, it is essential to consider that before 2004, the Chilean electricity market made no regulatory distinction for renewable non-conventional energies, there was no investment in transmission and innovates technologies did not exist. Nevertheless, during the last decade, there has been a promotion of renewables thanks to the following Laws (CNE and GTZ 2009; García-Pizarro, R. 2017; Ministry of Energy of Chile 2017):

1) Short Law I - Law Number 19,940/04: aimed to incentive the expansion of the electricity transmission and is the first Law which introduced the definition of Non-Conventional Renewable Energy (NCRE).
2) Short Law II - Law Number 20.018/05[6]: Established that distributors must supply more extended contracts for their regulated customers. Moreover, reserved 5% of the blocks of tender for NCRE, under similar price conditions to generating companies that achieve contracts with distributors.
3) NCRE Law - Number 20.257/08: established the current definition of NCRE. It sets a market share in NCRE from 5% to 10% in 2024.
4) Law 20/25 - Law Number 20,698/13 modified Law number 20,257 and established that starting in 2025, 20% of the energy withdrawals by electricity companies should come from NCRE, either from own production or contract. The obligation to generate from NCRE gradually increases annually starting in 2015.

[6] NOTE: Law short II was made when Argentines turned off the taps to feed their domestic supply. Therefore, there was uncertainty over the availability of Argentinean natural gas.

5) Regulates the payment of electricity tariffs for residential generators - Law 20,571 also known as Distributed Generation –This Law regulates customers' right to generate their electric power, consume it and sell their energy surpluses to electric power distribution companies.

Regarding the fifth point above, Poullikas et al. (2013) clarify concepts and misconceptions about Net Metering, which is used when an amount of energy generated by NCRE is compensated by electricity bill or to an exception in payment energy taxes. It works only for grid-connected systems and among the benefits is not just the use of green free electricity, but also excess energy sent to the utility can be sold back at retail price as well as reduce the demand on a strained grid. Through surveys in different countries (Europe, USA, Canada, Thailand and Australia) the authors demonstrate that there are a variety of Net Metering mechanisms depending on the particularities of each country or state. As a result, the research shows that there are not just one criterion for the definition of net excess generate credit but also the type of technology, the renewable energy sources for the power generation capacity limit, the type of customer and the type of utility.

2.5.2 Distributed Generation Law in Chile

The definition of Distributed Generation refers to a range of technologies which generate electricity at or near the place where will be used; this technologies can be solar panels and mix heat and power. It may supply a single or maybe part of a micro grid. The positive effect of Distributed Generation is that "it can help support delivery of clean can reliable power to additional customers and reduce electricity losses along transmission and distribution lines” (U.S EPA 2018).

To take advantage of the high irradiation levels, the Chilean government decided to create strong policies to stabilize the electricity prices and alleviate dependence on imported fossil fuels (Watts et al. 2015). However, according to Barrett et *al.* (2016), there is a lack of growth (and potential future growth) of the residential solar PV systems sector in Chile. In the same year, a newspaper claims "Solar energy and net billing that has not caught on in Chile" (El Mostrador 2016) after a couple of years another newspaper title a note as "Net-billing in Chile: little auspicious results" (La Tercera 2018). On the other hand, Hass *et al.* 2018 state that the Net-Billing Law had a modest initial effect. However, it showed high growth rates (700 system installed) by the end of 2016 (CNE 2017 in Hass *et al.* 2018). Until June 2018, there are 2,764 systems installed (CNE 2018c). Therefore, the PV system market is increasing but is not clear whether these improvements are those desired for a country with high potential for renewable energies.

Regarding the national situation, Hass *et al.* (2018) formulate the following question "Are there concrete barriers severely affecting the integration of solar technologies? Is it time for sunrise or sunset?" the authors identify barriers for NCRE focusing on large- and small-scale solar power plants, as well as industrial and residential solar water heaters. According to the authors, the solar market started with the Chilean energy crisis with high electricity prices (2008-2014). Currently, the authors express that the situation is different due to low fossil fuel prices, new coal generators in the market as well as hydropower generators. Therefore the electricity prices decreased directly. As a result, there is slower solar market development. Similarly to Hass *et al.* (2018), the study of Barret *et al.* (2016) assesses the lack of growth of the residential PV industry, providing recommendations for the future. First, the authors express that contrasted Net Metering policies (popular in the US and other countries) "the Chilean law does not reimburse consumers at the full retail rate for energy drawn from the grid." Secondly, there are no financial incentives as in the U.S or Germany, where subsidies played an essential role in developing the solar industry. The highlight recommendations of the study for increasing residential solar PV panels are: promote financing models; create consumer awareness programs; evaluate the argument for increasing the injection tariff; improve the enrolment process and create plans for significant distributed generation on the grid.

In contrast, Watt *et al*. (2015) are more optimistic and mention that during the recent period PV market have been increasing rapidly due to the PV lower prices as well as more awareness among consumers about sustainable energy, because of the excellent condition of solar power, several PV projects have been implemented without the necessity of subsidies. Therefore the solar market has rapid growth. The objective of their study is to analyse opportunities to take advantage of the solar market condition, modelling PV arrays in ten Chilean cities. The result shows how Net Metering and Net Billing affect the value of the PV production. Being Net Metering better policy that Net Billing because of the first give to the consumer a payment at the total retail rate for the energy injected. Nevertheless, some developed countries do not support this kind of policy due to economic unfeasibility. Under a Net Billing scheme, there is an advantage for consumers because "energy is recorded over longer time intervals and when installing a system with smaller capacity relative to household electricity consumption." The Net Billing scheme prevents an additional generation from injected energy to the grid which might be bought by the utility at the lower cost than the retail price.

It appears that there is an agreement among the authors that Chile has a strong potential for photovoltaic (PV) technology. However, it is not clear if the growing solar market has grown by leaps and bounds, as Watt *et al*. 2015 express, or reasonably modestly as Barret *et al*. (2016) and Hass *et al*. (2018) argue. The best scenario for deployment of PV residential solar is that there is more awareness among consumers about sustainable energy and as the low exponential cost of PV technologies. In contrast, the scenario that restricts the deployment of PV residential is low fossil fuel prices and no financial incentives for renewable generation. Given these points, it is essential to follow up on the country's energy policies and the effect on the use of renewables at the residential level.

2.6 Why California and Chile?

Despite the booming PV deployment in China and other cases of success such as in Europe (Germany, Italy, U.K, Denmark, Spain) Japan, Australia, India, and Brazil (IEA 2018). The State of California has been chosen because the similarities of the region in terms of climate and geomorphology with Chile (Hoffman 1995; Jiménez *et al.* 2008; .Mooney *et al.* 1970; Gulmon 1977) and consequence solar irradiation comparing the data given by National Renewable Energy Laboratory, Solaris and the Ministry of Energy Chile. This factor is necessary because of solar insolation determinate the location for PV technology and the electrical output. Also, as Zurita *et al.* (2018) state the initial investment of solar power is lower in countries with high irradiation than with low irradiation.

2.6.1 Climate and geomorphology similarities

As several authors recognize, there are similarities regarding climate and geomorphology in Chile and California (Mooney *et al*. 1970; Mooney 1977; di Castri 1991; Arroyo *et al*. 1995; Sax 2002 in Jimenez *et al.* 2008). Also, the two regions present a parallel latitudinal-climatic gradient, see Figure 2-1.6 with higher precipitation and lower temperatures at higher latitudes, which shapes the patterns of distribution of natural vegetation (Mooney *et al.,* 1970; Arroyo *et al.* 1995 in Jimenez *et al*. 2008). Moreover, interior and coastal mountain ranges and central valleys are remarkably comparable between Chile and California, having similar local climatic effects (Mooney *et al.* 1970 in Jimenez *et al*. 2008). For instance, as Chile, the State of California has different geographical regions and variety of weather, depending on different factors such as latitude, elevation, and proximity to the coast. The northern coast is colder, rainier and foggier than the southern coast. Thanks to the ocean there are moderate temperatures in the coastal areas. In the south-eastern part of the state, there is

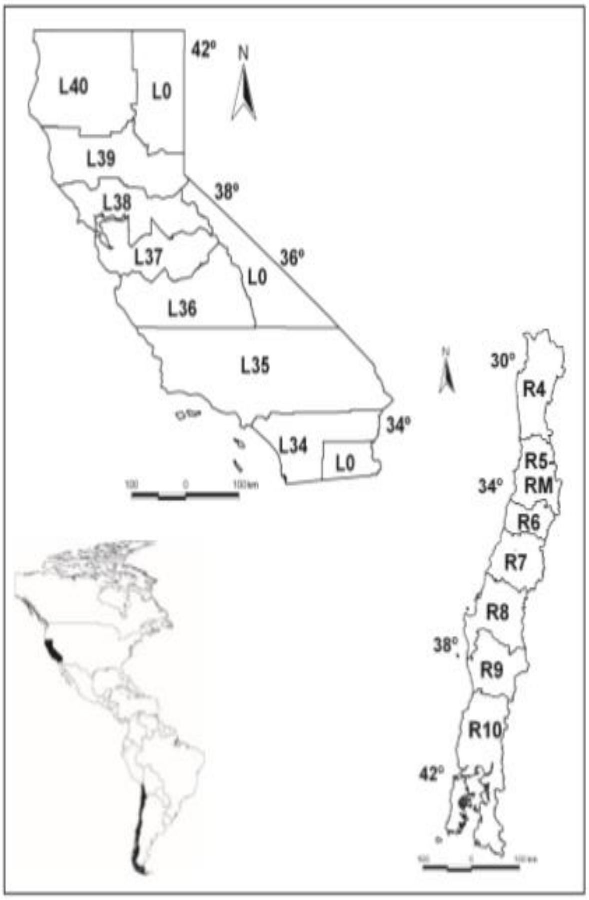

Figure 2-6.1: Locations of central Chilean and Californian regions. Latitudinal bands are indicated for Chile (R) and California (L). L0, in California, represents counties not considered in the analyses of Jimenez *et al*. Source: Jimenez *et al.* 2008

a desert, with hot and dry weather in the south-eastern part of the state. The Death Valley in the Mojave Desert experiences some of the hottest temperatures on Earth, which is the lowest point in the continental United States. The central valley has a Mediterranean climate and presents some of the most fertile and productive farmland. The mountain region contains two extinct volcanos as well as the tallest peak in the Sierra Nevada, the highest part of the continental United States (Chris Deziel 2018; WRCC 2018).

2.6.2 Solar irradiation similarities

In the State of California, insolation values are highest in areas of lower latitudes, in the summertime and clear skies with dry climates (Simons and McCabe 2005). California's Central Valley and the southern part of the state tend to have very high insolation, the range of insolation is between 3.8 to 6.3 kWh/m^2/day. Chile, as is seen in Chapter 2, has just as excellent conditions for solar energy as the State of California. The two regions have different yearly seasons but similar irradiation. Figure 2-6.2 shows a month-by-month comparison of Sacramento (34° 41' 12.4332" N) solar radiation levels with Santiago (33° 26' 50.9532" S) and Copiapó city (27° 22′ 00″ S). In Sacramento, California's capital city, the average monthly solar radiation level is 5.62 kWh/m2/day (Solar Energy Local 2018). The average monthly solar radiation in Santiago, in the central part of the country, is 5,1 kWh/m2/day and in Copiapó in the northern part of the country is 6,2 kWh/m2/day according to Ministry of Energy´s database.

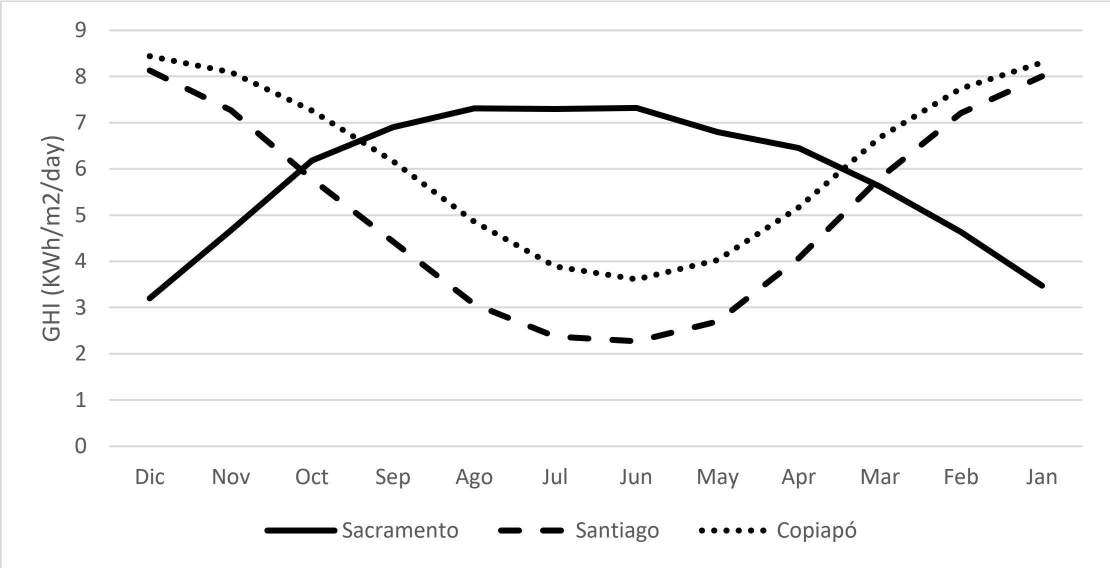

Figure 2-6.2: Month- by- month comparison of average solar radiation levels between Sacramento and Santiago and Copiapó, in the central part and northern part of Chile respectively. Source: The author´s elaboration based on data provided by Solar Energy Local 2018b and Ministry of Energy Chile 2018.

Comparative studies between Chile and California are mainly in the Ecological arena (Mooney *et al*. 1970; Mooney 1977; di Castri 1991; Arroyo *et al*. 1995; Sax 2002; Jimenez et al. 2008). In the electrical sector Watts and Ariztia (2002) compare the electricity crises of three countries (California, Brazil, and Chile) with the intention to obtain lessons for the Chilean electricity market. As two leaders in renewables, Keppley (2012) made a comparative analysis of renewable energy policy between California and German focused on actors and outcomes. However, it was not possible to find a study comparing Chile with a leader on PV energy, such as the State of California.

3. Methodology

The thesis is a qualitative and quantitative study which aims to develop a better understanding of the deployment of PV solar energy in Chile comparing with the State of California as well as to evaluate the Distributed Generation Law in Chile.

3.1 Methods data collection

This study is built on interviews, field notes, archival and documentary research in governments, research institutions and online media.

3.1.1 Interviews

In this section, the author used data triangulation, to develop a comprehensive understanding of the situation in Chile regarding the Distributed Generation Law. There are three groups of interviews from Chile: Group A: Experts from the public organisation related to Energy, Group B: Solar system installers, Group C: Consumers of PV solar systems. Additionally, one expert from the State of California, through personal communication. All the Chilean interviewees were contacted by e-mail (in which was attached the questions list as well as a consent form) and interviewed by phone. The answers were recorded and transcribed. See Appendix for the list of interviews and questions list.

Regarding the first group, the following institutions are responsible for energy policy and regulation in Chile: Ministry of Energy; National Energy Commission (CNE), Superintendence of Electricity and Fuels (SEC), Ministry of Environment through the Environmental Assessment Service (CNE and GTZ 2009; Central Energía, 2018). In this research seven interviews were from the regional office of the Ministry of Energy and one interview at the national level.

The second group, solar installers were contacted by the website of Superintendence of Electricity and Fuels (SEC). In this website, consumers can select an electric PV installer where the following information is available: region, company name and email. In total seven solar installers answered the interview. The installers were mainly from the central part of the country, Santiago.

The third group, consumers of PV solar systems. It was difficult to contact to them because most of the families contacted had thermal solar technology not PV solar for electricity. However, it was possible to contact at least three consumers of PV solar from the central part of Chile, Valparaíso. Therefore, the purpose of the interviews to consumers was only for understanding the reason which motivates the installation of PV systems.

This research has one interview with an American expert from the Public Utilities Commission in the State of California, Joy Morgan Ph D. Senior regularity analyst. She attended as the author of this thesis, to the international conference "Energy Policy and Programme Evaluation" on June 25 – 27, 2018 in the city of Vienna, Austria. In this place was possible to do a formal interview.

Some of the questions were obtained and modified from Robinson (2018) and Barrett *et al*. (2016). In total, 19 stakeholders were interviewed (see Appendix I). After each interview, the answers were compiled. The author enriched the discussion with an international and national literature review. Each interviewee has an identifier letter according to the group plus a number (e.g A1, B2) used in citations were in the list of interviews was removed to guarantee stakeholder anonymity.

3.1.2 Field Notes

During the research the author created notes in order to quantitative data found on the internet regarding descriptive information as well as reflective information (thoughts, ideas, questions, and concerns) based on interviews and data collected for a better understanding of the situation in Chile and the State of California according to the recommendation given by Labaree (2016).

3.1.3 Documentary research

This thesis focusses on Non-Conventional Renewable Energy (residential solar energy) in the Chilean Electricity Market. In Chile the following sources of information is used: National Energy Commission, Ministry of Energy of Chile, Ministry of Environment, Superintendence of Electricity and Fuel. As an international source of information: International Energy Agency, International Renewable Energy Agency, National Renewable Energy Laboratory, Organisation for Economic Co-operation and Development. And about the State of California the following online sources of information: California Energy Commission, Solar Energy Local, California ISO, and Federal Energy Regulatory Commission among others.

When the national information was not available online, the author asked for data information to the Ministry of Energy and the Superintendence of Electricity and Fuel in Chile directly, both organization answered the requirement. Therefore, personal communication by letter is provided in this thesis. It is important to note that in Chile since 2009 there is a "Law on Transparency" - Law No. 20285, which it gives citizens the right to obtain information held by public organizations.

3.2 Methods of data analysis

The method chosen to pursue the objective of this study comprises two different elements: First, a comparison of the Chilean Distributed Generation Law with the success case of the State of California and second analyse the Distributed Generation Law in Chile through an ex-post evaluation.

Regarding the comparative case, in the point of view of Pickvance (2005) a comparative analysis respond observed similarities and differences between cases exist and depend on the collection data from two or more cases, ideally according to a common framework. In the early phase of the study, it was confirmed that Chile has similarities in its geography, weather and solar resources with the State of California. Therefore, this research addresses the following question; how does Distributed Generation Law differ between Chile and the State of California? Considering that the State of California has extended experience in NCRE and Chile is starting its energy transition toward renewables. The comparative analysis has been conducted concerning:

- Electricity sector
- Policies that support environmental or climate goals
- The existence of Distributed Generation Law
- Incentive programs
- Impact of the Distributed Generation Law

The second component of the research is to evaluate the Distributed Generation Law in Chile. There are a variety of tools for policy evaluation. According to Start and Hovland (2004), the European Commission (2005) and Start and Hovland (2004) the common methodology recommended (among others) is SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats analysis). This analysis is a simple methodology to assess internal strengths and weaknesses and external opportunities and threats, it provides a simple overview of how a policy can be best be implemented (Start and Hovland 2004). The methods of data analysis for SWOT analysis in this thesis used the interview responses, following the structure is given by the European Commission in the document called "Strengths, Weaknesses, Opportunities and Threats in Energy Research" in 2005.

3.3 Limitations and delimitations of the research

- The study review residential solar energy focusing in photovoltaic (PV) systems. It does not include solar water heating (SWH).
- Due to time and financial resources, it was not possible to visit the State of California and Chile. However, it did not impede the collection of information since the two regions have online information and experts were available for interviews.
- According to Fertel et al. 2013 often SWOT analysis is subjective in its results, it could simplify the real problem, and it could be difficult to distinguish between internal and external factors, leading to confusion between strengths and opportunities or between weaknesses and threats.
- Another limitation is the low number of consumers interviewed. Due to lack of time, it was not possible to include more in a meaningful way in a different region of Chile. Most of the contacts have SWH but not PV systems. It is recommendable to include the experience of consumers in a subsequent study focusing on self-consumers energy.

4. Results

4.1 Case study - Chile and the State of California

The State of California is known as a successful case in the use of residential solar energy with roughly 20 years of experience (Scot Madden 2017). Hence the importance to compare similarities and differences with Chile which recently started with residential renewables energy since 2014 through the Generation Distributed Energy Law. It should be pointed out, as Table 4-1 shows, that although the Chilean territory is larger than the State of California, the population of the State of California is about twice than the Chilean population (U.S. Census Bureau 2017; INE 2018). In addition, the economy of the State of California is ten times bigger than Chile-based mainly in professional and business services (BEA 2018). Chile bases its economy in the extraction of natural resources and primary goods; the country is the world´s largest copper producer as well as a major exporter of agriculture, forestry and fishery products (OECD 2016). Moreover, the State of Chile is unitary, and its supreme authority is the President of the Republic (Ministry of Environment of Chile. 2016). The State of California is part of the federal government in the United States.

Table 4 -1
General description Chile and the State of California

Description	Chile	The State of California
Population	17.574.003 (a)	39,536,653 (b)
Area	756,096 km^2 (c)	423,970 km^2 (d)
GDP 2017	US$277,143 million (e)	US $2.746,9 billion (f)
Per-Capita GDP 2017	US$15.346,4 (e)	US $$58.272 (f)
Main industries	Extraction of natural resources and primary goods. It is the world´s largest copper producer (g)	Finance, insurance, real estate, rent, and leasing, professional and business services (f)

Source: a. INE 2018 b. U.S. Census Bureau 2017 c. Central Bank of Chile 2018 d. Britanica.com 2018 e. Countryeconomy.com 2018 f. BEA 2018 g. OECD 2016

Regarding residential solar energy in Chile and the State of California, the study compares the electricity sector and the Generation Distributed Law. The first topic gives a context about the electric generation by fuel type in each place as well as policies regarding energy and climate change. The second topic describes the Generated Distributed Law and the existence of incentive programs. Moreover, the Law´s impact during the recent period concerning numbers of residential installation in the two regions is described. In this chapter, it is possible to outline two main differences between residential solar energy. First, the State of California has a Net Metering Law whereas Chile has a Net Billing Law. Second, the State of California started to support distributed generation technologies since 1998, sixteen years earlier and with more incentives programs than Chile.

4.1.1 . Electricity sector

The electricity sector in the State of California is a paradigm of free competition (Watts and Ariztia 2002). On the other side, although the Chilean electricity sector is more conservative, it has been a pioneer, because it was one of the first countries in the world to deregulate and privatize its electricity sector, with the enactment of the Electricity Law of 1982 which is regulated and supervised by the authority (CNE and GTZ 2009; CE 2018).

The main differences between the two regions are the following; First, Chile highly depends on imported fossil fuel compared with the State of California. Second, the two places have different electricity supplies, for instance, Chile does not have nuclear power as the State of California and third, the State of California generates more electricity from renewables than Chile. The three differences are described below.

First, regarding the electricity generation by type of fuel, Chile does not have oil or natural gas of its own (IEA 2018). In 2014, Chile imported around 90% of its fossil fuel requirements (Ministry of Energy 2015). Unlike Chile, the State of California imported only a quarter of its electricity by 2016. The state generates crude oil and it is one of the largest producer of petroleum in the U.S. Furthermore, the State of California is a top producer of conventional hydro electrical power as well as is a top producer of renewables (EIA 2017).

Secondly, the Figure 4-1.1 shows the percentage of electric generation by fuel type in the State of California and Chile in 2015. The figure shows that the two regions have a variety of fuel types. Comparing electricity supplies, in Chile, most of the total primary energy came from fossil fuel and consisted in coal, oil and natural gas. Unlike Chile, in the State of California fuel coal-fired power plants have not been significant contributors to power generation. The California Energy Commission states that the electricity generation by 2015 was predominantly from natural gas (60%) followed by a diversity fuel type, among them nuclear power (10%) a source of energy which is being retired (two reactors were permanently turned off by 2013). Chile considered this type of energy source, but the Fukushima disaster in Japan by 2011 scrapped that idea, because the country is located in the "Pacific-Ring of Fire" an area of intense volcanic, earthquakes and tsunamis (Camacho- Horvits 2016). Similarly, the two regions have hydroelectricity which fluctuates year on year, depending on the hydrological conditions (IEA 2018; California Energy Commission 2018).

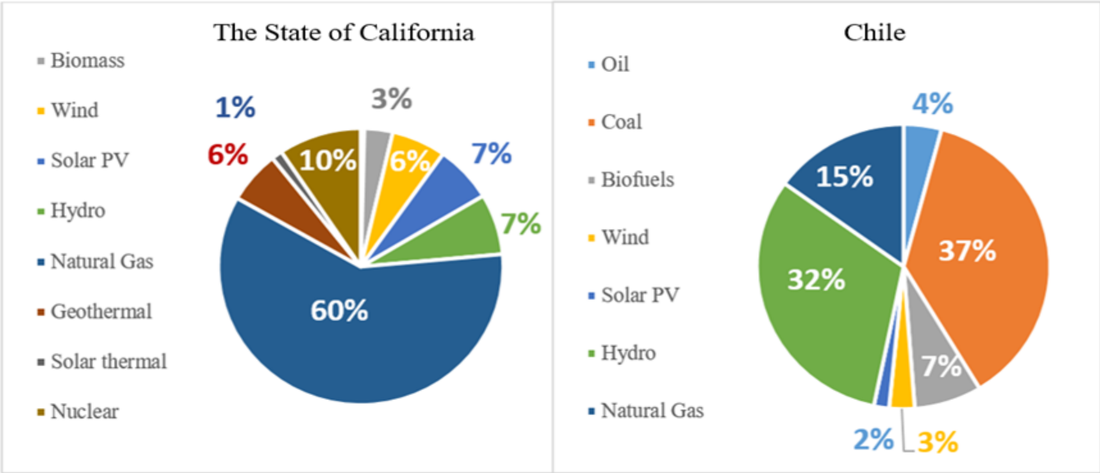

Figure 4-1.1: Percentage of electric generation by fuel type in the State of California and Chile in 2015. Source: The author´s elaboration based on data provided by California Energy Commission 2018 and International Energy Agency 2018c.

Third, the two regions have favourable conditions for green technologies due to climate and geomorphology similarities described in Chapter 2. The two regions have dry and sunny deserts for solar energy, favourable conditions for geothermal energy and long coast and sea power for wind power. In this sense, Chile is living its energy transition toward to renewables, and the State of California is already a leader in renewables. The state started .from the 90´s implementing renewable energy and climate change policies (Keppley 2012). Table 4-1.1 shows a comparison in the electricity sector in Chile and the State of California, the total system electric generation in the State of California is almost four times bigger than Chile and the contribution of renewable in the electricity matrix is higher in the State of California than in Chile.

Table 4-1.1
Comparison electricity sector in Chile and the State of California

	Chile		The State of California	
Total System Electric Generation (GW hours)	76.647	(a)	292.031	(b)
Imported energy	90%	(c)	26%	(d)
Main electricity supply	Coal (37%)	(f)	Natural Gas (60%)	(b)
Generation of electricity from renewables	18,3%	(e)	28%	(b)

Source: a. CNE 2017 b. California Energy Commission 2018 c. Ministry of Energy 2015 d. EIA 2017 e. CNE 2018 f. IEA 2018c

4.1.2 Policies that support environmental or climate goals

Regarding policies which support environmental or climate goal, Chile as well the State of California have implemented action plan specifically for energy and climate change goals. The two cases include clean electricity goals with different periods and targets. In the energy arena, since 2003 the State of California adopted the Energy Action Plan by the CEC, the CPUC and the Consumer Power and Conservation Financing Authority (an authority now defunct) (CEC.2018a). In 2005, a second plan was adopted, the Energy Action Plan II, the goal is to obtain an adequate, affordable, technologically advanced, and environmentally friendly energy. In 2008 instead of creating a new Energy Action Plan, there was an "update" of the Plan in the context of global climate change (State of California 2008).

In the case of Chile, the state adopted in 2015 the Energy Policy which proposes a vision of "Chile's energy sector by the year 2050 as being reliable, inclusive, competitive and sustainable". Four pillars sustain the Policy: Quality and Security of Supply, Energy as a Driver of Development, Environmentally-friendly Energy as well as Energy Efficiency and Energy Education (Ministry of Energy, 2015). In 2018 "La Ruta energética 2018-2022" [The energy path in English] was published. It aims to define the path and priorities in energy matters existing today (Ministry of Energy 2018). One of the measurements is “to reach four times the current capacity of renewable small-scale distributed generation by 2022” (Ministry of Energy of Chile 2018). Until February 2018 the capacity was 13.327 KW. Therefore, in 2022 it is expected to get four times that capacity (53.308 KW)[7]. Future analysis is necessary to follow up the goal.

In the climate change arena, the State of California has had programs to reduce GHG emissions for a long time. However, in 2006 marked the beginning of an integrated climate change program. Also, in 2017 the State of California published a Strategy for Achieving California's 2030 Greenhouse Gas Target. The State of California has different instruments for supporting environmental or climate goals such as The State's Energy Efficiency Requirements, Renewable Portfolio Standard, California's Cap-and-Trade program, Emission Performance Standards, Electric Vehicle Executive Order (California Air Resources Board 2017; Homer *et al*. 2016).

In the case of Chile, the country is highly vulnerable to climate change impacts as the State of California. Therefore in the framework of Paris Agreement Chile presented in 2016, its Intended Nationally Determined Contributions (INDC), which is committed to a quantified reduction of the intensity indicator of greenhouse gas emissions (GHG) for 2030 (Chilean Government 2015). Also in 2014, Chile was the first country in Latin-American to enact the first climate pollution tax or green taxes reform - Law 20,780 (IEA 2018d). As Figure 4-1.2 shows, both regions have clean electricity goals, and excellent progress 18% in Chile and 29% in the State of California, which demonstrate that they are relatively close to the target in 2025 and 2020 respectively. In long-term Chile has the higher target with 70% of clean energy by 2050.

[7] Ricardo Irrarazabal, undersecretary of Ministry of Energy, Chile. Letter communication. 27 July 2018.

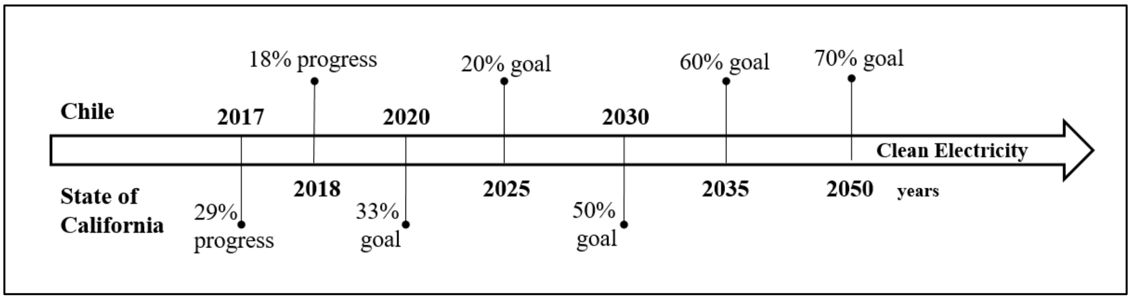

Figure 4-1.2: Comparative clean electricity goals in Chile and the State of California
Source: The author´s elaboration based on the California Air Resources Board. 2017; Ministry of Energy of Chile 2050; CNE 2018d; IEA 2018d.

4.1.3 Existence of Distributed Generation Law

The two cases regulate customers' right to generate their electric power, consume it and sell their energy surpluses to electric power distribution companies. Concerning the findings it is possible to highlight three points: The State of California started with the Distributed Generation Law in 1996 meanwhile Chile in 2014. Secondly, the State of California implemented a Net Metering law (NEM), and Chile implemented Net Billing Law. Third, the two regions have had modifications during the last period, in the State of California the last modification was in 2016 and Chile the modification is still in process, details about the Chilean Law changes are given thanks the interviews to the public sector and solar installers.

California's net-metering law (NEM) started in 1996, and it has been amended many times since its enactment, most recently by AB 327 of 2013, and by the CPUC in 2016 (Energy.com 2018). NEM allows customers generate their own energy, per each KWh of solar electricity supplied to the grid, consumers get a bill credit for one KWh of utility-generated electricity. When the production of solar energy is more than the consumer needs, the surplus can be used when the solar panels do not produce enough to meet the monthly use (CPUC 2018c).

To continue with the solar success, the California Public Utilities Commission (CPUC) created a next-generation program known as "Net Metering 2.0" (NEM 2.0). The modification preserve that homeowners and businesses "receive per-kWh credits for their solar electricity that is equal to the value of a kWh of utility electricity." This modification means that the economics of solar are still very favourable under NEM 2.0 (Energy Sage 2018). As Table 4-3.1a shows three main modification changes: i) Interconnection fee, which means that system owners pay a small one-time to connect their solar panels to the electric grid ii) In the original Net Metering policy, system owners did not have to pay non-by passable charges (NBC's)[8]. Under NEM 2.0, new system owners will have to pay NBCs, but only for the kWh of electricity delivered by the utility iii) Under NEM 2.0, TOU rates[9] is required, this means that the electric bills will be according to TOU rates schedules. Therefore, property with owner systems maximizes Net Metering credits by locating panels maximizing the orientation´s sun (Energy sage 2018)

Table 4-1.3a

Differences between NEM and the Current NEM 2.0

Law´s modification	**Former NEM**	**Current NEM or NEM 2.0**
Interconnection fee	none	$75 - $145
Non- by passable charges	Yes, based on “netted out” quantity of energy consumed over the course of the year	Yes, based on "netted out" quantity of energy consumed in each metered interval (1 hr for residential customers – 15 min for nonresidential customers)
Time of use rate	Non required	Required

Source: CPUC 2018c

[8] Non-bypassable charges (NBC's) are per-kilowatt-hour charges that are built into utility electric rates.

[9] TOU rates are designed to align electricity costs with demand across the electric grid. Electricity is most expensive at times of high demand, like late afternoon and early evening, which means that utility will charge more per kWh during those “peak hours.”

In Chile, Law for Distributed Generation, Citizen Generation or Net Billing Law; it became effective on October 22nd in 2014. It aims to grant regulated customers the right to generate their electric power, consume it and sell their energy surpluses to electricity distribution companies (Ministry of Energy of Chile, n.d.). It is a Net Billing law, since it does not pay the same price that the consumer cancels for its energy consumption to the distributors, which is known as "one-to-one netting." There is not a direct payment for energy injections. However, the injections of energy from the generation equipment must be discounted from the billing corresponding to the month in which they were made (ACESOL 2018).

The Law´s modification is still in process. According to the information given by the Congress, there are different points in the evaluation. Also, according to the interviewees from the public sector as well as solar panel installers there are two principal modifications in the discussion; the limitation size limit and the valuation of the energy injections (see Table 4-1.3b). Most of the interviewees indicated that the new modification probably would stop paying surpluses, promoting self-consumption and not the commercialization of energy, which has another regulatory framework for small distributed generation media [in Spanish, Pequeños Medios de Generación Distribuída - PMGD].

Table 4-1.3b
Differences between current Law and modification proposal DG Law in Chile

Contents	Current Law	Modification (proposal)
Installation size limit	100 kW	300 kW
Valuation of the energy injections	It valued at the energy "node price."	The options are: At the same price as the BT1 tariff or residential tariff lower than node price or non-payment.

Source: Cámara de Diputados de Chile [Chamber of Deputies of Chile] 2018a and interviews. *Note*: "node price" is the final user price of electricity less distribution added value and the single charge for the use of the trunk system [Sistema troncal in Spanish]. BT1: Measurement of energy whose connected power is less than 10 kW or the demand is limited to 10 kW (residential)

As Table 4-1.3c shows the main differences between the two cases are: i) Chile has a Net Billing Law where the valorisation of the energy consumed and the injections are in financial resources ($) meanwhile in the State of California the valorisation is in kWh ii) Unlike Chile, the State of California has a limit according the customer annual´s load. Regarding the available technologies, the State of California has the broader type of renewables. The two cases have similar applicable sectors as well in case of net excess generation favour the discount will be in the following bill.

Table 4-1.3c
Comparison of the DG Law in Chile and the State of California

	Chile (a)	The State of California (b)
Name´s Law – (enacted year)	Law N° 20,571 – Distributed Energy (2014)	Net-metering law (1996) Currently "NEM 2.0" or "NEM Successor Tariff."
Type of Law	Net Billing, calculated by subtracting the valorisation of the energy consumed and the injections, in $.	Net Metering, calculated by subtracting the energy consumed with the injected energy, in kWh.
Eligible Renewable/ Other Technologies	Biomass, Hydraulic energy (less than 20.000 kilowatts), geothermal, solar, wind, others. Installation of	Geothermal Electric, Solar Thermal Electric, Solar Photovoltaic, Wind (All), Biomass, Municipal Solid Waste, Fuel Cells using Non-Renewable

	efficient cogeneration (less than 20.000 kilowatts).	Fuels, Landfill Gas, Tidal, Wave, Ocean Thermal, Wind (Small), Hydroelectric (Small), Anaerobic Digestion, Fuel Cells using Renewable Fuels
Applicable sector	Regulated clients, for instance; residential, commercial or small industrial clients, schools, others.	Agricultural, Commercial, Fed. Government, General Public/ Consumer, Industrial, Local Government, Low-Income Residential, Multi-Family Residential, Non-profit, Residential, Schools, State Government
Installation size limit	100kW	No limit can only be sized up to customer annual´s load
Net Excess Generation	If there is a balance in favor of client, this will be discounted in the following bill and readjusted according to the consumer price index.	Credited to customer's next bill at retail rate.

Source: The author´s elaboration based on a. Ministry of Energy of Chile, 2012; Ministry of Energy of Chile, n.d. b. CPUC 2018c; Go Solar California 2018

4.1.4 Incentive programs Generation Distribute Energy Law

According to Joy Morgan from CPUC[10] the State of California is successful in the use of residential solar energy due to the California Solar Initiative (CSI) which granted a large amount of money, with the goal of market transformation. In addition, there was a federal tax credit which complemented the CSI. These actions contributed to jump start the residential solar energy.

Since 1998 the State of California started to support distributed generation technologies with the Emerging Renewables Program (ERP) which incentivized PV systems under 30 kW and other renewable energy systems under 30 kW. However, the program ended in

[10] Joy Morgan Ph D. Senior regularity analyst at Public Utilities Commission in the State of California. Formal interview. Vienna, June 27th, 2018

2007 when the California Solar Initiative (CSI) launched. Table 4-1.4a shows the diversity of the components of CSI, it must be stated that this program covers funds not only for homes but also, existing or new commercial, agricultural, government, and non-profit buildings. Secondly, the program includes solar photovoltaic (PV), as well as other solar thermal generating technologies. Third, the program includes low-income residents that own their own single-family home and meet a variety of income and housing eligibility criteria. Lastly, some component as CSI general program already meet the goal, with an incentive budget of $1.95 billion it was possible to install 1.750 MW of rooftop solar energy on businesses and existing homes (California DG Statistics 2018; CPUC 2018c)

Table 4-1.4a

Components of the Distributed Generation Incentive Programs in the State of California

Programs	**Description**	**Monitored by**
CSI General Market Program	This Program was designed with a declining incentive structure to support the California solar market's growth while gradually reducing its reliance on subsidies. The Program closed on December 31, 2016.	CPUC and administered by PG&E, SCE, and CSE
CSI Thermal Program	This program offers cash rebates on solar water heating systems for a single-family residential customer, multifamily, and commercial properties qualify for rebates on solar water heating systems and available solar pool heating systems.	PUC and administered by PG&E, SCE, and CSE
Multi-family Affordable Solar Housing (MASH) Program	This Program provides incentives to offset the cost of installing solar photovoltaic (PV) systems on multitenant affordable housing developments in California. MASH's goal is to combine energy efficiency and solar PV to help enhance the overall quality of affordable housing.	CPUC oversees the MASH program and administered by PG&E, SCE, and CSE .

Single-family Affordable Solar Homes (SASH) Program	This Program provides incentives to qualified low-income homeowners to help offset the costs of a solar electric system.	The CPUC oversees the SASH program and administered by GRID Alternatives
New Solar Homes Partnership (NSHP)	NSHP provides financial incentives and other support to home builders, encouraging the construction of new, energy efficient solar homes	CPUC and currently administered by the California Energy Commission
Self-Generation Incentive Program (SGIP)	This Program provides financial incentives to support existing, new, and emerging distributed energy resources that are installed to meet all or a portion of the electric energy needs of a facility	CPUC and administered by PG&E, SCE, Southern California Gas Company (SCG) and CSE

Source: California DG Statistics 2018; California Public Utility Commission (CPUC). 2018c; Go Solar California. 2018

In Chile, there are different financial initiatives administrated by different public services. The type of financing can be; subsidies, credits, state guarantees or tax benefits. These initiatives can be given at a national level or the regional, as well as a specific economic sector. According to the interviews, the most crucial incentive directly for residential solar energy is the Family Heritage Protection Program, which provides incentives to qualified low-income homeowners. The second program mentioned is the Public Solar Roofs Program, but this stimulates the market of PV in "public buildings" no in the residential sector, this program was created for the maturation of the PV market for self-consumption (Interview A1). See a description of each program in Table 4.1.4b.

Table 4-1.4b
Description of Public Programs in Chile

Programs - Year	Budget (US)/ Subsidies	Goal/Objective	Monitored by
Public Solar Roofs Program 2014	$13 million total budget	To stimulate the market of PV in "public buildings" and contribute to the maturation of the PV market for self-consumption.	Ministry of Energy
	$8.5 million (spent up until March 2018)	In March 2018 there was 4.9 MW bid capacity under this program.	
Family Heritage Protection Program 2006	The maximum subsidy can be 50, 55, 60 or 65 UF according to the region.	This subsidy allows to repair or improve social housing or housing whose appraisal does not exceed 650 UF Among a variety of options, PV solar panel is part of the Energy Efficiency Innovations.	Ministry of housing and urbanism

Source: MINVU 2018; Ministry of Energy of Chile 2018a. *Note*: 1 UF: $27.202 CLP (July 2018) Conversion Chilean Peso: CLP $1 is USD$662.

Regarding subsidies it is important to note that the Chilean government has concentrated subsidies in the Atacama region (III region), because in this region there was a natural disaster in 2015 when floods hit five municipalities or communes. Therefore in the framework of the reconstruction of the region, after the floods, the Ministry of Housing and Urban Planning, allocated subsidies for the installation of photovoltaic solar systems, between new and repaired homes of the affected families (ACEE 2018).

Figure 4-1.4 shows the number of projects, interconnected solar PV, under the Distributed Generation Law in Chile per type of financing. In 2017 the amount of private projects compared with the reconstruction projects in Atacama region were similar (623 and 632 projects respectively). In addition, the figure shows that between 2016 and 2017 the number of private and reconstruction projects increased more than double, in the case of reconstruction projects almost three times. Regarding private projects is expected that the year 2018 also will double the year 2017 (623 projects) because in Jun 2018 already had 468 projects. Regarding reconstruction projects there were 286 in Jun 2018, future data will indicate whether the number of project will increase or decrease. With reference to the public solar roofs program - in Spanish Programa Techos Solares Públicos (PTSP) – remains almost the same in the years 2016 and 2017 with 50 and 46 projects respectively. Other public funds are growing in 2018 compared to previous years. More details about Figure 4-1.4 by year and month see appendix III.

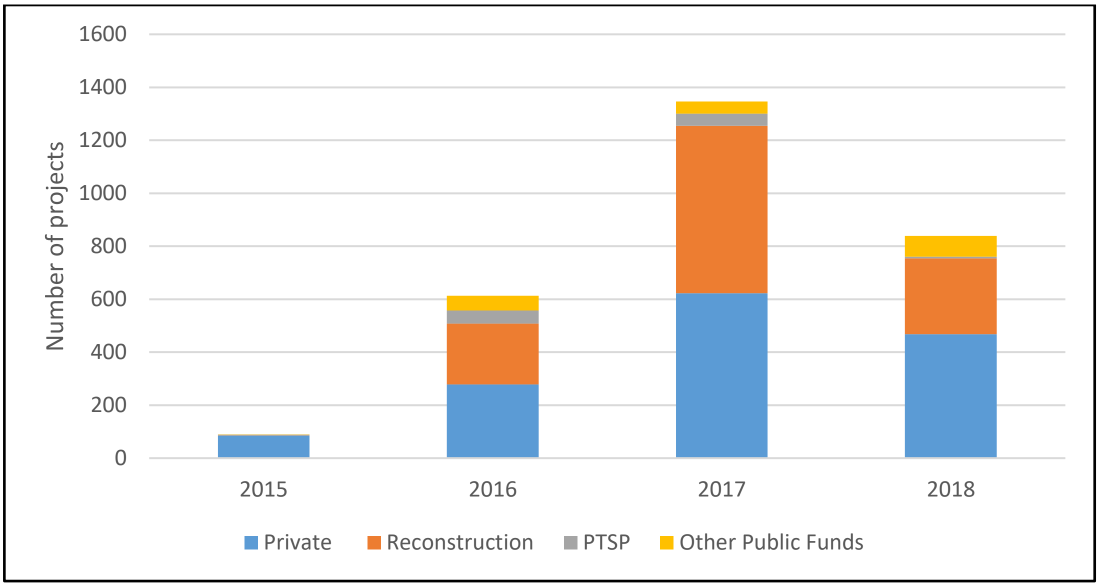

Figure 4-1.4. Number of Projects (interconnected solar PV) under the Distributed Generation Law in Chile per type of financing. Source: The author´s elaboration based on Superintendence of Electricity and Fuel, letter communication, August 2, 2018. PTSP: Public solar roofs program [in Spanish Programa Techos Solares Públicos]

4.1.5 Impact of Distributed Generation Law

This section presents the impact to the Distributed Generation Law in the two cases regarding a number of project implemented and distribution of projects by region in each case. Table 4-1.5 illustrates that in the State of California the energy capacity under the Generation Distributed Law is more widespread than Chile.

Table 4-1.5
Comparing Energy capacity under the DG Law in Chile and the State of California.

	Chile	**The State of California**
Capacity in 2018	9,422 KW	363,62 MW
Cumulative capacity	18,283 KW	6164,29 MW

Source: CNE 2018b; California DG Statistics 2018.

The Generation Distributed Energy Law (N°20,571) in Chile came into force once its regulation or it rules of procedure was published in 2014. Figure 4-1.5a shows that the Law had a slow start, but it has been continuously ascending. During the first years, the regulation had a modification to simplify procedures, clarify the situation of new buildings and housing complexes and to avoid entry barriers to the market. Nowadays electronic procedures for the processing of permits are implemented, reducing the timing connection (Cámara de Diputados de Chile 2018a). Figure 4-1.5a shows that there are in total 1.350 installations declared until 2017, this number will increase enormously by the end of 2018 because by May 2018 the total number of projects is already 865.

In the State of California, the implementation of the Net Metering Law as in Chile started at deficient levels, however, since 2007 when the California Solar Initiative (CSI) started continued in leaps and bounds (See Figure 4-1.5b). According to the EIA in 2016 The State of California "has nearly of the nation´s solar electricity generating capacity." As

Figure 4-1.5b shows until April 2018 there were in total 747.634 projects with permission to operate. These projects refer to a given interconnection address/project and some projects contain multiple interconnection applications.

Comparing Figure 4-1.5a and 4-1.5b, it is possible to note that regarding the implementation of the Distributed Generation Law, the State of California is 18 years in advance of Chile. In an interview on 27 Jun, 2018, Joy Morgan, Senior regularity analyst at Public Utilities Commission, indicates that since 2007 the number of projects started to increase due to the California Solar Initiative (CSI). In the case of Chile, a landmark is the reconstruction of Atacama region (III region), where the Ministry of Housing and Urban Planning, allocated subsidies for the installation of photovoltaic solar systems, between new and repaired homes of the affected families (ACEE 2018). Therefore, there are an increasing number of private as well as reconstruction projects since 2016. [11]

Consequently, as Figure 4-1.5c shows the leader in the implementation of the Law in Chile is in the Atacama region (III region) followed by the capital of the country or Metropolitan Region. Figure 4-1.5d shows the leader is in the state is San Diego with 117,791 projects followed by Los Angeles with 73,521 projects.

Comparing Figure 4-1.5c and 4-1.5d, it is possible to note that geographically Chile does not deploy the residential solar energy in regions with high irradiation as Arica and Parinacota (XV region),Tarapaca (I region) or Antofagasta (II region). In contrast, in the State of California, the leader in the state is San Diego, the southernmost city in the state.

[11] Superintendence of Electricity and Fuel, letter communication, August 2, 2018.

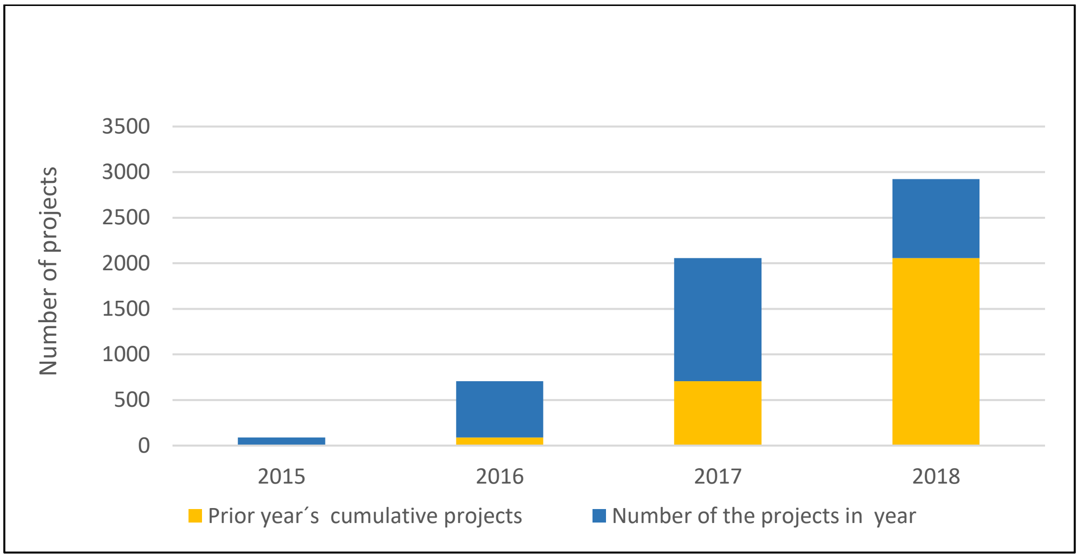

Figure 4-1.5a: Number of Projects (interconnected solar PV) under the Distributed Generation Law in Chile. Source: The author´s elaboration based on CNE 2018e

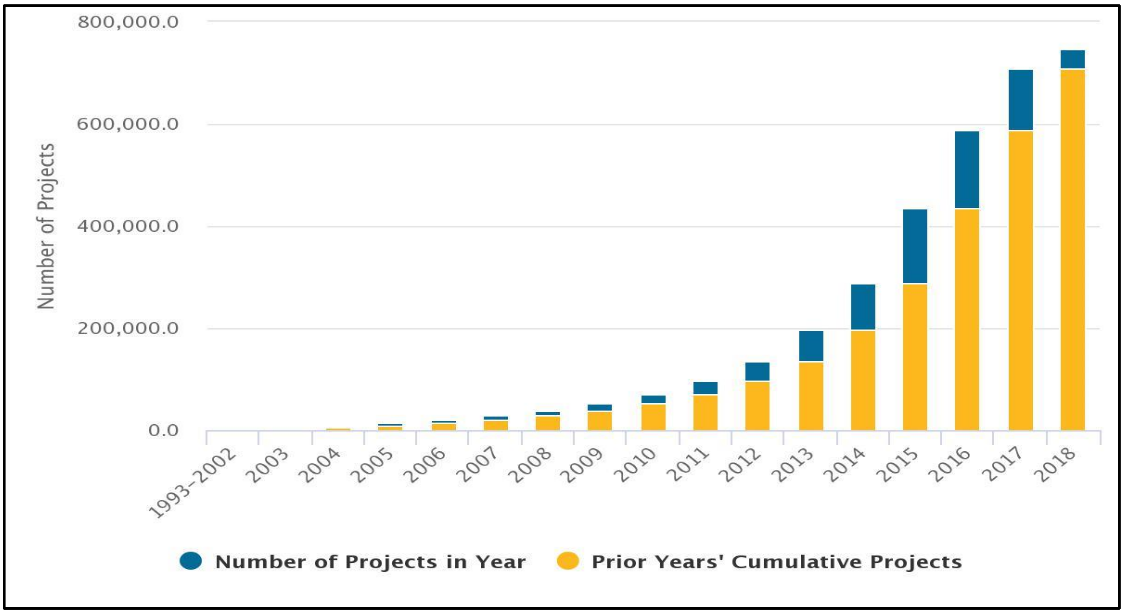

Figure 4-1.5b: Number of Projects (interconnected solar PV) under the Net Energy Metering (NEM) Source: California DG Statistics 2018

In Figure 4-1.5c and Figure 4-1.5d is possible to note that Chile does not deploy the residential solar energy in regions with high irradiation (the northern part). In contrast, in the State of California, the leader in the state is San Diego, the southernmost city in the state.

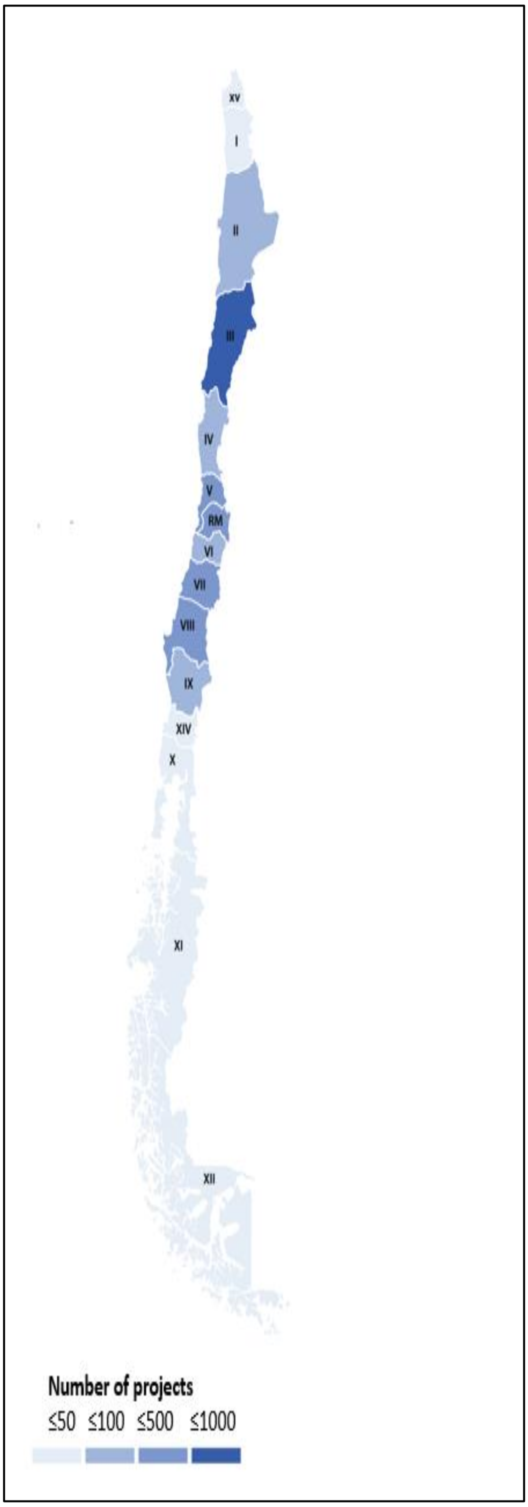

Figure 4-1.5c: Distribution of number of Projects (interconnected solar PV) under the Distributed Generation Law by regions in Chile. Source: The author´s elaboration based on CNE 2018e

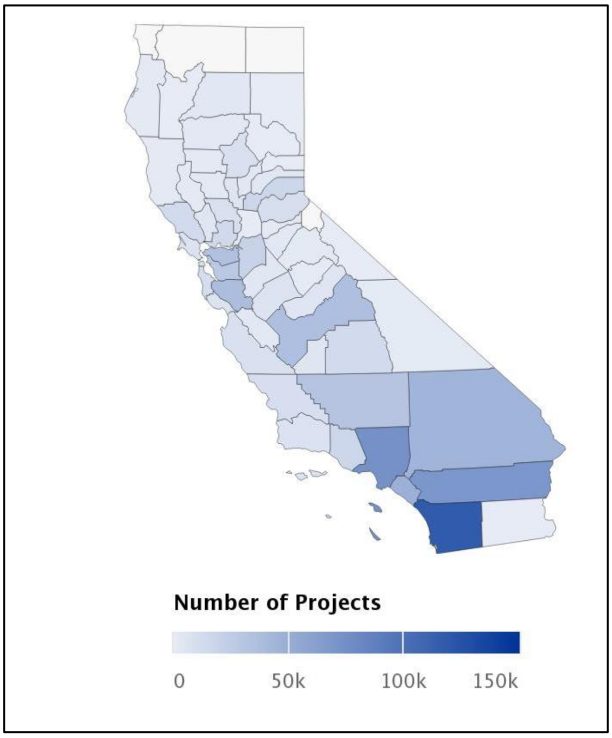

Figure 4-1.5d: Distribution of number of Projects (interconnected solar PV) under the net energy metering (NEM) by the city in the State of California. Source: California DG Statistics 2018.

4.2 SWOT Analysis Generation Distributed Law in Chile

This research evaluates the Distributed Generation (DG) Law in Chile evaluating the strengths and weaknesses of two areas: policy and measures followed by market and industry. Regarding opportunities and threats findings, the author uses the same areas. In this section, the author used information from interviews to develop a comprehensive understanding of the situation in Chile regarding the DG Law. The interviews were from experts from the public organisation related to Energy (Group A) and solar system installers (Group B). In this sections information given by consumers of PV solar systems (Group C) is briefly used, because the low number of participants.

4.2.1 Strengths and weaknesses DG Law - Policy and Measures (P&M)

In the arena of policy and measures, the main strength is the right of consumers to generate its energy with clear rules. Among the weaknesses there are mainly three: i) Lack of dissemination of Law ii) Unfair payment of surplus energy and iii) Time-consuming authorization process, mainly in some regions of Chile. An explication of each finding is provided below.

Most of the interviewees recognize the positive effect of the Law because it regulates and gives the right to the citizen to generate their energy. The current regulatory framework for residential solar energy in Chile is an easy authorization process. In addition, there are several technical online instructions and guides made mainly by the Superintendence of Electricity and Fuel (SEC) as well as by the Program of Renewable Energies and Energy Efficiencies in Chile. The Chilean government leads the program with German international cooperation, GIZ[12]. Therefore “It is easy to install the solar panels and connect them, the procedure in the SEC is clear" (Interview A1). On the other side, the authorization of solar panels currently is an on-line process, and there is accessible information to the installers and consumers.

Among the weaknesses, according to the interviewees, there is a lack of dissemination of the Law. Despite the seminars organized by the SEC around the country and online information, it seems that it is not enough. For example, the first consumer interviewed did not know of the existence of the law and their PV solar panels were installed without authorization; he made it by himself through online media. In the opinion of the author, this singular case demonstrates the accessibility of technology, the lack of knowledge of the Law and security risk implication but the desire to have energy sovereignty. As he expressed "I wanted to become independent, at least producing a little energy because the cost of the electricity is so expensive in this rural area" (Interview C1). Others consumers (with authorized facilities) did not know about the law either, because they received their apartment with solar energy. Therefore, as an interviewee expressed, "it must be taken to educational establishments, more TV advertising, because its dissemination has not been effective” (Interview B3).

Additionally, the Law does not mandate a fair payment of surplus energy. The payment for excess energy was a controversial point, because according to the Ministry of Energy the law seeks self-consumption, and avoid unfair competition with distributors.

[12] The German Agency for *International Cooperation* or Deutsche Gesellschaft für Internationale Zusammenarbeit (*GIZ*) an international enterprise owned by the German Federal Government

Therefore, it should be used for own consumption of those who produce it, not business from these self-consumption projects. However, from installers, this produces a disincentive for the implementation of the Law. As some responders suggest "The rules are more effective for distribution companies than for the consumer" (Interviewed B6) "The net billing model makes it more effective, even though the client loses" (Interview B7).

In addition, despite the process is online. In the point of view of installers from the regions (not from the Capital, Santiago), still the process takes a long time. In theory, the process should be 45 days, but in some cases, it takes 120 days, "there is no sanction to the distributing companies if they delay in answering" (Interview B3). However, thanks to the last modification the process reduces the time authorization, "it was reduced by 45% of the processing time, going from 55 working days to 30 working days" (Interview A5).

4.2.2 Strengths and weaknesses DG Law – Market and Industry (M&I)

In the arena of market and industry, the main strength is the positive image among some businesses which use clean energy. Regarding weaknesses in this area, there are mainly two: i) High cost of initial investment ii) The solar energy installation is still an immature market. An explication of each finding is provided below.

The Law gives the possibility to demonstrate a 'green image' enhanced by PV solar investment, which is a positive effect for some such as businesses restaurants and houses used as offices. According to a representative of the public sector "Per each KW that is connected by PV systems, tons of CO_2 are left to emit, in my opinion, they have motivated the installation of solar panels" (Interview A1). This approach is consistent with the results of the interviews which indicated that the reasons for the installation of PV systems were environmental awareness and secondly economic reasons.

Regarding weaknesses, the responders stated that the initial investment for PV is still too high for most of the Chilean families or middle-class families. According to the majority of the interviews "Economically the implementation of PV systems is not attractive for consumers, because if the grid is close to the house, it is cheaper than solar panels" (Interview A1). Moreover, it is essential to consider that in some regions the poverty indicators are the highest. Therefore people have other priorities. For instance, the middle class in Chile prefer to repair the house and garden instead of installing a PV system. The time of return of the PV solar investment could be approximately seven years (Interview A1).

Additionally, despite the strong energy public institutions in Chile, the solar installation market is still immature. The view of the installers is that more inspection regarding the PV solar installations is necessary. According to an interviewee "I have not seen other installers sanctioned by the norm" (Interview B3). Complementary it seems an immature technical knowledge among the installers, because "the lack of professionalism of the electric sector" (Interview B3). Additionally, it is stated that "although installers are certified, there is a lack of knowledge of the sector" (Interview A1). Moreover, there are some regions where weak labour supply inhibits the performance, "there are a low offer of certificated installers and no technical career in this area" (Interview A3). However, during the last few years, there are more alliances between them (associativity) to share experiences and increase technical knowledge.

4.2.3 Opportunities and Threats DG Law - Policy and Measures (P&M)

Regarding Policy and Measures, the first opportunity on an international level is the awareness around the world about global warming and the use of clean energy. At a national level, Chile has the opportunity to change its source of energy toward green technology to have a more reliable, competitive and sustainable energy. Among the threats is the modification or the creation in the future of new regulations, because these could discourage the use of PV solar energy. An explication of each finding is provided below.

During recent years, international awareness to limit global warming has contributed to the investment in green technology. Moreover, many governments have started their energy transition toward clean energies. For instance, the Chilean Intended Nationally Determined Contributions (INDCs) in the context of the Paris Agreement demonstrates the increasing national awareness about global warming and its effects. "There is a change of consciousness with the environment as well as a change of government policy to stop being a carbon-dependent country and more towards renewable energies" (Interview A4). In addition, there are more conscious people, about the importance of climate change and the use of renewable energies. Hence more consumers search for better options for electricity production.

Moreover, Chile needs to be an independent country on primary energy supply. Therefore renewable energy is the opportunity to be an energy independent nation. As an interviewee mention "If we produce our energy through solar, that has influenced PV to prosper" (Interview A2). Taking all the answer together, Chile needs to change the electricity matrix because the following reasons: energy demand growth, high cost of electricity based on imported fossil fuel, political disagreement with its neighbours which provided fuel, recurring droughts, increasing socio-environmental concerns with the use of the land declining share of hydropower in power generation as well as adverse effect on environmental of fossil fuel. Therefore, it is mentioned in the interviews and Chapter 2 that there is not just one reason for the Chilean energy transition.

New regulations or modification Law could also be a threat. According to some interviews, hypothetically the existence of new regulation could have a negative the implementation of PV solar panels. As an interviewee expressed "A threat is the sun right as the case in Spain, where there are certain limitations to install because they must do a procedure to make use of the sun or not" (Interview B7). Therefore new regulation in the future as "sun rights" could produce a serious setback to self-consumers. Another limitation is future new demands in the current is the Environmental Impact Assessment (EIA) to PV systems. "For instance, generator with 3MW have to do an EIA study. So the threat is that in the future a community that wants to implement PV is required to have an EIA study, which is expensive and slow procedure" (Interview B7). Regarding future modification of the Law, if the proposed modification Law pays less than currently, this will be a disincentive for auto-consumers. However, another point of view states that "the fear is that the system is transformed into business for each person and in this way, they become generators and not self-consumers of energy" (Interview A7). There are other regulations for small distributed generation media (in Spanish Pequeños Medios de Generación Distribuída, PMGD), hence the importance to limit the auto consumers payments, otherwise it could be unfair for PMGD.

4.2.4 Opportunities and Threats DG Law - Market and Industry (M&I)

Thanks to the interviews there are three opportunities identified in the arena of market and industry: i) More competitive prices electricity using renewables ii) Accessible green technology thanks to the constant cost decreasing of PV solar technology iii) Increasing national PV market with new capabilities and innovation. Among the threats there are three-identified: i) Lack of competitive prices in the northern part of Chile ii) Increased consumer disincentive, because of the lack of financial state incentives iii) Possible cheaper fuel alternatives than renewables. An explication of each finding is provided below.

As the interviews mention, Chile is a country with a high price of electricity. Therefore, this situation encourages the use of renewable which is more competitive. According to a consumer interviewed she saves 50% of electricity with PV systems (Consumer B2). In addition, another consumer expressed the decision to implement PV system in his house was because the electricity bill is expensive in rural areas, where renewable seem to be a solution.

The majority of the interviewees recognize the constant price reduction of solar technology. Although the initial investment is still high for most of the media class family in Chile, solar PV electricity costs have fallen its price during the last period. Therefore, as an interviewee expressed "Undoubtedly, the reduction of the costs of the main equipment, such as photovoltaic modules, conversion equipment, double reading meters and others will contribute to increasing self-consumers" (Interview A8). For instance, in 2017 the cost of PV solar (315w) cost CLP$120.000 (USD$181), this year the cost is CLP $100.000 (USD$151)[13] (Interview B2). Furthermore, the changes that occur in other countries affect Chile, for example with the improvement of technologies. (Interview A3). However competitive Chinese technology avoid developing Chilean technology because it would be more expensive, as interviewee B2 mentions "this is the result of a free market".

Chile has the excellent opportunity to increase the national PV market with new capabilities and innovation. As Joy Morgan from CPUC[14]mentions it is essential to "create a demand for the product" as in the case of the State of California, residential solar energy can transform the energy market creating more jobs, industries, innovations, a variety of business. For example, in the case of Chile "technical institutions starting to generate technical capabilities. Then, it could be an interesting opportunity because there will be a niche business" (Interview A1). Complementary, advancing to a higher offer of integrating companies or certified technical installers, will reduce the costs of the works and processing of the facilities, together, reducing the total investment costs, and therefore the reduction of the recovery times of the investment. (Interview A8). It is also mentioned that Chile becomes an exporter of technology and services for the solar industry according to the Energy Policy 2050.

[13] Conversion Chilean Peso: CLP $1 is USD$662.
[14] Interviewed in June 27th, 2018

On the other hand, the external threats to the effectiveness of the law are the lack of competitive prices for PV technologies in northern regions. As an interviewee from the northern region of Chile mentions, suppliers of technologies came from the central part of Chile. As a result, the cost for the equipment is high for northern cities like Antofagasta and Arica because of the considerable distance for transporting (1335 Km and 2036 Km from the capital respectively[15][16]). Therefore, it is necessary for a significant supplier in the northern part of the country, with the highest solar potential, to distribute best prices and high quality of PV solar panels, not only in Chile but also in Peru and Bolivia (Interview A4)

Another threat is the lack of financial incentives from the State, because it will decrease the incentive for self-consumes. Till now only the vulnerable socio-economic sector could have access to renewable subsidies in its houses. Therefore, without financial incentives it is difficult to increase the market because the public sector can obtain better prices. For instance, a school was inaugurated (through the solar roofs program) with a system of 70 kW at the cost of CLP$ 63 million (USD 95.760), the cost results CLP$ 900,000 per kW (USD 1.368) and a private company offer the same system at $ 2,100,000 per kW (USD$3.192) (Interview A1). Therefore, it is difficult for Chilean families to access to green energy without subsidies.

[15] From the capital of Chile to the northernmost city (Arica) is equivalent the distance from Portugal to Switzerland, 1908 Km.
[16] http://www.distanciaentreciudades.cl

Another external threat to the effectiveness of the law is the possibility of cheaper fuel alternatives than renewables. According the interviews could be three possible threats; i) low prices of fossil fuels in the future (Interview A1) ii) More fossil fuel project approved, in consequence, implementation of PV solar would be less attractive (Interview B6) iii) Cheaper cost of energy due to possible interconnections with other countries such as Peru (Interview A2).

After the SWOT analysis questions, the author asked about barriers in the implementation Distributed Generation Law among six options, based on the results given by Hass *et al*. 2018 who classify barriers in six groups: “economic, market, system integration, technical, regulatory and information barriers" the study asked to the participants to prioritize the six barriers in order of importance; the results of the interviews indicate in the first place “economic barriers” secondly “regulatory” followed by “information barriers”.

Finally, the diagnosis made by the Chilean government in 2017 states that the Distributed Generation Law, together with a series of regulations and complementary measures, has shown a series of successes regarding investment development, increasing coverage, and service quality increases. However, "it is observed that these achievements have been distributed unequally in the population and geographically, with some areas still with limited investment, low-quality service standards, high supply costs and high rates” (CNE and PUC 2017). These results are in line with the answer given by the interviews in this research.

5. Discussion

This chapter gives an overview of the significant findings of the study based on two components. First the discussion about a comparison of the Chilean deployment of residential solar energy focusing on policy instruments with the success case of the State of California. Second, the discussion about the results of Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis regarding the Distributed Generation Law in Chile. The two components include the answer to the two research questions below. For each question the following information is provided: main findings, relation with existing studies, possible causes of the results and limitation of the research.

5.1. How does DG Law differ between in Chile and in the State of California?

Regarding the implementation of the Distributed Generation Law, the State of California is 18 years in advance of Chile. The important point for the comparative analysis is that the two cases have comparable levels of solar irradiation. The two regions have similar weather and geomorphology, because the two regions are at a parallel latitudinal-climatic gradient. However, the cases differ regarding the deployment of residential solar energy. The results demonstrate that the State of California started at a shallow level. However since 2007 when the California Solar Initiative (CSI) started to grow drastically. In the case of Chile, the number of projects increased since 2016. The milestone that increased the number of projects is a natural disaster in 2015, in the Atacama Region where several numbers of subsidies were given by the Ministry of Housing and Urban Planning for the reconstruction of the region.

The significant differences between the two regions are the following: i) The State of California has a Net Metering Law whereas Chile has a Net Billing Law ii) The key to the success of the State of California is the California Solar Initiative (CSI) program which transformed the solar energy market. In Chile, the initiative programs are less diverse than the State of California, and their focus is low-income residents iii) The distribution of projects interconnected by solar PV system under the Distributed Generation Law by the city in the State of California is higher in the zone with greater irradiation. Unlike, the State of California, Chile does not present the most significant distribution in areas with the highest irradiation, the northern region. An analysis of each difference is described below.

First, Poullikas *et al*. (2013) state that there are a variety of Net Metering mechanisms depending on the particularities of each country or state. In this sense, this study agrees with the authors because in the case of Chile and the State of California there are not the same criteria for the payment for excess energy, type of technology, the renewable energy sources for the power generation capacity limit, the type of utility, and others. A more in-depth analysis would be necessary to answer which type of Law is more effective, Net Metering or Net Billing Law. However, as Barret *et al*. (2016) note that contrasted Net Metering policies, popular in the U.S and other countries, "the Chilean Law does not reimburse consumers at the full retail rate for energy drawn from the grid." In addition, Watt *et al*. (2015) state that Net Metering is a better policy than Net Billing, because the first give to the consumer a payment at the total retail rate for the energy injected. Therefore, as the results of this study demonstrate, it seems that the components of the Chilean Law are not economically attractive for a property solar PV systems. The possible causes of these results are two: i) To prevent additional generation from energy injected to the grid which might be bought by the utility at a lower cost than the retail price ii) Chilean state motivation for creating this Law. According to the Ministry of Energy, the Law seeks self-consumption, not business from these self-consumption projects. The limitation of this finding is the lack of economic analysis from the point of view of American and Chilean consumers, because it could give quantitative results to compare and validate the findings. This study only demonstrates general comparative results.

The second comparative result about Chile and the State of California is that Chile has fewer incentive programs than the State of California. This result is consistent with previous researches such as Barret *et al.* (2016) which indicate that in Chile there are no financial incentives as in the U.S or Germany, where subsidies played an essential role in developing the solar industry. Differently from Barret *et al.* (2016), Foster *et al*. (2017) state that if the cost of renewables is more competitive than fossil fuel, renewable energy can continue without subsidies. In this sense, the result of this study demonstrate that the Chilean state focus the subsidy programs to low-income residents. However, it is important to note that there are two main groups of projects in Chile during 2016 and 2017; "private projects" this means that several PV projects have been implemented without the necessity of subsidies and "reconstruction projects" after the natural disaster in Atacama region. Once the reconstruction is finished, it will be interesting to analyse in the future the distribution of photovoltaic projects in Chile.

In order to improve the solar energy market in Chile, the country could follow the case of the State of California because financial incentives for residential solar energy can transform the energy market creating more jobs, industries, innovations and a variety of businesses for citizens. The limitation of this finding is the lack of socioeconomic study to present different socio and economic scenarios. Future studies could demonstrate the positive effect of public investment in the future contrasting with the current situation. This research has presented general comparative results about financial incentive programs.

The third essential findings is that Chile does not take advantage of its zones with more irradiation for the development of residential solar energy, as does the State of California. In the light of existing research studies, there is an agreement among the authors that Chile has a strong potential for photovoltaic technology. The results from Watt *et al*. 2015 and National Energy Commission demonstrate that solar PV systems are growing in Chille. However, this study contributes the information that PV solar systems are increasing unequally among the regions especially among regions with the highest solar irradiation. Possible causes of this result are two: i. Chile is a centralized country, the energy market is mainly developed in the capital. The disadvantages of the northern region are the cost to transport technology as well as the lack of skilled labour ii. Financing is focused on one region (Atacama region) because a natural disaster provoked the reconstruction of houses incorporating green technology. Therefore, the Chilean state subsidises several houses with low incomes. Nowadays the region is leading the number of projects interconnected by solar PV systems.

As a limitation, this research does not complement the result from the point of view of consumers, comparing the north and central zone of Chile, where not only geography or climate conditions are different but also in economic terms. This research interviewed consumers but only for information gathering.

5.2. Which factors make the DG Law in Chile particularly effective or not?

According to IRENA 2014, the term effectiveness is related to the objectives met in a specific period, for instance, the amount of renewable electricity during a particular time. However, the growth in capacity does not explain whether the amount of renewable electricity is successful or not. Therefore it should be used with other measures (IRENA 2014)

In Chile, the number of PV residential solar system is increasing year by year. However the growth is unequally in the population and geographically. In the future, "The energy path 2018-2022" elaborated by the current government states that one of the measurements is to increase the current capacity from small-scale distributed generation four times than the current capacity by 2022. (Ministry of Energy of Chile 2018). Therefore, in 2022 it is expected to get 53.308 KW [17]. Future analysis is necessary to follow up the goal as well as the distribution of the projects among the regions and from the population.

The author chooses a SWOT analysis to assess internal strengths and weaknesses and external opportunities and threats, for providing an overview of which factors make the Distributed Generation Law in Chile particularly effective or not. Under this evaluation, the identification of weaknesses and external threats is essential for improvements. In this section, the interviews were an essential part of the research. In total there were 18 interviews from different regions of Chile. Therefore, the variety of regions represented enriches the results. The significant findings regarding the two areas; Policy and Measures as well as Market and Industry are the following.

[17] Ricardo Irrarazabal, undersecretary of Ministry of Energy, Chile. Letter communication. 27 July 2018.

Regarding Policy and Measures, all the interviews gave positive comments about the existence of the Law, because it gives the right to consumers to generate its energy with clear rules. The implementation of the Law is in line with the opportunity given by international commitments and awareness about global warming and the promotion of green technologies. Notably, the Law contributes among other actions to make the country energetically independent. Regarding weaknesses, the lack of dissemination of the Law is considered a barrier for its implementation as well as the mechanism chosen (Net Billing). The results given by the interviews are in line with previous researches studies such as Barret et al. (2016) and Watt *et al*. (2015) who state that Net Metering is better policy than Net Billing concerning the monetary gain of consumers. It is desirable that future modification will improve the current Law regarding installation size limit and maintain or improve the valuation injections.

In addition, the results are in line with Hass *et al.* 2018 who identify "information" as one of the barriers to the deployment of solar energy technologies in Chile. In connection whit the comparative case, the Distributed Generation Law in Chile could improve its dissemination as in the State of California, where citizens are informed in everywhere how to implement solar energy (websites, advertisements, billboards, TV ads, others).

In the arena of market and industry, the Law allows consumers to demonstrate a green image enhanced by PV solar investment. Then it is a positive effect on some businesses. The external opportunities are the competitive prices of renewables, in consequence the opportunity to increase the national solar market with new capabilities and innovation. Regarding weaknesses, first, the interviewees state that the initial investment for solar PV systems are still too high for most of the Chilean population. In this sense, two factors are essential: i) Chilean families could have other priorities (improve basic needs) before investing in renewables ii) It is important to consider energy efficiency before investing in renewables (especially thermal insulation in houses). Secondly, the interviewees state that there is an immature solar installers market. The same results are presented by Hass *et al*. 2018 who identify an immature solar market in Chile. The main threats in this area are the centralized energy market concentrated in the central part of Chile, making more challenging to develop the residential solar energy in regions with greater solar irradiation than in the capital of Chile in the central region. One of the barriers identified by Hass *et al*. (2018) is "economic" barriers, which is consistent with the first barriers identified by the interviews in this research. The threats identified by the interviewees is the lack of incentives not only to low-income families but also the middle class. The financial incentives could improve the development of residential solar energy.

Considering the results, the author suggests not only to increase the subsidies beyond the most vulnerable population but also to follow the case of the State of California State transforming the solar energy market. Considering the northern region where there are favourable irradiation solar conditions, undoubtedly, energy efficiency should go hand in hand with the implementation of residential solar energy. The residential energy sector, actions will not be productive if authorities or policymakers do not consider the Strengths, Weaknesses, Opportunities, and Threats of the current Law. Therefore, a summary of the SWOT analysis is in Table 5-2.

The limitation of SWOT analysis is subjectivity. Some of the answers in the interviews were confused internal and external factors, leading to confusion between strengths and opportunities or between weaknesses and threats. Future studies are necessary to complement the SWOT analysis.

Table 5-2
SWOT analysis summary of Distributed Generation Law.

	Strengths	Weaknesses
P&M	Give the right to consumers to generate its energy with clear rules. Easy and accessible procedure for authorization of residential solar PV system.	Lack of dissemination of the Law The Law does not mandate a fair payment of surplus energy. The process is time-consuming in some regions
M&I	Improves the image of the consumer through clean technologies	The initial investment for solar PV systems is still too high for most of the Chilean families There is an immature solar market.
	Opportunities	**Threats**
P&M	International commitments and awareness about global warming and the promotion of green technologies. Energetically, Chile has the opportunity to be an independent nation.	Future new Laws or Law´s modification could produce a disincentive to self-consumption.
M&I	High prices of electricity using fossil fuel encourage the use of renewables. The constant decreasing of solar technology prices. To increase national solar market with new capabilities and innovation.	Lack of competitive prices for PV technologies in northern regions. Lack of financial state incentives. Possible cheaper fuel alternatives to renewables.

Source: The author´s elaboration based on interviews

6. Conclusion

This study examined the deployment of residential solar energy in Chile focusing on Distributed Generation Law. After comparing the Chilean case with the State of California and a SWOT analysis of the Law, the results identified the differences between Chile and the State of California as well as factors that make the Distributed Generation Law in Chile effective.

The main findings regarding the comparative case study are the following: i)The two cases have different mechanism for Distributed Generation Energy. The State of California has a Net Metering Law whereas Chile has a Net Billing Law ii) Chile has less initiative financial programs for Distributed Generation than the State of California. The State has a success program called California Solar Initiative (CSI) program which transformed the solar energy market. iii) Unlike, the State of California, Chile does not have the most significant distribution in areas with the highest irradiation, the northern region.

After the SWOT analysis to the Chilean Distributed Law, the results demonstrate that the existence of the Law is the first step in allowing consumers to produce their energy. Therefore, after five years of implementation, the effectiveness of its results is positive considering the increasing number of projects. The main findings of this study are that external factors make the Law more effective than internal factors. External factors are: i. Decreasing cost of solar PV systems ii. International awareness about global warming and the promotion of green technologies. In contrast, an internal factor is the Net Billing scheme, because as the interview answers as well as previous research stated, for a property with solar PV system, the scheme is not economically attractive. In this sense, the first barrier identified through the interviews is "economic" due to the lack of subsidies (beyond vulnerable population) and the long-term return of investment in solar PV projects.

Taking the results together, the case of the State of California could be followed by Chile in order to improve the effectiveness of the Distributed Generation Law for the deployment of residential solar energy equally in the central and northern part of Chile with high irradiation. In this sense, the recommendation is to transform the solar residential market in Chile as in the State of California. Because the key is not only to increase the number of subsidies but also to increase program initiatives among stakeholders including diffusion, financial alternatives, innovation, education and others. In the long term, the state´s investment will give benefits to the cities. The result of the program will help cities to obtain reliable energy, inclusive, with competitive prices and sustainability. Following the vision of the Chilean Energy Policy 2050.

Previous research indicated barriers to the deployments of residential solar energy in Chile. This study has enriched the discussion through a variety of interviews made in the different regions of Chile. The results confirm that the development of residential solar energy in Chile is increasing, however, it is unequal in the population and geography. This result is in line with the social reality of the country, which is a centralized and unequal nation.

The opportunity for future research is to continue researching about Chile, a paradise of renewables but with barriers in its deployment. Nowadays, the country needs to change the energy matrix to renewable not just for secure energy supply but also for reducing greenhouse gases and to increase the competitiveness of prices. In this scenario, the Chilean government decided to create strong policies in order to change toward green energy, thanks to its favorable geographical conditions for renewable energy. Therefore, there are opportunities for future research to identify barriers to the deployment of renewables. In addition, to research new initiatives considering the view of consumers, as well as including an economic analysis about alternatives for increasing the national solar energy market in the residential sector.

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Appendix I – Interview List

Group A. Experts from the public organisation related to Energy	
Organization	Regions
Ministry of Energy	National Level
Regional office Min. of Energy	Arica y Parinacota (XV region)
Regional office Min. of Energy	Tarapacá (I region)
Regional office Min. of Energy	Atacama (III region)
Regional office Min. of Energy	Antofagasta (II region)
Regional office Min. of Energy	Valparaiso (V region)
Regional office Min. of Energy	Araucanía (IX region)
Regional office Min. of Energy	Biobío (VIII region)
Group B. Solar system installers	
Name	Regions
Fernanda Garrido	Araucanía (IX region)
Felipe Lopez	Atacama (III region)
Marcelo Ossa	Biobío (VIII region)
Sebastian Aguilera	Valparaiso (V region)
Joel Ancan	Santiago (Metropolitan region)
Andres Barrios	Santiago (Metropolitan region)
Cristian Hernandez	Santiago (Metropolitan region)
Group C. Three consumers of PV solar systems from Valparaiso region (V region)	
Joy Morgan Ph D. Senior regularity analyst at Public Utilities Commission in the State of California.	

Note: Letters and numbers of each interviewee were removed from this list, and the names of group A and C, to guarantee stakeholder anonymity.

Appendix II – Interview Questions

a. Interview questions to public organizations and solar system installers

Part 1: Deployment of solar PV systems

1. What does the solar PV installation process currently look like in Chile? Alternatively, in your region?

2. What is the consumer attitude towards PV systems?

3. The increase in the use of residential solar energy is due to existing regulations or market reasons (price/demand) or another factor?

4. What types of solar financing options, both public and private, are available in Chile right now?

Part 2: Evaluation Policy – SWOT analysis

1. What design elements in the law make it particularly effective?

2. What design elements in the law detract from its effectiveness?

3. What external opportunities can you identify that have or will contribute to the heightened success of Net Metering Law?

4. What external threats can you identify that have the potential to derail the effectiveness of Net Metering Law?

5. Select 3 of the following as a barrier of the Distributed Generation Law: a. economic and financial, b. the market, c. system integration, d. solar-technical, e. regulatory f. information barriers g. other

6. Could you recommend actions for the deployment of residential solar energy in Chile?

b. Interview questions to consumers

Part 1: Experience PV solar energy

1. Why did you decide to implement the PV system in your house?

2. How is your experience? Positive or Negative and why?

3. Do you know the Law 20,571 also known as Generation Distributed? or Net Billing?

Part 2: Evaluation Policy

1. What makes PV solar energy better than traditional electricity?

2. What areas does PV solar energy need to be improved?

c. Interview questions to Joy Morgan Ph D. Senior regularity analyst at Public Utilities Commission in the State of California.

1. In the state of California, the increase in the use of residential solar energy is due to existing regulations, markets reasons or another factor?

2. What is the consumer's attitude towards solar PV? Is there a general consumer awareness?

3. What design elements in Net Metering Law in the state of California make it particularly useful? Alternatively, could you identify the strengths of the Law?

4. What design elements in the Net Metering Law in the state of California detract from its effectiveness? Alternatively, could you identify the weakness of the Law?

5. Could you recommend actions for the deployment of residential solar energy in Chile?

Appendix III – Number of projects under the DG Law in Chile per type of financing.

This table provides information given in Figure 4-1.5e of the document, number of projects (interconnected solar PV) under the Distributed Generation Law in Chile per type of financing by year and month.

Mes	Privado	Reconstrucción	PTSP	Otros Fondos Públicos	Total
2015					
enero	0	0	0	0	0
febrero	1	0	0	0	1
abril	4	0	0	0	4
mayo	3	0	0	0	3
junio	3	0	0	0	3
julio	8	0	0	0	8
agosto	12	0	0	0	12
septiembre	5	0	2	1	8
octubre	15	0	0	0	15
noviembre	16	0	2	0	18
diciembre	17	0	1	0	18
2016					
enero	8	0	0	1	9
febrero	15	0	0	6	21
marzo	14	0	2	3	19
abril	27	0	23	0	50
mayo	22	0	3	1	26
junio	32	0	0	0	32
julio	42	0	2	5	49
agosto	30	0	0	13	43
septiembre	29	21	0	5	55
octubre	18	18	6	14	56
noviembre	14	98	2	1	115
diciembre	27	93	12	6	138
2017					
enero	39	70	2	1	112
febrero	48	30	12	3	93
marzo	46	63	22	1	132
abril	49	58	6	0	113
mayo	76	84	0	2	162
junio	45	0	2	0	47
julio	45	41	1	0	87
agosto	43	16	0	0	59
septiembre	59	53	0	0	112
octubre	81	64	0	12	157
noviembre	52	76	0	14	142
diciembre	40	77	1	12	130
2018					
enero	57	41	0	9	107
febrero	71	39	0	1	111
marzo	103	50	1	15	169
abril	78	68	1	18	165
mayo	77	35	4	9	125
junio	82	53	1	26	162
Total	**1453**	**1148**	**108**	**179**	**2888**

Source: Superintendence of Electricity and Fuel - in Spanish Superintendencia de Electricidad y Combustible (SEC): Letter communication. 2 August 2018. Note: Privado [Private], Reconstruccion [Reconstruction], PTSP: Programa Techos Solares Públicos [Public Solar Roofs Program], Otros Fondos Públicos [other public funds].