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TÍTULO DE LA MEMORIA DE TÍTULO

Renewable energy management, the Photovoltaic approach, the Italian way and the Chilean way of dispatching the energy, best practice and cross breeding opportunities

POR

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Abstract

The exponential increase in carbon dioxide (CO_2) concentrations in the atmosphere has raised the temperature of the planet, causing global warming with devastating effects on the environment. To mitigate, must be generated more renewable energy because it does not emit greenhouse gases (GHG) in the generation of the energy, so it is a clean solution that positively affects climate change. One of these energies is photovoltaic energy, which are cells that transform sunlight directly into electricity.

Although for neither Chile nor Italy, photovoltaic (PV) energy is not the main source of energy but is the one who have the biggest growth rate average. The installed capacity has a perfect correlation with the amount of incentives, so for Italy the biggest increases was because of the Conto Energia incentive, and now the Energy Regulation looks to do the same for reaching the 2030 target of the Paris Agreement. And, due to the large quantities of installed capacity, has achieved decreases in costs.

On the other hand, Chile have not reached that amount of installed capacity, but has launched so many projects this year that the estimated PV energy capacity through linear regression of 2022 will be reached and so the 2030 target. Also, because of its great potential, Atacama Desert is the best location worldwide for PV energy due of its high irradiation and average hours of sunshine per year, it has had big investments from other countries through the years and it is expected to continue.

New technologies have appeared in the market, which have better efficiency and so it can pick up more energy. Also, have opened new sectors, like Floating Photovoltaic technology (FPV).

As Russia is the second-largest producer of natural gas in the world, Ukraine war not only affected Italy, which is its main supply of energy, but also affected the other countries with the indirect effects. Because of it, is a good time for to Italy invest in PV energy, even in Chile, to become independent and return to the top 3 in the world of installed capacity, achieving its target.

Sumario

El aumento exponencial de las concentraciones de CO_2 en la atmósfera ha elevado la temperatura del planeta, causando un calentamiento global con efectos devastadores sobre el medio ambiente. Para mitigar, se debe generar más energía renovable debido a que no emite gases efecto invernadero en la generación de esta, siendo una solución limpia que afecta de manera positiva al cambio climático. La energía fotovoltaica es una de ellas, que son células que transforman la luz solar directamente en electricidad.

Si bien, ni para Chile ni Italia la energía fotovoltaica no es la principal fuente de energía pero si es la que tiene la mayor tasa de crecimiento promedio. Debido a que la capacidad instalada tiene una perfecta correlación con la cantidad de incentivos, el gran aumento en Italia se debió al Conto Energía, por lo que ahora el Decreto de Energía busca hacer lo mismo para alcanzar el objetivo de 2030 del Acuerdo de París. Además, debido a las grandes cantidades de capacidad instalada que ha alcanzado con el tiempo, ha logrado disminuciones en los costos.

Por otro lado, Chile no ha alcanzado esa cantidad de capacidad instalada, pero ha puesto en marcha una gran cantidad proyectos este año, que logró alcanzar el valor estimado de la regresión lineal de 2022, y así poder lograr la meta de 2030. Además, debido a su gran potencial del país, el desierto de Atacama es el mejor lugar del mundo para la energía fotovoltaica debido a su alta irradiación y horas promedio de sol al año, ha tenido grandes inversiones de otros países a través de los años y se espera que esto continúe.

El crecimiento en las tecnologías ha provocado mayor eficiencia, y por ende más energía, además de abrir nuevos sectores como lo es la tecnología fotovoltaica flotante.

Como Rusia es el segundo mayor productor de gas natural en el mundo, la guerra de Ucrania no solo afectó a Italia, que es su principal suministro de energía, sino que también afectó a los otros países con efectos indirectos. Debido a ello, es un buen momento para que Italia invierta en esta energía, incluso en Chile, para poder independizarse y lograr volver a estar en el top 3 de capacidad instalada en energía fotovoltaica en el mundo, logrando así sus metas.

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1. Introduction

Solar PV energy is the direct transformation of solar radiation in electricity through solar panels. According to the last report of the International Energy Agency (IEA), the "utility-scale solar projects continue to provide over 60% of all solar PV energy additions worldwide" (IEA, Solar, 2021). This renewable source it can be used to produce green hydrogen, a clean energy carrier that produces heat and/or electricity without emitting CO_2 (Verde, 2021).

Global warming, which has disastrous impacts on the environment, has been caused by the exponential growth in CO_2 concentrations in the atmosphere. The average global temperature rise must be maintained below 2°C, and efforts must be made to keep it below 1.5°C (IPCC, 2018); these solutions primarily focus on promoting renewable energy.

First, a methodological framework will be employed to establish where and how all of the information for the research was gathered. Second, the findings are presented; information is thoroughly covered for both the power market and photovoltaics, and analyses are done using all of the data. It begins talking about the regulations, systems and players of the electricity market, besides the effects of the war on both countries. Then the photovoltaic is analysed between the period 2000-2021, talking about the incentives, laws and regulations, and the main companies that produces this energy. Additionally, how things currently stand in 2022 and the investments made by others. With all of the prior knowledge, analysis and discussion are then performed, comparing both countries, highlighting new technology, costs, and other factors. Finally, the conclusion is made, summarizing the most crucial points based on the entire report.

1.1. General objective

The main objective is to compare the development of PV energy in Italy and Chile in order to find weaknesses and strengths of both energy policies.

1.2. Specific objectives

- Understand the electricity market, identifying its regulation, system and how different sources of electricity have been behaving over the years.
- Discuss the current context with the war in Ukraine, noting changes in the electrical matrix.
- Understand photovoltaic energy, estimating its behaviour for the following years and thus compare with the installed capacity of this year and its targets to 2030 according to the Paris Agreement.
- Analyse incentives and regulatory framework of photovoltaic energy relating it to increases in installed capacity.
- Recognize the largest photovoltaic energy generating companies in each country, relating it to investments.
- Compare the two countries behaviours. Distinguishing milestones, differentiating conditions, technologies, and costs.
- Develop improvements in both systems.

2. Methodology

For analysing both systems it will be done an investigation of the electricity market in general where it will be information about the regulation, how their electricity market system works and how the different players have behaved over the years of each country. Followed by this, there will be an analysis of photovoltaic energy in each country, where it will be information about its behaviour along the years, the companies that generates this type of renewable energy, the incentives, laws and regulations and investments in both countries, and also, an estimation of the installed capacity for each country. With all the information taken, it will be used to discuss and then take conclusions.

2.1.Electricity Market

2.1.1. Regulation

Because energy is for everyone, it must be regulated, and therefore in each country, each of them will be specified. In the case of Chile, the information was taken from the map of the energy sector published by the Ministry of Energy in 2021 (Ministerio de Energía, Mapa Normativo del Sector Energético Chileno, 2021). And for Italy, the national was taken from a study (Sterlicchio De Carli & Favaro, 2022) and the European level from ARERA, Authority for Energy, Networks and Environment (ARERA, 2022).

2.1.2. Electricity market system

The electricity market system is also different in both countries, so in Chile, the information was taken from Generadoras de Chile (Generadoras de Chile, Generación Eléctrica en Chile, 2022), who is the guild that represents the power generation companies that operate in the county. On the other hand, the Italian information was taken from TERNA, an essential element of Italy's electricity system, who works to make sure that it functions correctly for all parties and also works as the Transmission System Operator. (TERNA, How the electricity system works, 2022).

2.1.3. Players

The information on the key players of each country in the electricity market was taken from the International Renewable Energy Agency (IRENA), an intergovernmental organization that assists nations in transitioning to a sustainable energy future and acts as the main platform for global cooperation, a centre of excellence, and a database of knowledge on renewable energy policy, technology, resources, and finances (IRENA, Renewable capacity statistics 2022, 2022). This information was then used for the section 3.2.1., to analyse the behaviour of PV energy in Chile and Italy during the years 2000 and 2021.

2.2.Photovoltaic Energy

2.2.1. Both countries through the years

It was taken the information from IRENA (IRENA, Renewable capacity statistics 2022, 2022) to analyse the behaviour of both countries from 2000 to 2021.

2.2.2. Generator phase companies

In Chile, the information from the companies were taken from Generadoras de Chile, and so the information from each company was taken from their website. In the case of Italy, the information of the companies also was taken from their website.

2.2.3. Future of PV Energy

In both countries, the projects go through the Environmental Impact Assessment procedure of each country and are evaluated for making the best technical decisions and mitigate the impacts.

The information from Chile was taken from reports that the Ministry of Energy does every month about the projects in construction and inversion in the energy sector; January (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de enero de 2022, 2022), February (Ministerio de Energía, Reporte de proyectos

en Construcción e Inversión en el Sector Energía mes de febrero de 2022, 2022), March (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de marzo de 2022, 2022) and April (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de abril de 2022, 2022).

For Italy, the information about the new plants is not available to everyone, but from TERNA (TERNA, Photovoltaic Power, 2022) was taken the information on the PV energy production for the year 2020, 2021, and up to the date of 26/06 of the present year.

2.2.4. Incentives

In Chile, there are different ways to commercialize electricity in the different markets, and that information was taken from the National Energy Commission (CNE) (CNE, Tarificación, 2022). And the other information on incentives were taken from different news pages. In Italy, the information was taken from the Ministero dello sviluppo economico.

2.2.5. Regulatory framework

In Chile, the information on the laws and regulations was taken from the Library of the National Congress of Chile (Biblioteca del Congreso Nacional de Chile, Ley Chile, 2022) with support from the material it delivers Generadoras de Chile (Generadoras de Chile, Normativa Sectorial, 2021). The Italian information was taken from the Climate Change Laws of the World of Italy (LSE, 2021).

2.2.6. Finance and Investments

As both countries through the years, this information was also taken from IRENA, but from the section Finance and Investment (IRENA, Investment Trends, 2022). This information was taken to see how much other countries invested in Chile and Italy and who they were.

3. Results

3.1. Electricity Market

Electricity is used every day, for lighting and heating/cooling homes, to power televisions and computers. Is the flow of electrical power or charge obtained from the conversion of other sources of energy, where these primary sources can be renewable or non-renewable.

Renewable energy is produced by replenishing natural resources or processes because they come from the ocean, sun, wind, geothermal and hydroelectric, so they produce small quantities GHG or polluting emissions, and they are present in different technologies. GHGs are naturally and anthropogenic emitted gases, where this last one have a higher emission, which accumulate in the Earth's atmosphere and absorb the sun's infrared energy, creating the so-called greenhouse effect. Although the greenhouse effect is a phenomenon of regulation of the planet's temperature, the increase in the concentration of GHGs, both in quantity and in variety of some of the gases, the planet's atmosphere aggravates it, causing variability of the world climate better known as climate change.

On the other hand, non-renewable energy is limited in supply and cannot be used sustainably because is created from organic material that was once found in the remains of ancient plants and animals, so burning these sources releases carbon dioxide and other gases into the atmosphere. The four different types of this source are nuclear energy, oil, natural gas, and coal; the last three are referred to as fossil fuels.

It is known that renewable energy is better than non-renewable, because it does produce much less damage to the world, so there is the Paris Agreement that looks to mitigate climate change. It says that the average global temperature increase must keep below 2ºC and pursue efforts to limit the increase to 1.5ºC. There are 194 countries (Fassio, 2022) that have policies that address adaptation to climate change, but they are not making real progress.

3.1.1. Regulation

3.1.1.1.Chile

- Ministry of Energy (MINENERGÍA): Is the highest body that works in tandem with the President of the Republic to carry out governmental duties and administer the energy industry. Is in charge of creating and organizing the numerous strategies, policies, and regulations for the growth of the country's energy industry in a transparent and inclusive manner in order to guarantee that all Chileans can access energy securely and affordably.
- CNE: It is a public, decentralized, and independent entity connected to MINERGIA through the president. It is the responsibility of a technical body to analyse the costs, tariffs, and technical requirements to which production companies must adhere in order to provide an adequate, secure, and reliable service that is compatible with the most cost-effective operation for the generation, transport, and distribution of energy.
- Superintendence of Electricity and Fuel (SEC): Is a functionally decentralized service whose goal is to monitor and supervise adherence to legal and regulatory requirements, as well as technical standards on the generation, production, storage, transport, and distribution of liquid fuels, gas, and electricity. This is done to ensure that the provided services are of a high enough standard to be compliant with rules and do not endanger people or things.
- National Electricity Coordinator: This technical, independent organization is in charge of coordinating the operation of all SEN facilities that are linked together.
- Energy Sustainability Agency: This non-profit, private-law organization's primary goal is to advance, consolidate, and increase energy efficiency on a national and international scale. Additionally, it aims to put public-private ideas into action in the many energy-consuming industries, promoting the competitive and sustainable growth of the nation.

3.1.1.2.Italy

- ARERA: Is the Italian regulatory agency that oversees and regulates the electricity, natural gas, water services, waste cycle, and district heating industries. They must submit a three-year economic and financial plan to the Italian government, any appointment to the board of directors must adhere to a specific process involving both the government and parliament, and elected officials are prohibited from having any direct or indirect professional relations, including giving professional advice or holding office with any entity, despite the fact that they are independent of any state or governmental authority.
- The Energy Services Manager (GSE): Is a goal that has been set by the state to pursue and realize environmental sustainability through the two pillars of renewable energy and energy efficiency. For both the present and future generations, they help to create a future that is more sustainable. GSE so direct and oversee the public-interest businesses listed below:
    - Single Buyer (AU): This public corporation was established to provide power to residential users and SMEs that have not yet shifted to the free market.
    - Energy Market Manager (GME): It coordinates and oversees the markets for natural gas, electricity, and environmental protection.
    - Research on the Energy System (RSE): This organization conducts research in the electro-energy field, paying particular attention to national strategic projects of wide public interest supported by the Electricity System Research Fund.

At the European level:

- Council of European Energy Regulators (CEER): Represents national energy regulators in Europe before the European Union (EU) and on a global scale. The national regulators collaborate and share best practices via CEER.
- Agency for the Cooperation of Energy Regulators (ACER): Establishes a framework for national regulators to collaborate and give clarity and regulatory certainty at the EU level.

3.1.2. Electricity market system

The market for energy typically develops in three phases. This begins with the generating firms, whose job is to produce electrical energy. These are connected to substations with high voltage transmission capabilities, and then they are transported to the distribution sector, which is responsible for transferring energy from one location in the electrical system to the consumers. As every country is different, it will be detailed information for both Chile and Italy.

3.1.2.1.Chile

There are three electrical systems (Law 20,936), which function as a set of installations that are connected to their own generator, transmission, and distribution phase, where each one works as a single system. These are the National Electrical System (SEN), which connects Arica to Chiloe, the Aysen Electrical System (SEA), which connects the Aysen region, and the Magallanes Electrical System (SEM), which connects the Region of Magallanes and Chilean Antarctica.

Fig. 3.1. Systems in Chile

Source: (Energia Abierta, 2022)

Private businesses are solely responsible for the development of all activities in the energy market. These businesses make the necessary investments within the confines of the rules that apply to each of these sectors. The transmission and distribution phases are developed within a framework of regulated sectors due to the characteristics of monopoly that both phases have, while the generation phase is governed by norms of free competition.

The energy can get to two different users. The first type of customer is regulated and is when the connected power is less than or equal to 5,000 kW, in this case, the market has the characteristic of being a natural monopoly, so the law establishes that they are affected by price regulation. And the other type is the free customer, which is when the connected power is greater than 5,000 kW, which means, they have the negotiating capacity and the possibility of supplying electricity in other ways, such as self-generation or direct supply from generating companies, so the law provides for price freedom (CNE, Eléctrica, 2022).

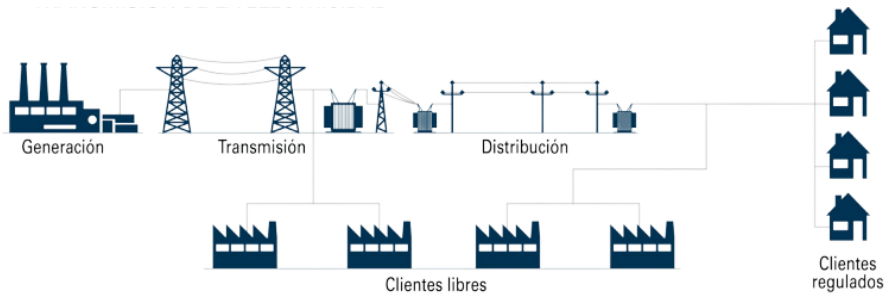

Fig. 3.2. Electricity system in Chile

Source: (Moreno Vieyra & Caba Rutte, 2019)

3.1.2.2.Italy

On one hand both the production and distribution phases are carried out by companies under a free-market regime. And in the other hand, the transmission phase is made by a private company owned 50% by the government called TERNA, i.e., is responsible for the management, maintenance, and development of the Italian high voltage electricity grid, and for dispatching, which consists of managing the electricity flows on the grid at any time. So, they operate in a natural monopoly system within a market regulated by the Italian Regulatory (ARERA).

In this system, there is only one user. The price for the consumer is determined by ARERA (EnerData, 2022).

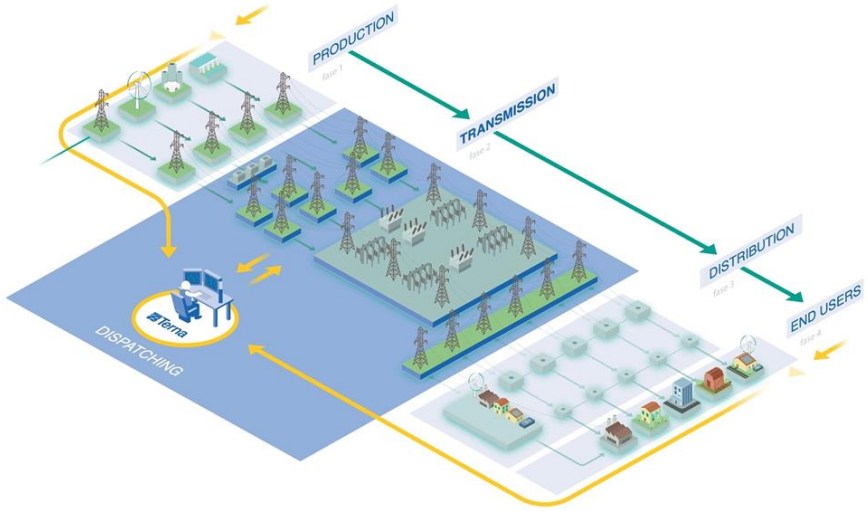

Fig. 3.3. Electricity system in Italy

Source: (TERNA, How the electricity system works, 2022)

So, in the following table, it can be seen the main differences between both countries.

Table 3.1. Comparing both electricity systems

	Chile	Italy
Number of systems	3 (SEN, SEA, SEM)	1
Production phase	Private companies under a free-market regime	Private companies under a free-market regime
Transmission phase	Private companies under-regulated sector	TERNA under natural monopoly
Distribution phase	Private companies under-regulated sector	Private companies under a free-market regime
Types of users	2	1

Source: Author's own creation

3.1.3. Players

It will be talked of installed electricity capacity because the available data across both countries are more recent than the generation of them.

3.1.3.1.Chile

Chile's main source of electricity is Renewable Hydropower, which comes from hydro energy, renewable energy that generates power by using the elevation difference, created by a dam or diversion structure, of water flowing in on one side and out, far below, on the other.

The second main source of electricity is natural gas from 2000 to 2013 and then in the year 2016, and coal the year 2014, 2015 and, from 2017 up to 2021, two non-renewable energies. This full information can be seen in the following graphic.

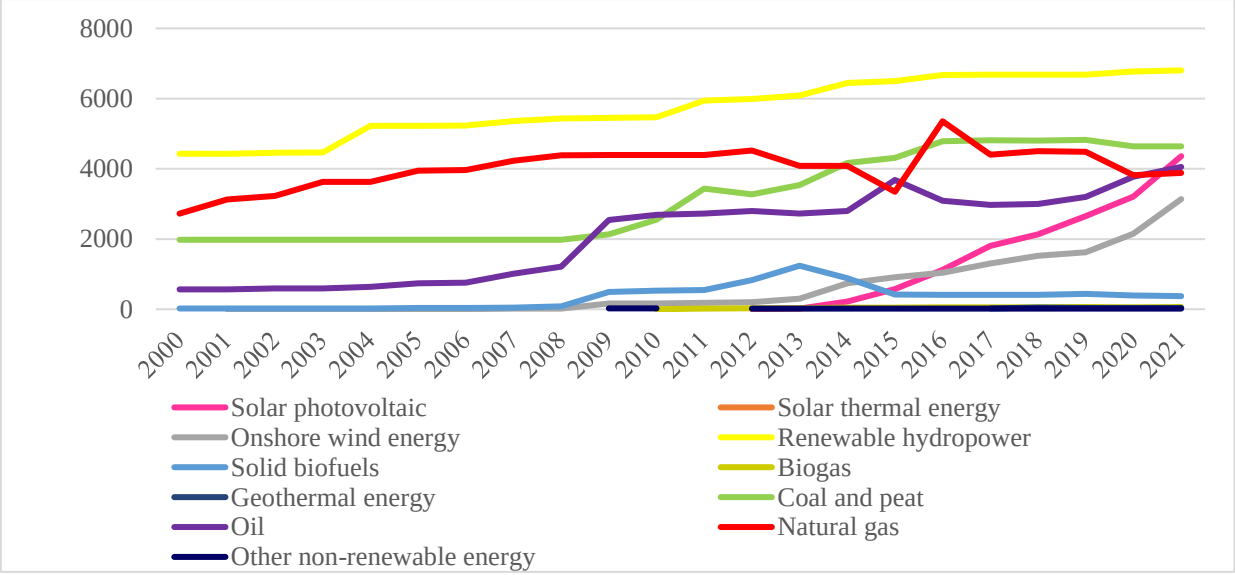

Fig. 3.4. Installed electricity capacity in the different sources through the years in Chile (MW)

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

Although the second source most used is not renewable, renewable energies like PV solar, biogas, and wind are the ones that have had a bigger growth rate in the past years. This

information can be seen in the following table in 3 years intervals, where the details of these calculations are shown in Annex one.

Table 3.2. Growth rate of installed electricity capacity of the different sources in Chile

	Solar	Wind	Hydro	Bioenergy		Geothermal
	Solar photovoltaic	Onshore wind energy	Renewable hydropower	Solid biofuels	Biogas	Geothermal energy
2001-2003		0%	0.27%	0%		
2004-2006		0%	5.69%	21.21%		
2007-2009		538.33%	1.40%	203.75%		
2010-2012		7.56%	3.27%	21.12%	446.05%	
2013-2015	727.99%	72.39%	2.77%	-10.83%	24.07%	
2016-2018	58.08%	18.85%	0.92%	-0.56%	5.20%	100%
2019-2021	27.00%	28.31%	0.63%	-2.66%	4.12%	-5.76%
Average	271.02%	95.06%	2.14%	33.15%	119.86%	47.12%

	Non-renewable			
	Coal and peat	Oil	Natural gas	Other non-renewable energy
2001-2003	0%	1.52%	10.19%	
2004-2006	0%	8.79%	3.02%	
2007-2009	2.59%	54.47%	3.52%	
2010-2012	16.48%	3.27%	1.01%	0%
2013-2015	9.78%	10.50%	-9.26%	0%
2016-2018	3.80%	-6.31%	14.84%	0%
2019-2021	-1.13%	10.68%	-4.55%	0%
Average	4.50%	11.85%	2.68%	0%

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

PV electricity has the biggest average growth rate through the years as it is seen in table 3.2. and also has the biggest growth rate of 727.99% in the period 2013-2015. So, it went from generating 0 MW in 2011 to 4,360 MW in 2021, which makes it the third main source in 2021. In the other hand, the coal, the second main source in 2021, had an energy capacity of 4,641 MW in that year and had a growth rate in the last period of -1.13%, which means that PV's energy growth will make it be the second main source in just a few years, and it could also get to the main. Also, biogas is growing very quickly, has the second-biggest average growth rate and, also has the third-biggest growth rate of 446.05% in the period 2010-2012. And the wind, that despite being in the number 6 position in 2021 concerning the main sources, it has had big increases, like the period 2007-2009 that grew 538.33%, that make it the second biggest growth average through the years.

3.1.3.2.Italy

In the last two decades, fossil fuels have been Italian's main source of electricity, a non-renewable energy. But the second main source was Renewable hydropower up to 2011, and from then up to 2021 it was solar photovoltaic energy, both renewable energy; renewable hydro from hydropower energy and solar photovoltaic from solar energy.

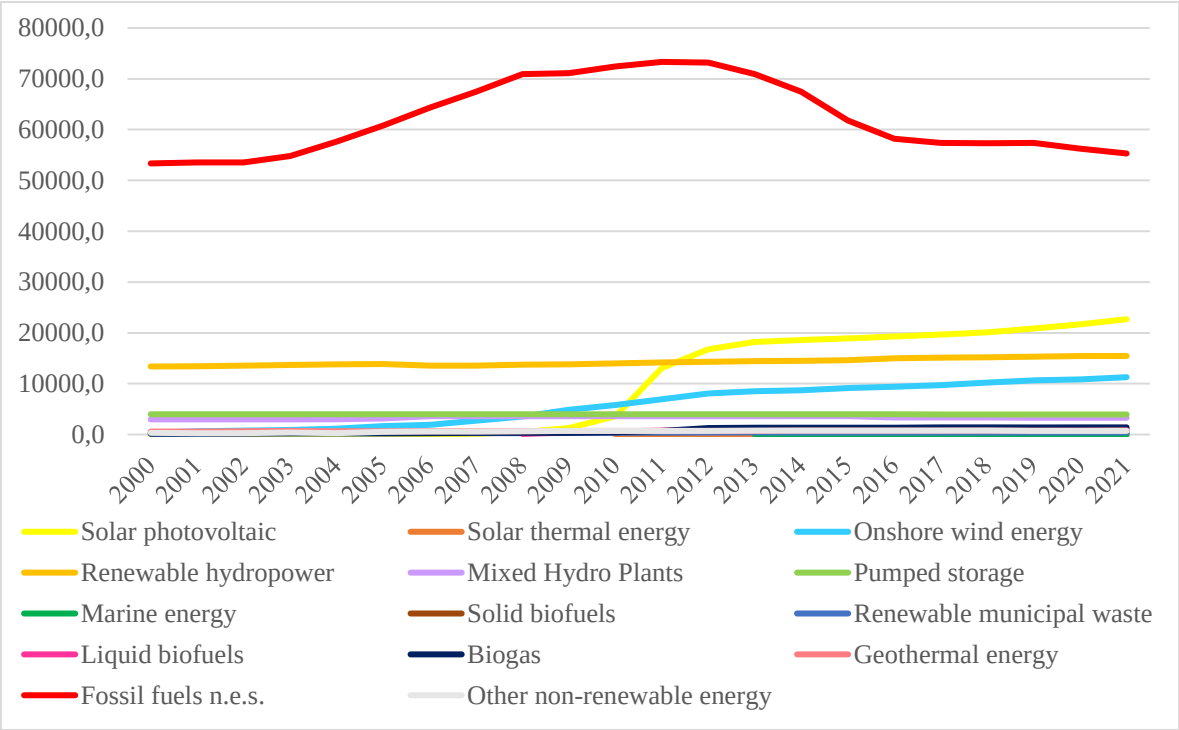

Fig. 3.5. Installed electricity capacity in the different sources through the years in Italy (MW)

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

In the year 2000 fossil fuels represented 70% of the installed electricity capacity, but with time, other energies started to grow up and let them be only 47% in the year 2021. Solar PV energy is the second main source of electricity in 2021 with 19.4%, although the percentage is much less than fossil fuels, solar PV energy has grown in a big way, and it can be seen in the following chart of the growth rate.

Table 3.3. Growth rate of installed electricity capacity of the different sources in Italy

	Solar		Wind	Hydro			Ocean
	Solar photovoltaic	Solar thermal energy	Onshore wind energy	Renewable hydropower	Mixed Hydro Plants	Pumped storage	Marine energy
2001-2003	11.15%		37.48%	0.78%	0%	0%	
2004-2006	20.42%		30.12%	-0.42%	6.28%	0.01%	
2007-2009	215.08%		36.98%	0.73%	0%	0%	
2010-2012	159.19%	0%	18.42%	1.19%	0.10%	0%	
2013-2015	4.08%	9.05%	4.1%	0.70%	0.11%	0.21%	16.67%
2016-2018	2.08%	0%	3.84%	1.25%	-2.11%	-0.35%	0%
2019-2021	4.11%	0%	3.3%	0.61%	-0.64%	0%	0.83%
Average	59.44%	2.26%	19.18%	0.69%	0.53%	-0.02%	5.83%

	Bioenergy				Geothermal	non-renewable energy	
	Solid biofuels	Renewable municipal waste	Liquid biofuels	Biogas	Geothermal energy	Fossil fuels n.e.s.	Other
2001-2003	21.56%	15.87%		12.47%	6.5%	0.89%	13.43%
2004-2006	-2.1%	3.56%		4.73%	-1.56%	5.5%	19.54%
2007-2009	7.01%	12.85%	220.44%	6.95%	1.19%	3.45%	6.14%
2010-2012	8.06%	2.37%	39.13%	53.42%	1.58%	0.97%	0.5%
2013-2015	4.77%	3.39%	0.38%	1.61%	1.83%	-5.47%	2.71%
2016-2018	6.08%	-0.25%	-0.98%	0.97%	-0.04%	-2.44%	0.73%
2019-2021	-0.32%	-0.78%	-1.34%	0.09%	1.50%	-1.18%	-2.61%
Average	6.44%	5.29%	51.52%	11.46%	1.57%	0.25%	5.78%

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

Solar PV is the energy with more growth through the years, and in table 3.3. it can be seen that this source takes two big growth rates: in the period 2007-2009 with 215.08% and in the period 2010-2012 with 159.19%. Fossil fuels are decreasing in the few last years, and since the period 2013-2015 has have only negatives growth rates which make it has an average of 0.25%. Although in the last years the solar PV energy has not had a significant increase as in previous years, it is still the one with the highest growth in the last 3 years, as shown in the table, so it could take first place in a couple of years if it keeps growing.

Another one that it has a high average growth rate is the liquid biofuels, coming from bioenergy; in the period 2007-2009, this source had the biggest increase with 220.44%.

3.1.4. Ukraine – Russia war

Each country has its economy and to measure this economic activity it is used the indicator called Gross Domestic Product (GDP). GDP calculates the total value of final goods and services produced by a country for a defined time and the most common way of calculating this is the following.

$$GDP = C + I + G + XN \quad (1)$$

Where C is consumption, I is investment, G is government expending and XN is net exports (exports – imports). So, it can be seen that the economies of one country depends on the relationship with the other ones too.

During the past months the War 2022 in Ukraine began, were in simple words, Russia attacked them. Russia is the world's largest country, and like Ukraine, it was a part of the Union of Soviet Socialist Republics (USSR) for a significant portion of the 20th century. With the Bolsheviks, Russia became the first Socialist state in the world, and many countries surrounding it began to attack it and eventually Russia regained them and entered the USSR, where one of them is Ukraine. Ukraine was one of the Union's most significant areas after World War II, and as the Union disintegrated over time, each country became more dependence. With Ukraine Crisis in 2014, Russia began to invade Ukraine anonymously, eventually, tension increased and on 24 February Russia attacked them with bombs (Faraldo Jarillo, 2022).

This brought many consequences worldwide, where even many countries began to part with Russia. So, this section is talked about consequences that brought to Chile and Italy in the electricity market.

On the one hand, Chile imports about 80% of natural gas and liquefied petroleum gas, mainly from the United States and Argentina (EMOL, 2022). Although Chile has a limited commercial and financial link with the countries in conflict -it exports less than 1% of its shipments to Russia-, it is the indirect effects that will have the greatest impact on our country. Russia is the second-largest producer of natural gas in the world and one of the largest oil producers. And since Chile imports, almost all the crude oil it uses, the shortage of hydrocarbons affects import costs (El Mercurio, 2022).

On the other hand, Italy is high dependence on Russian energy, which is its main supply with 40% of the country's gas (Raney, 2022). So, with the war 2022, the natural gas prices become even bigger than they were before; reaching a maximum historical on the 8 of march in oil and natural gas so electricity also reached it, and from there, the coal worldwide grew to 246.22% from 01/01/2022 until 01/07/2022 and the natural gas 171.9% (Trading Economics, 2022).

Italy has taken a series of decisions, like for saving energy, the maximum temperature for the air conditioner in schools are of 25°C from 01/05/2022 until 31/03/2023 (Giuffrida, 2022), also ARERA lowered taxes for gas and also cancel general charges to lower the tariffs on April for electricity and gas and also the social bonus, a bonus that allows third sector entities to find a new way of financing, will be strengthened (Enerdata, 2022). And another thing that made the Italian government was approving the "Decreto Energia 2022" that will be talked in the section 3.2.5.

The EU has committed to get to the end of the dependence on Russian fossil fuels and so accelerate the transition to clean energy with the REPowerEU Plan. This plan had put actions to save energy, diversify supplies quickly substitute fossil fuels by accelerating Europe's clean energy transition, and smartly combine investments and reforms. Where in boosting renewable energy, they increased the target from 40% to 45% by 2030, in which as solar PV energy is one of the fastest technologies to roll out, they put a target in this of almost 600 GW by 2030. The Commission presented the EU solar strategy and introduced the European

Solar Rooftop Initiative. Also, wind energy is something they want to take advantage, of because up to the moment, Europe is the global leader in offshore wind, but the supply chains need to be strengthened and permitting drastically accelerated. With these renewable energy resources, it can be made renewable hydrogen, which is an energy carrier that does not pollute, and so this will be key to replacing natural gas, coal, and oil in hard-to-decarbonise industries and transport. REPowerEU sets a target of 10 million tonnes of domestic renewable hydrogen production and 10 million tonnes of renewable hydrogen imports by 2030 (European Commission, 2022).

Meanwhile, Italian Ministers have tapped numerous countries to find the capacity to try and replace the 29 billion cubic meters Italy receives from Russia, the country is driving to cut its reliance on Russian gas. On April 20th, Italy penned a deal with Angola, their second-biggest gas supplier for 2021 (Aljazeera, 2022).

The reduction of Europe's energy dependence on Russia will lead to an acceleration of the transition process towards renewable energies. With this, by the increase in renewable energies, the costs of these will decrease even more, being cheaper than fossil fuels and so is going to be preferred the clean solution. The opportunities for both countries will be very great due to the impulse in research and development to optimize the efficiency of such technologies in Italy, which can improve the processes for this type of energy in Chile and will also generate a greater drive towards increased production and export of green hydrogen.

3.2.Photovoltaic Energy

3.2.1. Both countries through the years

Chile has the highest solar radiation in the world in the Atacama Desert, within a year they have global horizontal radiation of 2,700 kWh/m^2 and normal radiation of 3,800 kWh/m^2, and also it has more than 4,200 average hours of sun. (Tahmann, 2022). Nonetheless, Italy is in the sixth position in the world ranking of the countries with the highest PV energy solar power installed as of 2020, placing much higher than Chile (Orús, 2021).

The following table represents the percentage of PV energy of each country comparing with the world for periods of three years and the details of its calculations its shown in annex two.

Table 3.4. Percentage of PV electricity capacity of each country in the world from the year 2000 until 2021 in periods

Country	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	2016-2018	2019-2021
Italy	1.56%	0.83%	3.37%	14.53%	10.77%	5.25%	3.10%
Chile				0%	0.13%	0.43%	0.47%

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

Chile had set itself the goal of reaching 2025 with an installed generation capacity in non-conventional renewable energy (NCRE) plants, equivalent to 20% of the country's energy matrix. But that goal was more than met six years earlier. In October, NENCs reached 5,828 MW of installed capacity, which is currently equivalent to 23% of all electricity generation in the country, according to a recent report by the ACERA (Negocios e industria, 2019).

In recent years, this country has become South America's guide to clean energy, for the ability to use renewable sources, and for its conviction to point the way to a carbon-free world.

Because of a tax incentive in Italy, PV electricity capacity additions in the first half of 2020 were higher than in the same period last year, increasing by 12% the new installations (News, 2021).

The following table is the summary of photovoltaic energy growth in both countries presented in the section 3.1.3.

Table 3.5. Percentage of the growth rate of each country from the year 2000 until 2021

Country	2000-2002	2003-2006	2007-2009	2010-2012	2013-2015	2016-2018	2019-2021
Italy	11.15%	20.42%	215.08%	159.19%	4.08%	2.08%	4.11%
Chile					727.99%	58.08%	27%

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

Although Chile has bigger increases, it can be seen in table 3.6. that it is extremely far from the quantity of photovoltaic electricity that Italy has. This is because Italy started generating this energy long before Chile, so the following table it will be analysed similar stages from their start-up to the same period; phase 1 will be 2008 in Italy and 2015 in Chile.

Table 3.6. PV electricity capacity of each country from similar phases (MW)

Info: Phase 1 in Italy is in 2008 and in Chile 2015, Phase 2 in Italy is 2009 and in Chile 2016 and so on.

Country	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
Italy	483	1,264	3,592	13,131	16,785	18,185	18,594
Chile	576	1,125	1,809	2,137	2,654	3,205	4,360

Source: Author's own creation with data from (IRENA, Renewable capacity statistics 2022, 2022)

As different from both countries, that it can also be seen in table 3.6. both Italy and Chile had big steps in the PV electricity, but that impulse to want to continue growing was greater in Italy because it lasted more years and that's why Chile has not grown in the same way as Italy for the same periods. It was the increase of triennium 2008-2011 the one that positioned Italy as the second country in the world by total installed capacity (Corrias, Felici, & Ciorba, 2021).

According to the Climate Clock, created by artists, scientists, and activists to raise awareness about climate change, humanity has only 7 years to stop CO_2 emissions (Climate Clock, 2022). And if the growth is linearly increasing, Italy and Chile will be having the following capacity in PV electricity for the next seven years. Those values were calculated with linear regression that is detailed in annex three.

Table 3.7. PV electricity capacity of each country in the future (MW)

Country	2022	2023	2024	2025	2026	2027	2028
Italy	25,728.8	27,114.2	28,499.6	29,885	31,270.4	32,655.8	34,041.3
Chile	4,246.6	4,725.9	5,205.2	5,684.5	6,163.8	6,643.1	7,122.4

Source: Author's own creation

According to the estimation showed in the table 3.7., in Italy it is supposed to grow in 2022 a 13.4%, but Chile is estimated to decrease 2.6%. It is important that this last one does not occur because it is important to mitigate the climate change by using renewable sources.

3.2.2. Generator phase companies

3.2.2.1.Chile

3.2.2.1.1. Enel

This Italian company is the world leader in the energy sector, and they guide the energy transition from fossil sources to renewable sources. One of their businesses, Enel Green Power, creates electricity from sustainable resources, including geothermal, hydropower, and wind in addition to solar energy.

The following chart displays the solar PV energy projects in Chile through December 31, 2021.

Table 3.8. Total installed capacity of the different projects of Enel (MW)

Projects	In operation	Under construction	Approved
Azabache	60.9	2.1	
Campos de Sol	375.2		
Carrera Pinto	97		
Chañares	40		
Diego de Almagro	35.9		
Domeyko	204		
Finis Terrae	194	104.32	
La Silla	1.7		
Lalackama I	60		
Lalackama II	18		
Pampa Solar Norte	79		
PMGD Dadinco	3		
PMGD San Camilo	3		
Sol de Lila	161.3	1.6	
Valle del Sol		162.79	
Parque Solar Samantha			115.81

Source: Author's own creation with data from (Enel, Chile, 2021)

Campos de sol is the largest photovoltaic electricity plant in Chile commissioning in 2020, located in Atacama Region. This plant involved a total investment of about $320 million and avoids the emission to the atmosphere of more than 900,000 tons of CO_2 per year (Enel, EGP construye la planta solar más grande de Chile, 2019). Finis Terrae is very important because, besides it will make a big solar plant, its extension will be of bifacial (Enel, Enel Green Power Chile inicia la construccion de la segunda etapa del Parque Fotovoltaico Finis Terrae, 2020).

Despite being the company with the highest generation of solar energy in the country, they always look for a way to continue growing. Was approved the Parque Solar Samantha that seeks to be built in the Metropolitan Region and that, unlike the rest, incorporates a Battery Energy Storage System which will allow renewable energy to be delivered to the SEN at

times when the project is not generating energy, as well as improvements to the comfort and safety standard for workers in the work facility required for the construction phase (Electricidad, 2021).

3.2.2.1.2. Électricité de France S.A. (EDF)

This French company that building a neutral energy future in CO_2, reconciling the preservation of the planet, welfare, and development, thanks to electricity and innovative solutions and services (EDF, Our Corporate Social Responsibility Commitments, 2021).

The projects of solar PV energy in Chile are shown in the following chart to the date of 11/05/2022.

Table 3.9. Total installed capacity of the different projects of EDF (MW)

Projects	In operation	Under construction
Bolero	146	
CEME 1		480
Santiago Solar	115	

Source: Author's own creation with data from (EDF, Acelerar la transición energética de Chile, 2022)

CEME 1 will be the largest solar plant in terms of installed capacity with its commissioning in 2023. This project was carried out together with AME, a Chilean company, in a 50/50 joint venture, in the Atacama Desert, that it's located in the Antofagasta region, and its exceptional levels of solar irradiation will be able to supply around 400,000 Chilean homes while avoiding the emission of 280,000 tonnes of CO_2 per year. The solar park will consist of 860.000 photovoltaic electricity modules and will cover approximately four hundred hectares, the equivalent of 370 football fields (EDF & AME, EDF Group and AME finalise financing for Chile's largest solar plant, 2021).

Santiago Solar is also a project owned 50/50 with AME with 36,000 solar PV electricity panels. And Bolero solar plant is equally owned by Marubeni, a Japanese partner.

3.2.2.1.3. Colbun S.A.

Colbun S.A., a Chilean-based firm with twenty-six power generation in Chile and Peru, is committed to the production, distribution, and sale of electrical energy. The following chart shows Chile's solar plants as of November 5, 2021.

Table 3.10. Total installed capacity of the different projects of Colbun (MW)

Projects	In operation	In development
Diego de Almagro I and II	230	
Inti Pacha		486
Jardín Solar		437
Machitura	9	
Ovejería	9	

Source: Author's own creation with data from (Colbun, 2021)

Colbun is a company that has grown significantly. In the recent year was the commissioning of Project Diego de Almagro. For the next years, it will start operating Inti Pacha and Jardín Solar that which were recently environmentally approved, so they are in development. Those will be in the north of Chile, specifically in Antofagasta and Tarapaca region.

3.2.2.1.4. Statkraft

This Danish business is the biggest producer of renewable energy in Europe and a top player in the global clean generation industry. The following chart shows Chile's photovoltaic energy plants as of 11/05/2021.

Table 3.11. Total installed capacity of the different projects of Statkraft (MW)

Projects	In evaluation	In development
Parina		232
Pauna	671	
Tamarugo		362

Source: Author's own creation with data from (Statkraft, Proyecto Statkraft Solar, 2022)

Pauna Solar Photovoltaic Park is an initiative that to date is the largest in the SEN and it is estimated to start operating in 2024. This project will use an area of 809 hectares, and it will be located in the commune of Maria Elena, in the Region of Antofagasta. It will be composed of more than one million solar modules with bifacial technology, elements that will capture the solar radiation and transform it into electricity. In addition, the initiative includes a lifting substation, two alternative connections, and an area for the installation of batteries with storage capacity of four hours (Statkraft, Statkraft ingresa a evaluación ambiental el proyecto solar más grande de Chile, 2021).

It is evident that major investors like Enel, EDF, and Statkraft are not Chilean firms but instead international ones. However, it is clear that Chilean businesses, such as Colbun and Ame, have begun to expand in recent years.

3.2.2.2.Italy

3.2.2.2.1. Iren

This Italian firm, which manages integrated water services, environmental services, and technology services, is one of the biggest and most active multiutility companies in Italy. It works in the power, gas, and thermal energy for district heating sectors.

The photovoltaic energy plants up to the date of 11/05/2021 in Italy are in the following chart.

Table 3.12. Total installed capacity of the different projects of Iren (KW)

Projects	In operation
Borgaro	18.8
G. Bruno	39.96
Germagnano	18.8
Martinetto	163.8
Ravina	10.47
Telessio	12.4
Volpiano	18.8

Source: Author's own creation with data from (IREN, 2022)

This year, European Energy has agreed to sell 121.5MW of PV electricity capacity located in the Italian Southern region of Apulia to Iren Spa, which means, it was sold out the Palo del Colle and Troia projects. And also, Iren and European Energy have just announced ties between them for the creation of new photovoltaic electricity projects in Italy; equal to a total of 437.5 MWp distributed over four sites in Lazio, Sicily, and Puglia, of which 38.8 MWp already authorized (Ou Lü, 2022).

Table 3.13. Total installed capacity of the different projects sold to IREN (MW)

Projects	In operation
Palo del Colle	18.5
Troia	103

Source: Author's own creation with data from (Ou Lü, 2022)

Troia was connected to the Italian network at the end of June 2020 and today is the largest single connection plant ever built in Italy that extends over 1,500,000 square meters, supplying around 50,000 homes. It was built with the last generation of modules, which allow double performance in the same space, allowing an annual saving of approximately 80,000 tons of CO_2 (European Energy, Progetti in Italia, 2022).

3.2.2.2.2. EF Solare Italia

With over 300 plants spread over 17 regions and an installed capacity of over 850 MW, this Italian company is the market leader in PV energy in the nation. The following chart includes the average installed capacity of each plant throughout the various areas.

Table 3.14. Total installed capacity of EF Solare in each region of Italy (MW)

Region	Installed plants	Total capacity	Average capacity of each plant
Piedmont	20	31	1.55
Lombardy	12	18	1.5
Veneto	14	16	1.14
Friuli-Venezia-Giulia	3	1	0.33
Emilia-Romagna	10	119	11.9
Tuscany	9	18	2
Marche	8	18	2.25
Umbria	3	4	1.33
Lazio	50	154	3.08
Abruzzo	5	13	2.6
Molise	8	6	0.75
Campania	16	71	4.44
Apulia	79	150	1.9
Basilicata	1	1	1
Calabria	14	39	2.79
Sicily	45	141	3.13
Sardinia	11	53	4.82

Source: Author's own creation with data from (EF Solare Italia, 2022)

Fig. 3.6. Regions of Italy

Source: (Tourpia, 2021)

The most important projects of PV energy can be seen in the following chart.

Table 3.15. Total installed capacity of the biggest projects of EF Solare (MW)

Projects	Region	In operation
Alfonsine 1	Emilia Romagna	34.8
Alfonsine 2	Emilia Romagna	24.9
Cassiopea	Latium	24
Fiumesanto	Sardinia	29.06
S. Alberto	Emilia Romagna	27.5
Terreno Lanuvio	Latium	22.8

Source: Author's own creation with data from (EF Solare Italia, 2022)

EF Solare Italia has lots of little projects, and those big ones make 0.16 MW, which represents 0.02% of the whole installed capacity in the country.

3.2.2.2.3. Acea

This Italian business is a pioneer in the water industry and a leading player in the energy, environment, and distribution of electricity industries. The Business Plan 2020-2024 (Acea, Acea Business Plan 2020/24, 2020) mentioned investments specifically in PV electricity, both scale and consumer; 1,000 plants installed in 2024. Currently, they have thermoelectric and hydroelectric power plants. Acea has 73MW of installed solar plant capacity as of the end of 2021, and by the end of 2024, they intend to increase its portfolio by about 747 MW (ACEA, ACEA GROUP RESULTS 2021, 2022).

In June of this year, the company inaugurated Piana di Santa Chiara photovoltaic energy plant, located in Basilicata Region with a total of 20MW, which makes it the biggest PV energy plant in that region (Acea, Inaugurated in the Municipality of Ferrandina (Matera) Basilicata's largest 20 mw photovoltaic plant, 2022).

3.2.2.2.4. Enel

This Italian corporation only uses geothermal, hydro, and wind energy. In reality, they are building and creating solar energy, as shown in the following chart.

Table 3.16. Total installed capacity of the different projects of Enel (MW)

Projects	Under construction	In development
Augusta solar plant	1.5	
Casei Gerola		4.5
Malvezzi	17	

Source: Author's own creation with data from (Enel, Italy, 2022)

Both projects have the technology of ground-mounted solar panels, avoiding Casei Gerola's 3,000 metric tons of CO_2 per year, and Malvezzi's about 11,000 tons.

3.2.2.3.Comparison of the biggest PV energy plants in each country

As it was said, in Chile the biggest plant up to date is Campos de Sol from Enel, and in Italy is Troia from Iren. So, the next chart is compared the main thing of those two plants.

Table 3.17. Comparing the biggest plants of Chile and Italy

	Campos de Sol	Troia
Company owner	Enel	Iren
Year that started	2020	2020
Location	Atacama Region, Chile	Apulia, Italy
Capacity installed (MW)	375.2	103
Total investment (MM USD/MW)	$320	$140 [1]
Hectares used	1,600	150
CO_2 saving (tons)	900,000	80,000
Quantity of PV energy panels	1,000,000	275,000

Source: Author's own creation

From the chart, it has been taken the following information and the mathematics are in the annex four:

- One panel in Campos de Sol uses $16m^2$ and in Troia $5.4m^2$.
- One panel in Campos de Sol saves 0.9 tons of CO_2 and in Troia 0.29 tons.

[1] Troia and Palo del Colle were sold for 166 million EUR, that was 121.5MW, so the 103 from Troia was sold in 140.7 (European Energy, European Energy sells largest solar park in Italy, 2022)

- One panel in Campos de Sol cost $320 and in Troia $509.

The difference in of tons savings of CO_2 could be because of the different panels they use, also because of the bigger panels that have Campos de Sol, and it could be also because of the different sun in the different places.

The big difference in costs of one panel are because the data founded for Troia was the price at which it was sold, and as the plant was already in a launch it was expensive than if it had been build.

And as it was said, these will be not the biggest ones in both countries in a couple of years; Pauna from Statkraft in Chile is already in evaluation with 671MW, and Acea Group has more than one project under development because they want to reach their 747 MW target of PV electricity.

3.2.3. Future of PV Energy

3.2.3.1.Chile

With the information taken, it was estimated the capacity in the new plants of 2022. From January to April the values of the installed capacity are the new projects that came into operation those months according to the reports of each month; for january (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de enero de 2022, 2022), february (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de febrero de 2022, 2022), march (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de marzo de 2022, 2022) and april (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de abril de 2022, 2022). And then from May until December, the values are from the projects under construction in the report of April (Ministerio de Energía, Reporte de proyectos en Construcción e Inversión en el Sector Energía mes de abril de 2022, 2022), in which, the information included the estimated time in which they would begin to operate.

Table 3.18. Estimated PV electricity capacity of the new projects in Chile in 2022 (MW)

Month	Capacity MW
January	194.4
February	462.4
March	18
April	85.6
May	414.3
June	204.7
July	228
August	15.3
September	654.1
October	2.9
November	12
December	645
TOTAL	2,936.7

Source: Author's own creation with data from reports of MINERGIA

In 2021 the electricity capacity of the new projects was 1,154.57MW, with a total of 4,360 MW of all PV electricity installed capacity. So, the total in 2022 should be 7,296.7MW which means that it will grew by 67.73%; data that is much bigger than the linear regression made in the section 3.2.1.

Also, this year according to reports, until April, were accepted 84 projects, being a total of 2,858 MW, 484 other projects are waiting to be classified, which are equivalent to 44,186 MW, and other 26 projects were admitted to processing which equals a total of 2,073.8MW. These projects are expected to start operating in mid-2023 because approved ones are expected to be built in about a year and a half. Those admitted for processing are expected to be accepted in 199 working days, which was the average time it took for newly approved projects to be accepted and so the ones in qualifying are expected to be accepted in 100 working days. Then the latter two, adding the year and a half of construction, are expected to start operating in June 2024.

3.2.3.2.Italy

Up to the date of 26/06/2022 that the photovoltaic energy plants had a production of 23.23GW. And up to the last 2 years the information can be seen in the following table.

Table 3.19. Photovoltaic electricity Power 2020 – 2021 in Italy (GW)

	2020	2021
Total production	21.63	22.57
New production	0.73	0.94

Source: Author's own creation with data from (TERNA, Photovoltaic Power, 2022)

Up to date, the production of the new plants PV energy in 2022 is 0.66 GW and from table 3.19., it can be seen that in the past two years not only the production has increased, but also the new production. So, if the opening of new PV energy carries on, on the way it is going at the end of 2022 it will be an amount of 23.58 GW of installed capacity in total; 1.32 GW in 2022, i.e., it will grow a 4.5%. In the estimation made in the section 3.2.1., in 2022 if Italy behaves in a linear manner, the year 2022 should grow by 13.4%, which means that it is generating less than it should.

3.2.4. Incentives

3.2.4.1.Chile

Firstly, generators can market their energy and power in one of the following markets:

- The market of large consumers, at a freely agreed price.
- In the case of energy destined for clients with a regulated price, the market of the distribution companies, at a Knot Price.
- The Economic Freight Dispatch Centre of the respective system, at a marginal hourly cost.

Also, at this moment the Small Distributed Generation Media (PMGD), which are project with a maximum potential of 9 MW, can connect to the network of Medium Voltage Distribution Companies. And it is aimed at companies that have a high consumption of electrical energy helping them to reduce their monthly monetary expenditure (SOLCOR, 2021).

That is a project that can be financed by different economic incentives that give Corporation for the Promotion of Production (CORFO), which is under the Ministry of Economy, Development and Tourism in charge of supporting entrepreneurship, innovation, and competitiveness in the country along with strengthening human capital and technological capabilities.

The Solar Energy Research Centre (SERC) is a scientific research centre in solar energy, with special emphasis on developing the high potential of the Atacama Desert in Chile. They created the following projects

- Ayllu Solar: Aims to create human capital to promote the sustainable development of urban and rural communities in the region of Arica and Parinacota, through the use of solar energy, to contribute, from science, to improve the quality of life of its inhabitants. To date, it has six different projects that are Caleta Vitor, Azapa, Camarones, Visviri, La Estrella, and Pampa Concordia.
- Atacama Module and System Technology Centre (AtaMoS-Tec): Develops technologies for the solar photovoltaic energy industry in Chile in a strategic bet for the sustainable growth of the country with CORFO funds.

Also, in 2020 the government gave the following subsidy, which will mark a before and after in PV energy because it will begin to increase the self-consumption.

- Solar Home: This is a program of the Ministry of Energy, to promote the use of renewable energies through the installation of photovoltaic electricity panels connected to the grid (without batteries). Families from Arica to Punta Arenas will be able to access 1kWp or 2kWp systems at a lower price and thus be able to reduce their expenses (Agencia de Sostenibilidad Energética, 2021).

There were two versions of the program; in the first one awarded 3,040 PV energy panels and the second one was of 3,500 (Casa Solar, 2021).

For the first version, tenders have only been made in five areas and a further eight are missing in the Solar Home incentive as can be seen in the following chart.

Table 3.20. Tenders in 5 of the 8 zones of the first version of Solar Home project to date 05/2021

Area	Type of system (kW)	Number of projects tendered	kW of projects tendered
Puente Alto	1	151	151
	2	99	198
Maipú	1	63	63
	2	117	234
Rancagua	1	61	61
	2	49	98
La Florida	1	56	56
	2	94	188
Talca	1	92	92
	2	58	116
Total		840	1,257

Source: Author's own creation with data from (Casa Solar, 2021)

As not all areas have been tendered and there's only information on the amount quantity of solar panels, for analysis will be used the supposed that the other eight zones will behave in the same way, i.e., the quantity of each type will represent the same percentage than the tendered ones.

So, according to it, it was taken the percentage of the five zones for each type of system and was used to calculate the amount of each type for the remaining 2,200 panels. With that information was took the amount of installed energy of the first version of this project, and it can be seen in the following chart and detailed in annex five.

Table 3.21. kW of the remaining areas in the first version of Casa Solar

Type of system (kW)	% of each type in the tendered areas	Number of projects for the remaining areas	kW of projects
1	50.4%	1,108	1,108
2	49.6%	1,092	2,184
		Total	3,292

Source: Author's own creation

Then, under the assumption mentioned above and the information mentioned, the first version of Solar Home project will acquire photovoltaic electricity panels for 3,040 houses, which means 4,549 kW of energy. And so, if the second version behaves similarly, will contribute with 5,239 kW.

3.2.4.2.Italy

The most common incentive mechanism in Europe is the FITs. This mechanism obligates an electricity provider to purchase electricity generated by renewable energy producers in its relevant area, paying a tariff determined by public authorities and guaranteed for a specific period.

It is known that the famous "Conto Energia" was the incentive that caused a great growth in PV energy. In 2005 was issued the first (MINISTRO DELLE ATTIVITA' PRODUTTIVE, 2005) and was a FIT mechanism to incentivize the production of PV energy. The first Conto Energia benefited only the grid-connected PV electricity systems with rated power from 1 kW to 1 MW, which, were categorized according to the PV electricity plant power, for 20 years with constant remuneration and after that time, the producer could benefit from the net-metering option or sell the energy to the electricity provider. But this was not the one who led the country to great growth, but in fact, due to it was simplified the procedure for obtaining the benefit (Favuzza, Di Dio, La Cascia, Massaro, & Zizzo, 2015), it was the Second Conto Energia that was issued in 2007 (MINISTERO DELLO SVILUPPO ECONOMICO, 2007), as can be seen in the section 3.2.1. That one changed the FITs' values,

distinguishing among different classification of the PV energy plants. Thanks to its success, in 2010 it was announced the Third Conto Energia (MINISTRO DELLO SVILUPPO ECONOMICO, 2010) which introduced new rules and new tariffs for new classifications of PV energy plants. Then in 2011 the fourth Conto Energia (Ministro dello Sviluppo Economic, 2011) was established, which entailed a gradual reduction of FIT incentives to gradually align the public incentive with the technology costs and at the same time maintain stability and certainty in the PV electricity market.

It should be noted that these large incentives cause a substantial increase in related costs for both taxpayers and final electricity consumers because these incentives are paid by all on consumer bills via a specific surcharge called the A3 subcomponent. Therefore, to contain costs and preserve the overall sustainability of these electricity bills, in 2012 the Fifth Conto Energia was introduced, which included an annual spending cap. As a result of this, in 2014 established the Spalma Incentivi Legislation was established, where for the existing PV electricity plants with a nominal capacity above 200 kW was modified the FIT support rate in three options.

The following table indicates each Conto Energia showing, its number of total PV electricity plants, power installation, and PV electricity plant typology taken by an article.

Table 3.22. Conto Energia data[2]

FIT(s) regulation	Number of total PV plants	Power installed [kW]	PV plant typology
DM 28/07/2005: First "Conto Energia"	5,725	163,431	Not-Integrated-in-building
D.M. 19/02/2007: Second ‘‘Conto Energía	203,734	6,807,772	Partially-Integrated-in-building and Building-Integrated PV plants
D.M. 06/08/2010: Third ‘‘Conto Energia	39,638	1,573,705	On buildings (85%)
D.M. 05/05/2011: Fourth ‘‘Conto Energia	204,551	7,754,187	On buildings (88%)
D.M. 05/05/2011: Fifth ‘‘Conto Energia	98,137	1,412,646	On buildings (86%)

Source: Extraction of (Favuzza, Di Dio, La Cascia, Massaro, & Zizzo, 2015)

Recently, from 1 February 2022 to 31 December 2022 the Antifrodi Regulation was issued and these incentives for photovoltaic electricity installations with a power of more than 20 kW benefit from fixed tariffs deriving from the energy account mechanism (not dependent on market prices). Benefits are facilities that went into operation before 2014 and that currently benefit (in addition to the fixed incentive enjoyed) from the income from the sale of energy that, in this situation of expensive gas bills, is remunerated at much higher prices than might be expected at the time of investment decisions (Bovino, 2022).

Also, in the past years, the government gave the following incentives:

- FER1 Regulation: It was enacted in 2019 and provides renewable energy plants with incentives of around €1 billion a year. This incentive aims to support the development of approximately 4.8 GW of generating capacity by 2021 (Steinhauer & Narducci, Italy: The 2019-2020 incentives regime for renewable energy plants, 2020).

[2] Italian economic incentive to promote the use of photovoltaic energy.

- Superbonus 110%: Encourages the construction sector and at the same time responds to the important climate and environmental challenges. It provides for a deduction rate of 110 percent for expenditure incurred until 30 June 2022, 31 December 2022, and 30 June 2023 for specific cases, for single-family residential buildings and apartment buildings, natural persons, apartment buildings, autonomous centres of social housing, or similar entities and interventions considered priority (motor) and secondary (towed) (Governo Italiano, 2022).

Although FER1 Regulation is not available this 2022, and the other two will finish this year, in the following years there are likely to be more incentives, impacting an increased number of areas, like we can see in 2022 that the Superbonus is for lower quantities, wanting to make PV energy in every corner of the country, up to the biggest companies.

And also, there were more energy incentives in the past years, such as Isole Minore, Nuovo Bando Smart Grid, Detrazioni fiscali, Certificati Bianchi, Fondo nazionale efficienza energetica, among others. Even there where some for municipalities; Progetti di efficientamento energetico (Ministero dello sviluppo economico, 2022).

3.2.5. Regulatory framework

3.2.5.1.Chile

- Regulation 15 (2002): Establishes the agreement with the United Nations Development program on the project "Chile: Removal of Barriers to Rural Electrification with Renewable Energies."
- Law 20.698 (2003): Encourages the growth of the energy grid through the use of unconventional renewable energy sources, and mandates that the Ministry of Energy conduct public tenders for the supply of yearly blocks of energy from NCRE.
- Law 19.940 – “Ley Corta I” (2004): Regulates the transfer of electrical energy, creates a new tariff structure for medium-sized electrical systems, and makes the changes it suggests to the general law of electrical services.
- Law 20.018 - “Ley Corta II” (2005): In order to "strengthening the security of supply in the face of external uncertainties in the supply of fuels difficult to replace

immediately in international markets" the regulation of the electricity sector was changed. This requirement stated that "public distribution service concessionaires must have at their disposal a permanent supply of energy which, in addition to their generation capacity, will enable them to satisfy the total projected consumption of their regulated consumers for, at least the next three years".

- Regulation 262 (2006): Promulgates the agreement on climate change efforts with the Kingdom of Denmark.
- Law 20.257 (2008): Imposes a 10% ERNC quota requirement on businesses that sell energy in SEN.
- Regulation 267 (2008): Promulgates the 2007 “renewable energies and energy efficiency program” agreement on financial cooperation with Germany.
- Regulation 84 (2009): Promulgates the agreement on the Renewable Energy Efficiency Project IV between the governments of the Federal Republic of Germany and the Republic of Chile.
- Law 20.698 (2013): Encourages the expansion of the energy matrix by 20% using renewable, non-conventional sources of energy.
- Law 21.118 (2018): Promotes the development of residential generators.
- Law 21.305 (2021): This law intends to create the First National Energy Efficiency Plan, which will be updated every five years. The Ministry of Energy will work with other ministries to complete this plan, and citizens will be encouraged to participate.
- Law 20.571 – Net Billing (2021): Gives consumers the opportunity to sell any excess energy at a set price straight to the power distributor.

3.2.5.2.Italy

- Finance law (2000): Creates a fund for the improvement of energy efficiency and the development of renewable energy sources. It covers up to 80% of the cost of programmes for solar collector installation.
- Law 239 (2004): Established measures, such as the expansion of the trading of green certificates from renewable and CHP projects to include hydrogen, served to

restructure the energy markets and promote competition. Additionally, it decreases the original value of 100 MWh every green certificate to 50 MWh.

- Finance law (2008): For a 15-year incentive term, allows small renewable facilities that were installed after January 1, 2008, to select between green certificates and a feed-in tariff method.
- Law 102 (2009): Is intended to accelerate the adoption of more sophisticated, effective, and energy-saving technology.
- Law 116 (2014): It regulates the restructuring of feed-in tariffs for photovoltaic energy plants with a capacity more than 200 kW. There are three types of restructuring: current, fixed reduction, and variable restructuring.
- Law Regulation 145/20131 - Destinazione Italia Regulation (2014): Incentives for renewable electricity producers, tax incentives for the energy efficiency of buildings and improve the White Certificate mechanism.
- Law 221 (2015): Measures to safeguard the environment, the oceans, and other natural areas. The standards for the systems for the recovery and recycling of the modules have been defined in PV energy.
- Law 37 (2019): Establishes rules for the fulfilment of obligations resulting from Italy's EU membership.
- Regulation-Law 34 - relaunched Regulation (2020): Modifies the tax laws to promote energy efficiency, solar installations, and electric vehicle charging stations; there was a superbonus of 110%.
- Law Regulation 17 – Energy Regulation (2022): One of the areas of intervention is the acceleration of the process of identifying areas that are immediately suitable for the installation of PV electricity systems. Other is to simplify and accelerate permitting procedures for plants located in such areas. And also facilitate the self-consumption of energy from renewable sources (Rocco Viscontini, 2022).

3.2.6. Finance and Investments

As was seen in the section 3.2.4., the increase in incentives is proportional to the increase of installed capacity in photovoltaic energy.

According to IRENA, in Chile and Italy, between the years 2000 and 2018, the biggest investments came from China. In Chile followed by the United States and in Italy by EU Institutions, as can be seen in the following chart.

Table 3.23. Amount of Investment made in Chile and Italy from 2000 until 2018 by the different organizations

	Amount (2019 USD million)		% amount	
	Chile	Italy	Chile	Italy
China	940.51	904.96	37.32%	66.62%
EU Institutions	0	453.51	0%	33.38%
United States	832.8	0	33.05%	0%
International Finance Corporation	248.85	0	9.88%	0%
Inter-American Development Bank	165.82	0	6.58%	0%
Development Bank of Latin America	159.62	0	6.33%	0%
Climate Investment Funds	85.99	0	3.41%	0%
Green Climate Fund	51.07	0	2.03%	0%
France	22.33	0	0.89%	0%
Germany	9.74	0	0.39%	0%
Global Environment Facility	2.67	0	0.11%	0%
Austria	0.23	0	0.01%	0%
Spain	0.18	0	0.01%	0%

Source: Author's own creation with data from (IRENA, Investment Trends, 2022)

Concluding from that table it can be seen that the biggest investments in Chile do not come from our own, because only 6.33% comes from an institution from Latin America. On the other hand, in Italy, although China was the biggest investor, the EU has invested a big amount of money.

The biggest investment in Chile was in the year 2012 at 1,003.54 USD and in the section 3.1.3. it can be seen that the PV energy growth rate of the period 2013-2015 was 727.99%. For Italy happened the same, in 2010 was the biggest investment, and in the period 2010-2012 the growth rate was 159.19%.

4. Analysis and discussion

4.1. Electricity Market

It is evident that despite both electricity markets having the same phases, they do not function in the same way. Firstly, regarding the problems of connectivity in Chile, there are three systems whereas in Italy there is only one. Secondly, although both systems have private companies in the distribution phase their market regimes differ; in Chile as a result of the monopoly characteristics it is regulated, while Italy operates under a free market. And also, the transmission phase is very different, in Chile, there are lots of companies operating under a regulated sector, however, in Italy, there is just one company under a natural monopoly.

Having one only system is way much better because those areas that have not great potential can receive the electricity needed. Two or more systems make everything different, quality and reliability of supply are different, also, as there are different quantities in the two different systems although they are in the same country, power and energy products can be cheaper in one of them than the other one (Rudnick, 2018). In Chile there are a total of five areas of ice accumulation; Northern Patagonian ice field located entirely in the Aysen Region, Southern Patagonian ice field located between the regions of Aysén and Magallanes and Chilean Antarctica, Ice on the peninsula Muñoz Gamero located in located in the Magellanes Region and the Chilean Antarctic, also as Ice on the Island Santa Inés and Carlos III and Ice in the Darwin Mountain Range (Institulo Chileno de Campos de Hielo, 2022). Because of that, it is orographically very complex to have a single system. If Chile could have a single system, it would increase competition between generators, raise the number of bidders for customers and thus optimize the average cost of generation, decreasing (La Tercera, 2010).

On the other way, having one only company in the transmission phase makes the process much more efficient with high-voltage and very-high-voltage lines, such as TERNA. But in the other way, this natural monopoly can take advantage in an easier way than if it were more companies and use tactics to gain an unfair advantage by using collusion, mergers, acquisitions, and hostile takeovers, so it’s very important to regulate them correctly (THE INVESTOPEDIA TEAM, 2022). In this same way, the distributor’s companies in Chile can take bad advantage of this.

As they are different countries and have different lands, they use their resources in different ways to take advantage of them. Through the years in Chile, the main resource has been hydro followed by other fossils, and in Italy, it has been gas and the second most used since 2019 has been solar. In both countries, solar energy has been the one which has the biggest increase, so they can make them their main source along with other renewable energies.

As both countries are governed by free competition, they not only use the energy they produce, but they also buy energy from other countries, and that is why they have been affected by the war. As Italy purchases gas directly from Russia, it has felt a greater impact than Chile. This could be viewed negatively as a result of the prices, but they can take advantage of it, and it can provide an opportunity to invest more in PV solar energy, and even maybe invest in the vacant Chilean lands that carry so much potential.

4.2.Regulation and incentives

There are not only differences in the system, but they are also different in many other ways. Like as they are regulated in different ways; Chile mainly by MINERGIA and Italy by ARERA, and of course in different governments, they have different laws and incentives. Throughout the years, Italy has had more laws and incentives from the government for PV energy, not only on a national and European level but also domestically. And it is known that Conto Energia was the main factor that caused such a large increase in solar energy in Italy in the past years. And now, Decreto Energia looks to contribute to the reduction of energy costs for Italian companies and so is a practical approach to unblock the PV electricity growth (Rocco Viscontini, 2022).

As renewable energy is a fairly new concept, the target policies and support mechanisms introduced by many governments have played an important role in the growth of energy throughout the world and so this energy has achieved great growth in recent years, according to IRENA; where in 2000 the electricity capacity installed was only of 808 MW and in 2021 843,086 MW, which means an increase of 104,242% in 21 years.

The IEA has had the Photovoltaic Power Systems Programme (PVPS) since 1993 and in the last report of Trends in Photovoltaic Applications, published in the year 2021, it was written

that in the year 2020 approximately 52% of all PV electricity installations in the world were receiving a predefined tariff for part or all of their production (IEA, Trends in PV Application 2021, 2021).

Since 2015 China has been the leader in PV energy (IRENA, Country Rankings, 2022). Since 2009 the country has been applying two subsidies; the solar roof program and Golden Sun Demonstration Project. Where with those programs, in just two years it was evident in 500 MW installation. Renewable energy incentives implemented in China can be classified as VAT refund, energy performance contracting, FIT incentives, financial funds, and financial subsidies. One of those is the 15% of tax exemption to technology producers, the other is the 0% VAT refund for energy sales obtained from PV electricity systems over the years has put out tenders of projects with 10 MW and 60 MW. So, in less than a year the target of 100 GW installed power was achieved ahead of the target date set, moving from number seven to number one in six years (Kılıç & Kekezoğlu, 2022).

In Italy, 2008 was the year in which the maximum spread of PV energy plants occurred, thanks to the Second Conto Energía, in the year 2014 almost 97% of Italian towns have at least one PV energy plant (Favuzza, Di Dio, La Cascia, Massaro, & Zizzo, 2015). And in the year 2011, the whole program took Italy the world leader in PV energy markets as it was said in the IEA PVPS 2021. One study analysed the linear correlation index (LCI) in Italy between the installed capacity and the total amount of incentives and for the period 2006–2019, LCI had a value of 0.988, which means perfect correlation i.e., the increase of the capacity is directly related to the level of the given incentives (Bianco, Cascetta, & Nardini, Analysis of technology diffusion policies for renewable energy. The case of the Italian solar photovoltaic sector, 2021).

In Italy, the incentives have not been as big as Conto Energia, but a couple of incentives financed by CORFO have been made. In addition, recently Solar Home was closed having a success of two versions, where the first version is expected to contribute with 4,549 kW of installed capacity and the second one with 5,239 kW.

4.3.Costs of implementing PV electricity

This increase in PV energy has also favoured a sustained decline in costs, increasing competitiveness. LCOE is defined as the price at which the generated electricity should be sold for the system to break even at the end of its lifetime. Because of the steadily improving technologies, economies of scale, competitive supply chains, and growing developer experience, the global weighted-average LCOE of utility-scale solar PV electricity fell 85% between 2010 and 2020. Even, solar PV electricity passed from being more than twice as costly as the most expensive fossil fuel-fired to equal to or less than the cost of purchasing energy produced from fossil fuels (IRENA, Renewable Power Generation Costs 2020, 2021).

Because of the time and quantity that Italy has in the PV solar energy sector, the utility-scale solar PV electricity total installed costs decreased 85% between 2010 and 2020; from 5,274 to 781 USD/kW. Chile, for its part, had a cost of 1,047.1 USD/kW in 2020. According to the data of IRENA, the greatest decrease of this cost in Italy was the year 2012 with 48%; from 4,978 to 2,601 USD/kW (IRENA, Renewable Power Generation Costs 2020, 2021). As could be seen in table 3.5., the period between 2010 and 2012 had a growth rate of 159.19%, the biggest since that date up to now, which means the growth rate and decrease in cost are directly related. Since 2010 and 2020 Italy has had an average the growth rate of 45.8% and has had a decrease in costs of 85%, and so as Chile has had an average the growth rate of 300.4%, with the time costs are expected to come down quickly because of it is potential.

In table 3.17 it is compared the two largest plants in each country, and it can be concluded that a panel of Campos de Sol costs $320 and one in Troia $509. Although the investment made in Campos de Sol was from its installation in 2020 and that of Troia was the sale price in 2022, the value of one solar panel in the Italian plant is 159% more expensive than the Chilean one. And considering that in 2020 the cost of photovoltaic energy in Chile was 132% more expensive than in Italy, the development costs in Chile are not so high, so decreasing costs could develop projects at low prices.

In an article (Umberto, Ernesto, Cesare, & Ivano, 2018), it was said that the profitability of PV electricity plants mainly depends on the following factors:

a) solar irradiation and related energy yield

b) revenues from the sale of the electricity generated
c) value of the incentive granted
d) taxation and tax deductions

4.4.PV energy in residential sector

In Chile, the year 2020 the second main consumer of electricity was the residential sector, with an 19% followed by copper (División de Políticas y Estudios Energéticos y Amb & Ministerio de Energía, 2021). Even though, Chile does not take advantage of its potential in solar energy and has almost no residential PV prosumer (RPVP) market. Recently, some people carried out a study Identifying barriers and opportunities in the deployment of it (Osorio-Aravena, de la Casa, Töfflinger, & Muñoz-Cerón,, 2021). After analysing all of the data from 2018, the results revealed that the irradiation levels, investment cost, the annual discount rate, and the regulatory scheme are all critical parameters in the profitability assessment of a residential PV electricity project.

One of their suggestions to accelerate the deployment of residential PV electricity systems in Chile was to implement incentive and financing options, at least, for families with less income and in locations with yield levels less than 1,300 kWh/ kWp-year. As was mentioned before in the section 3.2.4., the Ministry of Energy announced the Solar Home. This incentive is not as big as Conto Energia in terms of quantity of kW, nor the first one, but this incentive will undoubtedly bring growth; the first Conto Energia brought 163,431 kW and the first version of Solar Home is estimated to bring 4,549 kW. In 2020, Chile had 19,116,209 inhabitants and Italy 59,449,527 (Banco Mundial, 2022), that is, the population in Chile is equivalent to 32.2% of the population in Italy. Similarly, the incentive in Chile is equivalent to 19% of that in Italy, in terms of the number of total PV electricity capacity.

In addition, the new Net Billing law allows the self-generation of energy based on Non-conventional Renewable Energy and efficient cogeneration. This gives users the right to sell their surplus directly to the electricity distributor, which unlike Net Metering, is at a regulated price. In the Net Metering, customers are charged their full energy price per kWh with the same rate for the energy that is contributed to the network, whereas Net Billing is charged

based on their net use of kWh, using different tariffs to assess the contribution of energy to the grid and the electricity consumed in a traditional way.

As noted above, the Conto Energia was paid by the population on the electricity bill through component A3. In Chile cannot be at such a level, because the average salary equals 1,001 EUR (Datosmacro.com, Chile - Salario Medio, 2022) and in Italy, 2,836 EUR (Datosmacro.com, Italia - Salario Medio, 2022), and the price of the electricity in euro in Chile is 0,159 kWh and in Italy 0,214 kWh (GlobalPetrolPrices.com, 2022). That means that, if in a month there are 730 hours, a Chilean pays 11.6% of its salary in electricity and an Italian pay only 5.5%, which means that it is not feasible to use in Chile earmark taxes to not decrease the quality of life. So, the best option in Chile is to use subsidies given by the government. Also, is so good that other countries are taking advantage of Chile's benefits because of their richness, as it could be seen in the section 3.2.6.

It should be noted that domestic users install solar PV electricity plants, not because of its climate benefits, but because of their benefits of reducing electricity bills, and increasing the sustainability of their houses, among others (Bianco, Cascetta, & Nardini, Analysis of technology diffusion policies for renewable energy. The case of the Italian solar photovoltaic sector, 2021).

4.5.Solar irradiation

Higher solar irradiation levels rise average annual operation hours, being PV electricity system degradation rates equal, thus translating into additional revenues and making investments more profitable in comparison with assumptions made when setting support tariffs.

In Chile, the year 2015 some people from Federico Santa Maria Technical University made an analysis of the sensibility of PV energy in the country for a plant of 30 MW with panels mounted by a two-axis tracker, to maximize the energy collected from the sun (Bustos, Toledo, Contreras, & Fuentes, 2016). As it can be seen then, the north of Chile has higher radiation than the south. Calama, in the Antofagasta region, which is a city in the north, presents the maximum Capacity Factor (CF), doubling the value of Puerto Montt, in the

Region of the Lakes, which is a city in the south and which presents the minimum value and the same for the annual energy production. But, although solar radiation is bigger in Puerto Montt than in Punta Arenas, Punta Arenas CF's is bigger because of the large amount of rain in the city of Puerto Montt. So, the solar radiation is directly related to the CF, but also to the amount of rain. Also, the potential of mitigation of GHG emissions for a year and financial analysis followed the same trend behaviour as the CF and annual energy. So, the different results were because of the different solar radiation that the different regions had.

One article that makes a methodology of Köppen-Geiger-Photovoltaic (KGPV) climate classification and implications (Ascencio-Vásquez, Brecl, & Topič, 2019) concluded that the best location for PV energy is the Atacama Desert-Chile area, in the region of Antofagasta, because of the very high irradiation and the high numbers of sun hours due to the relative vicinity to the equator. The Global Solar Atlas (Global Solar Atlas, 2022) says that Antofagasta Region, that in where is locates the Atacama Desert, has global horizontal irradiation (GHI) between 5.61 and 7.44 kWh/m^2, where up to the date of May of 2022 the region takes the first place of the region with the biggest amount of installed capacity, with the 34.1% (CNE, Capacidad instalada de generación, 2022).

It could be interpreted that Chile has bigger solar radiation, but that does not mean that in Italy it is bad; Furthermore, the following will talk about the regions similar in radiation between the countries, but that Italy takes more advantage of.

In Italy, the region with the best global horizontal irradiation is Sicily, with 4.22 kWh/m^2 of minimum and 5.01 kWh/m^2 of maximum. This one is very similar to Biobio Region in Chile; with a GHI between 4.26 and 5.17 kWh/m^2, whereas Sicily has the 6.8% (GSE, 2022) of the total installation of PV electricity and Biobio only the 0.5% (CNE, Capacidad instalada de generación, 2022); with an installed capacity of 1,542MW in Sicily and 25.8MW in the Biobio region.

The following table it is compared two plants; one is located in Sicily and the other one in Biobio.

Table 4.1. Comparing two plants in different countries with similar GHI

	El Resplandor	Augusta
Location	Biobio, Chile	Sicily, Italy
Capacity (MW)	3	1.5
CO_2 emissions avoided (metric tons annually)	2,900	1,500

Source: Author's own creation with data from (Impulso, 2020) and (Enel, Augusta Solar Plant, 2022)

On one hand, El Resplandor started operating in the year 2020 and Augusta will start by the end of 2022, because of the 3Sun PV energy modules with multi-junction technology that uses the second one, there are avoided more CO_2 emissions per capacity installed.

Apulia is the region with the largest amount of PV energy in Italy with 13%, and also is the region with the biggest average plant size (GSE, 2022). Its average GHI is 4.37 kWh/m^2 and it is similar to Araucania in Chile which has 4.38 kWh/m^2. The main difference is that the percentage of installed PV energy in this last one is 0, so although is demonstrated that PV energy functions over there because in Italy they have a lot of PV electricity installation, in Chile they do not take advantage of what they have; and is the third region with the worst average of GHI, excluding Aysen and Magallanes and Antarctic that both information didn't appear.

Although this, in table 3.17. it can be seen that Campos de Sol saves more tons of CO_2 than Troia, which means is more effective, that could be interpreted because of the bigger GHI, and better technology used. That does not mean that it does not generate or is not an efficient plant, as it supplies around 50,000 homes. This was a long project because although was connected to the grid in 2020, its development started in 2007 and after a long acceptance, it started to build the first 63 MW under the fourth Conto Energia program in 2011. That did not result because of financial issues, but with time they could resolve it (Brigido, 2020).

Within the second and the third region of Italy with the most installed PV electricity, which is Lombardy and Emilia Romagna, happens the same thing with the first one; Regions of the Lakes and of the Rivers doesn't have installed PV energy. What does, is that these last two

regions are the regions that have the worst GHI, and in the other eleven regions there is even a little bit of installed PV energy.

It exists different types of PV electricity technologies, where they even pick up different amounts of solar radiation even though they are in the same location. A clear example is a study carried out in the coastal zone of Antofagasta where two technologies were compared, amorphous/microcrystalline thin film and mono-Si, under the same condition with the influence of solar irradiance, dust accumulation on the module surface, and ambient temperature (Ferrada, Araya, Marzo, & Fuentealba, 2015). The energy yield is the real amount of energy obtained from the solar panel, so the larger the better, and so, discovered in the study was that mono-Si modules achieved an energy yield of 1,760 kWh/kWp per year and thin films 1,690 kWh/kWp per year. In a clean condition, the effect of temperature results is more relevant than the efficiency, so at the peak ambient temperature, the thin film can perform better than mono-Si and in the minimal, both are the same. In this condition, the performance ratio (PR) of the variation from winter to summer, resulted to drop less in thin-film than mono-Si. The dust, condition produces a gradual reduction in the performance of the thin-film technology, so in this condition, mono-Si is better. As dust accumulating in the modules and temperatures increase, the performance decreases at a higher speed compared to the situation of the temperature decreases. In this condition, the PR was better in mono-Si, but in winter thin film improved much more after the same number of days than the other. So, they could conclude that the effect of dust accumulation was more severe for the thin films than for mono-Si. Thin films will always require cleaning, independently of the season. Mono-Si may not be cleaned in summer since the improvement from dusty to clean condition is low.

4.6.Growth of technology in the world of PV energy

Through the years, PV energy has evolved and to date, there are four generations, which through those the different technologies have different characteristics, for example, in their costs, life cycle, temperature, light condition, conductivity, transport, among others, and also have different efficiency and manufacturing methods (Pratap Singh, Kumar Goyal, & Kumar, 2021). From 2010 until 2020, the performance of PV electricity panels grew; the module

efficiency grew by 24%, the module power by 55%, and the capacity factor by 17%, and also because of all this growth, PV electricity module prices decreased by 93% (IRENA, Renewable Technology Innovation Indicators: Mapping progress, 2022).

One new technology is the FPV which is PV energy on water modules, a global trend of electric energy production that opens new opportunities that have not been fully explored. It has several advantages like avoiding competing with agricultural or green zones and can advantageously integrate other renewable energy source technologies (Cazzaniga & Rosa-Clot, 2021).

According to the 2021 Italian photovoltaic energy statistical report, 69.8% of the installed photovoltaic energy power is made of polycrystalline silicon, 24.7% monocrystalline silicon, and 5.5% thin film or other materials (GSE, 2022).

Polycrystalline silicon, also known as multi-crystalline, is a technology of the first generation of which solar cells are made from several fragments of silicon melted together and since the cells are made of multiple crystals, the electrons have relatively less space to flow. One important advantage is that they have a lower cost, have a simpler manufacturing process and, there is less wastage of silicon while manufacturing these panels. But some disadvantages are that they have a lower efficiency (13-16%), they require larger surface areas, and also, require more space (Team ProductLine, 2020).

On the other hand, Chile does not have information on the percentage of types of energy used, but it could be seen in the last projects that are using the leapfrogging strategy.

In 2020 Campos de Sol started operating. This PV electricity plant has more than one million bifacial photovoltaic electricity panels, able to maximize energy production thanks to a technology that captures the sun's rays on both sides, generating an average of 12% more energy than traditional panels (Enel, EGP construye la planta solar más grande de Chile, 2019).

Also in 2020, a Chilean company called Developer Solarity inaugurated the first FPV plant connected to the electricity grid; 1,500 meters of 456 photovoltaic electricity modules which is equivalent to the monthly electricity consumption of 116 households, or about 626,400 kWh (PV Magazine, 2020).

Currently, under construction is the project Andes Solar II B of the US company AES, which will be the most efficient solar park in the world. It will provide 180 MW, of which 10 MW will be built using the Maverick technology; modular and prefabricated solar panels that allow their installation in a third of the time than normal panels, using half the surface. And also, will have integrated a system of batteries that will provide 112 MW (AES, 2021).

4.7.Types of plants size

With the speed at which technology is growing today, it has undoubtedly allowed efficiency to improve and grow in the markets for solar PV energy, which has led to the global weighted-average capacity factor increasing from 13.8% in 2010 to 16.1% in 2020. (IRENA, Renewable Power Generation Costs 2020, 2021). And this could be the reason in 2019, 60% of total solar PV electricity investment was of utility-scale solar PV energy dominated deployment capacity (IRENA, Renewable Power Generation Costs in 2019, 2020). So, in the same line, Chile has much more potential for solar PV electricity because of its solar radiation, and that demonstrates why chart 3.23. can be seen that there are a bigger number of investors in Chile than in Italy. Also, in most important companies of PV electricity in Italy are locals, unlike in Chile, where the most important companies are foreign; even the largest photovoltaic electricity park this last one is from Enel, an Italian company.

This does not discourage the country to continue growing, so that's why Italy has had lots of incentives, and those incentives, like Conto Energia, were targeted at small-scale plants, for the residents. Just remember that Troia was attached to the fourth Conto Energia and because of financial problems, they could not continue for a while.

So, because of the incentives in Italy and the potential in Chile, it can be seen in section 3.2.2., although Italy generates more photovoltaic energy, its projects are much smaller in terms of installed energy than in Chile, where the biggest plant is 3.6 times greater in comparison with that in Italy.

In Italy, 60% of all the PV electricity installations up to 31/12/2021 are concentrated in the power range between 3 kW and 20 kW, followed by the range of 1 kW and 3 kW with 32% (GSE, 2022) and it is a result of various subsidies that the government has given, as is

demonstrated in table 3.22. that the last 3 Conto Energia were mostly PV electricity on buildings. To build utility-scale plants its necessary to obtain authorization that firstly, there are limited, and second, it takes a period of between 1 and 1 and a half years to obtain it (Enel, How much solar energy Italy produces and where it's produced, 2020), or even 4 years as in Troia between their development and acceptance.

4.8. Importance of implementing renewable energy

As it was talked about in the very beginning, boosting the use of renewable energy helps the environment, reducing the amount of CO_2 on the planet and thus improving the quality of life of people by slowing the growth of the planet's temperature. If heating exceeds 1.5°C, the temperature of the planet will increase, there will be extreme natural phenomena, crops affected by what will be food insecurity, in addition to water scarcity, irreversible rise in sea level, and even extinction and displacement of species (Pacto Mundial Red Española, 2022).

The United Nations Framework Convention on Climate Change (UNFCCC) is the one who sets out the framework and principles to achieve the stabilization of GHG emissions. And the first agreement called for industrialized nations to reduce CO_2 emissions and the presence of GHG in the atmosphere was the Kyoto Protocol, which was approved in December of the year 1997. In 2015 it was replaced by the Paris Agreement, which includes climate agreements and commitments linked to incentives and laws to promote renewable energy from all major GHG-emitting countries to reduce their climate-altering pollution (Tardi, 2021). One clear example is Conto Energia in Italy, that was established to increase the amount of photovoltaic energy and thus achieve its climate commitments.

One of the rules of the UNFCCC is to update the emissions inventory every two years. Italy's total GHG emissions decreased by 17.4% during the period 1990-2017, where in 2017 the energy sector was the main emitter with 77.5% of all the emissions. Since 2006, this decreasing trend was due to an increase in energy production from renewable sources, such as the photovoltaic energy that, as shown in section 3.1.3.2., is currently in the second place with the highest installed capacity and has the highest growth rate average. And also, was

because of a further decrease in the use of oil products in the generation of electricity (Ministry for the Enviroment Land and Sea, 2019).

Chile is a small emitter, which in 2020 contributed approximately 0.23% of global emissions, compared to Italy which was 0.87% (Ritchie & Roser, 2020). But from 1900 to 2018 the emission of GHG increased by 128%, whereas in 2018 the Energy sector was the main emitter of GHGs accounting for 77% of total emissions. The main cause of the trend is the sustained increase in the country's energy consumption, including the consumption of coal and natural gas for electricity generation (Ministerio del Medio Ambiente, 2020).

At the moment Chile has very ambitious targets for 2050 and so has 3 scenarios (Ministerio de Energía, Transición Energética de Chile, 2022):

- Slow recovery post covid-19: Is projected assuming the economic and social impact due to the pandemic. Efforts are focused on improving air quality in cities through regulating the use of firewood, as well as implementing energy efficiency measures in homes.
- Towards Carbon Neutrality by 2050: The projections assume better economic conditions globally and locally, hand in hand with a rapid drop in the costs of clean technologies. So, it considers the adoption of new technologies, makes it possible to achieve higher levels of penetration of electromobility and efficiency measures in the productive sectors. This scenario makes it possible to achieve Carbon Neutrality by 2050.
- Accelerating the Energy Transition: Is considered a rapid economic and social recovery after the pandemic. In this scenario, the massive deployment of renewable energy in the electrical system, hand in hand with the incorporation of storage solutions, enables electricity consumption in all sectors of the economy. In this scenario the electrical system will operate 100% emissions-free by 2050 and the Carbon Neutrality commitment will be reached before that year.

For the Paris Agreement, both governments and countries have set targets for 2030. In Italy, according to the Integrated National Plan for Energy and Environment, the target for PV energy is 50 GW (Ministry of Economic Development, Ministry of the Environment, & Ministry of Infrastructure and Transport, 2019). If the market continues to operate as it is

doing, PV energy in 2028 will be 34 GW, as was seen in the section 3.2.1., and so the target of PV energy will not be reached. One study also estimated it, with the hypothesis that from 2020 the new capacity will continue the linear trend added in the period 2016-2019 (Bianco, Cascetta, & Nardini, Analysis of technology diffusion policies for renewable energy. The case of the Italian solar photovoltaic sector, 2021). In an analysis from IEA, it was said that in 2020 only 25 MW out of 1,000 MW was awarded to PV electricity developers because of the rules prohibiting the use of agricultural land (IEA, Renewables 2020 - Analysis and forecast to 2025, 2020), but the new Energy Regulation will accelerate the number of installations.

On the other hand, Chile has a target of producing the 80% of renewable energy by 2030 in the electricity generation (Ministerio de Energía, Transición Energética de Chile, 2022). IEA said in its last report that Chile is well on track and that even, PV energy growth is expected to accelerate after 2022 because the government has fast-tracked the environmental approvals of 55 solar projects as a Covid-19 economic recovery efforts (IEA, Renewables 2020 - Analysis and forecast to 2025, 2020). In this way, in the section 3.2.1., the estimated installed capacity for 2022 was 4,246.6 MW, but as it can be seen in the section 3.2.3. that estimated was already reached it and that if it is reached that estimation, the year 2022 it would grow up 67.73%, a much bigger increase than in the past period 2019-2021. Although currently the amount of renewable energy in the energy matrix is 54.2% and in the year 2000 was of 45.8%, as the non-renewable energies has the lowest average growths rates, including some in the last period with negative values, and renewable energies, with such unexpected increases, could reach the target. But it is important to note that in the electrical projections made by the Ministry of Energy for achieving carbon neutrality by 2050, the target was not reached the years 2020, or 2021 and by 2022 is 9.3 GW, which means we still have to make it to the finish line (Ministerio de Energía, Generación & Capacidad, 2020).

It is time to work together, in both countries solar PV electricity is the most important renewable energy. As it was said, if targets are not reached a bad quality of life will be for everyone.

5. Conclusions

Electricity is used every day and it comes from renewable or non-renewable sources, which is the reason why the main emitter of GHG in both countries is energy. Although Italy's main source is Fossil Fuels, the second one since 2011 has been PV electricty. Where this last one increased considerably due to the incentive Conto Energia; a study in Italy revealed that LCI was perfect between the installed capacity and the amount of incentives. So, during the period 1990-2017, the GHG emissions decreased by 17.4%. After the big incentive, with a growth rate of 339% in 2007, the increases began to fall reaching growths of 1.65% in 2015 and the past year 4.81%. IEA said in its last report that if its growth continues like that, it will not get to the target, and so the Energy Regulation was approved in the year 2022. This regulation will speed up plant installations and it is the perfect timing because of the War in Ukraine, to begin to become independent in terms of energy and thus be able to be the first in the world in photovoltaic energy.

The great trajectory that Italy has had in photovoltaic energy has managed to reduce its costs by 85% during the period 2010 and 2020. And as technology has grown very fast, the new generation has appeared. But Italy has not installed many plants in the past years, and the process for installing big plants is so slow and the incentives have not been as good as Conto Energia. On the one hand Italy have Augusta, which will start operating at the end of 2022 and because of its technology of 3Sun PV electricity modules with multi-junction technology is better than El Resplandor, a Chilean PV electricity plant since 2020 in an area with similar solar radiation, avoiding more CO_2 emissions. But it does not have much new technology, comparing Campos de Sol and Troia, both from 2020, but this last one its development started in 2007, the Chilean plant was more updated and so they used bifacial modules, avoiding much more CO_2 than Troia. Also, in Chile, the FPV technology was already installed, as also other ones like Maverick technology.

Although Chile's main source of electricity is Hydropower, the second and third one was always non-renewable. That has been the responsible for the huge rise in GHG emissions. In Italy, solar PV energy also has a higher growth rate average and could reach the main source in a couple of years. This is because of the ambitious targets for 2050, and at the moment, they have proposed 3 scenarios, where the last one accelerating, reach zero-emissions before

2050. According to the linear regression estimation, this last will not be reached, but because of the estimation with the projects that are already functioning from 2022 and the ones that are under construction and have a due date in 2022, it is demonstrated that the growth is not linear due to the value was already reached. Although Solar Home, is not as big as Conto Energia, will boost the RPVP, that was not taken advantage of. But, profitability of PV electricity plants also depends on the factor of the solar radiation, that according to the methodology of KGPV, Atacama Desert has the best location for PV energy worldwide, and so the country have lots of investors and it will continue growing, expecting to have a decrease in the costs during time. A French company is constructing the biggest PV energy plant in Chile in terms of installed capacity and a US company is constructing the most efficient solar park in the world, using the Maverick technology.

Concluding, Italy must take advantage of all their knowledge and take advantage low costs to install new technologies. And Chile has a long way, but it is on a good track to take all advantage of its resources, like implementing incentives for residential PV electricity panels that they could take to a big growth, like Conto Energia in Italy.

The time to mitigate the climate change is now, and if it is not mitigated, it will bring devastating effects on the planet, which will affect everyone's quality of life. So, the potential in space, technology, costs, among others, must be harnessed to save the world.

6. Glossary

ACER: Agency for the Cooperation of Energy Regulators

ARERA: Authority for Energy, Networks and Environment

AtaMoS-Tec: Atacama Module and System Technology Centre

AU: Single buyer

CF: Capacity Factor

CNE: National Energy Commission

CO_2: Carbon dioxide

CORFO: Corporation for the Promotion of Production

EU: European Union

FIT: Feed-in tariff

FPV: Floating photovoltaic

GDP: Gross Domestic Product

GHG: Greenhouse Gases

GHI: Global Horizontal Irradiation

GME: Energy Market Manager

GSE: The Energy Services Manager

IEA: International Energy Agency

IRENA: International Renewable Energy Agency

KGPV: Köppen-Geiger-Photovoltaic

LCI: linear correlation index

LCOE: Levelized Cost of Energy

MINENERGÍA: Ministry of Energy

NCRE: Non-Conventional Renewable Energy

PMGD: Small Distributed Generation Media

PR: Performance Ratio

PV: Photovoltaic

PVPS: Photovoltaic Power Systems Programme

RPVP: residential PV prosumer

RSE: Research on the Energy System

SEA: Aysen Electrical System

SEC: Superintendence of Electricity and Fuel

SERC: Solar Energy Research Centre

SEM: Magallanes Electrical System

SEN: National Electrical System

UNFCCC: United Nations Framework Convention on Climate Change

USSR: Union of Soviet Socialist Republics

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8. Annexes

8.1. Annex 1: Calculation of the growth rate of generation of energy of the different sources

Firstly, it had to be taken the generation from the webpage for each source in each year (2000 – 2021).

Then solve the following equation for each year in each source.

$$Growth\ rate_t^i = \frac{Generation_t^i - Generation_{t-1}^i}{Generation_{t-1}^i} \quad (2)$$

Where:

$i = \ energy\ source$

$t = year\ (2001, \ldots, 2021)$

So, for each country the table is the following:

Table 8.1. Chilean renewable energy growth rate

	Solar		Wind	Hydro	Bioenergy		Geothermal
	Solar photovoltaic	Solar thermal energy	Onshore wind energy	Renewable hydropower	Solid biofuels	Biogas	Geothermal energy
2001				-0.07%	0%		
2002			0%	0.63%	0%		
2003			0%	0.25%	0%		
2004			0%	16.93%	0%		
2005			0%	0.04%	63.64%		
2006			0%	0.11%	0%		
2007			900%	2.41%	22.22%		
2008			0%	1.44%	84.09%		
2009			715%	0.35%	504.94%		
2010			0%	0.28%	7.35%		
2011			12.88%	8.76%	4.18%	850%	
2012			9.78%	0.77%	51.82%	42.11%	
2013	650%		49.01%	1.7%	49.04%	0%	
2014	1,373.33%		144.52%	5.76%	-28.71%	55.56%	
2015	160.63%		23.64%	0.84%	-52.83%	16.67%	
2016	95.31%		14.18%	2.65%	-1.68%	8.16%	
2017	60.8%		25.6%	0.19%	0%	5.66%	
2018	18.13%		16.78%	-0.07%	0%	1.79%	100%
2019	24.18%		6.3%	0.04%	7.71%	5.27%	-17.29%
2020	20.79%		32.65%	1.34%	-10.26%	-7.53%	0%
2021	36.02%		45.98%	0.5%	-5.44%	14.63%	0%

Source: Author's own creation

Table 8.2. Chilean non-renewable energy growth rate

	Coal and peat	Oil	Natural gas	Other non-renewable energy
2001	0%	0.32%	14.73%	
2002	0%	4.23%	3.3%	
2003	0%	0%	12.55%	
2004	0%	7.4%	0 %	
2005	0%	16.86%	8.75%	
2006	0%	2.13%	0.33%	
2007	0%	33.49%	6.82%	
2008	0%	19.59%	3.6%	
2009	7.78%	110.31%	0.15%	
2010	19.63%	5.81%	0.02%	0%
2011	34.62%	1.06%	0%	
2012	-4.8%	2.93%	3%	
2013	8.22%	-2.66%	-9.7%	0%
2014	17.65%	2.46%	0.03%	0%
2015	3.48%	31.71%	-18.09%	0%
2016	10.93%	-16.07%	59.94%	0%
2017	0.56%	-3.76%	-17.79%	0%
2018	-0.08%	0.91%	2.39%	0%
2019	0.42%	6.6%	-0.38%	0%
2020	-3.85%	18.09%	-14.89%	0%
2021	0.05%	7.35%	1.62%	0%

Source: Author's own creation

Table 8.3. Italian solar, wind, hydro and ocean energy growth rate

	Solar		Wind	Hydro			Ocean
	Solar photovoltaic	Solar thermal energy	Onshore wind energy	Renewable hydropower	Mixed Hydro Plants	Pumped storage	Marine energy
2001	5.26%		82.92%	0.5%	0%	0.53%	
2002	10%		17.47%	0.75%	0%	-0.53%	
2003	18.18%		12.05%	1.08%	0%	0%	
2004	19.23%		28.95%	0.63%	-0.1%	0.03%	
2005	9.68%		45.08%	0.73%	4.94%	0%	
2006	32.35%		16.33%	-2.61%	14.02%	0%	
2007	144.44%		42.06%	0.33%	0%	0%	
2008	339.09%		30.46%	1.17%	0%	0%	
2009	161.7%		38.41%	0.69%	0%	0%	
2010	184.18%		18.75%	1.08%	0%	0%	
2011	265.56%	0%	19.4%	1.55%	0%	0%	
2012	27.83%	0%	17.11%	0.93%	0.31%	0%	
2013	8.34%	7.42%	5.43%	0.9%	0%	0%	
2014	2.25%	19.72%	1.65%	0.36%	0.33%	0.63%	0%
2015	1.65%	0%	5.23%	0.84%	0%	0%	33.33%
2016	2.02%	0%	2.7%	2.48%	-7.89%	0%	0%
2017	2.07%	0%	3.76%	0.79%	1.55%	-1.05%	0%
2018	2.16%	0%	5.07%	0.48%	0%	0%	0%
2019	3.77%	0%	4.39%	0.76%	-2.16%	0%	0%
2020	3.76%	0%	1.79%	0.95%	0.24%	0%	2.5%
2021	4.81%	0%	3.73%	0.11%	0%	0%	0%

Source: Author's own creation

Table 8.4. Italian bioenergy, geothermal and non-renewable energy growth rate

	Bioenergy				Geothermal	Non-renewable energy	
	Solid biofuels	Renewable municipal waste	Liquid biofuels	Biogas	Geothermal energy	Fossil fuels n.e.s.	Other
2001	1.38%	11.5%		10%	-2.88%	0.42%	-16.42%
2002	31.22%	18.13%		13.13%	16.23%	-0.06%	11.51%
2003	32.07%	17.99%		14.29%	6.16%	2.31%	45.2%
2004	-0.78%	2.91%		4.69%	-9.19%	5.19%	-27.82%
2005	-5.79%	1.31%		5.97%	4.52%	5.5%	69.61%
2006	0.28%	6.45%		3.52%	0%	5.79%	16.82%
2007	0.84%	7.27%		11.9%	0%	4.89%	3.94%
2008	14.64%	4.14%		6.08%	0%	5.17%	1.48%
2009	5.54%	27.12%	220.44%	2.87%	3.58%	0.27%	13%
2010	-7.31%	1.85%	56.5%	33.7%	4.75%	1.85%	-0.5%
2011	3.69%	3.63%	26.87%	52.5%	0%	1.2%	1.01%
2012	27.79%	1.62%	34%	74.04%	0%	-0.14%	1%
2013	12.64%	10.88%	1.42%	3.38%	0.14%	-3.1%	7.08%
2014	2.31%	-1.2%	-1.3%	1.44%	5.35%	-4.89%	0.79%
2015	-0.65%	0.48%	1.01%	0%	0%	-8.41%	0.26%
2016	11.2%	-1.45%	-0.7%	1.2%	-0.13%	-5.8%	0.92%
2017	-0.13%	-0.21%	-0.63%	1.44%	0.02%	-1.4%	0.63%
2018	7.18%	0.89%	-1.62%	0.28%	0%	-0.1%	0.66%
2019	-0.71%	-3.92%	-2.32%	0.51%	0%	0.11%	-7.54%
2020	-0.25%	1.59%	-1.7%	-0.24%	0.6%	-2.04%	-0.29%
2021	0%	0%	0%	0%	3.89%	-1.6%	0%

Source: Author's own creation

And finally, it has to be taken the average from the 3 years that group together, as the following equation.

$$Growth\ rate^{i}_{t-(t+2)} = \frac{Growth\ rate^{i}_{t} + Growth\ rate^{i}_{t+1} + Growth\ rate^{i}_{t+2}}{3} \quad (3)$$

Where:

$i = \ energy\ source$

$t = year\ base\ (2001, \ldots, 2021)$

8.2. Annex 2: Percentage of PV electricity capacity of each country in the world

With the information from the electricity capacity of PV in each country and the world, it was used the following equation.

$$\%PV\ electricity\ capacity^{i}_{t} = \frac{PV\ electricity\ capacity^{i}_{t}}{PV\ electricity\ capacity\ world_{t}} \quad (4)$$

Where:

$i = country\ (Chile, Italy)$

$t = year\ (2000, \ldots, 2021)$

And the PV electricity capacity of the world was taken from IRENA (IRENA, Renewable capacity statistics 2022, 2022).

So, it gets the following information.

Table 8.5. Percentage of PV electricity capacity of each country in the world

Country	2000	2001	2002	2003	2004	2005	2006	2007
Italy	2.35%	1.83%	1.53%	1.32%	1.02%	0.75%	0.74%	1.29%
Chile								

Country	2008	2009	2010	2011	2012	2013	2014
Italy	3.28%	5.53%	8.9%	18.18%	16.5%	13.25%	10.59%
Chile					0%	0.01%	0.13%

Country	2015	2016	2017	2018	2019	2020	2021
Italy	8.47%	6.53%	5.04%	4.16%	3.57%	3.05%	2.69%
Chile	0.26%	0.38%	0.46%	0.44%	0.45%	0.45%	0.52%

Source: Author's own creation

And then, for the ranges of three years, it has to be used equation (3) but with %PV electricity capacity data.

8.3. Annex 3: PV electricity capacity of each country in the future

The 7-year data was projected with the causal method, which was performed based on historical quantitative background. And it is used the following equation (Sapag Chain & Sapag Chain, 2008).

$$y(x) = a + bx \tag{5}$$

Where:

$a \text{ and } b \text{ has to be estimated}$

$x = year\ (2022, \dots, 2028)$

So,

$$a = \frac{\sum Y}{n} - b$$

$$b = \frac{n\sum XY - (\sum X)(\sum Y)}{n\sum X^2 - (\sum X)^2}$$

Where:

$n = quantity\ of\ historical\ years$

$Y = electricity\ capacity\ of\ each\ historical\ year$

$X = number\ accompanied\ to\ each\ year, that\ the\ sum\ of\ all\ has\ to\ give\ 0\ or \pm the\ last\ or\ first\ number$

So, each table is the following.

Table 8.6. Estimation of photovoltaic energy for Chile in 7 years with the linear regression method

Year	Y	X	XY	Y2	X2
2012	2	-5	-10	4	25
2013	15	-4	-60	225	16
2014	221	-3	-663	48,841	9
2015	576	-2	-1,152	331,776	4
2016	1,125	-1	-1,125	1,265,625	1
2017	1,809	0	0	3,272,481	0
2018	2,137	1	2,137	4,566,769	1
2019	2,653.69	2	5,307.39	7,042,113.08	4
2020	3,205.44	3	9,616.31	10,274,832.8	9
2021	4,360	4	17,440.03	19,009,661	16
Total	16,104.14	-5	31,490.74	45,812,327.9	85

Source: Author's own creation

Where n = 10, so

$b = 479.31$

$a = 1{,}850$

Table 8.7. Estimation of photovoltaic energy for Italy in 7 years with the linear regression method

Year	Y	X	XY	Y2	X2
2000	19	-11	-209	361	121
2001	20	-10	-200	400	100
2002	22	-9	-198	484	81
2003	26	-8	-208	676	64
2004	31	-7	-217	961	49
2005	34	-6	-204	1,156	36
2006	45	-5	-225	2,025	25
2007	110	-4	-440	12,100	16
2008	483	-3	-1,449	233,289	9
2009	1,264	-2	-2,528	1,597,696	4
2010	3,592	-1	-3,592	12,902,464	1
2011	13,131	0	0	172,423,161	0
2012	16,785	1	16,785	281,736,225	1
2013	18,185	2	36,370	330,694,225	4
2014	18,594	3	55,782	345,736,836	9
2015	18,901	4	75,604	357,247,801	16
2016	19,283	5	96,415	371,834,089	25
2017	19,682.3	6	118,093.75	387,392,658	36
2018	20,107.6	7	140,753.12	404,315,135	49
2019	20,865.27	8	166,922.2	435,359,701	64
2020	21,650.04	9	194,850.36	468,724,232	81
2021	22,692.04	10	226,920.4	514,928,679	100
Total	215,522.23	-11	1,119,025.84	4,085,144,354	891

Source: Author's own creation

Where n = 22, so

$b = 1{,}385.42$

$a = 1{,}0489$

Finally, with a and b estimated, it can be taken the electricity capacity of each country in the next 7 years.

8.4. Annex 4: Comparing the biggest PV energy plants in Chile and Italy

For the space that uses one panel in each country it was taken by the following way:

$$Hectares\ of\ one\ panel_i = \frac{Total\ hectares\ used\ for\ the\ PV\ plant_i}{Quantity\ of\ PV\ panels_i} \quad (6)$$

Where:

$i = Campos\ de\ Sol,\ Troia$

And as the numbers are so little,

$$1\ hectare = 10{,}000 m^2$$

For the CO_2 that saves one panel in each country it was taken by the following way:

$$CO_2\ savings\ of\ one\ panel_i = \frac{Total\ CO_2\ savings\ of\ the\ PV\ plant_i}{Quantity\ of\ PV\ panels_i} \quad (7)$$

Where:

$i = Campos\ de\ Sol,\ Troia$

And the same for the inversion that each company had to do for one panel in each country:

$$Inversion\ of\ one\ panel_i = \frac{Total\ inversion\ of\ the\ PV\ plant_i}{Quantity\ of\ PV\ panels_i} \quad (8)$$

Where:

$i = Campos\ de\ Sol,\ Troia$

8.5 Annex 5: Estimating the total kW of the first version of Solar Home

First, with the information of the quantity of PV electricity panels in the first version of this incentive and the information of the quantity of ones that where already tendered, was taken the total number of PV electricity panels left.

$$Number\ of\ projects\ left = total\ of\ projects - projects\ already\ tendered \quad (9)$$

Then, with the information of the projects already tendered it was taken the percentage of each type of system with the following equation.

$$\%\ Projects\ of\ system\ i = \frac{\sum Projects\ of\ system\ i}{Total\ of\ projects} \quad (10)$$

Where,

$i = (1,2)$

So, with that information, (9) was multiplied with (10) for each system, for calculating the quantity of projects of each system for the left ones.

And for calculating the quantity of kW of the first version of Solar Home it was multiplied this latest calculation with the type of system; 1 or 2 kW.

9. Tittle Memory Summary

UNIVERSIDAD DE CONCEPCIÓN – FACULTAD DE INGENIERÍA

RESUMEN DE MEMORIA DE TÍTULO

Departamento	: Departamento de Ingeniería Civil Industrial
Carrera	: Ingeniería Civil Industrial
Nombre del memorista	: Francisca Smith Piel
Título de la memoria	: Renewable energy management, the Photovoltaic approach, the Italian way and the Chilean way of dispatching the energy, best practice and cross breeding opportunities.
Fecha de la presentación oral	:
Profesor Guía	: María Magdalena Jensen Castillo
Profesor Revisor	: Jorge Rodrigo Jiménez Del Rio
Concepto	:
Calificación	:

Resumen (máximo 200 palabras)

Because of the increase in CO_2 concentrations in the atmosphere, the temperature of the planet has raised, causing climate change. The Paris Agreement looks to mitigate this through incentives and laws that promotes renewable energy for the generation of electricity and PV is one of this.

Even though PV electricity isn't the first source of energy in Chile and Italy, is the one with the biggest growth rates since the year 2000. For Chile, this source is relatively new, in 2012 it was installed for the first time the first plant, even though, through the years they have been using the leapfrogging strategy due to the solar radiation that the country has. In the other hand, Italy has been using this energy for much more years and so due to that and to the Conto Energia, their costs have decreased and also its GHG emissions. Despite

this, they still have a long way to go to achieve their goals by 2030 and thus be able to stop climate change. Although the war brought negative consequences to everyone, it is time to take advantage of this and grow with renewable energy, as the EU seeks to do with the REPowerEU Plan.