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CLIMATE CHANGE AND THE PROBLEM OF ENERGY

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ABSTRACT

Due to the progress of society, the consumption of energy is dramatically increasing. As a consequence of the consumption, the emission of greenhouse gases has also increased exponentially and the effects of its accumulation are causing important environmental variations.

In the last two decades, the international community has understood that the utilization of renewable energies is vital to minimize the impact that electricity generation has in the environment. For this reason, the majority of countries in the world have started to install electrical capacity that uses renewable energy to produce power.

Spain is a country with a great potential of generating electricity because of the number of hours of sun, the number of rivers and the orography, a cause of important wind flows. In this thesis, the first hypothesis has been to study if Spain would be able to satisfy the whole energy demand of electricity with renewable energies. The result, although impressive, has not been sufficient to rely entirely on renewable resources. A complementary energy source is required.

After studying the benefits and drawbacks of fossil fuels, this study has reached a conclusion: nuclear power would be perfect to support renewables. As nuclear plants do not emit carbon dioxide, they are a great solution to avoid emissions and the problem of the climate change.

1. MOTIVATION

The reason why I have selected the topic *Climate Change and the Problem of Energy* is mostly related to my background. Before entering the MSc in International Management at Esade I completed a degree in Chemical Engineering at Universitat Politècnica de Catalunya. During the 5 years of studies I learned and understood better how critical is the current environmental crisis and to what extent renewable energies are crucial in the near future. In fact, my master thesis in engineering tackled the issue of renewable energies: *Increasing the Efficiency of Cogeneration Units using an Organic Rankine Cycle*. Briefly explained, the project's objective was to study the feasibility of the usage of biogas to generate electricity through a more efficient technology (cogeneration units).

After entering Esade, and by studying subjects such as geopolitics and global operations, I delved into the economic effects of climate change and the international affairs conflicts caused by the distribution of natural resources. Moreover, I have a deeper knowledge of the costs that renewable energies entail and the impact that *greener* energy policies would have for the world.

This master thesis focuses on the matter of climate change and the effects of renewable energies from an economic perspective. Furthermore, it will reveal the technical challenges of adopting renewable energies as the main power source in the context of the energetic industry.

2. INTRODUCTION

The world is changing. Efficiency is wanted everywhere to reduce costs and increase sustainability, from our house to the industry. The society is finally understanding that climate change is a reality, and that the harm that humans have caused and are still causing to the planet is enormous [1].

Investment in new technologies to increase efficiency is higher than ever, but so are the pollution levels [2]. The growing economies, which represent a great business opportunity for companies, have a negative effect on the environment and the use of resources. Fossil fuels consumption is also at the highest level, and even the most optimistic forecasts show that in no more than a century the cost of extraction of oil will make the process not profitable anymore [3].

The goal of this master thesis is to make a full analysis of the climate change problematic. Firstly, the emissions per country/region will be studied. It is important to evaluate the dependence of each country on fossil fuels to understand the effects that a change in the energy sector would have.

The question will be the following: ***Is it feasible and economically profitable for a country to depend entirely on renewable energies?*** There are several countries that have plenty of natural resources and because of this, from a qualitative approach, it seems possible for them to not rely on fossil fuels anymore. Spain is one of this cases, as it is a country without important energetic resources but with an enormous potential of renewable energies: hydraulic, solar and wind amongst others.

After having studied the feasibility of a green energy policy, if it proves to be insufficient, the energy profile should not only include renewables but also non-renewable technologies: ***Which would be the most recommended and why?***

3. METHODOLOGY

The theoretical research will be based on scientific papers, studies, projects and books.

For the first question, “*Is it feasible and economically profitable for a country to depend entirely on renewable energies?*”, a technical approach will be developed to quantify the potential impact on emissions that renewable energies would have on the country. A comparison between different countries will be done to understand if the Spanish government has fostered the development of greener policies.

The second section, “*Alternatives to renewable energies*”, will be approached in a completely different way. A qualitative study of the different technologies (coal, oil, gas, nuclear and renewables) will be made and different examples will be studied. A very interesting comparison will be to study the energy policies that France and Germany have taken, as are two opposite

The third part, *“Proposal for the case of Spain*” will be the outcome of the two previous sections. The goal will be to support renewable energies with the less polluting technology and to understand if it is a feasible solution.

A last reflection about the energy industry will be made. Multiple changes in the upcoming years are very possible, as new technologies are being developed and there are constant demographic changes.

4. ANALYSIS AND DISCUSSION

In this section, a qualitative and quantitative analysis of the energy landscape will be carried out. Firstly, the objective will be to understand the current situation that renewable energies are facing and how have they evolved in the last years. The study will be focused on Spain, as it is a country with great potential that is underperforming in this aspect and has been involved in huge international controversy regarding renewable energies.

All the figures and calculations are done for electricity production. The objective of this study is to analyze the feasibility of generating electricity with renewables. It is worth mentioning that transportation and heat production are not considered in this study when calculating the numbers.

4.1. IS IT FEASIBLE AND ECONOMICALLY PROFITABLE FOR A COUNTRY TO DEPEND ENTIRELY ON RENEWABLE ENERGIES?

Not a long time ago, this would have been a surrealistic question. For any country, the possibility of not relying on fossil fuels would have been a utopia. In the 20th century, multiple conflicts and crisis happened because of fuel and other fossil resources. Some examples are the oil crisis of the seventies and the consequences of the Gulf War in 1990, conflicts that demonstrated that the World relied heavily on fossil fuels and that few countries had the capacity to affect the life of billions of people.

Nonetheless, in the last years, multiple examples have shown that another reality is possible.

4.1.1. ***Portugal, Costa Rica and many other as cases at hand***

From the 7th of May, 6:45 a.m. to the 11th at 5:45 p.m., Portugal satisfied the entire demand of electricity with renewable energies [4]. Thanks to the combination of heavy wind and thanks to the large flow of rivers for hydropower, the country produced electricity entirely with renewable energies during 107 hours. Portugal has almost doubled the percentage of production with renewables in the last 3 years, from a 26% in 2013 to 50.4% today [5].

Costa Rica is another great example of good energy policies. From of 2016 to the date, the country has been able to produce electricity only with renewable energies [6]. Thanks to the heavy rains the river reservoirs are at full capacity, which enabled this efficient production. The capacity of production with renewables in the country is 75% from hydropower and the remaining 25% is almost equally shared by geothermal and wind power [7].

Other examples which prove that another energy landscape is possible are the following:

- Denmark uses wind to generate 42% of its electricity [8].
- Scotland has been able to produce during a few hours enough electricity from wind to cover the whole demand of the country [9]. It was in very specific weather conditions, but the government is aiming at a greener future.
- Uruguay is the leading country of South America in installed electricity generation capacity with renewables, reaching almost a 95% of the total electric production [10].

4.1.2. ***Spain and its natural resources***

Spain is an example of a country with a great variety of natural resources. These bring to the country an excellent opportunity to increase the use of renewable energies to generate electricity. In fact, Spain production of fossil fuels is very poor, which forces the country to import resources from other countries, generating a deficit in the economic balance. Spain produces locally the following percentage of fuels for energy production [11]:

- Nuclear: 0%
- Coal: 36.5%
- Oil: 0.2%
- Gas: 0%

Overall, Spain only produces the 23% of the consumed fossil fuels to generate electricity. On the other hand, Spain is one of the countries with more sun hours in Europe (Figure 1).

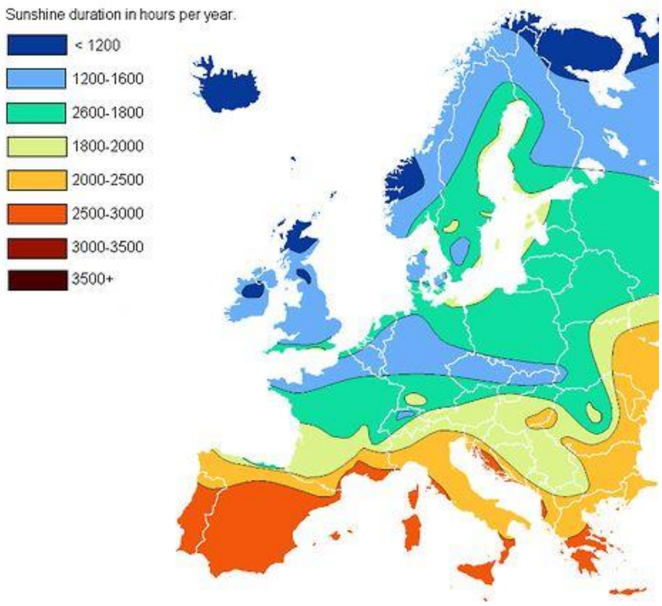

Figure 1. Sunshine duration per year in Europe. From "Metric Maps" - NASA

There are regions, such as the Mediterranean coast and the Southern regions, with more than 2,000 hours of sun per year. In addition, the country has veyy important rivers [12] such as Duero (675 m^3/s, 1000 km) and Ebro (600 m^3/s, 930 km) and with a great height difference between the origins of the rivers and the sea. Furthermore, because of the complex orography of the country, there are great winds that are used to generate electricity with wind mills.

4.1.3. ***Energy profile: Spain***

Currently, most of the papers that describe the situation of Spain as negative in any field mention the financial crisis of 2008 as its main cause. In this section, the evolution of the energy consumption of Spain and the development of the renewable energies will be shown.

The total electrical capacity installed in Spain can be found in Table 1.

Table 1. Electrical capacity installed in Spain. Year 2015. [13]

RESOURCE	INSTALLED POWER (MW)	% TOTAL
NUCLEARº	7,573	7.13%
COAL	10,936	10.29%
FUEL/GAS	2,490	2.34%
COMBINED CYCLE	26,670	25.10%
COGENERATION	6,728	6.33%
HYDRO	20,353	19.16%
WIND	23,020	21.67%
SOLAR (1)	6,964	6.56%
OTHER RENEWABLES (2)	1,501	1.41%
TOTAL	**106,235**	

(1): Includes both Thermal and Photovoltaics
(2): Includes biogas, biomass, geothermal, tidal and waste

Table 1 does not represent the production of electricity by source, but the maximum capacity that the country has to produce from each source.

Regarding the electricity production, the sources are shown in Table 2.

Table 2. Electricity generated in Spain. Year 2015. [13]

RESOURCE	GENERATION (GWh)	% TOTAL
NUCLEAR	54,755	20.46%
COAL	52,789	19.73%
FUEL/GAS	6,497	2.43%
COMBINED CYCLE	29,357	10.97%
COGENERATION	25,108	9.38%
HYDRO	30,819	11.52%
WIND	48,109	17.98%
SOLAR (1)	13,321	4.98%
OTHER RENEWABLES (2)	6,821	2.55%
TOTAL DEMAND	**267,576**	

Each source has some characteristics that have to be understood to explain the energy profile of the country:

Nuclear: undoubtedly, it is the most controversial source of energy. In terms of emissions of CO_2, NO_x and SO_x it is completely clean. The main problem is related to the fuel that nuclear plants use (uranium), as it is a very radioactive and unstable element. When the fuel has to be replaced, the waste treatment becomes dramatic as the emission of radioactive subatomic particles will last for decades. During the last 50 years there have been different nuclear disasters such as Fukushima (2011), Chernobyl (1986) and Mayak (1957) that have generated a huge debate around nuclear energy.

Nonetheless, it is a source of energy that most countries use. One of the biggest exponents is France, with 59 power reactors producing 75% of the electricity of the country [14]. Spain has 10 nuclear plants, satisfying the 20.46% of electricity that the market demands (Table 2).

Nuclear energy has a particularity that is key to understand the energy profile of any country: a nuclear plant cannot be temporary paused [15]. Because of the nature of the technology, the process of electrical generation has to be continuous. Uranium reaction cannot be stopped, continuously generating heat that evaporates the water that will make the turbine of the plant rotate to finally generate electricity. If this process would not happen, the core of the reactor would dramatically increase its temperature and could, at the end, explode. For this reason, nuclear energy is used as "base energy", a source that is constantly producing electricity (around 7000 MW).

Coal: It is one of the most classic energy source of history. It is the less efficient fossil fuel, as it has the lowest heat capacity (the energy that can be obtained from a kilogram of fuel). Because of this reason, more coal has to be burned to obtain the same energy that could be obtained with less, for example, oil. And the more fuel is used, the more pollution is produced. Figure 2 shows the comparison between the three most used fossil fuels in terms of emissions (coal, oil and natural gas).

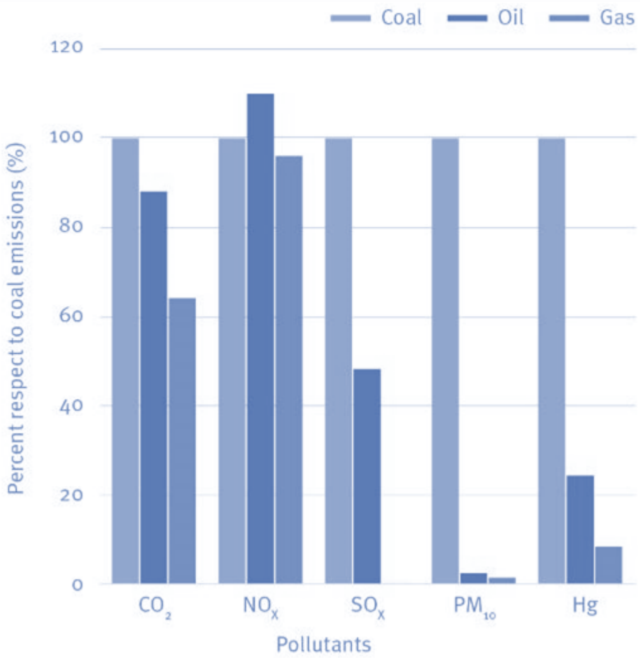

Figure 2. Relative Emissions of Pollutant Generated during Fossil Fuel Power Generation [16]

This figure shows a clear caveat: the use of coal has to be drastically reduced to mitigate the progress of the climate change.

Its low price, big reserves and easiness of extraction makes coal the most used fuel to generate electricity in the world. For example, power generation of coal in China accounted for 73% share for a total of 5.73 million GWh in 2014 [17]. For this reason, it is not a surprise to see that China is the leading country in the World regarding the emissions of pollutants with around 10.4 billion tons of CO_2 [18]. Coal is the most used fossil fuel to generate electricity in Spain as well, with 19.73% of share.

Oil: It is the most commonly used fossil fuel in the world and the second regarding electricity generation. Compared to coal, the price is higher (crude oil 48.06 USD/bbl and thermal coal 39.5 USD/st [19]), the heat capacity is higher (41,900 kJ/kg compared to 25,000 kJ/kg) and the emissions, as seen in Figure 2. Relative Emissions of Pollutant Generated during Fossil Fuel Power Generation [16], are lower.

Even though it is a better fuel in terms of efficiency and sustainability, it is the 2^{nd} most damaging energy source for the environment, adding to the fact that the reserves are expected to last for no longer than 50 years [20].

Because of its price, Spain barely uses the imported fuel to generate electricity. Only a 2.43% of the electricity is produced from this fuel.

Combined cycle: These types of thermal plants use natural gas as its fuel. As it happens with coal and fuel, the main problems are the emissions and the scarcity of the reserves.

Russia is an example of a country that massively uses natural gas to produce electricity with around 48% of share [21]. In Spain, 11% of electricity is produced with natural gas, although the total capacity is around 25%. This is explained by the fact that combined cycle plants are used as a “support production”, which would be the opposite of “base production” (nuclear plants). These plants are only used when the rest of the production plants are not able to satisfy the energy demand, having the function of a backup. This function has been assigned to natural gas not only because of the easiness of “turning on and off” the combined cycle plants but also because of the cost of natural gas, which is higher than the rest of fossil fuels [20].

Cogeneration: This type of plants is a technologically more evolved solution compared to the previously described ones. Cogeneration can be defined as the sequential production of electricity and thermal energy from the same primary energy source. While electricity is consumed by all the machinery or electric devices, the main purpose of thermal energy is to use it in industrial processes. While thermal plants (i.e. coal) have a very poor efficiency because of the heat waste, cogeneration plants are able to reutilize the wasted thermal power to heat water. The use of cogeneration units is a great step towards sustainability, although it is not the final solution: a fuel is still needed. Most cogeneration plants use natural gas because of the quality of the resource, and for this reason pollution is high. Some cogeneration plants have started to use biogas as an alternative source for primary energy with excellent results [22].

In Spain, cogeneration represents 9.4% of the total electricity production, with the addition that these plants are usually working most of the time because of its high efficiency [22].

If the sum of the aforementioned production technologies is made, the result is that Spain is currently producing the 63.1% of electricity with non-renewable resources. A 36.9% of production with renewable energies is not an extraordinary number, but it is over the EU-28 share (27.5%). Table 3 shows a list of different countries and its share of power generation with renewable energies.

Table 3. Comparison of Share of electricity generated with renewable sources [10]. Year 2015

COUNTRY	SHARE OF RENEWABLES
ARGENTINA	0.45%
AUSTRIA	70%
BELGIUM	13.4%
CANADA	59%
CHINA	20.7%*
COSTA RICA	99%
CROATIA	45.3%
DENMARK	48.5%
FINLAND	31.4%
FRANCE	18.3%
GERMANY	28.2%
GREECE	21.9%
IRELAND	22.7%
ITALY	33.4%
JAPAN	12.2%
NETHERLANDS	10%
PORTUGAL	52.1%
ROMANIA	41.7%
SLOVAKIA	23%
SLOVENIA	33.9%
SPAIN	36.9%
SWEDEN	63.3%
UNITED KINGDOM	17.8%
UNITED STATES	13.4%**
URUGUAY	94.4%

*data from 2013 [23]. IEA

** [24]

Regarding the characteristics and key points of each renewable, it is important to consider the possible effect of seasonality and the availability of the natural resource; the renewable energy profile of a country like Sweden will be completely different of the one from Germany, for example.

Wind: it is the second most used renewable energy source (15.5% of the electricity from renewables, a figure that represents 3.7% of the total electricity production in the world) and the most used in Spain with a 48.6% of the renewables and 18% of the total electrical production of the country [13].

Although it is true that seasonality has an effect, it is less important than in other natural resources such as hydropower. Only the countries that have the appropriate orography (the combination of mountains, valleys, differences of heights…) can enjoy a great capacity of generation.

Spain is the 5th country in the world by total capacity of wind power installed:

Table 4. Top 6 countries in terms of power generation from wind [10]

COUNTRY	TOTAL CAPACITY (GW)
CHINA	129.3
UNITED STATES	74
GERMANY	45
INDIA	25.1
SPAIN	23
UNITED KINGDOM	13.6

The total capacity of wind power installed in the world is 433 GW.

Hydropower: it is the most popular renewable energy in the world, with almost 70% of the overall electricity produced from renewables and a total production of 16.6% of the whole electricity produced in the world. In Spain, it is the second most used renewable with the 31.1% of importance in renewables and 11.5% of total production.

As hydropower is highly dependent on seasonality, it is the most appropriate technology in the following environments:

- Spring and Autumn in non-tropical countries.
- Rain seasons in tropical countries
- Countries with wide and fast-flowing rivers

The countries that rank higher in hydropower production are the following:

Table 5. Top 6 countries in terms of power generation from hydro technologies [10]

COUNTRY	TOTAL CAPACITY (GW)
CHINA	296
BRAZIL	92
UNITED STATES	80
CANADA	79
RUSSIA	48
INDIA	47

The total capacity of hydropower installed in the world is 1,064 GW, which compared to the wind power (433 MW) represents a difference of 2.5 times.

Solar: the 4th most used renewable technology used in the world, with 12.2% of relative importance in the sustainable resources. In Spain, solar energy represents 5% of the total production of electricity and 13.4% within renewables.

The seasonality, although important, it is not the key factor for solar technologies. The main drawback is the number of hours of production, as at night production is impossible. The low capacity and efficiency of batteries limit this technology as well. Furthermore, solar panels have an efficiency of around 10% [25], which is another factor that diminishes its potential.

In the world, the installed capacity of solar plants is the following:

Table 6. Top 8 countries in terms of power generation from solar technologies [10]

COUNTRY	TOTAL CAPACITY (GW)
CHINA	43.5
GERMANY	39.7
JAPAN	34.4
UNITED STATES	25.6
ITALY	18.9
UNITED KINGDOM	9.1
FRANCE	6.6
SPAIN	5.4

4.1.4. ***Case of study: Can Spain fully produce electricity on renewables?***

<u>Current situation</u>

In the last years Spain has undergone a period of stagnation in the installation of new plants. Figure 3 andFigure 4 [13] show the progress of installed power and the percentage against the non-renewable sources of power.

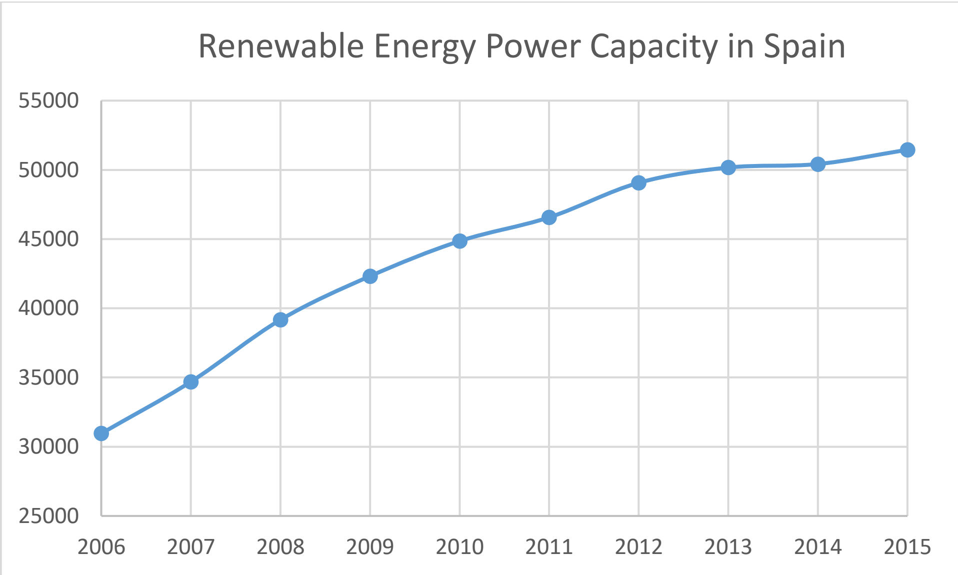

Figure 3. Annual evolution of the total capacity (MW) of power plants using renewable resources

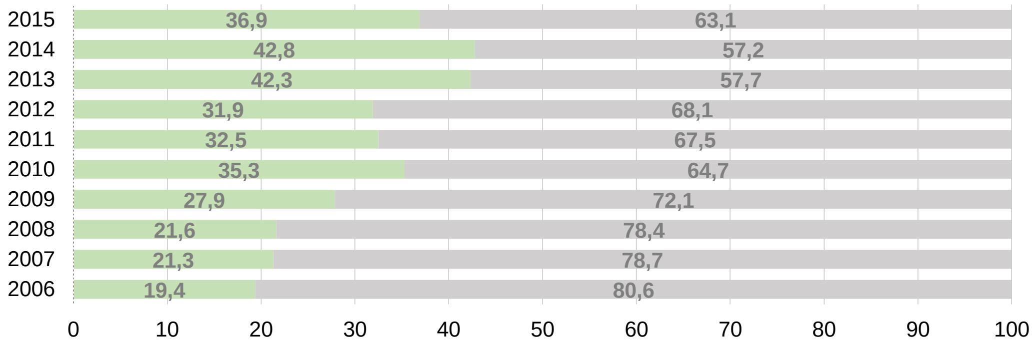

Figure 4. Comparison between renewable resources (green) and fossil fuels (grey) used in power generation during the last decade

As mentioned in section 4.1.3, most of the problems which have happened in Spain are considered a consequence of the financial crisis of 2008. Observing Figure 3, it is clear that in this occasion it is not the case. The installation of renewable energies has stopped, especially the last 3 years. Compared to the different examples shown in section 4.1.1, the Spanish government has taken some unjustifiable decisions.

In 2010, Spain started a process to limit the aids that the renewable sector receives. The *Real Decreto ley 14/2010* established a cap for the hours of financied production of any renewable plant (4,235 hours). The approval of the law Ley 15/2012 [26] aimed to adjust taxes for energy sustainability.

Before to the approval of this law, electrical tariff deficit reached the 24,000 million € [27]. The main points that this reform included were:

- Apply a tax to the production of electricity.
- Apply various taxes to nuclear energy.
- Apply a tax to the utilization of continental water for hydro electrical production.
- Increase taxes to the utilization of fossil fuels.
- Eliminate several aids for the selling of self-generated energy.

Two of these points that affect severely the renewables are the tax to the production of electricity and the elimination of multiple aids for the self-generation of energy.

Currently, the company that produces electricity and introduces it to the network has to pay a tax of 7% for all the production. This means that the final economic benefit will be the 93% of the electrical output. The government expected an income of 2,000 million € per year [27], but what they probably did not predict was the effect that this tax would have for the industry, causing the closing of several production plants whose benefit was close to the 7% of the energy produced.

Moreover, a reform of the energetic policies (Ley 24/2013) [28] has aggravated the situation for renewables in Spain. The objective is to regulate electric power generation from renewable energies, mainly reducing the subsidies to these technologies.

The situation of renewable energies has dramatically changed during the past months with a new law that targets companies that want to sell energy produced by these energies. The approval of a new law (Ley 24/2013 of 26th of December 2013) and its implementation (6th of June 2014) limits the economic benefit of production companies that receive subsidies to 7.5%. The mechanism of the new method of retributions, in simplified words, is the next: the state gives the subsidy to the company, and at the end of the year the benefit is calculated and the subsidy is returned until the benefit is reduced to 7.5%. A study of the Spanish cogeneration association (ACOGEN) demonstrates that this reform, since its announcement in the summer of 2013, has paralyzed 1800 MW of cogeneration. It also shows that the monthly production has been reduced in a 22% since the final approval of the law (26/12/2013) [29]. This has happened in all the sector.

Apart from the economic limitation, this reform brings another type of restriction regarding the production of biogas: the time of operation is limited to 4,235 hours. If the company decides to operate more time, there will be no extra retribution for this extra hours.

This situation has not been ignored by the international community. Spain is currently the leading country in terms of International Requests for Arbitration in Europe for energy policies [30]. But not only formal institutions are pushing the Spanish government for a rectification: even international newspapers have criticized the government of the Partido Popular for this incomprehensible position [31]. In this article the journalist ridicules the fact that the Spanish government considers itself as the owner of the Sun, because Spain is the only country in the world where there is a tax to the self-production of energy with solar panels.

The production of electricity from renewables, as shown in Table 7, is the following:

Table 7. Power production in Spain - only from renewables [13]. Year 2015

RESOURCE	PRODUCTION GWH	PERCENTAGE
HYDRO	30,819	11.5%
WIND	48,109	18%
SUN	13,321	5%
OTHER	6,821	2.5%
TOTAL	**99,070**	**37%**

To satisfy the whole demand (267,576 GWh) with renewables, the production of electricity should almost be triplicated.

To make this calculations, some formulas have to be described:

$$Energy\ capacity\ (kW) = \frac{Energy\ produced\ (kJ)}{time\ (s)}$$

$$Energy\ demand\ (Wh) = Capacity\ (W) \cdot time\ of\ production\ (h)$$

Assumption 1

Making an accurate calculation for the three main renewable energies is a very complex process. The first important value that has to be calculated is the hours of production of each technology. The assumption is that each technology is currently working at full capacity, which means that the number of hours will be the same independently of the installed capacity.

Table 8. Calculation of average hours of production

RESOURCE	CAPACITY MW	PRODUCTION GWh	HOURS
HYDRO	20,353	30,819	**1514.2**
WIND	23,020	48,109	**2089.9**
SUN	6,964	13,321	**1912.8**
OTHER	1,501	6,821	**4544.3**

This numbers are, of course, an approximation of the reality. They represent the average number of hours, which means (i.e.) that maybe the hydropower is working at full capacity 500 hours and with less capacity the rest of the year.

Calculation

Nevertheless, and considering the limiting factors for each technology, the number of hours is accurate for Spain. The following images show the daily production of the three renewables for the first day of each month of 2015.

Table 9. Comparison between demand and renewable energy produced for each month of 2015 [32]

MONTH	DEMAND (GW)		WIND (GW)		HYDROPOWER (GW)		SOLAR (GW)	
	Max	Min	Max	Min	Max	Min	Max	Min
JANUARY*	34.3	19.3	3.5	1.3	9.3	0	3.9	0.05
FEBRUARY	34.1	21.7	13.5	8.1	7.2	1.0	3.9	0.05
MARCH	30.4	20.8	11.1	7.5	7.4	0.7	3.8	0.06
APRIL	31.0	21.6	9.1	7.2	7.9	0.6	5.6	0.1
MAY*	27.3	24.5	7.7	4.8	5.9	0.4	4.9	0.04
JUNE	32.4	20.7	4.0	0.4	6.6	0.5	5.1	0.05
JULY	37.4	25.4	8.0	2.9	5.6	0.4	5.1	0.05
AUGUST	29.8	22.0	6.0	1.6	4.7	0	5.1	0.05
SEPTEMBER	35.9	24.0	6.0	3.2	4.0	0.4	4.5	0.05
OCTOBER	32.9	21.8	4.7	0.6	5.4	0.4	4.9	0.06
NOVEMBER	27.4	18.9	12.9	4.0	4.7	0	2.5	0.02
DECEMBER	37.0	23.2	1.7	0.8	7.5	0.4	3.5	0.04

As shown in Table 9, the availability of renewable energy varies during the day and the month.

Figure 5. Curve of daily power demand (MW) shows a typical energy demand curve for a normal day (11th of May of 2016):

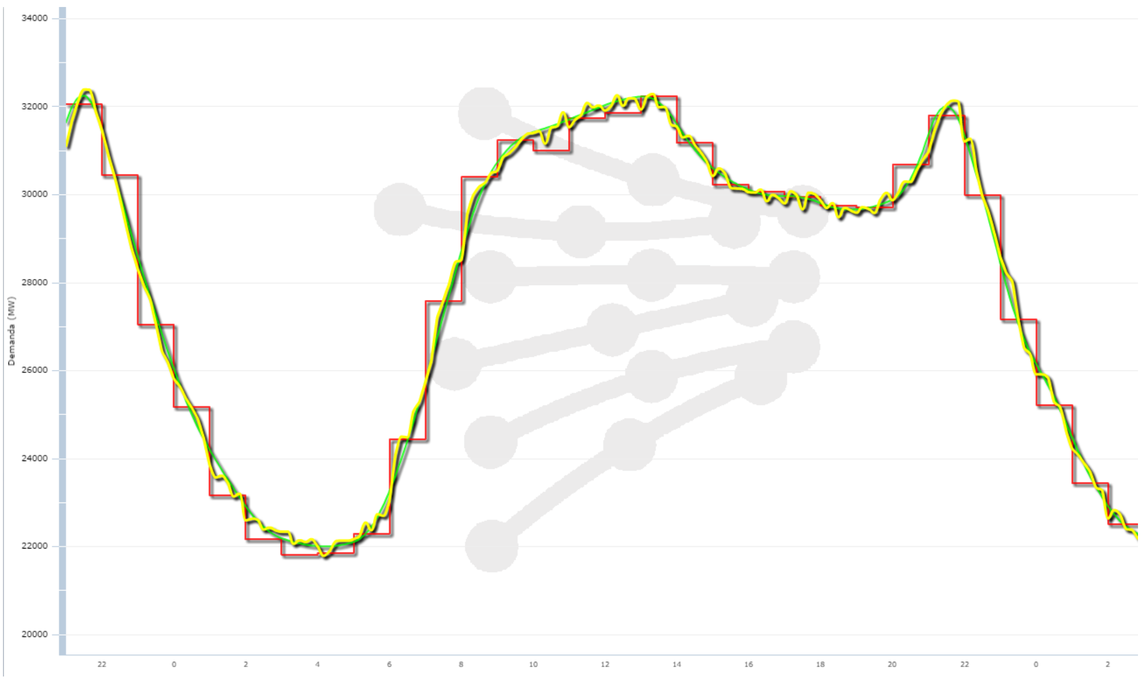

Figure 5. Curve of daily power demand (MW) [32]

As it can be seen, the demand shows important variations during the day. There is one clear valley of minimum demand (in this case, 21794 MW at 04:10). During night hours the demand is lower because of obvious reasons (people sleeping, lights and devices turned off, etc.). When people wake up the demand starts growing, reaching a peak at midday (32293 MW at 13:20). From lunch time to dinner there is another valley, as less people are working (minimum of 29492 MW at 18:30). Another peak coincides with the dinner time, when people cook, has free time at home and watches TV or uses internet (32110 MW at 21:50).

Depending on the day of the week this curve may be moved (on weekends the energy demand begins later, as people sleep more hours) and also depending on the month (at summer, the air conditioning elevates all the demand).

Now let's compare Figure 5. Curve of daily power demand (MW) with the three following figures, which are the production from wind (Figure 6), hydropower (Figure 7) and solar (Figure 8 andFigure 9).

Figure 6. Capacity utilization of Wind power the 11/05/2016 [32]

Figure 7. Capacity utilization of Hydropower the 11/05/2016 [32]

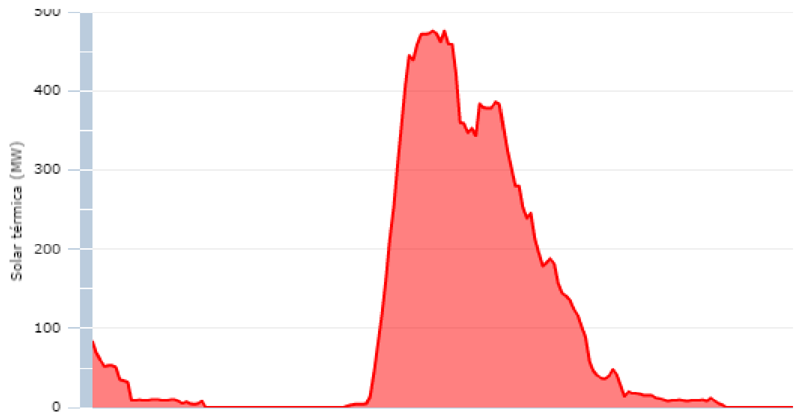

Figure 8. Capacity utilization of Thermal solar power the 11/05/2016 [32]

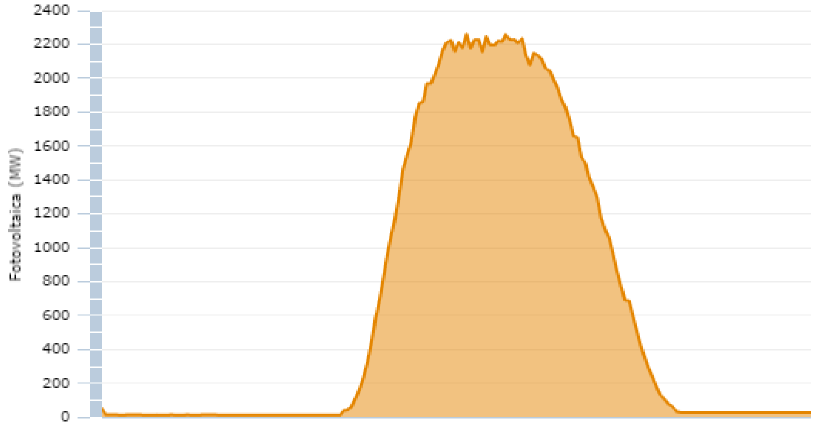

Figure 9. Capacity utilization of Photovoltaic solar power the 11/05/2016 [32]

By observing these graphs, some conclusions can be extracted:

- Solar power is very limited and it can only operate a few hours per day. It cannot be used neither as a base energy nor as a support.
- Wind power is very unpredictable. It is constantly working but there is no guarantee of availability.
- Hydropower is the most predictable renewable energy source as it is strictly correlated to the rain and to the snow accumulated in the mountains. The only problem is that it is only big in volume during spring and autumn.

After having observed the 3 most used renewable sources to generate electricity, it is clear that the feasibility of surviving with only these 3 technologies is hardly achievable.

<u>Assumption 2</u>

Of course Spain can continue to install more wind power stations, but as observed previously, the country is already in the 6th worldwide position of this technology. From this numbers, it is assumable that the country is already obtaining almost the highest quantity of energy obtainable with this technology considering the available surface.

Regarding hydropower, the government could make more investments in new reservoirs. But it is true that it is a slow process and also very expensive. It could be assumable a 50% increase of hydropower, a growth rate that was achieved in the past (Figure 3), arriving to 46,228 GWh. The total electricity produced from renewables would be 114,479 GWh. Spain would still need 153096 GWh of extra power to operate at 100% under renewables.

Solar plants: a possible solution

As seen in Table 6, a European country such as Germany has an installed capacity of 39.7 GW of solar plants. Spain, on the other hand, 6.9 GW. This is a paradox, as the difference of sun hours per year is clearly in favor of the Spanish country (Figure 1). This clearly indicates that the energy policy in Spain is not working properly and that the government should make a change in its decisions and benefit the installation of solar plants to satisfy the demand and to continue developing a new environmental landscape.

Assumption 3

Let's assume that Spain installs enough solar plants to reach the same solar power of Germany. Also, it has increased the installed hydropower capacity up to a 50% (as mentioned in assumption 2). The new renewable energy landscape would be the following:

Table 10. Hypothetical renewable resources landscape

RESOURCE	CAPACITY MW	HOURS	PRODUCTION GWh
HYDRO	30,529	1514.2	**46,228**
WIND	23,020	2089.9	**48,109**
SUN	39,700	1912.8	**75,938**
OTHER	1,501	4544.3	**4544.3**

The new total power production would be 174,819 GWh. It represents 65% of the 267,576 GWh, a more coherent share of renewable production considering the enormous potential that Spain has regarding natural resources.

Nevertheless, it is true that these numbers are still far from the objective of a 100% renewable resources country. Increasing the use of biofuels and biomass would be a possibility, but the installed capacity (assuming that the number of operating hours would remain the same, 4544.3 h), Spain would need a capacity of 21,412 MW from biomass and biogas.

In addition, in punctual situations the country would not be ready to satisfy the whole demand of energy. For example, a night with no wind and in a season where rivers have a smaller flow, the whole demand should be covered with this 21.4 GW of biomass and biogas, a number clearly insufficient compared to Table 9 (for example, July 2015).

4.2. ALTERNATIVE SOLUTIONS TO IMPROVE

After having analyzed the results in section 4.1, it is clear that nowadays it is very unlikely that a country is able to produce electricity only from renewable resources. In this section, the objective will be to create a potentially beneficial scenario for the electrical production in Spain.

Since the main objective of this thesis is to study the emissions and its effect on the climate, the scenario created in this section will be oriented to the reduction of pollution and the maximization of the use of renewable energies.

As it has been studied in the section 4.1.3, nuclear energy has no operational emission of pollutants. In this section, the study of different power generation sources and the environmental restrictions will be made in order to classify each resource and its benefits and drawbacks. Two cases will be specially studied: Germany and France. While the first is shutting down all the nuclear plants, the second produces 75% of electricity from nuclear power.

4.2.1. ***France as the demonstration of the feasibility of an electricity generation system based on nuclear energy***

France is the greatest example of a country that relies almost entirely on nuclear plants, with a total share of electricity production of over 75%. In 2007, almost 50% of electricity of the European Union that came from nuclear plants was produced in France [34], a figure that shows the magnitude of the country's policy.

The implementation of nuclear energy was a reaction of the French government to the first oil crisis of the century. During the decade of the 70s, and as a consequence of the decisions taken by western countries regarding the Yom Kippur war, the world faced the most important oil crisis ever. The intended lack of supply by the Arabic exporting countries (OAPEC) emphasized the already growing worldwide inflation while reducing the economic activity of the affected countries, causing a severe geopolitical conflict. Thus, the affected countries took several important measures to reduce the fuel dependence and founded the International Energy Agency. In spite of this changes, a second energy crisis began in 1979, affecting importantly the United States and demonstrating that there was (and there is still) high dependence on the fuel from the Arab petroleum exporting countries. France was one of the countries that was involved in the first conflict, concretely at the Sinai War of Egypt, and as a consequence the OAPEC countries embargoed the exportation of oil to the French country (among others). After the embargo, France realized that its energy policy was not the ideal: they were (and are) one of the largest economies of the world, and the second country in GDP of the EU right behind Germany [35], but its lack of natural resources to produce energy made them very reliant to imports of coal, oil and gas.

It was in 1974 when the Prime Minister Pierre Messmer announced that the country would start a new era of electricity production based on nuclear power [36]. This plan set ambitious goals, with the intention of having built 170 nuclear plants by the year 2000. Although this goals were not reached (France currently has 58 power reactors), the country has reached a production of 436 TWh, with 63 GW of electrical capacity installed [37]. The benefits of this energy plan are multiple:

- France is one of the countries with the cheapest cost of electricity production of the EU.
- France has the lowest level of emissions of CO_2 coming from electricity production per capita, since nuclear energy produces no pollutants.
- It is the country with the highest energy independence of the European Union.
- The country exports a great quantity of electricity to the neighboring countries (a total of 67 TWh in 2014). This figure puts France in the first position of the world in terms of net exports of electricity. The successive country is Canada, with 46 TWh (a 45% less than France). This fact is tremendously beneficial for the country to balance other imports/exports, having a positive impact in the country's economy (over 3B € per year [38])

For all this reasons, the French government is not willing to change its energy policy. Due to the life utility of some nuclear plants, some of them will be closed (a nuclear plant is usually used during 40 years on average). In October 2014, the National Assembly approved the *Energy Transition for Green Growth*. In this pack of measures, some changes to the current energy policies were specified [39]:

- Nuclear contribution to electricity supply will be capped at a 50%.
- Greenhouse gas emissions will be reduced by 40% by 2030 compared to 1990 levels, a number that will be increased to the 75% at mid-century.
- Energy consumption levels at 2050 have to be equal to the current consumption.
- Renewables energy electricity production share should increase to 32% by 2030.
- Carbon dioxide taxes to electricity producers should be increased from 14.5€ to 100€/tCO_2 by 2030.

All this measures have to be understood as an adaptation of the current energy policy to reduce emissions and to foster the use of renewable resources to produce electricity. This is aligned with the goals that have been recently set in the COP21.

4.2.2. ***COP21 – Paris agreement***

The COP21 was a conference of the UN about climate change that was held in Paris in December 2015. The main purpose of this forum was to reach a new agreement that would give continuity to the Kyoto Protocol and eventually update its measures and make it more feasible and adapted to the current situation. There are various objectives that 187 of the 195 participant countries have agreed on, being the most important the one of maintaining the global average temperature until 2050 of 1.5 Celsius degrees in order to avoid "catastrophic consequences" [40].

It is clear that the key factor will be to control the emissions of carbon dioxide, as it is the main cause of climate change. In fact, the emissions of CO_2 have been constantly increasing during the whole 20th century, and so are they doing in the 21st. A study from the IEA showed some relevant information about the level of emissions, comparing the OECD countries with the non-OECD economies (mostly growing economies together with giants like China and Russia):

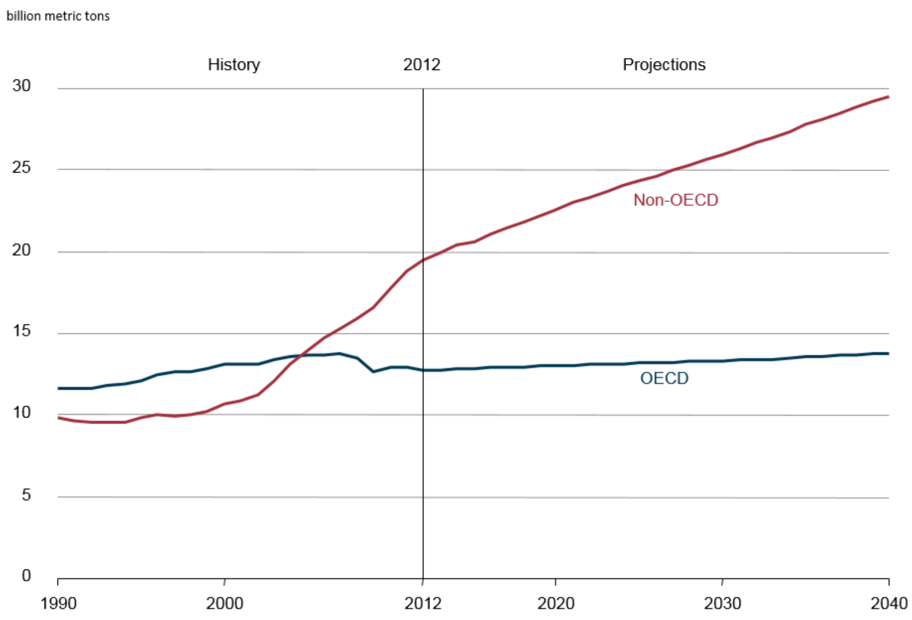

Figure 10. Comparison between OECD and non-OECD CO_2 emissions [41]

As it can be seen in Figure 10, and because of the stabilized economies and the slow development and growth of the population in the OECD countries, it is more feasible that they can maintain a steady level of carbon dioxide emissions. With these levels, studies believe it would be possible to comply with the COP21 requirements.

Nonetheless, the major concern regarding emissions is related to growing economies. Because of their uncontrolled and fast development, the energy system is not able to satisfy the whole demand with the “less polluting” structures (renewables and nuclear), and fossil fuels are used to increase the capacity. Furthermore, the most used resource to produce energy in these cases is coal [42], the most polluting option that can be used to generate electricity.

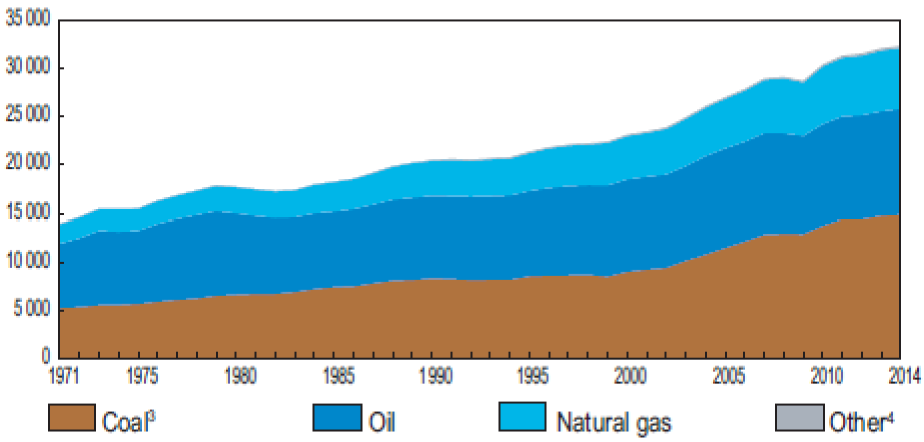

Figure 11. Historical consumption of fossil fuels in MTon [43]

Figure 11 is a clear indicator of the increasing problem of the growing economies. China first (in the 2000s decade) and now India amongst others have made the CO_2 emission from coal increase dramatically in this century. In fact, 45.9% of the emitted CO_2 is produced by coal, followed by oil (33.9%) and natural gas (19.7%) [37].

The frenetic development of China in the last two decades is a fantastic example of the aforementioned difficulties.

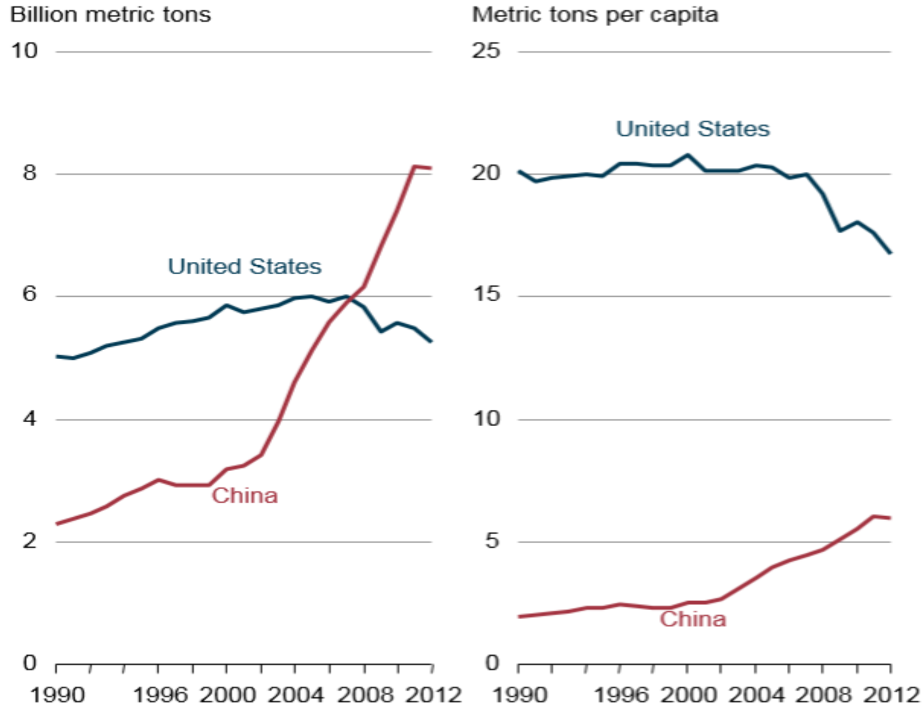

Figure 12. Carbon Dioxide emissions comparison between China and USA [41]

In figure Figure 12, the two countries with the highest level of emissions in the world are compared. As it can be seen, the growth of China's emissions began in 2002, multiplying by more than 3 times the level of pollution in less than one decade. This is caused by various reasons, being the clearest factors the industrialization of the country, the growth of the population and the improvement of the population's wealth, with the increase of private transport.

In fact, in 2014 these differences were even higher. China emitted 9.1 Bt of CO_2 while United States maintained the level of 2012 with 5.18 Bt of CO_2. India (2.1 Bt of CO_2) and Russia (1.47 Bt of CO_2) closed the top 4 countries in level of emissions [37]. The total emissions of year 2014 were 32,381 Mt of CO_2.

CO_2 is, undoubtedly, the main concern regarding climate change. Other greenhouse effect gases are nitrous oxides (NO_x) and sulfur dioxide (SO_2), which are mostly generated by fossil fuels. For example, when SO_2 is emitted to the atmosphere, it reacts with the oxygen in the air and then SO_3 is produced. Its accumulation causes the feared phenomena known as acid rain:

$$SO_3 + H_2O \leftrightarrow H_2SO_4$$

With all these problems and its potential devastation, it is clear that the use of fossil fuels has to be drastically reduced. For this reason, this thesis defends nuclear energy as a realistic solution to the emissions problem to complement renewable energies.

Nonetheless, there are various countries that have a clearly negative position regarding the use of nuclear energy, and that are currently dismantling its nuclear plants or will do it in the future.

4.2.3. ***The fear of nuclear energy***

Nuclear plants have been considered as extremely dangerous installations by a great part of the population. The general belief has created a fear atmosphere that has surrounded nuclear plants, especially since the Chernobyl catastrophe. In a national poll carried out by the French government in 2003, 70% of the population affirmed that they were being poorly informed on energy matters. And more importantly, 58% thought that nuclear plants caused climate change, while only the 46% thought that coal plants did so [38]. This result clearly shows that a great part of the population totally ignores the facts about the energy industry and that there has been an excessive demonization of the nuclear energy.

Despite this, it is true that the potential harm that a nuclear plant can cause is extremely higher than what a fossil fuel plan can do.

Chernobyl (1986) and Fukushima (2011) accidents, the two most notorious events, have worsen the reputation of nuclear energy.

Chernobyl

The 26th of April of 1986, a nuclear disaster happened in the city of Pripyat, in Ukraine. Until 2011 it has been considered the most devastating accident of the history of nuclear plants. Chernobyl was the most important power generator of the Soviet Union.

The accident was caused because of a human error. When a safety procedure was being tested, an instability of the reactor happened. Tooling system was not pumping at the appropriate flow, and for this reason the core of the reactor started to heat up. The accumulation of steam because of the high temperature dramatically increased the pressure and eventually caused an explosion of the nuclear reactor.

As a direct consequence of the explosion and fire extinction works, 31 people died. Abnormal levels of radiation were found all over the World, and the index of cancer increased dramatically in the region [43].

Fukushima

After the earthquake of 9 Richter degrees that occurred on 11th of March of 2011, a tsunami reached the coast of Japan. Giant waves which could measure up to 38 meters hit the whole eastern coast of Japan.

Fukushima nuclear plant was devastated by the giant waves. When it was built in 1971, and although it was known that tsunamis could hit the Japanese coast, the protection wall measured just 6 meters. This excess of confidence caused the biggest nuclear disaster of history. Three nuclear fusions happened, and tons of radioactive material were emitted to the sky and to the ocean. As it happened in Chernobyl, radioactivity spread all over the World.

These two famous cases, among others, show that nuclear energy has a devastating potential. This is the main reason why a lot of organizations fight against nuclear power, and even some governments have abandoned the use of this energy source. But it is also true that both accidents were caused by human errors (or even worse, a combination of human errors and natural disasters). With the development of nuclear technology, the safety has increased and so has its efficiency. For example, in the French location of Flamanville, a new nuclear power plant is about to begin its operations. It uses a new type of pressurized water reactors that will increase its safety without reducing the power capacity [44].

French engineers continue developing technologies to improve safety and protecting the environment from the nuclear waste. On the other hand, Germany has started an era of “nuclear shutdown”.

Germany and its plan to shut down all the nuclear plants

After Fukushima's catastrophe, the German government held an extraordinary meeting to evaluate the energy policy of the country. At that moment, Germany was producing 22.4% of energy with nuclear power [45], and had a total of 17 nuclear reactors.

During the first phase of this measure, 8 reactors were permanently shut down (the ones that had been more years operating), reducing to almost 50% the production of electricity from this resource. The government's plan was to compensate the energy deficit with renewable energy. As seen in section 4.1.3, Germany is currently in a very strong position regarding renewables (45 GW wind, 39.7 GW solar, 7.1 GW biogas and 5.6 GW hydro [10]), a share that currently represents the 28.2%. In 2011, this figure represented the 17%, a fact that shows that the Teutonic country is fostering the use of renewable resources.

Angela Merkel, Germany's chancellor, added another reason to the shutting down of the nuclear plants: reducing the emissions of CO_2 thanks to the proliferation of renewable energy power plants. The result of this measure has been less successful than expected, as Germany has had to compensate the reduction of nuclear power with natural gas plants and also with the most polluting power plants, coal.

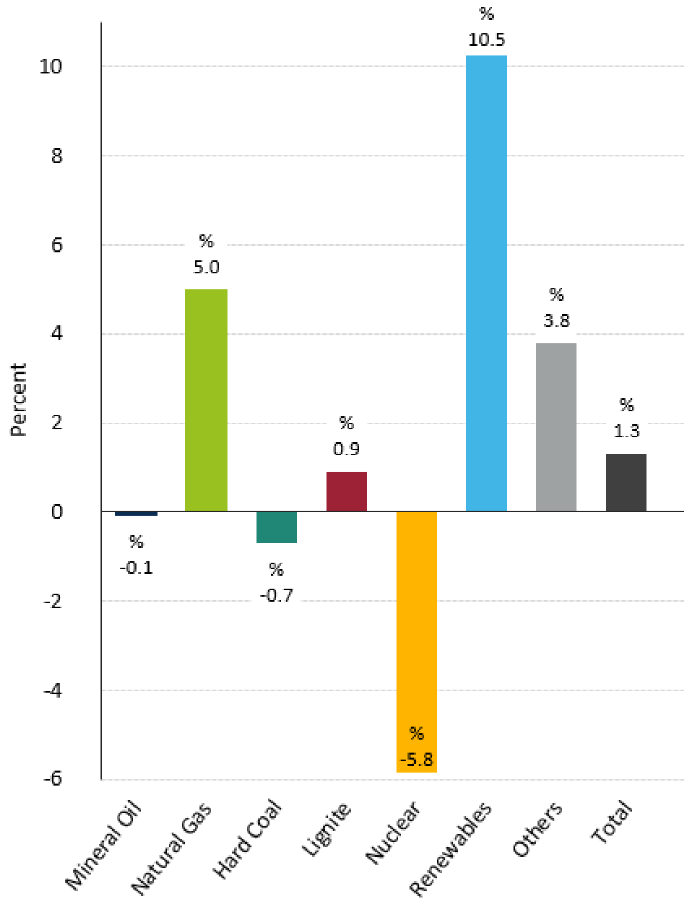

Figure 13. Difference (%) of resource utilization between 2014 and 2015 in Germany [46]

Figure 13 shows the difference of use of the different resource to generate energy from 2014 to 2015. Besides the aforementioned fact of the compensation of nuclear energy with natural gas and lignite (besides renewables), it is also interesting to see that the total energy production increased in 1.3% points. As the local market demand has not increased, the German electricity generation industry has found potential clients in foreign countries like Austria. The German government subsidizes renewables to foster its utilization, a fact that reduces the price of energy and incentivizes the production with this resources.

Regarding the installed capacity, 50% of the installed capacity comes from renewable resources [47], a very impressive figure:

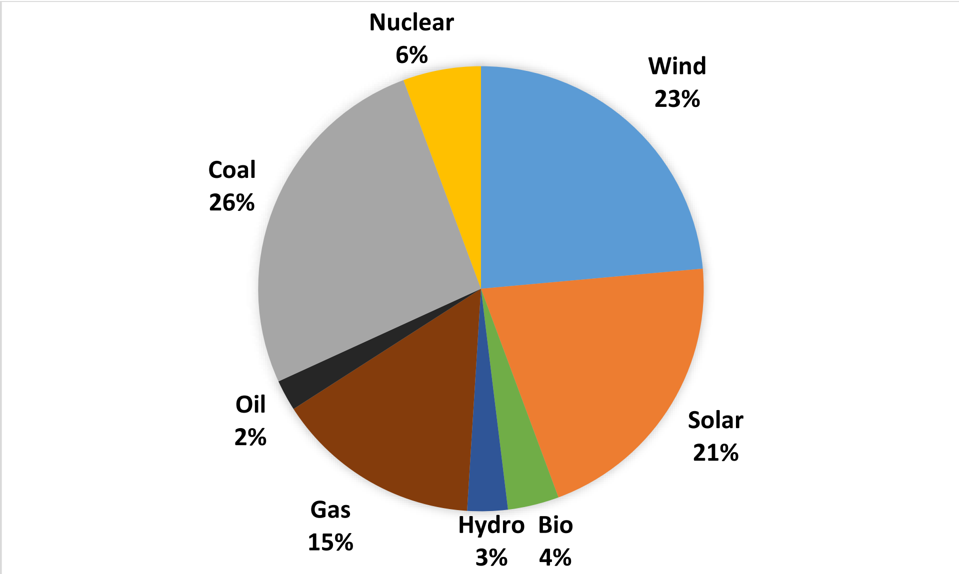

Figure 14. German energy profile, 2015

But, as happened in the case of Spain (and any other country), the total contribution to the electricity production is notably below this figure (in Germany, as mentioned above, renewables contribute to a 28.2% of the total generation). This is because of the non-constant availability of natural resources (wind in calm days, sun at night or in rainy days and hydro power in dry seasons). For this reason, Germany still relies a lot on fossil fuels and faces the same problem that this study has faced in the analysis of section 4.1: it is almost impossible that a country sustains its entire electricity generation on renewable energies.

*4.2.4. **Comparison of power generation technologies***

As seen in sections 4.1 and **¡Error! No se encuentra el origen de la referencia.**, the combination of different energy generation technologies is mandatory for a country to have a sustainable and consistent power production. In this section, a quantitative comparison of the different available technologies will be done.

For each energy, the following criteria will be studied:

- Emissions (Em)
- Price (P)
- Resources availability (Av)
- Dangerousness (D)
- Consistency of supply (S)
- Efficiency of the technology (Eff)

A comparative score from 1 to 5 will be given to each technology, being 5 the technology that outperforms the rest and 1 the resource that has a poorer result.

Furthermore, the criteria of evaluation will have a different weight, as it cannot be quantified in the same way the price or the dangerousness (i.e.).

Quantitative analysis

	Em *x2*	P *x1.5*	Av *x1.5*	D *x3*	S *x1.5*	Eff *x1*	TOTAL
RENEWABLES	5	3	5	5	1	1	**39.5**
NUCLEAR	5	5	3	1	3	5	**34.5**
COAL	1	4	2	3	5	2	**29.5**
OIL	2	2	1	2	4	3	**23.5**
NATURAL GAS	3	1	1	2	3	4	**23.5**

Explanation

Emissions

As it is vital to reduce the emission of pollutants to stop the fast increase of World's temperature, the multiplier has been x2.

Regarding the emission of pollutants of the different resources, there is a lot of debate to decide which is the cleanest. On one hand, most of the renewables have 0 emissions (wind, hydropower and solar), but biomass and biofuels are burned and during the combustion there is emission of CO_2. On the other hand, although it is true that nuclear energy has 0 emission of greenhouse gases, during the elaboration of the uranium fuel CO_2 is produced.

Regarding fossil fuels, and as it has been mentioned in section 4.1.3, the highest emission of CO_2 and other gases is produced by coal, being oil the second worse option and natural gas the "cleanest" fossil resource.

Price

Energy production and consumption is a very important concept in the economic balance of a country. Furthermore, after the financial crisis, this factor is even more relevant. The multiplier is x1.5.

Renewable energies, in terms of operation, could be considered the cheapest resource. But it is important to be aware that each government subsidizes renewable plants. Without this effort, renewable energy plants would not be economically beneficial for the owner until a few years after the construction.

Regarding the cost of fossil fuels, coal is the one with most availability and cheapest extraction. Natural gas is the less abundant (it is found in oil sediments), and for this reason the cost is higher.

Resources availability

For a long-term power generation system, it is crucial that the resources are available for long term. Relying a big share of the energy profile to a technology that will not last long would represent a new investment in other types of plants to replace the dried resource. For this reason, the multiplier is x1.5

From the available data:

- Renewables: inexhaustible
- Uranium [48]: 200 years
- Coal [20]: 120 years
- Oil [20]: 45.7 years
- Natural gas [20]: 62.8 years

In this case, and because of the enormous difference between renewables and the rest of resources, extra points of difference have been given to its score.

Dangerousness

It would have no sense to rely on an extremely dangerous technology, independently of the efficiency of the technology. Fortunately, and although it is dangerous, nuclear energy cannot be considered dangerous enough to not be used. The multiplier is the highest, x3.

In that case, and without any doubt, nuclear energy scores the lowest. Chernobyl and Fukushima are some of the examples that support this result. On the other hand, renewables almost have no potential harm for humans, although biogas could eventually cause explosions. Regarding fossil fuels, oil and natural gas are more volatile and explosive, and for this reason they score higher than coal.

Consistency of supply

Not only the availability of resources is important, but also the level of supplies. This is the main drawback of renewable resources, as humans cannot control the nature. Multiplier 1.5.

Coal is the most extracted resource for energy generation, while oil is also very popular but its use is mostly for transportation.

Efficiency of the technology

The last concept is also of great importance. A more efficient technology means that less energy will be wasted during the production of electricity, and also that less power plants will be required to meet the demand. The multiplier is x1.

Nuclear energy has the highest efficiency, as most of the energy of the nuclear is used to generate steam and there are few losses in terms of thermal losses. The opposite would be renewable energy plants, especially solar plants (efficiency ≈ 10-15%). Coal plants also have enormous thermal losses, while natural gas is used in combined cycle plants and cogeneration, more sophisticated installations with higher efficiencies.

4.3. PROPOSAL FOR THE CASE OF SPAIN

The objective of this section is to make a recap of sections 4.1 and **¡Error! No se encuentra el origen de la referencia.** and to offer the solution to the Spanish problem of the energy sector.

Currently, Spain energy profile is the following:

Table 11. Electricity generated in Spain. Year 2015. [13]

RESOURCE	GENERATION (GWh)	% TOTAL
NUCLEAR	54,755	20,46%
COAL	52,789	19,73%
FUEL/GAS	6,497	2,43%
COMBINED CYCLE	29,357	10,97%
COGENERATION	25,108	9,38%
HYDRO	30,819	11,52%
WIND	48,109	17,98%
SOLAR (1)	13,321	4,98%
OTHER RENEWABLES (2)	6,821	2,55%
TOTAL DEMAND	**267,576**	

With a renewable share of renewable energy of 36.9%.

After having studied the possibility of having an energy system entirely based on renewables, the final proposal of section 4.1 was the following:

Table 12. Hypothetical renewable resources landscape

RESOURCE	CAPACITY MW	HOURS	**PRODUCTION GWh**
HYDRO	30,529	1514.2	**46,228**
WIND	23,020	2089.9	**48,109**
SUN	39,700	1912.8	**75,938**
OTHER	1,501	4544.3	**4544.3**

Obtaining a net production from renewables of 174,819 GWh. It represents a 65% of the 267,576 GWh.

The remaining 35% of energy production (92,757 GWh) will have to be produced from a non-renewable resource.

In section 4.2, after the evaluation of technologies, the conclusion was clear: each technology has benefits and drawbacks, and depending which goal does the country want to achieve it will use a different resource. In growing economies, the use of the fast and cheap coal is the most extended solution, without giving importance to the level of emissions.

But as it has been seen in section 4.2.2, the results of COP21 have been very clear, pointing to the greenhouse gases as the most important threat for the environment. The non-renewable resource has to follow the following criteria:

- Low level of emissions
- Cheap price
- Lasting technology
- Demonstrated success in other countries

Nuclear energy fulfills the 4 requirements. A cheap energy source that would drastically decrease the level of greenhouse emissions. Furthermore, the neighbor country (France) has demonstrated that a system based on this resource is possible. Indeed, the safety of the technology has been proved (58 reactors in France have caused no accidents in all their operational period) and the possibility of natural disasters in Spain that could repeat a dramatic catastrophe like in Fukushima is almost inexistent.

Spain currently has 7.57 GW of nuclear power installed, producing 54,755 GWh. This represents a utilization time of 7233 hours on average per nuclear plant (a year has 8760 hours, but some of these hours are used for maintenance tasks).

As aforementioned, Spain would need 92,757 GWh to fulfill the whole energy demand. This would mean that the country would need a capacity of nuclear power of 12.8 GW. 35% of nuclear energy would be satisfied in this way. The profile would be as it follows:

Table 13. First proposal of a new energy profile

RESOURCE	CAPACITY MW	PRODUCTION GWh	SHARE
HYDRO	30,529	46,228	17%
WIND	23,020	48,109	18%
SUN	39,700	75,938	28%
OTHER Ren	1,501	4544	2%
NUCLEAR	24,200	92,757	35%
TOTAL	**107,550**	**267,576**	

But this would not solve the problem of inconsistent "supply" of renewables. With the proposed solution, the country would for sure have energy deficit during some specific seasons or days. For this reason, the proposed solution is the following:

- Renewable energies: 50% of production
- Nuclear energy: 50% of production

With this solution, and considering the previous proposal for renewable energies (174,819 GWh) as the 50%, Spain would need to produce exactly the same quantity of energy from nuclear plants. This would represent an installed nuclear capacity of 24.2 GW. There would be days with energy surplus, which could be sold to Italy or Portugal, and in some days when the production would not be enough because of special weather conditions, Spain could import cheap energy from France.

Spain would become a country with 0 emissions from electricity generation. In the worst case scenario, some combined cycle plants (natural gas) could be used as a backup to fulfill the energy demand. In that way, Spain would also abandon the use of coal and use oil just for transportation.

Table 14. Final proposal of the new Spanish energy profile

RESOURCE	CAPACITY MW	PRODUCTION GWh	SHARE
HYDRO	30,529	46,228	13%
WIND	23,020	48,109	14%
SUN	39,700	75,938	22%
OTHER Ren	1,501	4544	1%
NUCLEAR	12,800	174,819	50%
TOTAL	**107,550**	**349,638**	

4.4. THE UNCERTAIN FUTURE OF ENERGY

Performing a study of the energy profile of a country and giving potential solutions is something temporal and, in the long term, inaccurate. The development of new technologies, discovering new resources, a geopolitical conflict, the growth of new countries or even a natural catastrophe can transform a solution that today seems feasible a complete non-sense for the future.

In this section, a qualitative study of some hypothetical and/or probable changes can definitely affect the future of energy positively and/or negatively

Improvement and development of technologies

- The efficiency of solar plants is an important matter nowadays. The low efficiency of this installations require a lot of solar plants to be built. With a higher efficiency, less plants would be required to obtain the same electricity.
- Another important point for the scientific community is the nuclear waste. A better treatment of this products would definitely be more environmentally friendly, improve the reputation of nuclear energy and even allowing a larger reutilization of uranium products.
- A new technology is being developed: nuclear fusion [49]. A technology that will increase the efficiency, produce no radioactive products and would use hydrogen isotopes as fuels.

Lack of resources

As it has been mentioned in section 4.2.4, the resources of fossil fuels will not last forever. It is mandatory that the use of renewable energies is increased, and governments should foster it (contrary to what happens in Spain). Furthermore, the recent history has seen multiple wars for the resources, and it would not be unlikely that in the future more conflicts could happen.

Being self-sufficient in terms of electricity production should be a goal for each country to avoid situations like the energy crisis of 1970.

Demographic changes and pollution

The last reflection of this analysis and discussion section will be pointing to the growing economies. China, the country with the largest population of the World, contributes to more than 25% of global pollution. India also has an important share of emissions. If developed countries adapted their energy policies to drastically reduce emissions but growing economies keep burning coal as its main resource, the whole process would be useless. International organizations of regulation should be more strict in terms of energy policies to protect the environment.

5. CONCLUSIONS

The aim of this paper has been to study the feasibility of a 100% renewable energy policy to generate the electricity of Spain and to find possible alternatives to solve the problem of the climate change and emissions.

After having analyzed the current energy landscape of Spain and having compared it to other examples, there are some conclusions that have been extracted:

- Spain has great potential thanks to its natural resources and should implement a more ambitious energy policy. The government should not tax the solar production and massively invest on it.
- The 100% renewable energy landscape in Spain is nowadays impossible. The investment in solar plants would be enormous, and unfortunately the Spanish economy does not allow this expense to happen. Said so, this does not mean that the country should not begin to evolve and to become less dependent on fossil fuels, especially because the imports of coal, crude and natural gas represent a huge expense in the economic balance of the country.
- Even with the assumptions made in the analysis, Spain would need a base power supply. If Spain decided to adopt a 0% emissions country, combining renewables and nuclear plants would be a feasible solution for the country.

- Nuclear energy has been extremely demonized, and an important share of the population ignores the multiple benefits that this technology has for the environment and the economic balance of a country. Nonetheless, it is also true that it is the most dangerous technology, and to use it as one of the main production source (as in France), the installations have to be safe and located strategically to avoid disasters.
- A combination of renewables and nuclear energy it a feasible solution for Spain. With years, investment and the development of better technologies, it seems possible that a totally renewable country is achievable. But nowadays, the reality is that renewables have to be combined with a base energy. Nuclear energy, as seen in the case of France, would be a very positive solution to the energy problems in terms of emissions and economy.
- Nevertheless, the electric consumption will grow in the future. And with the popularization of the electrical car and other devices, the nights will definitely be more demanding with the electric network than what they are now. The accumulation technologies (batteries and cells) have to evolve, and so need to do it the production technologies (solar plants still have a maximum efficiency of 15%).
- Not only a consistent energy system is necessary. Politicians have to be very conscious about their key role in the climate change problem and they have to foster the utilization of renewable energies. This is the complete opposite of what has happened in Spain in the last years.

- There is no unique solution to the energy problem, as every energy resource has its benefits and drawbacks. It is vital to study the possibilities of each country to elaborate a sustainable energy plan. In the case of Spain, it would be clever to replicate the French model, since it has shown a very positive impact in its energy balance and economic balance as well.

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