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Treball de Final de Grau

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TÍTOL: Renewable Energy Communities: Solution for the Spanish energy crisis

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GRAU: *Grau d'Economia (Docència en Anglès)*

DATA: *29/05/2022*

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1. Introduction: Energetical Worldwide Situation

Energy consumption is present in every ounce of our daily activities and lifestyles. We use electricity for every small action or need we have in our life's; from charging our phones, to even moving machines in factories to produce goods and services. Since we have sense of reason, we have seen how this huge demand for electricity and energy has been always satisfied with ease; and even during some periods, paying low prices for its enjoyment.

Since the beginning of the industrial revolution, we have seen how we have been "burning" all kinds of energy sources; from fossil combustibles as petroleum, to more sophisticated sources like uranium used for nuclear energy. This huge energy source consumption levels led by our capitalist's society has helped us overcome huge problems that we have faced over our history and evolve more than we as society could have ever imagined. But unfortunately, these days of uncontrolled and freeriding energy consumption seems to have been arrived to an end.

In 2020 the Coronavirus pandemic hit us unpredictably and obligated us to refuge ourselves in our homes. During that period of time; although energy consumption increased exponentially, all economic activity remained closed which led to some sort of camouflage to the problem that was over to come. When we returned to our full normality a year later and therefore business regained their current activity, we saw how the energetic demand couldn't be fulfilled with the current levels of supply and a huge rise in prices for electricity happened around the continent.

This problem is not something it has come to us overnight. Shortage of raw materials, political tensions and an obsolete energy wholesale market are some of the reasons that have caused this huge increase in electricity prices; that at the same time, have led to an increase of production costs for companies and more expensive bills for households, translating in inflation and loss of wellbeing. A method to solve this problem needs to be found because after lots of years, we arrived to a situation that seems irreversible; because besides the price-energy issue, environmental crisis is something that is also just around the corner and because of it, some objectives like the ones stated in the *Paris Agreement* are a must to be reached and fulfilled

To solve these issues all together, renewable energy community system is presented as a solid alternative to the current energy structure and system. To summarize in a very few words, it consists in using all the knowledge gathered over the years of renewable energy sources and apply them in small communities to favor the self-sustainment and energetic efficiency. For being such as manageable and versatile it could be considered the solution to the shortage of electric energy and to environmental pollution, or at least part of it.

But before getting more deeply in renewable energy communities, we are going to be developing, analyzing and understanding the main causes that over the years have led us to the current energetical situation. After that we will be looking to the other side of the coin to see the consequences we are experiencing now and some that may arrive in the near future if we do not take letters in the matter. The approach to these two faces of the coin is going to be making first a wider approach of the situation focusing our attention in Europe and then switching more particularly to our country, Spain.

After exposing causes and consequences, we are going to be changing or view towards renewable energy communities where we are going to be explaining more deeply about its story, what they are and how they affect both economy and society. All this study is going to be conducted through various research papers, articles, books and webpages in order to have a more diverse, variety of opinions and points of view on the topics of the research.

After all the proper research has been done, to try to corroborate and see if the hypothesis mentioned before can be sustained. We are going to be developing a mathematical macroeconomic model where we are going to be contemplating three agents: Households, Firms and Government. On this we will try to arrange a model to see if in an economy where the expenditure on community energy projects is done by the government; and financed through taxes like on electric consumption (kind of what we have nowadays in our electric bill), and with the proper fiscal policies and organization, households, firms and government can maintain or even increase their wellbeing, efficiency and utility level respectively.

Regardless of the feasibility of the model and results obtained, the objective of study and exercise is going to be really helpful to make ourselves an idea; or at least, an approaching point of what could be a model based in this kind of technology.

Also, the reason why this approach on the renewable energy community has been made is because a need for change has to be made regardless of the current economic effects. Environmental, health and sustainability of the planet are issues that need to be addressed and with the characteristics of this project a better understanding of the situation and how to fix it can be properly done. Besides that, the huge potential of Spain as a country for this kind of technology has been the motive for this idea to grow.

2. Energy Pricing Problem

In a similar path as the rest of the world, we have seen how the energy worldwide price has been rising on the last years due various factors: Lack of supply, an equivalent increase in the price for the energy raw materials, costs for the emission of CO2; and specially in Spain's case, political reason from 20 years ago. But, before starting analyzing the effects that Spain has experienced, we have to first understand where the problematic comes from and how it has affected in a bigger scope.

2.1 Triggering factors

All Europe is battling a record-breaking increase in energy prices that has putted in alert the whole post-pandemic economic recovery. This situation constrained household incomes and retarded the so desired green transition.

Every problematic always starts for a reason. Therefore, to be able to have a clearer and more in-depth explanation of what happened, we are going to be dividing the causes/triggering factors and then analyzing them to see if they have a relation between them.

As we all know, the gas market through pipeline supplies in Europe is divided by 3 countries: Russia, Norway and Algeria. As usual response in a capitalist-based economy, when suppliers of a determined good see the price of their good go up and also having a spare capacity to supply that demand, you could use the given chance to sell more gas (energy) at a higher price rate and make more money. Surprisingly that didn't happen; and despite this high price, they have not supplied more gas to Europe. They have kept their supplies at the regular volumes, which translates in low supply against an increasingly gas demand.

At the same time; because of the scarcity, companies from all around Europe were forcing its way in order to acquire and get their hands on raw materials and energy itself. These two facts together made the price for all energy related goods to rise steadily. As a result, we had high breaking record prices by the month of August, where normally prices for all kinds of energy; but specially gas, are way cheaper than on the rest of the year. So, the effects were starting to be clear: We had prices with historically high peaks and reserves at minimum levels due the shortage of supply.

2.1.1 Increase in the cost of Raw Materials

The whole problematic started in the last's years winter. Obviously when the winter arrives, it comes together with a huge decrease on temperatures, unfortunately on 2021 were way lower than expected. People from all around Europe began to increase its energy consumption; and in the same measure, the demand for power to warm-up homes and buildings. The effect that this had was a direct decrease in gas reserves; that if a theorical 100% accounts for a full level of reserves for Europe, it soared to a 30% left by March.

Everyone thought that the surplus of energy demand was overdue the arrival of Spring Season, but they did not expect that together with the new season, the vaccination campaign would gain traction in every country; and consequently, business activities began to intensify again its workload. Offices started to open again leaving telecommuting partially, restaurants and other service focus business reopened knowing that there were a huge load of consumers desiring to spend all their lockdown savings.

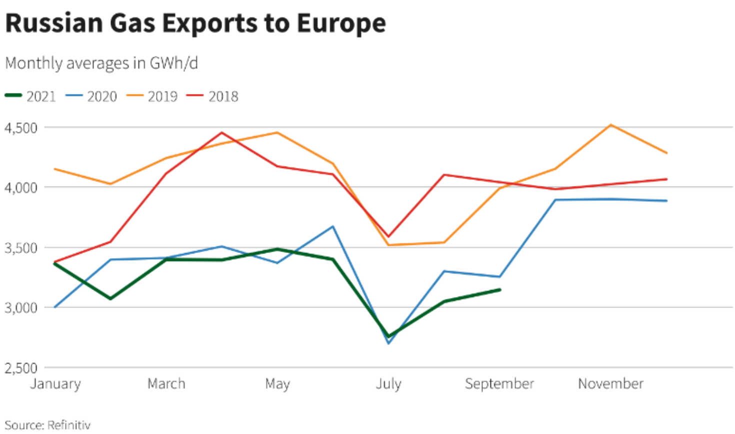
As we can see, as the economic recovery went further, further went also the wave for energy demand. This demand increased during the summer when hot temperatures forced people to use air conditioned and cooling systems. European countries like Spain were not the only ones that were starting their recovery, also East-Asian countries joined Europe countries in this energy expenditure path to re-start rapidly their economies because; as they were the originators of the pandemic, their economies were completely ravaged.

2.1.2 Political Issues

As we all know, politics are such a big part of the energetical shortage problem. Sometimes, rumors and believes of a politic action led to aster some kind of dominance. In this crisis, the role of the Russia nation has been one of this kind of movements.

We mentioned before that one of the reasons for the shortage of energy is due a lack of raw materials, that caused an increase in cost of goods. The current level of raw materials supply is that low because of Russia; EU's leading exporter, seems to be giving signs that Moscow wants to control the energetical crisis through to the controversies generated by the *Nord Stream 2.* The *Nord Stream 2* is a 1230 kilometers conduct located under the Baltic Sea that connects Russia and Germany; that although being finished a long time ago, hasn't begun working because some bureaucratic issues. This energetical project received lots of critics from inside and outside the continent due that it was enlarging the dependence on fossil fuels and asserting the geopolitical influence of Russia's president Vladimir Putin.

Some of the reasons that gave more credibility to this sore of "tyrannical" behavior from the president Putin is that the gas company *Gazprom*; the pipe's main runner, declared that the Russian government hasn't had any kind of involvement for the lack of supply problem, although they think that the stream line should be put in function "as soon as possible". Therefore, the question arises, why they want to promote the opening of a pipeline that transports a material that "in theory" is experiencing one of the highest shortages of stock ever?



On the other hand, Vladimir Putin and the Kremlin laughed at EU for refusing to sing a long-term contract for gas provision, following by pressing them to reach more flexible agreements. Besides all that, the thing that got the critics thinking that the timing for the gas shortage is too convenient for the actual energetical pricing crisis were the words of the President Vladimir Putin, I quote *"Russia can increase gas supplies to Europe as soon as Germany approves the new Nord Stream 2 pipeline"*. Also, he followed by saying *"Gazprom could increase flows by an extra 17.5bn cubic meters via the new pipeline "the day after tomorrow" if regulators approved it "tomorrow""*.

As we can see, political issues have not been able to solve, or at least provide a partial solution to the shortage of energy supply that Europe was experiencing. Even they distorted more the relations between Europe's main gas provider; Russia, and the European Union. At the same time, rising accusations of more than 40 members of the European Parliament asking to the European Commission to start an investigation for *"possible deliberate market manipulation by Gazprom and potential violation of EU competition rules"*.

2.2 Current Situation of the European Energy Market

We have analyzed the detonant and the two major triggering factors of the huge crisis in energetical crunch. Because of raw materials or maybe due political reasons, what is clear is that these two have had and still have a tremendous effect in the energetical market as far as prices concerns. In this chapter we are going to be analyzing the current situation and the possible evolution for the problematic in the near future.

In average for all European countries, the whole sale price for electricity (price stablished for what traders pay in the wholseale market) tripled in 2021 to an average of 97 megawatt-hour, acounting for the highest MWh price in almost 20 years of electricity prices. This is a clear result from the 2021 economic recovery; that since the slowance in demand for electricity, natural gas and hard coal in 2020 have sent the energetical market prices to the roof.

Numbers speak for themselves, we can see how natural gas in Europe costs as much 150€/MHw. In 2021, on average increased 49€/MWh more than the maximum and 5 times higher than in 2020. Hard coal prices also increased to more than 30€/MWh. As a result we find that between 2020 and 2021 the increase in electricty, oil and natural gas prices has been the highest and making all time records. This is why under the following increase in energy prices, if the annual consumption of a household for gas accounted for 20000 KWh, means it payed in 2021 on average 1700€; a substantial increase against the 1600€ of 2020 on average. Therefore the household payed 740€ more for gas. Same thing happens with electricity prices; due it's 18% increase, for a household of 4000KWh annually translates into having to pay 215€ more in 2021 than in 2020.

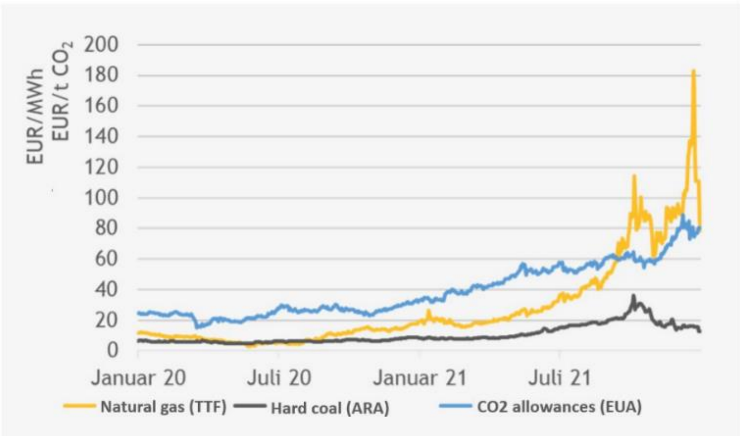


Chart: Daily fuel and CO2 allowance prices 2020-2021. Data sources: Ember Carbon Price Viewer, EEX Transparency Platform, marketwatch.com.

The situation therefore is that all the European countries are facinge rising gas prices that have driven up the global electricity price a lot more than on the previous year. To understand the current situation we have to understand how the wholesale electriticty market works.

The whole energy market sale works under the basis of marginal pricing; also known as pay-as-clear market. This makes that all energy and electricity producers (doesn't matter the source: fossil fuels to renewable) place bids in to the market and offer their energy in relation with their production costs. Usually this bidding starts with the cheapest energy resources; such as renewable energy, all the way up to the most expensive ones like natural gas.

Because almost all countries want to rely in fossil fuels in order to meet all its power demands, the final price of the electricity will be determined by the price of coal or natural gas. Therefore in the case that the price of gas becomes more expensive like nowadays, the electicity bill/price will increase according to it.

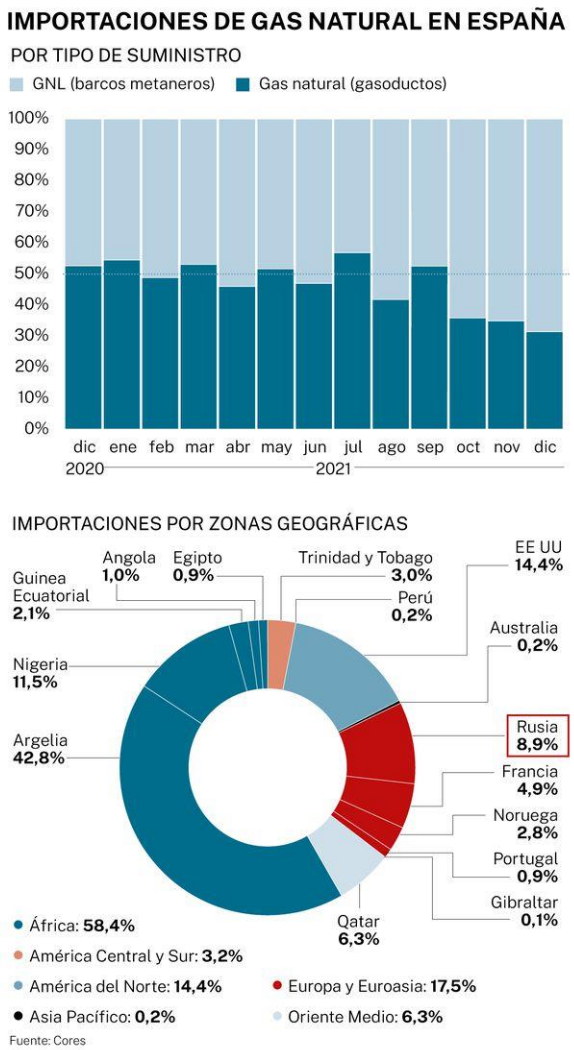
The way of how energy wholesale market works has been criticised by european member countries due that at the end of the day; by using this binding method, the final bill that the consumer have does not show the benefits for the currently greener energy transition. Although; on the other side, the majority of member countries together with the European commition think that the way that the market operates is definetely the best way; due that through a marginal pricing method, the results are more transparent, efficient and investment attractive.

One alternative to "pay-as-clear" system menctioned before would be the called "pay-as-bid". This system would allow the energy producers be able to place a bid (an offer, a price) they want from the market. By this new method we would see how the price that would be put in the market would be therefore based on offer and not on generation costs. This alternative is yet to be studied, but experts say that this method could suppose costlier bills and transparency decrease.

2.3 Current Situation of the Spanish Energy Market

As obvious as it may sound, Spain has been also affected by the European if not global energetic crisis. Lack of raw materials to be able to produce electric energy has been a pain for the pricing of electricity in our country. At the same time, Germany and other northern countries have stocked themselves up with gas coming; as we explained before, from Russia. Russia with its Nord Stream 2 problematic and threads have generated between them and the European Union members a huge situation of tension due the lack of protection against cold temperatures from the region and huge lack of gas reserves and upcoming supply.

Spain when the problematic between Russia and EU members started was in the beginning affected but not in a huge way. Time went by, and not to long after, Argelia who has been the main gas provider for the last 30 years stopped the service due the non-renovation of the gas suppliance contract on the 31st of October of 2021, and together with the political tensions between Argelia and Marrakech arising, we lost the first, one and only pipeline that most capacity holds in terms of suppliance to our country; the so called GME (Maghreb-Europe), that crosses Marrakech and connects with Europe through Tarifa's sea ground.



On the other side, although we can rely in the *Megdaz*; the pipeline that comes straight also from Algeria, it does not have even a 50% of transportation capacity that the GME had. In consequence Spain has been found under the necessity to switch to liquefied natural gas, that is imported via maritime; supposing an increase in cost 150%, in a period of time were Spain is also suffering from historically high electricity prices.

This situation has made United States in 2022 overcome Argelia in terms of main gas supplier for our country, covering 34.6% of our demand. In January of 2022 arrived from the US through their trans-oceanic ships 13103 GWh of liquified natural gas through the Atlantic, against the 1961GWh imported a year ago in 2021. On the other side; Argelia who was until then, the leader in terms of gas exporting, has only supplied 25.4% of January's Spain demand with a total of 9620 GWh. This situation was already been predicted during the past year, where there were similar tendencies on gas exports from both countries, US was getting a bigger stake and Algeria was reducing its.

In resume, in 2022 Spain's has updated its importing patter by switching to liquid natural gas (65.7%) and leaving behind raw natural gas with a 31.3% of the total gas imports. This numbers account for a change on tendencies as mentioned before; due that in 2021, the imports of gas were 45,5% and 54,6% respectively. It seems fair to mention that Spain does not only imports liquid natural gas from the United States, it also imports it from other sources such as Nigeria (13,3%), Oman (5.3%), Russia (5,8%) and small stakes from various countries like: Egypt, Guinea Equatorial and Trinidad y Tobago.

The current tensions between Russia - Europe and Argelia – Marrakech together with the change of supplier from Spain; by switching from natural gas to liquified one, has put our country in a key position for the mission to warm Europe. Because of the bellicose conflict in Ukraine and the consequent shutting down of Russian pipelines, European Union has reached us to help regasify the liquid natural gas imported and then send it to Europe through the Pyrenees pipelines. This plan was mainly assembled because of three reasons:

- Spain's capacity of regasification (7 out of 20 European liquid plants of natural gas are located in Spain)
- Spain has Europe's 30% and 25% capacity of storage and regasification respectively
- Indirectly to reduce the gas dependance and avoid then negotiation with Russia

Therefore, Spanish role in the actual economic and energetical crisis can have a key factor in the lives of the European citizens from Northern Europe that need desperately gas to make live sustainable during their cold winters.

On the other side; as we have been analyzing, the motives for the war are various and all related to the shortage of supply because of actual non-existence of it, or maybe for political reasons both in Russia and Africa. But Spanish electrical system in particular has other problems non-related to suppliance or political tensions between countries. Spain has been having an endemic problem on their own electrical system for more than 20 years. And various presidents have tried to arrange and find a solution for a problem, that nowadays seems impossible to fix which translates in consumers becoming the ones to pay for their try-to-fix failed attempts.

During more than two decades, all governments that have been elected to lead the Spaniard country have been trying to dissemble, fix and re-build a system clearly almost dead. This situation plus the rise on electricity prices due the increase of gas and the C02 emission expenses rose have made the consumers having to deal with political costs that account almost a 50% of their electric bills.

All changes started in 1997 with a transition to reach a further adaption with the European electric market (*Ley del Sector Eléctrico*). The next three years after that, politicians started making changes in order to try to reach for a more liberalized and competitive energy market; but in the year 2000, the *Tarifa's deficit* arrived because of Rodrigo Rato. Rato was the economic vice-president under Jose Maria Aznar's presidency.

Aznar; under the advice of Rato, stablished *"El Real Decreto 1432/2002"*, this decree stablished that an electric tax or rate could never be bigger than the IPC, even if the cost of making energy became more expensive. This deficit-based system was made to achieve the inflation requirements made by the European Union as a condition for the newcomer countries that wanted to join the euro. Obviously, basing a system on a deficitary strategy was not such a great idea, and that can be clearly seen because in 2002 the deficit surpassed the 1000 million euros, obligating to the current president Jose Maria Aznar to make consumers pay for the expenses with an increase of a 1.5% in the electric bill two years in a row; 2003 and 2004.

As years went by, the deficitary electric system proposal in order to keep with the European inflationary rates were doing its duty. Although the inflation rate achieved was enough for Spain to enter the Euro, we can see that the deficit stayed until the end of Aznar's presidency in 2000, accounting for at least -70 million of euros, peaking in 2002 with a deficit of -1297 million of euros.

From 2004 to 2011 entered in the presidency of Spain the Socialist party, leaded by José Luis Rodríguez Zapatero. During his presidency, there was a really aggressive investment and gamble for renewable energies. The problem was that renewable sources were in a really early stage of development and although it was not a bad idea what they were proposing long-term, the expenses on green technology in the early 2000's were too high to even try to gamble for it. In consequence this investment in renewable energies supposed a huge increase in the electric system costs with deficit numbers even reaching the accumulated -26000 million of euros in 2011.

In the year 2004 we had a deficit of -182 million, then in the year 2005 we were under a deficit of -4089 million of euros, the price MWh went from 27.94€/MWh to 53.68€/MWh from 2004 to

2005 respectively; computing for an increase of 92.12% from year-to-year price. Once again, the bad management from the government in electric system had to be paid by the consumers that had to deal with prices for MWh between 39.35€/MWh up to 64.43€/MWh in Zapatero's presidency and never returning to prices below 30€/MWh like with Aznar.

When in 2011 Zapatero's presidency finished, it leaved behind terrible repercussions for the electric system in Spain. Then in 2012; for better or for worse, the new president Mariano Rajoy had to apply some of the biggest measures of the history of electric system to guarantee the sustainability of the system. In 2013 *Tarifa's deficit* peaked with 28700 million of euros accumulated of deficit; meaning that during that period, the billing of the whole system was equal to the accumulated deficit. In order to reduce and revert de situation, the reform made in 2013 consisted in:

- An increase in consumers bill by 3.2%
- An increase of the access tolls by a 6.5% (Access tolls are a stake of the consumer's bill that account for the cost of making the electricity or gas arrive to your home)

These two changes were made with the aim to gather 900 million € to cover the deficit. After them, they applied:

- A tax of 7% on electric companies for the generation of electricity

This tax in particular was applied to gather annually an extra 1700 million of €; that in reality, was being paid by consumers. The electric companies in charge; as they are private entities, were charging the effects of this new tax to consumers through their electric consumption bill.

On another side, other 900 million were given by the "*Presupuestos Generales del Estado*" to cover the additional costs that supposed all the out-of-peninsula electric infrastructure; territories such as Ceuta, Melilla and islands. In addition; the increase made because of the tax collection, accounted for cuts in distribution and earnings, that were made in order to gather extra money to solve the problem. At the end, the problem was never solved or fixed, just were subsequent temporally patch after patch.

In conclusion, more than two thirds of the *Tarifa's* deficit were made with socialists energetical models. In my opinion, it would not have any sense for both political parties to be pointing each other regrets when both of the political parties created deficit.

This situation happened due that they refused to make consumers pay for costs that were due to pay; all because they didn't want to lose their favor in the government elections. On the other side; we can all agree that at that time, investing in expensive renewable technologies as we did was not a smart move because it enlarged the deficit, creating a budget whole that the consumers ended up having to deal with because; at the end, if the government imposes high taxes on energy companies, they are going to derive those extra costs through the consumption bill to consumers.

Therefore, what can be clearly seen is that we need a change in the structure of our energetic system; maybe the creation of a public company of energy, or maybe switch to green energetical sources, but what is clear is that Europe and Spain both are now starting to experience the effects of wild consumption in our electric bills and we need to start to apply some changes before the actual situation gets more out of hand.

2.4 Consequences of the past and present situations

In the chapter before this one, we have seen what are the main causes of the current energetical crisis. From raw materials shortage, to political tensions “war”. In the case of Spain, we have seen even endemical problems in the internal electric system foundations of it. This is why; whatever are causes we have seen in the past, the consequences that we are going to be facing in Europe and Spain are going to be really nearly identical, volatility and inflation. One is going to be the detonator of the other because the inflation of prices comes from a volatile price of energy, that makes prices for electricity go higher, affecting households, companies and countries.

The position of the European Union against this current volatile behavior of energy prices have become an actual endemic risk for the economy until the expected green energy shift arrives to bring stability to markets. But until that happens, volatility in terms of energy prices would be the “new normality” if governments from each country do not apply any kind of measures to control it. For example, one of the main ideas that has been thought to control these levels of volatility in energy prices; that as we have seen affects lots of other markets in terms of inflation, can be lowering the tax rates in energy therefore reducing the energy bills. These measure here in Spain has been applied, Spanish government has reduced the electricity tax from 5.1% to 0.5%.

Together with lowering the tax rates, some other measure that can be applied in order to control this volatility and try to help the most vulnerable would be:

- <u>Introduction of Social Programs</u>

Social programs that are going focused in the relief and help of the poorer and vulnerable households and medium/small businesses. The main objective behind it is to try to prevent households and firms to see how the electricity supply to their homes and entities has to be cut off because them being unable to face extremely high payments.

- <u>Pump cash into the economy</u>

The idea that many governments are looking because of the current volatility and inflationary tendency of the economy is to inject high quantities of cash into their economies like France did with their "*chèque énergie*", were they tried to help households and firms by giving cash checks to pay electric bills and other utilities.

- <u>Energetical Firms renegotiation of contracts</u>

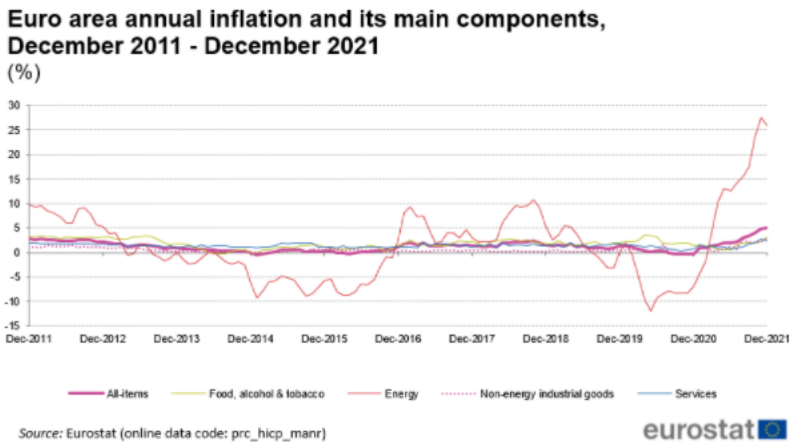
Another alternative that governments all around Europe have been trying to apply has been renegotiating the electricity-providing contracts that they have with its respective energy firm providers. The main intention behind this is to change a bit the energy market binding system where the energy is sold according to the production costs, therefore if instead of this energy providing, or firms could give a fixed price for energy supply rather than a variable and volatile one, households would have a predictable and more consistent price.

The main reason for governments to negotiate with energy providing firms a fixed-bill for consumers, is because variable ones are more effected by random fluctuations. Then when energy prices go down; like on the 2020 where pandemic, households' bills become deeply underpriced. On the other side, when the energy price go up like on the current energy market situation, consumers then have to face extraordinarily high bills.

In the case of Spain, we have seen how the government stablished a reduction on the fiscal pressure in the electricity bill. This with the intention to reduce as much as possible the negative effect of the rising energetic prices. The fiscal measures applied by them consisted in a reduction of energy taxes from 21% to 10% over the price.

From extreme volatility caused during the last year, we have seen how the energy prices have been constantly rising and have become one of the main causatives of inflation in Eurozone countries. Nowadays, we account that we have experienced an increase of the 3.2% in terms of food prices; even arriving in some cases like in December, up to 5%.

In terms of production prices, which account the price that a producer has in order to transform some input in an output, rose by 24.2% from December of 2020 to 2021. This increase has accounted for one of the highest rates recorded and clearly showing a trend of rising inflation. These increases in the production prices have indirectly affected consumer prices and also competitiveness for companies on the global market due that if producing prices rise, costs rise, and in consequence the final price.



This translates in an equal reduction of households' purchasing power and reduction of the product possibility to be sold abroad due the increasing difficulties to compete with pricing of foreign products.

These measures mentioned above are becoming key during this period of extremely high volatility. The main objective has been controlling inflation and having stability in terms of prices. But what has become obvious is that these measures; although are good and really caring for the economy and households, have only a temporally lifespan because the current energetic situation cannot be hold or controlled only with these measures. This has led besides all the bad consequences of the current energetical worldwide crisis, to some good repercussions from it. The best and most important has been the contemplation and goal setting from the European Union to finally make a solid transition to green/renewable energy.

One of the biggest steps in this transition has been the obligation from the European Union to force power supply companies to be part of the EU's Emissions Trading System, or also called ETS. ETS is the world's biggest carbon market, its design is based on "cap and trade", which accounts for a system were governments set a maximum emission permission for a company (only one permit, is not a regulation for all companies), that allows them to have the right to pollute until a certain quantity. This right can be sold, and acquired for a monetary exchange with another company. The main objective with that is that by guaranteeing some pollution permission, you avoid having levels way higher than what you may have without it. At the same time, it also benefits companies that have reduced a lot their emissions due that they can earn extra money for not having pollution needs due its investment, and then selling these permits.

In the case of Europe, the European Union decide a cap on the greenhouse gases permitted for the firms to release. At the same time; it creates <u>permits per unit</u> of carbon emitted, allowing companies to buy and trade these permits among them depending if for their activity have higher or lower pollution needs than the other companies. On the other side, the European Union each year tights the cap level and charges more for the permit prices, generating a tendency for companies to abandon fossil fuels and change their energy supply to greener options.

3. Renewable Energy Communities

As we have seen in the previous chapter, the worldwide current energetical crisis has left the European, and therefore the Spanish economy in a really harmful position. Volatility in terms of prices, together with economic inflation are some of the final effects that the lack of raw materials shortage, political tensions and the designed structure of energy wholesale market has left to us. Households and consumers with all these events have suffered a huge loss of purchasing power because of the huge bills energy bills they have to pay and having to deal with increasing production costs for goods that they end up paying for.

On the other side besides all the bad repercussions and because of the bad functioning of the energy "environment" we are experiencing now that a need for a change has arrived. Nowadays more than ever the request for a transition to a green and sustainable energy is in everyone's mouth, and the solution to achieve the European Union plans of zero percent of carbon emissions by 2030 may have been invented decades ago. We are talking about Renewable Energy Communities.

Energy communities' main function is organizing and conducting collective energetical actions that are going to help us lead the way to the so desired energy transition. Also, the citizens would become the ones in charge of this evolution. At the same time, renewable energy communities have a really active role in working for the acceptance of renewable energy and its respective projects. This work on acceptance is primarily done to enhance the attraction on private investments and new capital on the green energy transition. Last but not least, energy communities can broadly help individuals and citizens that joins them to step up on their energy efficiency and flexibility; allowing them to lower their consumption, and as consequence lowering their electricity bills and starting an energy storage option for their green produced energy that can supply future personal or third person demands.

The objectives and motivations achievable through renewable energy communities (by community meaning a group of people that share something between them) are in most of the cases shown in the motivations of the members that wants to join or already are part of the "organization". In other words, the analysis of the individual motivations and the contextual factors surrounding the community will help determining the nature of the project, together with its past and future direction. The objectives and motivations of projects and of its participants can be diverse, but it can be easily classified in:

- Project Motivations

These motivations make reference to all kind of objectives and goals the main project and the community have and wants to reach. Each project has its own goal and objective to reach, the motivation from the individuals is what shape and distinguish it from other projects with similar goals.

- Individual Motivations

Individual Motivations are what gives the level of differentiation between projects of similar nature. Inside the project, individuals within the big and common objective are going to try to satisfy their own without compromising the global objective. The three main types of motivations that we can find for a community to pursue are: economic, environmental and social. For obvious reasons, environmental motivations are the ones that seems to be more frequent among projects, some examples of environmental motivations are diffusion of nuclear power (between 1970 and 1980 was one of the main environmental forces) or climate change (that has been the main topic from 1990 until now).

On the other side, economic motivations which are the second main motivation for renewable energy community projects are closely related to the type of project it is stablished. Some examples for it would be if a project offers a return on investment for the participants, then that would become an economical motivation for an individual to join a project. Or on the other side, if a community offers energy supply to its participants for their own consumption, this would benefit them economically by reducing their energy bill.

Last but not least we find the social motivations, that although they are as important as environmental or economic motives, the mere fact that an individual chooses to join a renewable energy cooperative is automatically making them concerned and having social motivations (because of its global characteristic, some experts doesn't know if catalogue it as a motivation or not) but for social motivations can account: social identity with a group, relational goods and peer feeling, and even political motivations. Therefore, motivations far from materialist perspective, are fundamental for the psychology of the individual.

In conclusion, renewable energy community projects are really diverse, objectives and motivations that define each one of them makes them even more distinguishable. But what is clear is that the role of the individuals within the community helps outlining its nuances and defining the willingness of people to participate in the project; and also, to determine the potential of it in the near and far future.

3.1 History of energy communities

Now that we have presented a bit what renewable energy community projects are, we are going to get a little bit in depth on its story, to see where the concept was born and in what places from the world these projects have more presence. As some may know, the first appearance of a renewable energy communities is accounted in the mid-seventies; in Denmark, and later on followed for other European countries such as Germany and UK. Denmark has been always a leader in terms of wind energy, fact that shows the huge relation of the country with green and sustainable sources.

3.1.1 Denmark

As said before, Denmark was the country where the first renewable energy community project was found, project that obviously was based and helped in the development of wind sector. The first renewable energy community project was born in 1970 after the oil crisis that Denmark suffered. This oil crisis made them think, and almost reach out to nuclear energy to supply themselves with the energy they needed. Thankfully they started researching for alternatives (besides the nuclear) to be able to reach their needed levels of energy. After couple of years, they began with energetical experiments related to wind due the huge amount they had in the area. Once they reached with the formula to exploit that; they began not only with its own self-sufficiency, they started the commercialization of wind energy. This huge investment was firstly financed through an entrepreneurial civil society that gave a substantial contribution for the initiation of the project.

After this, a huge spread of local wind energy cooperatives were born in the following two decades after the commercial decision. These cooperatives invested huge quantities of money in the development and installation of turbines to generate the so desired energy. Estimations show that around late 90's-early 2000, most of Denmark turbines were owned by those cooperatives and small owners. The following years a huge success in the energetic industry by Denmark was seen, were almost all of its energy production was wind generated and having huge economic gains from it. This success from the small owners and wind cooperatives happened due two main reasons:

- Local Communities participation
- Industry focused development

When the idea for the development for wind energy appeared, the translation to its success happened because there was a common settlement for it with industrial policies that favored the way by enhancing big investments on it, economic support, tax removals and feed in tariffs.

In addition to these reasons, there was a huge role from Danish local authorities in the energy sector; that together with a decentralized market, generated a huge supportive environment where you could find local authorities and communities working together with the politic side for the creation and establishment of wind farms. This wind farms ended up being owned by farmers/households or companies and its investors, locating them in rural areas (because of their strongly windy lands) in lots of small parcels.

When the early 2000s went by, a change of the Denmark government rulers happened. This new government was not against, but was way less supportive of green technologies. In addition, this new government issued for the liberalization of the electricity market; that in consequence, supposed such a strong hit for the developed local energy model based on cooperatives, which accounted basically all the renewable energy sector for Denmark. Later on, between 2003 and 2007 all the funds destined to the renewable energy were suspended, also the tariff scheme that was years later designed in order to favor the development of the renewable energy was replaced and generic renewable energy fiscal system was stablished. In consequence to this, during these two four years of governance no new wind turbines were installed in Denmark. In addition, because of the harsh policies applied, also huge quantities of wind cooperatives collapsed (especially the ones that were newly stepping into the game).

After the new government party left in 2007, protests and activists against new wind projects appeared, but in 2009 a new tariff system was introduced that supported again the green development and enhanced again the creation of new wind turbines from new large project developers and investors, not from the local communities and entities like before the restrictions.

Some of the measures that Denmark government applied back then are still present up today such as: a local community fund to give financial support to existing and new turbines and a commercial character fund to finance the construction of new projects related with wind energy. These legislations applied after 2009 paved the way for Denmark to have nowadays more than five thousand wind turbines, of which more than 20% of them are owned by cooperatives, local farmers or landowners. In addition, from all the companies behind these turbines, all of them have to give by law 20% of their shares to local communities or entities.

3.1.2 Germany

In the case of Germany, the model on which they have based its energy system has been slightly decentralized. Although federal entities give and sets the objectives and targets to reach for, the main states of the country have margin of decision by choosing at their pleasure how and when implement each project, their allocation and what kind of subsidies they want to give to each of them.

Besides Denmark, we can see how Germany has also a huge tradition and history of energy local cooperatives entities. Although most of them have been privatized, still there is a huge number of them being locally owned by cooperatives. Nowadays; although they still a huge amount, the number of wind cooperatives have been drastically reduced in comparison of solar cooperatives. On the other side, wind cooperatives have a far older story than solar ones.

For wind energy cooperatives all began in the 1990s with huge helps from the German government through a fiscal system feed-in tariff model. This made that the generation of electricity of this group became larger than the solar source. As the years went by, privatization, competitors and commercialization of this kind of energy generated a reduction in public ownership of wind sources. Nowadays the number of wind capacity still owned by local communities or German citizens is still pretty high with a 20% of the total.

On the other side, solar cooperatives have been in Germany kind of the new because of their recent appearance in the renewable energy cooperatives game. Unlike the wind cooperatives, solar ones are based in a collaboration between local government and citizen's model. Its origin as said before has been kind of new because it happened after the 2008-2009 economic crisis where all countries in the world were looking for the creation of new economic models. This necessity for something new also in terms of energy suppliance made solar cooperatives grew in such a fast way, going from only 4 cooperatives in 2007, up to 200 in 2010.

In Germany the beginning of the renewable energy sources idea took place because of the political strategy named *Energiewende*. This concept, that in English accounts for energy transition, has been a plan developed by Germany back in 1980s when the anti-nuclear protests and movements were strong around Europe, this concept evolved over time and even became a government program in 2010. The main objective that *Energiewende* over time has been to achieve a low-carbon, nuclear free energy system. This strategy arranged in 1980s has been instituted in Germany, with the main objective of gaining public support that; once achieved, explained the participation and involvement of citizens and communities in the renewable energy area. The results for Germany thanks to the *Energiewende* are easily identifiable in its huge stable policies and regulation framework for the renewable energy communities' sector and the huge commitment of German society onto it.

3.1.3 United Kingdom

The last of the first countries where the concept of renewable energy communities took appearance is United Kingdom. Although we are going to get more in depth, we must say that after twenty years since its appearance in the country of Britain, the participation and usage of this type of source in the British electrical system has been really limited and scarce. One of the reasons for this to happen has been that when the renewable energy communities appeared in the UK; during the ear 1990s, the electric market had a huge and extensive presence of liberalization and privatization. This directly translates in a system dominated by international groups and with a minimal presence of local or public entities.

This situation was not an ideal starting point for renewable energy communities to arise; but thanks to some renewable energy sources support policies, the appearance of the first projects began be set on place. Although this was a step forward for the United Kingdom, this first project had a structure based in an open market mechanism, this feature made it difficult for small-scale projects to succeed and acquire benefits from it. As time went by, the *renewable obligation scheme* (the name that the support policy acquired) helped to promote projects every year regardless of their generation capacity. At the beginning, only projects with the capacity to provide more than 50 Megawatts were allowed but as time went by projects of smaller plants (50 kilowatts minimum) were allowed.

For the United Kingdom the introduction and later development of renewable energy communities had since its beginning in 2000 a competitive problem due lack of technology differentiation and also, because of the lack of rural development in terms of community enterprises uncharged of energy development. These problems held United Kingdom's development on renewable energy communities for 10 years. For UK's renewable energy communities, the year 2010 supposed a turning point in terms of development thanks to the introduction of a feed-in tariff scheme. This new fiscal policy stablished together with public loans and tax incentives, an incredible and really effective results in the stimulation on renewable investment. From 2010 to 2014, the number of community owned capacity went from 28 Megawatts to 105 Megawatts. This happened because of the risk-reduction and as consequence of the new tariff and fiscal scheme, that attracted new financial investments and resources to the game.

This period of growth came to an end in 2015; when in a similar scenario as Denmark, a new and conservative political party became elected. They reformed the whole structure made for the renewable energy applicability. This new government bet on renewables obligation and contracts, which are obviously designed for large projects and companies. By this, they made again the United Kingdom's future of renewable energy communities uncertain once again.

3.1.4 Needs for a sustainable Renewable Energy Community

After making a little research and summary of the renewable energy communities' history around Europe and countries with a bigger development on them, we have seen that for renewable energy communities to be created and subsist, some factors and conditions need to take place. From all countries, I have seen that only 3 conditions need to apply:

- Supportive Policy Framework

Renewable energy community projects are most of the time small in terms of electric generation capacity in comparison with larger/commercial projects, and if they have to compete with one another, the first ones have absolutely no chance to be competitive because of their efficiency production level. On the other side, renewable energy community projects are a risky type of investments, this is why they have always fund rising difficulties. Therefore, giving them tools to reduce the level of riskiness of the investment and attract capital to develop projects is mandatory. Some of the tool's government need to apply are feed-in tariffs; that as we have seen in the 3 countries before, is the most effective tool for renewable energy community projects development.

- Local Authorities Role

For a renewable energetical community project to be fully developable, local authorities have to be able to identifying opportunities in those projects and then play a key role for their forward development. At the same time, these local authorities need to be aware and have some knowledge about the energy sector before starting the collaboration with the initiators of the renewable energy community project. Because as we have seen in many countries; due privatization of the sector, having no idea or control of the sector and getting in involved in it can harm it more than we can think.

- Government Switches

Not all parties knows the benefit of renewable energy and the good influence and impact it can has in our health and future. The fact that the election of a different political to run the country can make that if they are not in favor of green technologies and energy create new energetical policies reforms that will end up erasing the development of renewable energetical projects stablished in the previous political period.

3.2 Renewable Energy Communities impact on Society

The development of renewable energy communities has affected in the structure and way of functioning of energy markets. Renewable energy community projects also have a consecutive effect on the economies surrounding it, in a major or more local way. At the same time, the appearance of this type of energy source, can generate an increase in the levels of support for renewable energy and citizen's environment awareness. The impact that renewable energy communities can have in society and economy for members and non-members communities is mandatory to be able to define the framework of regulations and policies that will support and help in the development of the project; and at the same time, reducing its risks and costs.

The evidence of renewable energy communities in different countries is diverse, weak and even in some places biased. But case studies, interviews, surveys and other study sources have shown us that between the effects caused, exist some kind of correlations related to the type of renewable energy community. On one side, the energy community of place tends most of the time to have stronger local economic impacts than communities of interest (private or of other kind) that most of the time, tend to have less focus or less intrinsic value.

On the other side, the type of legal entity chosen to develop the project on can be important to determine the response of the people in accepting the project. In addition, the governance chosen for the internal structure of the community government can help in the local economy's impact by the project (for example with the decision of on or what invest the profits).

In conclusion; if we analyze the level of influence or the potential of a renewable energy community project, we see that as more local ownership has the project and more policies are made towards it, larger and stronger positive impacts these projects are going to have in the local economic development of the region.

3.2.1 Renewable Energy Communities impact on local economy and energy system

One thing that renewable energy community projects have to differ from the traditional energy projects are it's starting costs. Because of the lack of perception of them being a professional organization, some lack of confidence from other members of the energy market can be present. Therefore, the projects based on renewable energy tend to be perceived as riskier than the traditional ones.

At the same time, although renewable energy community projects may have higher direct costs, those are compensated with the positive impact they have in the economy, communities, environment and on its own members. Some examples for it may be the increase in the number of jobs they create around their projects, increase in terms of GDP on rural areas and the usage of local suppliers, technicians and professionals.

These benefits can be clearly seen in the return on investment for members, redistribution of revenues and job creation. At the same time, revenues generated by the projects can contribute to finance and support the so desired welfare state that includes: education, social care, culture and housing. Or for example, can be used to be reinvested in finance energy savings and investment services.

What it should be clear is that renewable energy community projects are perceived as new and challenging ''threat'' for the so stablished traditional system in the energy sector. And; although some negative impacts may arise from the development of this renewable projects, the fact that so many positive effects are confirmed in various fields such as: financial, energy flows, market structures and final costs for consumers. Make that their values towards inclusion and solidarity become something that passes unaware for most of society.

3.2.2 Renewable Energy Communities impact on energy transition

As we have previously seen, renewable energy communities present projects for the development and obtention of new and cleaner energy. But besides being a supplier of ideas and alternatives, it can also have a major role in helping the population to overcome the fear of renewable energy projects at a local level.

Studies show that when we are talking about acceptance of renewable energies, we need to divide this acceptance in two or three types:

- Community Acceptance: it makes reference to the acceptance of renewable energy plants from local stakeholders.
- Socio-Political Acceptance: it makes reference to the support and acceptance from the stakeholders, investors and public opinion.
- Market Acceptance: it makes reference to the acceptance of some type of technologies of the market and their diffusion on the community.

Therefore, what has been able to extract from this is that for each type of project and technology being used in, the level of acceptance is going to differ from each of the three acceptance groups and; in consequence, the level of energy transition that is going to be experienced. In addition to it, community acceptance relies on the personal experience that you have had around renewable energy (for example living around a plant) acts as a solid indicator for a substantial increase in renewable energy social acceptance.

This is the reason why renewable energy community projects tends to make energy transition better for newcomers and for people that already had been involved in renewable energy. These community projects give participation and ownership to the community where it is placed; and also, asks citizens to play a role on it. By his methods, the involvement in the project rises together with the understanding of what it has been done there. Later on, they see the benefits from it. This is why we can say that renewable energy community projects tend to help communities and their respective individuals to be more supportive on taking action against climate change, be in favor on renewable energies and public policies supporting them.

On the other side, it is fair to be said that not all the energy transition acceptance and its good relation with renewable energy communities project is going to make disappear all the opposition against them, sometimes economical or indirect/future well-being benefits are not going to be enough to compensate for the fear of losing their quality of life.

In conclusion, changing the perceptions of those who can be against of renewable energy is going to be hard, biased and limited.

3.2.3 Renewable Energy Communities impact individuals' behavior towards energy

We have been analyzing towards various studies how renewable energy community projects can influence on local economy, energy sector, thoughts, considerations towards energy transition and switch from traditional sources to more renewable and green ones. Last but not least, we will be analyzing how for better or worse the renewable energy community projects can impact on ones' behavior in energy consumption. This is what has been shown from multiple studies; specifically, in one done in *Ecopower*, a Belgian Cooperative. In this study, they were compared to a sociodemographic sample from Belgium and they saw that the electricity consumption is positively correlated with being member in a cooperative.

Therefore, the idea that for individuals/people who has higher energy consumption may have more reasons to join a renewable energy source cooperative right? This is a correct statement because renewable energy community projects provide multiple things besides greener energy. The one that may interest this type of consumers may be assistance and advice on energy consumption and efficiency. Therefore, these projects do not only look to just change the way or source from where we are going to obtain the energy, it also tries to change perceptions and behaviors towards energy saving and conservation.

The results from the *Ecopower* study showed that 64.7% of individuals who had joined a community project were now saving more energy. Also, from this sample of individuals, a 37% showed that these change in energy consumption were not decision-based, it was as a consequence of services and advise provided by the cooperative. In addition to it, what also needs to be accounted is that because they are part of a cooperative, saved energy is still existing due that the main individual works as supplier and demander of the good. Therefore, from this 64.7% individuals that started to save this new energy have also shown signs of flexibility in terms of energy treatment because now they are able consume it or sell it; and besides that, still having its current scheduled production.

Therefore, we can extract from this study is that renewable energy community projects besides providing energy alternatives, they provide development of knowledge and skills in so different areas such as project management, energy technologies, business development, communication, finance and law.

All these attitudes and qualities are learned through time and length of membership in the community. The sense of community potentiates all through social environment for their members to motivate each other to become better in energy saving and other related fields.

4. Practical Part: Proposal of a Renewable Economic Model

4.1 Problem Presentation

From the beginning of this project, we have been analyzing the causes and consequences of the shortage of energy supply that Europe and Spain are suffering nowadays. As a partial or total solution for the problem, a following proposal of an economic system based on renewable energy supplied by renewable energy communities is going to be developed. In this final part of the project, we will be testing our hypothesis of economical sustainability of an economy based on consumers owned renewable energy projects. To do this so, we will be assembling an infinite horizons macro-economic model where through taxes, government is going to be the one fully financing the project. Then; besides checking and testing the sustainability of the model, we will try to see if for the model agents: households, firms and government; a hybrid renewable energy system (combining renewable and non-renewable) helps to improve and maximize the utility, efficiency and sustainability of the them.

For us to be able to assemble the model, we will begin asserting the different types of parameters and variables that later on will be used in the model. When that is finished, we will be constructing with the variables and parameters presented the utility functions and restrictions for the three main agents. When that is finished, we will be trying to find the equilibrium and consequently the steady state to try to solve the problems for Households, Firms and Government. At the end, we will be analyzing the results obtained from computing the equilibrium to check the sustainability of the model and its behavior.

4.1.1 Endogenous Variables

An endogenous variable is a variable in a statistical model that changes due its relationship with other variables of the model. In other words, it is a dependent variable that expresses what type of change expresses a variable. In the model created for Households, Firms and Government we are going to have endogenous variables accounting for example: The amount of labor firms is demanding, the amount of the community project the households are going to be in possession of, the level of household's consumption and the level of energetical consumption…. All of this with its respective mathematical expression that can be seen in the table below.

Endogenous Variables	
L_{st}	Labor Supply
K_{st}	Capital Supply
C_t	Household Consumption
L_{dt}	Labor Demand
K_{dt}	Capital Demand
I_{gt}	Government's Investment
K_{gt}	Government's Capital
ES_t	Energy Consumption
ER_t	Renewable energy Consumption
ENR_t	Non-Renewable Energy Consumption
ES_{Ht}	Household's Energy Consumption
ES_{Ft}	Firm's Energy Consumption

4.1.2 Exogenous Variables

Besides the endogenous variables, we find another type of variables that I have considered mandatory for the construction of the model/problem, the exogenous variables. These types of variables are considered the opposite of the endogenous ones, they have a completely independent behavior. In conclusion, they don't dictate or correlate any change in another variable. In the table below you can see what are the exogenous variables I have chosen to construct the problem:

Exogenous Variables		
P_t	Production Prices	1
P_{Ct}	Price on Consumption	1
P_{It}	Price on Investment	1
P_{ESt}	Price on Energy Consumption	1
TR_t	Transfers from the Government	0
A_t	Productivity / Technological Progress	1

4.1.3 Parameters

Last but not least, to be able to compute the model/problem on renewable energetical community projects I assembled a hand of model parameters that are going to help me estimate it. A model parameter acts as an internal variable for the model, this characteristic makes parameters a must to be able to make predictions and estimate data. You can check in the table above the parameters chosen to develop the problem:

Parameters		
σ	Elasticity between goods or energy consumption	0.33
ϕ	Renewable Energy Share	0.429
η	Disutility from the supply of labor	0.429
ν	Elasticity between Consumption and Labor	1.429
δ	Depreciation of Capital	0.05
δ_g	Depreciation of Public Owned Capital	0.05
β	Discount Factor	0.9615
α	Share of labor expenditure in total output	0.40
λ_S	Elasticity between consuming Renewable or Non-Renewable	0.0598
θ	Capital stock's share	0.99
χ	Integration Cost	0.50
γ	Elasticity between capital stock and energy service	0.47
φ	Share of Renewable Energy on Total Energy	0.45
A_r	Productivity of the public capital stock in renewable energy production	0.0328
T_C	Government Tax over Consumption	0.21
T_{ES}	Government Tax over Energy Consumption	0.0511
T_W	Government Tax over Labor Wage	0.20
T_K	Government Tax over Capital	0.07

4.2 Agents Construction for the Problem

4.2.1 Household Problem

As it has been said before; after assembling the proper parameters and variables for our model, we are going to be developing the problem for the consumer/households. Firstly, we are going to be presenting the household utility together with its proper restriction. After that; and trough Lagrange methodology, we are going to be extracting the respective partial derivations for its variables that later by using substitution, we will use to find their respective Euler Equation, optimal household capital and labor supply, and households energy consumption.

$$\max_{c_t,\, ES_t^H,\, l_t^s,\, K_t^s} \sum_{t=0}^{\infty} \beta^t \ln\left(\left(c_t^{\sigma} + \phi\, ES_t^{H\,\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu}\, l_t^{s\,1+\nu} \right)$$

s.a

$$(1+\tau_c)P_t^c C_t + P_t^I\left(K_t^s - (1-\delta)K_{t-1}^s\right) + (1+\tau_{ES})P_t^{ES} ES_t^H = (1-\tau_w) W_t l_t^s + (1-\tau_k) r_t K_{t-1}^s + TR_t$$

4.2.2 Firms Problem

Once the consumers problem establishment is finished, we will arrange the restriction equation for the firm. The firm's equation will help us determine the equations to find the optimal values for Labor demand, capital demand, and firm's energetical consumption. Below we will be addressing the Firm's utility function together with its restriction.

$$\max_{l_t^d,\, K_{t-1}^d,\, ES_t^f} P_t . A_t\, l_t^{d\,\alpha} . \left(\theta (K_{t-1}^d)^{\gamma} + (1-\theta) ES_t^{f\,\gamma} \right)^{\frac{(1-\alpha)}{\gamma}} - W_t l_t^d - r_t K_{t-1}^d - P_t^{ES} ES_t^f$$

4.2.3 Governments Problem

Once the two main agents'; consumers and firms', utility and restriction functions have been assembled. We will proceed to develop the equation for the public agent, the Government. As we all may suppose, government is mainly financed by tax collection. As mentioned before, taxes are parameters that will be adding to each one of their respective endogenous variables (such as wages or Energy consumption) to determine what quantity of it is paid to the public state.

$$\tau_c C_t + \tau_w W_t l_t + \tau_K r_t K_{t-1} + \tau_{ES} P_t^{ES} ES_t^H = I_t^g = G_t$$

$$K_t^g = I_t^g + (1-\delta_g) K_{t-1}^g$$

As we said in the beginning of the mode, we have aimed to create with this model a renewable energy project where the capital for its development and function is financed fully by the public expenditure issued by the government; and at the same time, the government will be financing it via public earnings from taxes. Besides that, and because the electric system is a public state competence in our country, we will also be determining the restrictions and functions for energetical consumption inside the government's stake.

$$ES_t = \left(\varphi ER_t^{\lambda_s} + (1-\varphi) ENR_t^{\lambda_s} \right)^{1/\lambda_s}$$

$$\tau_t^{ES} = \rho \tau_{t-1}^{ES} + \varepsilon_t$$

$$ES_t = ES_t^H + ES_t^f$$

$$\tau_t^K = \rho_K \tau_{t-1}^K + \varepsilon_t$$

$$ER_t = \left[\frac{A_R}{1 + \chi\left(\frac{ER_t}{ES_t}\right)} \right] K_{t-1}^g$$

4.3 Equilibrium and steady state computation

After constructing the utility functions and restrictions for the model agents. Through first order conditions and system of equations methodology, we tried to find the optimal equations for each of the variables of the agents. When all of them have been obtained, we computed the equilibrium to see under what conditions labor, capital and goods and services cleared, and what quantities and variables need to be satisfied with each other.

Then after the long process, we arrived to the final step: The Steady State. The Steady State is a condition or state where everything is balanced. In addition, in the steady state we have the position and behavior of variables defined, because they are not going to be changing over time. Because of us having 11 variables in our model, we are going to be needing 11 equations to be able to determine the values and results for the model. Then we compute:

$$-\left(c^{\sigma}+\phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}}\left(P^{c}c^{\sigma-1}+\beta c^{\sigma-1}\cdot\left(P^{I}(1-\delta)+(1+\tau_{K})r\right)\right)=0$$

$$l=\left[\frac{\left(c^{\sigma}+\phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}}\phi ES^{H\,\sigma-1}\left((1+\tau_{w})W\right)}{-\eta\left((1+\tau_{ES})P^{ES}\right)}\right]^{\frac{1}{\nu}}$$

$$(1+\tau_{c})P^{c}C+\delta KP^{I}+(1+\tau_{ES})P^{ES}ES^{H}=(1-\tau_{w})Wl+(1-\tau_{K})rK+TR$$

$$\alpha PAl^{\alpha-1}\left(\theta K^{\gamma}+(1-\theta)ES^{f\,\gamma}\right)^{\frac{(1-\alpha)}{\gamma}}-W=0$$

$$(1-\alpha).P.A.l^{\alpha}.\left(\theta K^{\gamma}+(1-\theta)ES^{f\,\gamma}\right)^{\frac{1-\alpha-\gamma}{\gamma}}\theta K_{t-1}^{\gamma-1}-r=0$$

$$(1-\alpha).P.A.l^{\alpha}.\left(\theta K^{\gamma}+(1-\theta)ES^{f\,\gamma}\right)^{\frac{1-\alpha-\gamma}{\gamma}}(1-\theta)ES^{f\,\gamma-1}-P^{ES}=0$$

$$\tau_{c}P^{c}C+\tau_{w}Wl+\tau_{K}rK+\tau_{ES}P^{ES}ES^{H}=PI^{g}$$

$$I^{g}=\delta_{g}K^{g}$$

$$ES=\left(\varphi ER^{\lambda_{s}}+(1-\varphi)ENR^{\lambda_{s}}\right)^{1/\lambda_{s}}$$

$$ES=ES^{H}+ES^{f}$$

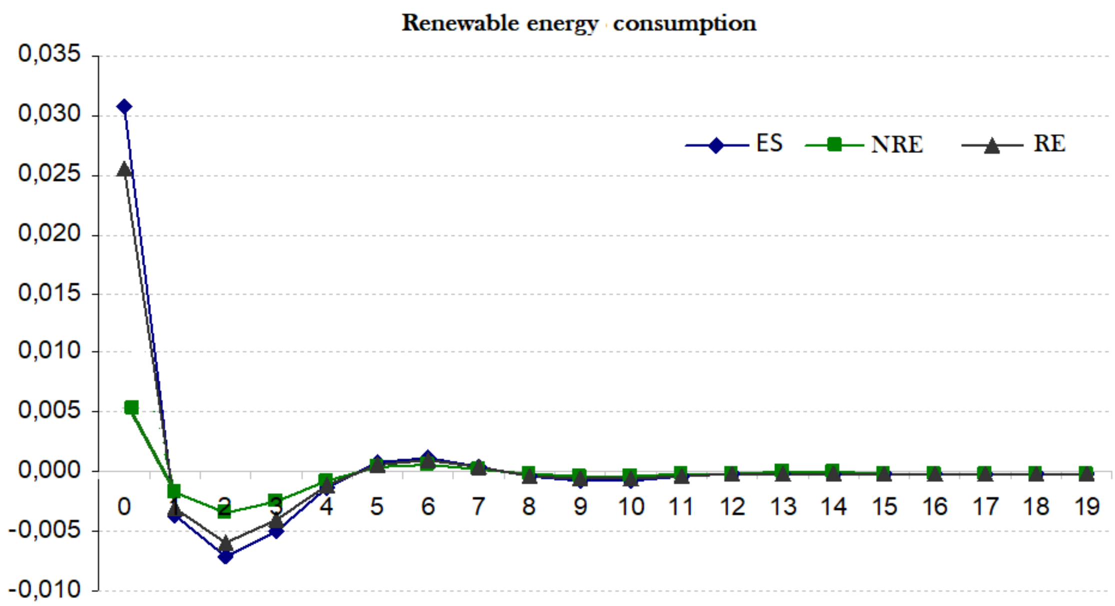
$$ER=\left[\frac{A_{R}}{1+\chi\left(\frac{ER}{ES}\right)}\right]K^{g}$$

4.4 Model Solution

Up this point, we have presented the variables, equations, the equilibrium and the steady state calculations for the model. All of this through all the mathematical expressions and functions that we have extracted through various system of equations, derivatives and other mathematical methodologies. But once the steady state was reached, help in order to compute, obtain and graph the results was going to be needed; because with eleven variables to work with, it would have been complicated to do it by hand. This is why with the help of MATLAB we have been able to graph and study the relations between equations and its respective variables to know exactly how increases or decreases in certain variables affected the other's behavior.

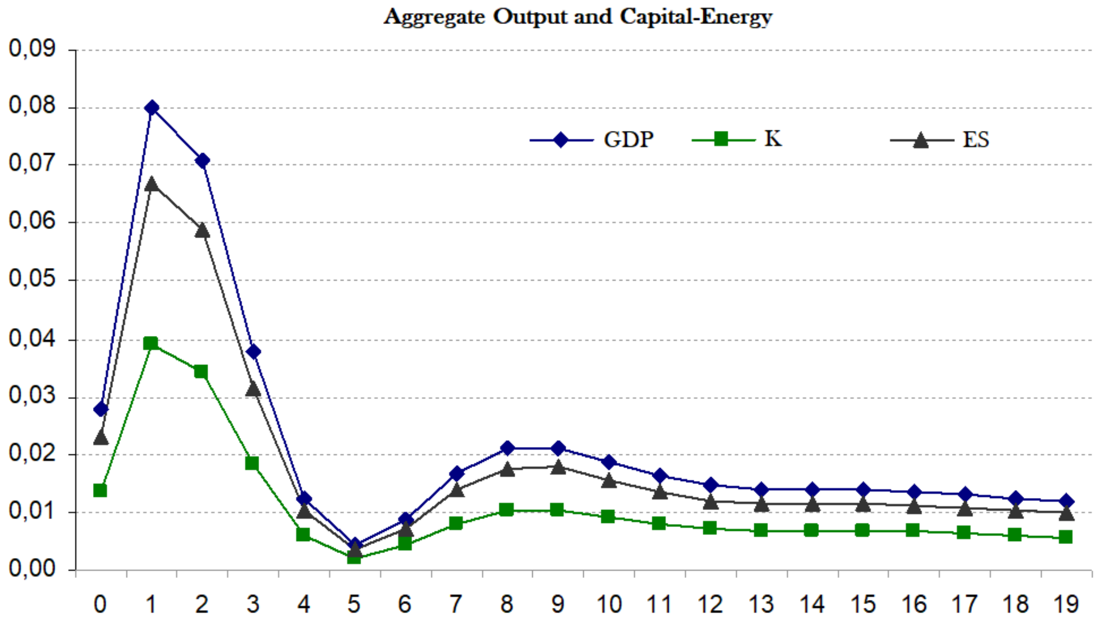
The main objective of this project has been to study if solving the current Spanish energetical supply crisis was viable or at least partially feasible trough basing our electrical system on renewable energy community projects as the main supplier of energy. In addition to it, in the model that I propose, we have gone a step further and also proposed to be the government the agent in charge to assume the investment on capital (renewable energy community projects) which will be owned by the households. At the same time, this capital is going to be financed through taxes imposed by government in: consumption, wages, capital and energy; being the last two the main collectors of money for it. With this being said, we are going to proceed with the analysis of the results obtained.

First of all, the first exogenous variables to be affected by this new model were Energy Consumption, Renewable Energy that; together with the Non-Renewable, rose their numbers of contribution. This happened because Renewable energy projects were the agents where direct investment happened, then the increment of their service supply happened together with its increase in consumption rates from other agents because of the huge price decrease.



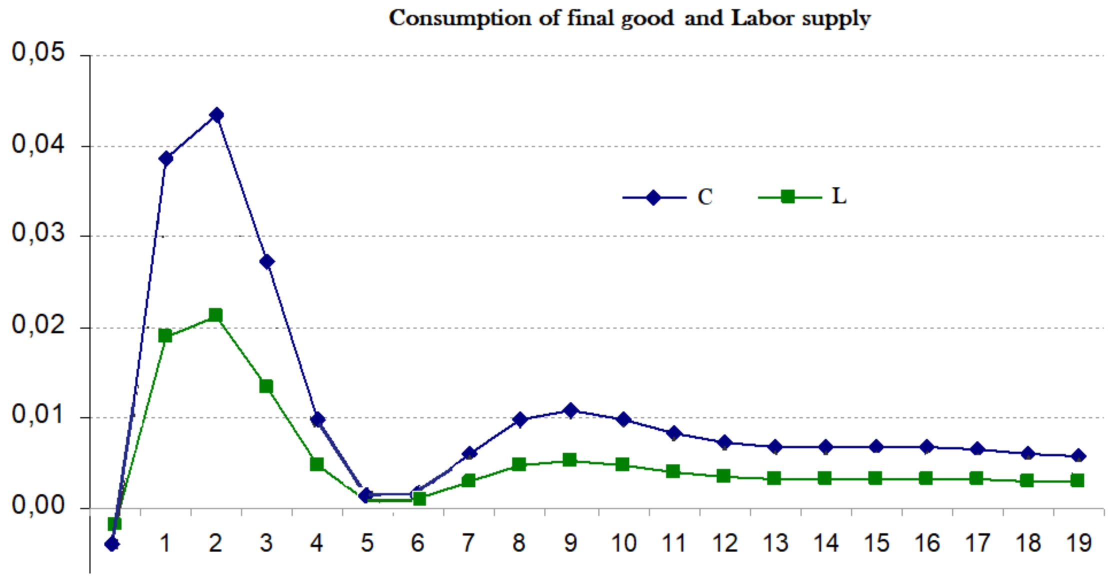
As said before, the first thing that we can see with the results obtained is that by doing an investment in renewable energy community projects the service of either renewable as non-renewable energy sources is going to be arising. Because of the growth on the service of energy, we are going to be seeing an exponential decrease in the in the electric energy service cost. Indirectly this investment in the projects on renewable energy is going to have the same effect than if government would have given a subsidy to firms' production. By either of two ways, what government did with the investment on energy projects had a parallel effect in the production costs; that had an exponential decrease. Less energy price as factor of production, less production costs for the firms.

Subsequently; if firms find themselves with cheaper production costs, prices are going to start decreasing because of them being in a situation of perfect competition market. If prices on goods sold by firms are going to be cheaper, households are going to have greater purchasing power and increase their consumption rate in a bigger scale. All of this translating into a really positive impact in Spain's GDP.



On the other side, the same behavior can be seen on Household's utility function. Government by financing households' capital and therefore investing in the renewable energy projects, Households are going to see how their purchasing power is going to be rising. Besides seeing this effect on the graph, it could be assumed as the variable "ES" was located in the left side of Household's restriction function, therefore accounting for an expenditure that together with its tax (t_{ES}) was an important part of the its purchasing limitations. Once Households increase their purchasing power, because of the investment on renewable energy from the government, the households are going to be having the same effect like as the government had given to them a subsidy; and they will proceed to rise their consumption rates.

From the Households side, when the shock because of the investment in renewable energy projects happen it can be seen that in the consumption behavior there is a little decrease both in consumption on final goods and labor supply going under 0.00 of standard deviations. This behavior happens because; although the investment increases the purchasing power of households, all of the government expenditure on it is financed through taxes. Therefore, on the early stages of the shock; households because of them having to pay more taxes to cover the investment, their consumption will decrease rather than be rising. On the other side, Household's labor supply, is going to be having a similar behavior because of the utility function the Households are using.



Following this decrease in consumption and labor in Period 0, we can see how the consumption of final goods and labor supply will have a really exponential recovery because also for the investment on renewable energy; that by rising its sectors dominance, firms are going to be demanding more renewable energy because it being cheaper. This would therefore reduce production costs for companies that are going to be capable; as the time goes by, to hire more workers. Also, households rise its consumption rates on final goods because of the cheaper prices.

The graphs analyzed above have been representing more than just a straight increase of variables, they express the standard deviations of them. By this method, we measure the volatility of the variables that were used to solve the question for the model. In conclusion, if the volatility of the variable was positive, the variable then rises up on the Y axis. On the other side, the X axis represents the periods of time that we have used to estimate the model.

Therefore, we can conclude that the effects of an increase in the investment from the government side on renewable energy community projects to be the main energy supplier and sustain the energetical system gives in general good results.

Regardless of the short consumption decrease on final goods after the shock, the general trend that Households, Firms and Governments with its main representative exogenous variables are a positive volatility during three to four periods. One of the main reasons for that is the shock this economy experiences through the capital investment; that because of capital variable being present on the other functions, generates what is called in macro-economic terms a transmission mechanism. This means that although having a positive effect on a small scale, ends up transmitting it to the bigger picture. In this case the type of transmission that we have seen has a fiscal nature, which means that by changes on the fiscal policy, changes in the economy are generated as whole and in particular; the prices levels. As consequence, we will find changes for example in inflation, output, consumption and investment.

In conclusion, the results given by this model show and refute the theoretical hypothesis that we formulated before computing it. An economy that bases its energetical system on renewable energy projects, through a government investment on them, and financed through taxes is going to end up not only having similar results of before the energetical crisis, it is going to be improving households' utility by enhancing consumption and labor rates, firms' efficiency by reducing production costs, government satisfying its own restriction and goods and service markets; and even having an increase in the GDP level.

Besides all that, the main characteristic that has made me believe on the theoretical feasibility; besides the rise of the variables of this model, has been that the solution graphs of the three agents which we were mainly focused on all converge at the end. This is really important, because to guarantee feasibility of a theorical model we need it to return to the steady state. This need is because by this methodology, the problem is solved in to the long-run and then shows the results as a simulation in the short one, being the reason why the effect is going to be transitory, and a convergence at the end for the feasibility is mandatory.

Conclusions

Regardless of the results obtained with the model created, we have seen in this project how the energy and electric system is constructed and functions. Besides the application of renewable energy communities and its green sources in system, some arrangements and changes are mandatory to be done to guarantee that everyone can access and benefit from the switch towards renewable electricity. The study of the subject has shown to us that regardless of any changes in the source of energy, it is mandatory for us to change the way that European energy wholesale market operates. The pay-as-clear system is just another tool from the oppressor energy providers to control and have the energy market on their hands. As you would know by this point, until this system of wholesale is removed no matter what kind of renewable source we introduce. Due that all countries still rely in fossil fuels, the introduction of a renewable energy sources is meaningless. This is why renewable energy projects can be useful, because with its implementation you would have the whole country not having to rely anymore on wholesale energy market, because its own production would me more than enough to sustain the whole country and the final price of the electricity, will not be determined by the price of coal or natural gas anymore.

If we talk then about oppresor energy providers, we put as example the role of Russia in this energetical crisis. This suppliance stop from the Russian political administration was indeed to assert dominance and control in the worldwide energetical crisis. This attitude from Russia helps refutate more the position we have adopted in this projects towards the renewable energetical projects. The application of renewable projects can instantly leave this type of preasures from energy tyrants obsolet, because the level of independe and selfgeneration of electricity is so high, that the no-need-to-rely (at least entirely) on the external market for energetical supply is achivable. At the same time, the switch from foreign supply to self sustainability is going to be reflexed in the accountability of the country because of the foreing imports reductions and then more economic disponiblity for other projects and investment will be available.

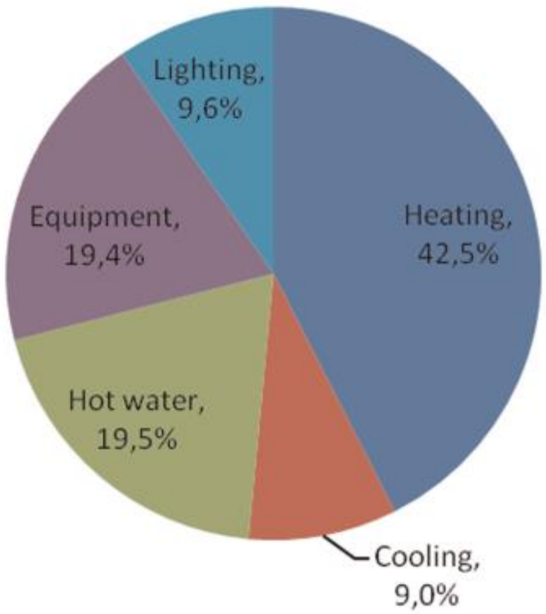
In the case of Spanish Energetical system, we have seen how the whole system is messed up. Contributors still tax paying the mistakes and errors made 20 years ago by politicians that were only trying to ill-hold the system to do not stain their political image; and on the other side, a market with a tremendous dependence on foreign energy markets to supply the country with energy. Althought some investments were made in the past on renewable sources (with disastrous effects), nowadays technology has evolved more than we could have ever imagined, and Spain within Europe is one of the countries with more potential to implement renewable energy community projects for its abundance in renewable energy sources, the regulation on energy production, and law’s and decrees supporting sustainability.

Althought Spain has really strong basis supporting green enegry development; at the same time, cooperatives in Spain haven’t been taked into account by the Electric Sector Law; and until not while ago, cooperatives althought their enormous energy-generation capacity were not allowed to participate on the electricity market. This being the reason why few cooperatives marketing electricity exists. In Spain, only four of all projects are recognized as “real” community projects, being these four the only ones that are starting to operate on the electricity market. As we have also seen from analyzing history and behaviours of renewable energy projects, the investement in this kind of renewable energy generation processes implys huge financial risks. Financiation of the project at the beginning is a difficult task because in the early stages no income is being generated by the project, that’s the reason why from my perspective government financing and expenditure could facilitate the entrance in renewable projects ownership from households, instead than large companies. In addition, changes in renewable energy regulations need to be made in Spain to allow an easier trading and marketing of energy from cooperatives. The fact that by law they didn’t allow cooperaitves to trade in the energy market until now has had in concequence an inexistent web of coopeartives that could have helped in a huge way in the current energetical crisis at european and national level.

Last but not least; in Spain regardless of the potential in renewables and alternative sources, there is a tremendous insensitivity with enviromental issues and global warming. This is why besides the monetary benefits community projects can offer, these projects have to become one of the main tools to fight against climate change, a worlwide issue affecting everyone. Because of that, changes in sensitivisation of society and education on the field needs to be done to promote and enhance the collective belive in the idea.

Besides everything mentioned before, we have to stop looking into the past and focus our vision into future solutions. The results of our model have shown that possibilities of building a new system based on Renewable energy communities are there; therefore, we must know how are we going to be applying it in Spain and what things need to change to transform the theory into reality.

In Spain no investment or legislations to favor the appearance of renewable energy projects have been made until really recently; and therefore, leaving various niche sectors in energy market for renewable energy communities to cover. In Spain heating, cooling and hot water is the energy consumption gap with the biggest share of energy demand in most buildings. Therefore, a proper solution to the actual energy problem would be the installation of district heating networks in form of renewable energy projects; such as the ones that exists in Denmark. For these networks to be fully renewable could base the functioning of their systems on renewable energy, but also: waste heat from industrial processes, efficient heat pumps, cogeneration heat, solar thermogenic generation machines and absorption chillers for cooling purposes.



Distribution of energy consumption in the building sector. Source: IDAE (2010).

Besides the heating networks as energy projects, another niche sector where Spain could be leader of is the production and commercialization of Biofuels. Spain is a country with a really strong farming history that with the existing and future addition of more farming cooperatives, and by diversifying their activities and investing into getting in biofuels market, a huge new stream of revenue can be obtained. In addition, legal framework for this kind of renewable energy project is already existing; and unlike on the energy market, these cooperatives have already access to trade in the fuels market, which translates in benefits since day one.

For the Spanish Government to be able to have a solid government expenditure/investment on those two community projects niche's, is necessary enhancing an analysis on technical and economic feasibility. Firstly; because that being a new market opportunity, expenditure needs to be done with a cautionary manner and distributing properly the economic resources. In addition to it; although we have proposed in our macro-economic model based on community projects financed fully by government expenditure, gathering money and attracting investors would be really hard, this is why a good analysis could help because as more available money is ready to invest on the projects, sooner the capitalization from them can start in terms of energy production and economic earnings.

Last but not least, we must not forget that besides any opportunity in the heating/cooling sector and on biofuel market Spain can have as renewable energy communities, solar electricity generation through renewable energy projects is also a sector were Spain because of its climate conditions due its incredible geo-localization can have a tremendous impact and benefits. The issue with this niche is that unlike the two previously mentioned, regulations and financial incentives in Spain to develop it are in tremendous low levels. Unavailability to enter to electric energy markets from community projects; together with regulations and laws with no proliferation or development in the area, makes me assume that currently no interest from Spanish government in the field is present. In conclusion, although it would be a really solid option to consider in form of community energy project, until no incentives are present, I would totally reject the investment.

After the feasibility results showed by the model and, seeing the huge potential Spain have in the market of renewable energy communities it would not be strange for us to see some behavioral change in the coming years towards the area. The problem is that nowadays Spanish framework, together with society believes in our country could account for a bigger impediment than the economic side. In this project we have talked about needs a renewable energy community project has in order for it to function, and in the case of Spain some good things can be extracted from it. First of all, to go along with the model proposed in this project, Spanish Law needs to frame a more supportive network of policies to be able to reduce the riskiness of these projects and be able to attract more investors on it. To do this so, I would recommend the enhancing of feed-in-tariffs to pave the way for possible investors that may appear. Although the mentioned before is and would be the first step into the appearance of more solid renewable energy projects. As history has shown us in many countries like Denmark, Germany and United Kingdom, is that government switches that may occur from elections can be harmful for the development of new policies. In the case of Spain, we have been seeing almost since the beginning of time that either right or left political parties as soon as they become elected, they start reforming and changing every improvement, policy or framework development made by the previous government. In the case of renewable energy policies this can be very bad for its evolution, because a stagnation in its growing phase is more than likely to happen in our country.

As mentioned before, the Spanish society is one of the European societies with less environmental concerns and acceptance on green alternatives. This translates perfectly with the current state of renewable energy projects in or country, that together with the policies enhanced by governments; as representatives of the people, have not made more effort than what other northern European countries leading Europe have imposed them to do on the field.

For this reason, regardless of the theorical feasibility of the model presented and the needed changes in terms of legislations and framework mentioned above, I believe that the change has to start by changing society's approach and perception on renewable energy and community projects.

As humans it's in our nature the fear of change, thinking that something new may be not enough good or even better than the existing methodology or characteristic. In order to fight against that and turn the theorical feasibility of the model into reality, education on the field is mandatory for renewable community projects to work in Spain or anywhere else. First of all, the main thought society is going to have when this new type of energy scheme shows up is going to be that it is going to be affecting society's social welfare (job loss, higher taxes, decrease in consumption power…) this is why, the first step has to be a campaign promoting the returns these projects have for the ones that decide to become members of them; such as, job creation, redistribution of revenues and returns on investments. In addition, it has to be shown to the society how all revenues generated by this kind of projects can contribute to finance and create a better welfare state. In conclusion, it has to be clear for the society that community projects are not a "threat" of any kind.

Once monetary fear it has been eradicated, this being one of the major fears of our society nowadays. I would suggest as second step, helping society to overcome their rejection/mistrust in renewable energy. As we discussed in this project, there are different types of acceptance depending on the type of renewable community project stablished. But I believe that because of the urge as consequence of the current energy crisis, the acceptance level have to be treated as a whole and not on groups. This is why I would suggest forcing the project involvement of individuals and giving them ownership in the projects where Spain has competitive advantage. All of this because community projects acceptance in most part relies on personal experience, and by incentivizing an active role from citizens there, they will have a better understanding of what it has been done.

In my opinion these two steps must be the base where renewable energy projects need to be constructed. The reason why I believe this is because by doing this, society will get more in touch with green energy, and will slowly change its behavior towards energy consumption and efficiency.

With all of this being said, the final conclusion for this project would be that renewable energy communities provide such a tremendous positive impact on the economy, society and environment. But on the other side, the scale of this impacts depends on the type of community.

In addition to it; regardless of the competitive advantages Spain can have on renewable projects, for these projects to become successful a good policy and regulation framework needs to apply, a framework that encourages the decentralization of communities in terms of distribution networks. Last but not least, something that is imperative to exist is social acceptance for renewable energy, environment and climate actions, because it doesn't matter the effort that political side can do to stablish new energy sources. If all political parties; due they behave as representatives of the whole society, are not in favor and supporting these new green methods, all the effort made by a group is going to be destroyed by the other, and not steps forwards are going to be done. The creation of new renewable community projects in Spain must become mainstream for our economy and society if we want them to be a sustainable model for future generations.

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Appendix

Model Computation

Households Problem:

$$\max_{c_t, ES_t^H, l_t^s, K_t^s} \sum_{t=0}^{\infty} \beta^t \ln\left(\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{1+\nu} \right)$$

s.a

$$(1+\tau_c) P_t^c C_t + P_t^I \left(K_t^s - (1-\delta) K_{t-1}^s \right) + (1+\tau_{ES}) P_t^{ES} ES_t^H = (1-\tau_w) W_t l_t^s + (1-\tau_k) r_t K_{t-1}^s + TR_t$$

Variables Endógenas

l_t^s: oferta laboral

K_t^s: oferta capital

C_t: consumo

ES_t^H: consumo Electrico Hogares

Variables Exógenas

$P_t^c, P_t^I, P_t^{ES}, TR_t$

Parámetros

$\sigma, \phi, \eta, \nu, \tau_c, \delta, \tau_{ES}, \tau_w, \tau_k$

firms Problem:

$$\max_{l_t^d, K_{t-1}^d, ES_t^f} P_t A_t l_t^{d\alpha} \left(\theta (K_{t-1}^d)^{\gamma} + (1-\theta) ES_t^{f\gamma} \right)^{\frac{(1-\alpha)}{\gamma}} - W_t l_t^d - r_t K_{t-1}^d - P_t^{ES} ES_t^f$$

Variables Endógenas

l_t^d: Demanda laboral

K_t^d: Demanda capital

ES_t^f: consumo Electrico firma

Variables Exógenas

P_t, P_t^{ES}, A_t

Parámetros

θ, γ, α

Gobierno:

$$\tau_c C_t + \tau_w W_t l_t + \tau_k r_t K_{t-1} + \tau_{ES} P_t^{ES} ES_t^H = I_t^g$$

Servicio Electrico:

$$ES_t = \left(\varphi ER_t^{\lambda_s} + (1-\varphi) ENR_t^{\lambda_s} \right)^{1/\lambda_s}$$

; ER_t: Energia Renovable

ENR_t: Energia No Renovable

$$ES_t = ES_t^H + ES_t^f$$

$$ER_t = \left[\frac{A_R}{1 + \chi\left(\frac{ER_t}{ES_t}\right)} \right] K_{t-1}^g$$

$$K_t^g = I_t^g + (1-\delta_g) K_{t-1}^g$$

Households Problem:

$$\underset{c_t, ES_t^H, l_t^s, K_t^s}{Max} \sum_{t=0}^{\infty} \beta^t \ln\left(\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu} \right)$$

s.a

$$(1+\tau_c) P_t^c C_t + P_t^I \left(K_t^s - (1-\delta) K_{t-1}^s \right) + (1+\tau_{ES}) P_t^{ES} ES_t^H = (1-\tau_w) W_t l_t^s + (1-\tau_K) r_t K_{t-1}^s + TR_t$$

$$\mathcal{L}(c_t, ES_t^H, l_t^s, K_t^s, \lambda_t) = U(c_t, ES_t^H, l_t^s)$$
$$- \lambda_t \left[(1+\tau_c) P_t^c C_t + P_t^I \left(K_t^s - (1-\delta) K_{t-1}^s \right) + (1+\tau_{ES}) P_t^{ES} ES_t^H - (1-\tau_w) W_t l_t^s - (1-\tau_K) r_t K_{t-1}^s - TR_t \right]$$

$$\frac{\partial \mathcal{L}}{\partial C_t} = \beta^t \frac{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{\frac{1-\sigma}{\sigma}} \cdot c_t^{\sigma-1}}{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t (1+\tau_c) P_t^c = 0 \qquad (1)$$

$$\frac{\partial \mathcal{L}}{\partial ES_t^H} = \beta^t \frac{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1}}{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t (1+\tau_{ES}) P_t^{ES} = 0 \qquad (2)$$

$$\frac{\partial \mathcal{L}}{\partial l_t^s} = \beta^t \frac{-\eta l_t^{s\,\nu}}{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t (1+\tau_w) W_t = 0 \qquad (3)$$

$$\frac{\partial \mathcal{L}}{\partial K_t^s} = -\lambda_t P_t^I + \lambda_{t+1} P_{t+1}^I (1-\delta) + \lambda_{t+1} (1+\tau_K) r_{t+1} = 0 \qquad (4)$$

(1) ~ (4)

(1)

$$\beta^t \frac{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{\frac{1-\sigma}{\sigma}} \cdot c_t^{\sigma-1}}{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t (1+\tau_c) P_t^c = 0$$

$$\beta^t \frac{\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{\frac{1-\sigma}{\sigma}} \cdot c_t^{\sigma-1}}{\left(\left(c_t^{\sigma} + \phi ES_t^{H\sigma} \right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu} \right) \left((1+\tau_c) P_t^c \right)} = \lambda_t$$

(4)

$$-\lambda_t P_t^I + \lambda_{t+1} P_{t+1}^I (1-\delta) + \lambda_{t+1} (1+\tau_K) r_{t+1} = 0$$

$$-\lambda_t P_t^I + \lambda_{t+1} \left(P_{t+1}^I (1-\delta) + (1+\tau_K) r_{t+1} \right) = 0$$

1 ~ 4

$$\beta^t \frac{\left(c_t^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot c_t^{\sigma-1}}{\left(\left(c_t^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)\left((1+\tau_c)P_t^c\right)} = \lambda_t \qquad (1)$$

$$-\lambda_t P_t^I + \lambda_{t+1}\left(P_{t+1}^I(1-\delta) + (1+\tau_K) r_{t+1}\right) = 0 \qquad (4)$$

$$-\beta^t \frac{\left(c_t^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot c_t^{\sigma-1}}{\left(\left(c_t^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)\left((1+\tau_c)P_t^c\right)} \cdot P_t^I + \beta^{t+1} \frac{\left(c_{t+1}^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot c_{t+1}^{\sigma-1}}{\left(\left(c_{t+1}^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_{t+1}^{s\,1+\nu}\right)\left((1+\tau_c)P_{t+1}^c\right)} \left(P_{t+1}^I(1-\delta) + (1+\tau_K) r_{t+1}\right) = 0$$

$$-\frac{\left(c_t^\sigma + \phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot c_t^{\sigma-1}}{\left(\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)} + \frac{\beta\left(c_{t+1}^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot c_{t+1}^{\sigma-1}}{\left(\left(c_{t+1}^\sigma + \phi ES_{t+1}^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_{t+1}^{s\,1+\nu}\right) P_{t+1}^c} \left(P_{t+1}^I(1-\delta) + (1+\tau_K) r_{t+1}\right) = 0$$

2 ~ 3

$$\frac{\partial \mathcal{L}}{\partial ES_t^H} = \beta^t \frac{\left(c_t^\sigma + \phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1}}{\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t(1+\tau_{ES})P_t^{ES} = 0 \qquad (2)$$

$$\frac{\partial \mathcal{L}}{\partial l_t^s} = \beta^t \frac{-\eta\, l_t^{s\,\nu}}{\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t(1+\tau_w)W_t = 0 \qquad (3)$$

$$\beta^t \frac{\left(c_t^\sigma + \phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1}}{\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t(1+\tau_{ES})P_t^{ES} = 0 \qquad (2)$$

$$\beta^t \frac{\left(c_t^\sigma + \phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1}}{\left(\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)\left((1+\tau_{ES})P_t^{ES}\right)} = \lambda_t$$

$$\beta^t \frac{-\eta\, l_t^{s\,\nu}}{\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}} - \lambda_t(1+\tau_w)W_t = 0 \qquad (3)$$

$$\beta^t \frac{-\eta\, l_t^{s\,\nu}}{\left(\left(c_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)\left((1+\tau_w)W_t\right)} = \lambda_t$$

$$\beta^t \frac{\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1}}{\left(\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)\left((1+\tau_{ES})P_t^{ES}\right)} = \beta^t \frac{-\eta l_t^{s\,\nu}}{\left(\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)\left((1+\tau_w)W_t\right)}$$

$$\beta^t \frac{\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1} \cancel{\left(\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)}\left((1+\tau_w)W_t\right)}{\cancel{\left(\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{1/\sigma} - \frac{\eta}{1+\nu} l_t^{s\,1+\nu}\right)}\left((1+\tau_{ES})P_t^{ES}\right)} = -\beta^t \eta l_t^{s\,\nu}$$

$$\beta^t \frac{\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1} \left((1+\tau_w)W_t\right)}{\left((1+\tau_{ES})P_t^{ES}\right)} = -\beta^t \eta l_t^{s\,\nu} \longrightarrow l_t^s = \left[\frac{\left(C_t^\sigma + \phi ES_t^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1} \left((1+\tau_w)W_t\right)}{-\eta\left((1+\tau_{ES})P_t^{ES}\right)}\right]^{\frac{1}{\nu}}$$

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firms Problem:

$$\underset{l_t^d,\, K_{t-1}^d,\, ES_t^f}{\text{Max}} \; P_t A_t l_t^{d\,\alpha} \left(\theta (K_{t-1}^d)^\gamma + (1-\theta) ES_t^{f\,\gamma}\right)^{\frac{(1-\alpha)}{\gamma}} - W_t l_t^d - r_t K_{t-1}^d - P_t^{ES} ES_t^f$$

$$\partial l_t^d \quad \alpha P_t A_t (l_t^d)^{\alpha-1} \left(\theta (K_{t-1}^d)^\gamma + (1-\theta) ES_t^{f\,\gamma}\right)^{\frac{(1-\alpha)}{\gamma}} - W_t = 0$$

$$\partial K_{t-1}^d \quad (1-\alpha) . P_t A_t . l_t^{d\,\alpha} . \left(\theta (K_{t-1}^d)^\gamma + (1-\theta) ES_t^{f\,\gamma}\right)^{\frac{1-\alpha-\gamma}{\gamma}} . \theta K_{t-1}^{d\,\gamma-1} - r_t = 0$$

$$\partial ES_t^f \quad (1-\alpha) . P_t A_t . l_t^{d\,\alpha} . \left(\theta (K_{t-1}^d)^\gamma + (1-\theta) ES_t^{f\,\gamma}\right)^{\frac{1-\alpha-\gamma}{\gamma}} . (1-\theta) ES_t^{f\,\gamma-1} - P_t^{ES} = 0$$

Gobierno:

$$\tau_c C_t + \tau_w W_t l_t + \tau_K r_t K_{t-1} + \tau_{ES} P_t^{ES} ES_t^H = I_t^g = G_t$$

$$K_t^g = I_t^g + (1-\delta_g) K_{t-1}^g$$

Servicio Electrico:

$$ES_t = \left(\varphi\, ER_t^{\lambda_s} + (1-\varphi)\, ENR_t^{\lambda_s}\right)^{1/\lambda_s}$$

$$\tau_t^{ES} = \rho\, \tau_{t-1}^{ES} + \varepsilon_t$$

$$ES_t = ES_t^H + ES_t^f$$

$$\tau_t^K = \rho_K\, \tau_{t-1}^K + \varepsilon_t$$

$$ER_t = \left[\frac{A_R}{1 + \chi\left(\frac{ER_t}{ES_t}\right)}\right] K_{t-1}^g$$

Vaciado de Mercado:

* Mercado de Capital: $K_t^s = K_t^d = K_t$

* Mercado de Trabajo: $l_t^s = l_t^d = l_t$

* Mercado de Bienes y Servicios:

$$P_t \cdot A_t\, l_t^{d\,\alpha} \cdot \left(\theta (K_{t-1}^d)^{\gamma} + (1-\theta)\, ES_t^{f\,\gamma}\right)^{\frac{(1-\alpha)}{\gamma}} = P_t^c C_t + P_t^I I_t + P_t I_t^g$$

Equilibrio:

Variables Endogenas: $C_t, K_t, l_t, w_t, r_t, ES_t^H, ES_t^f, ES_t, I_t^g, ER_t, K_t^g$

Variables Exogenas: $TR_t, A_t, P_t^c, P_t^I, P_t^{ES}, P_t$

Parámetros: $\sigma, \phi, \eta, \nu, \beta, \delta, \alpha, \gamma, \theta, \delta_g, \lambda_s, \varphi, A_R, \chi, \tau_K, \tau_c, \tau_w$

$$(\text{Eq } 1) \quad -\frac{\left(C_t^{\sigma}+\phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot C_t^{\sigma-1}}{\left(\left(C_t^{\sigma}+\phi ES_t^{H\sigma}\right)^{1/\sigma}-\frac{\eta}{1+\nu} l_t^{1+\nu}\right)}+\frac{\beta\left(C_{t+1}^{\sigma}+\phi ES_{t+1}^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \cdot C_{t+1}^{\sigma-1}}{\left(\left(C_{t+1}^{\sigma}+\phi ES_{t+1}^{H\sigma}\right)^{1/\sigma}-\frac{\eta}{1+\nu} l_{t+1}^{1+\nu}\right) P_{t+1}^{c}}\left(P^{I}(1-\delta)+(1+\tau_K) r\right)=0$$

$$\left(C^{\sigma}+\phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}}\left(P^{c} C^{\sigma-1}+\beta C^{\sigma-1} \cdot\left(P^{I}(1-\delta)+(1+\tau_K) r\right)\right)=0 \Rightarrow -1+\beta\left((1-\delta)+(1+\tau_K) r\right)=0$$

$$(\text{Eq. } 2) \quad l_t=\left[\frac{\left(C_t^{\sigma}+\phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES_t^{H\,\sigma-1}\left((1+\tau_w) W_t\right)}{-\eta\left((1+\tau_{ES}) P_t^{ES}\right)}\right]^{\frac{1}{\nu}} \rightarrow l=\left[\frac{\left(C^{\sigma}+\phi ES^{H\sigma}\right)^{\frac{1-\sigma}{\sigma}} \phi ES^{H\,\sigma-1}\left((1+\tau_w) W\right)}{-\eta\left((1+\tau_{ES}) P^{ES}\right)}\right]^{\frac{1}{\nu}}$$

$$(\text{E.q } 3) \quad (1+\tau_c) P_t^{c} C_t+P_t^{I}\left(K_t-(1-\delta) K_{t-1}\right)+(1+\tau_{ES}) P_t^{ES} ES_t^{H}=(1-\tau_w) W_t l_t+(1-\tau_K) r_t K_{t-1}+TR_t$$

$$(1+\tau_c) P^{c} C+\delta K P^{I}+(1+\tau_{ES}) P^{ES} ES^{H}=(1-\tau_w) W l+(1-\tau_K) r K+TR$$

$$(\text{Eq } 4) \quad \alpha P_t A_t (l_t)^{\alpha-1} \cdot\left(\theta (K_{t-1})^{\gamma}+(1-\theta) ES_t^{f\,\gamma}\right)^{\frac{(1-\alpha)}{\gamma}}-W_t=0$$

$$(\text{Eq } 5) \quad (1-\alpha) \cdot P_t \cdot A_t \cdot l_t^{\alpha} \cdot\left(\theta (K_{t-1})^{\gamma}+(1-\theta) ES_t^{f\,\gamma}\right)^{\frac{1-\alpha-\gamma}{\gamma}} \cdot \theta K_{t-1}^{\gamma-1}-r_t=0$$

$$(\text{Eq } 6) \quad (1-\alpha) \cdot P_t \cdot A_t \cdot l_t^{\alpha} \cdot\left(\theta (K_{t-1})^{\gamma}+(1-\theta) ES_t^{f\,\gamma}\right)^{\frac{1-\alpha-\gamma}{\gamma}} \cdot (1-\theta) ES_t^{f\,\gamma-1}-P_t^{ES}=0$$

(Eq 7) $\tau_c P_t^c C_t + \tau_w W_t l_t + \tau_k r_t K_{t-1} + \tau_{ES} P_t^{ES} ES_t^H = P_t I_t^g$

(Eq 8) $K_t^g = I_t^g + (1-\delta_g) K_{t-1}^g \longrightarrow I^g = \delta_g K^g$

(E.q 9) $ES_t = \left(\varphi ER_t^{\lambda_s} + (1-\varphi) ENR_t^{\lambda_s} \right)^{1/\lambda_s} \longrightarrow ES = \left(\varphi ER^{\lambda_s} + (1-\varphi) ENR^{\lambda_s} \right)^{1/\lambda_s}$

(Eq 10) $ES_t = ES_t^H + ES_t^f \longrightarrow ES = ES^H + ES^f$

(E.q 11) $ER_t = \left[\frac{A_R}{1 + \chi\left(\frac{ER_t}{ES_t} \right)} \right] K_{t-1}^g \longrightarrow ER = \left[\frac{A_R}{1 + \chi\left(\frac{ER}{ES} \right)} \right] K^g$