Energy and fuel Energy and fuel poverty in the XXI century

Jesús Serrano Moreno

4th Semester – Final Thesis

Sustainable Energy Planning & Management

2016, June

AALBORG UNIVERSITY
STUDENT REPORT

Table of Contents

1. Introduction

This written report is a result between the cooperation between a master student from Aalborg University and the study case based in Exergy. To introduce the reader to the context of this project the chapter introduces how energy, nowadays, represents a big influence in the society.

After this, a brief description of the most important challenge (energy and fuel poverty) that governments and organizations has to deal with for the development of energy, is studied. The last part of the chapter mentions the five risk factors that involve this challenge (energy and fuel poverty).

1.1. Introduction of Citizens Energy Needs

Around the world, energy is required for many of the services expected in modern society. The energy is important in social services sectors such as education and health and relevant in economic sectors from household production or farming, to industry.

The development of a country and their inhabitants is closely linked to the type and extent of access to energy. However, because of the energy and fuel poverty, the access to energy is a continuous challenge for governments and development organizations. The energy and fuel poverty refers the situation where individuals are not able to adequately heat (or provide necessary energy services) in their homes at affordable cost.

The International Energy Agency (IEA) defines the energy poverty as a lack of access to modern energy services. These services are defined as household access to electricity and clean cooking facilities.[1] According to the Energy Poverty Action initiative of the World Economic Forum, the access to energy is fundamental to improve the quality life and an imperative key for the economic development.

This report is focused in the energy and fuel poverty of the European dwellings. It is studied the different reasons and barriers that the inhabitants find in order to keep their home adequately warm. The report studies the situation in Europe because the information available for other countries outside of Europe is limited. However, the replicability of this project in the rest of world is one of the discussions developed during the report.

The fuel and energy poverty affects a wide range of families and individuals. The EU Survey on Income and Living Conditions (EU SILC) estimates that around the 11% of the EU population (54 million European citizens) were unable to keep their home adequately. The most susceptible households to energy and fuel poverty combine low income with an additional degree of vulnerability such as the elderly, the disabled and single-parent families. Furthermore, those disadvantaged households are also likely to occupy cold damp properties with inadequate heating systems and poor insulation. The low quality of such homes increases the difficulty to keep them sufficiently warm.

[1] IEA: http://www.iea.org/topics/energypoverty/

The energy and fuel poverty can be identified through a number of relevant indicators. The main statistics about the population at risk poverty are obtained from households with an income of 60% of the median national income register by the Eurostat[2].

The primary contributing factors to energy and fuel poverty have been found to be a combination of low income levels, high energy prices and low levels of energy efficiency. The author Ian Preston mentioned in his article that the socio-technical risks for household regarding energy and fuel poverty is a gathering of five factors. These five factors are the following:[3]

1) The impact of rising energy prices relative to income growth
2) Accessing cheaper fuel prices
3) Energy needs
4) Energy efficiency
5) Policy impacts

The following chapter, Problem Analysis, presents in more detail each of the five risk factors regarding energy and fuel poverty mentioned previously. The factors are analysed in order to evaluate the different issues which are linked to the development of the energy poverty in the European Union.

2 The European Statistic Office, Eurostat, is the statistic office of the European Commission which produces data about the European Union and promotes the harmonization of statistical methods of member states.

[3] 4Fuel and poverty, Ian Preston (June, 2014) https://www.cse.org.uk/downloads/reports-and-publications/fuel poverty/Fuel_and_poverty_review_June2014.pdf

2. Problem Analysis

The Problem Analysis will look into a more detail aspects of each of the five risk factors in order to conduct the project into the research question in which the study case will be focus. As it is explained in the introduction, the report is focused in the European situation because there are more studies which could give a deeper vision of the real reasons and barriers for the development of the energy and fuel poverty in the European dwellings.

The problem analysis will start by stating the European Commission perspective for the energy and fuel poverty in Europe. The chapter will end using the European perspective to evaluate the impact of each factor in the development of the energy and fuel poverty.

2.1. Energy and Fuel Poverty in European dwellings

Energy and fuel poverty is a current problem of the European life condition for around the 11% of the European population [4]. The European Commission has detected and has defined this problem under the legislation or common rules for the internal electricity and gas markets, adopted and entered into force in 2009, the Directives (2009/72/EC and 2009/73/EC) to require to the Member States to take action to address this issue:

"Energy poverty is a growing problem in the Community. Member States which are affected and which have not yet done so should therefore develop national action plans or other appropriate frameworks to tackle energy poverty, aiming at decreasing the number of people suffering such situation. In any event, Member States should ensure the necessary energy supply for vulnerable customers. In doing so, an integrated approach, such as in the framework of social policy, could be used and measures could include social policies or energy efficiency improvements for housing. At the very least, this Directive should allow national policies in favour of vulnerable customers (2009/72/EC (53))".

The European Statistic Office has developed an analysis in order to explain the reason of why, nowadays in Europe, the energy and fuel poverty is a relevant topic. The analysis involved the percentage of population per country who is at risk of this poverty. To assess the percentage of the population at risk of poverty, the incomes and energy and fuel prices in each country were taken in account.(Eurostat, 2012).

Figure 1 shows the distribution by country of the percentage of the population at risk for poverty, where it is easy to appreciate that Southern and Eastern countries of Europe are at higher risk of poverty. In 2012, the highest percentage of populations at risk of poverty were found in some of the most newest countries in became part of the European Union: Romania (40-50%), Hungary, Croatia, Cyprus, Latvia, Lithuania (30-40%) and those hit by recent economic crisis (Ireland, Greece (30-40%)). This is followed

[4] The EU Survey on Income and Living Conditions (EU SILC, 2012

by countries with a 20 to 30% share such as Poland, Italy, Malta, Spain, Portugal, Estonia, Slovakia, Belgium and the United Kingdom.

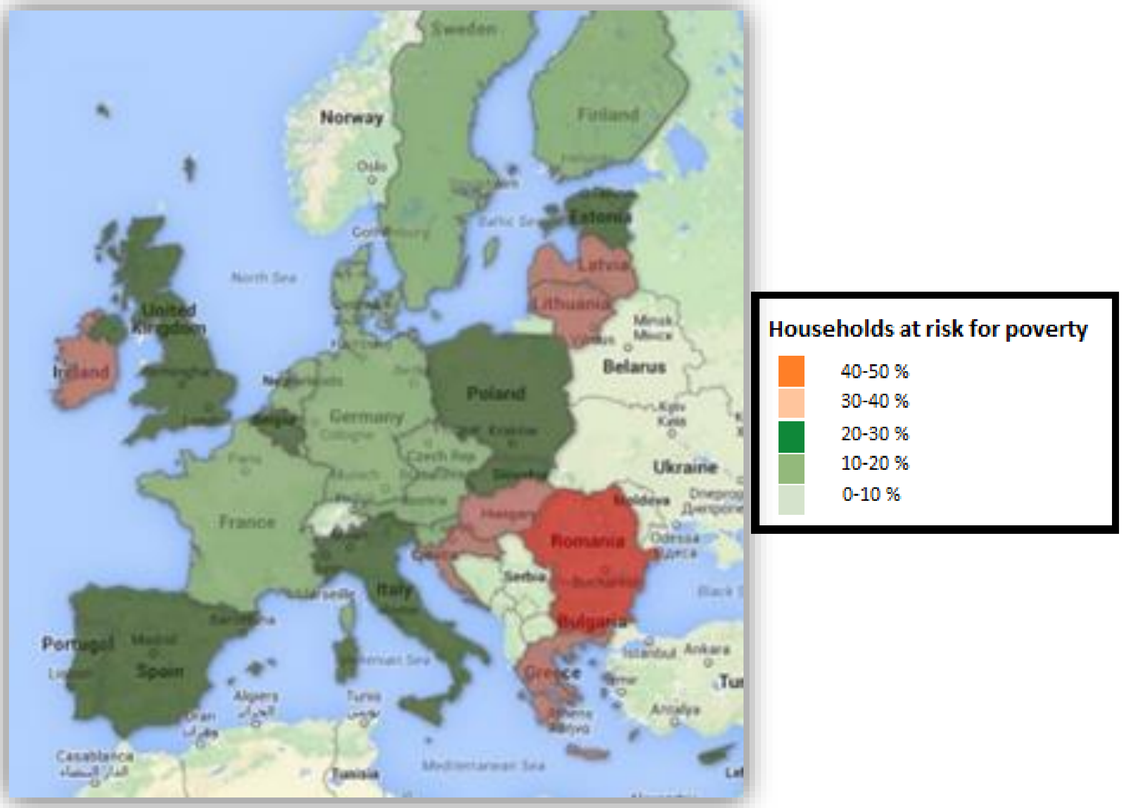

Figure 1 Households at risk for poverty per European Country (%) (Eurostat, 2012)

The following section will present in more detail the first risk factor for the energy and fuel poverty as well as the evaluation that linked the factor with the European perspective.

2.2. Responsible factors of the energy and fuel poverty development in European Union.

As mentioned before, this section evaluate how the five responsible factors of risks for household regarding energy and fuel poverty, defined by Ian Preston, affects the European situation. The different data available will be analysed to check how these factors are involved in the actual energy and fuel poverty in Europe. This study will aim to show which of these factors are the most relevant for the European citizens in order to furthermore propose a solution to avoid or at least reduce them.

2.2.1. The impact of rising energy prices relative to income growth

The impact of rising energy prices relative to income growth is the first factor described by Ian Preston in the section above. This chapter shows the evolution of the electricity prices in the last years. This information is needed because as it is explained in the next chapter some of the heating systems in Europe are individual devices which work with electricity.

According to the Eurostat's data regarding the household electricity prices of the member states during the last years, the prices between 2008 and 2014 have increased significantly in the European Union (EU). The Figure2, shows this increase since 2008 to the second half of 2014 across the EU Member States, the household electricity prices in the EU have increased more than 30%.[5]

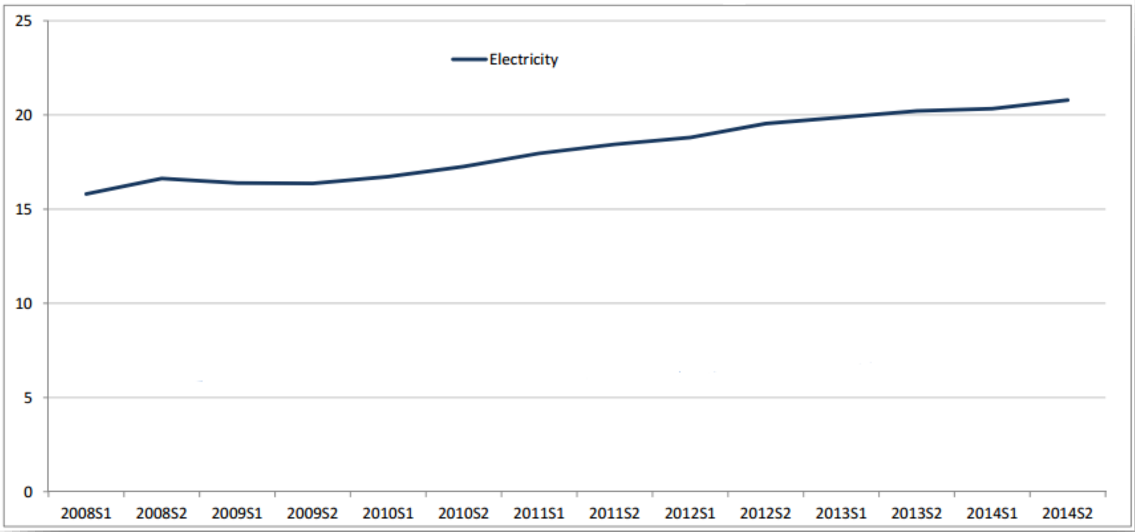

Figure 2. Evolution of household electricity and gas prices in the EU (in € per 100 kWh, all taxes and levies included)

The main reason of this increase in some European countries has been the rising taxes and levies that support rapid growth of renewables. The European Commission report states that during this period as European average, electricity network costs have risen a 18.5% and taxes & levies have risen a whopping of 36% for households. It is possible to appreciate the increment of the taxes and levies in the Figure 3, electricity price evolution by component. [6]

[5] Eurostat May 2015, Energy prices in the EU

[6] EEnergy Informer- Fereidoon Sioshansi (April, 2014)

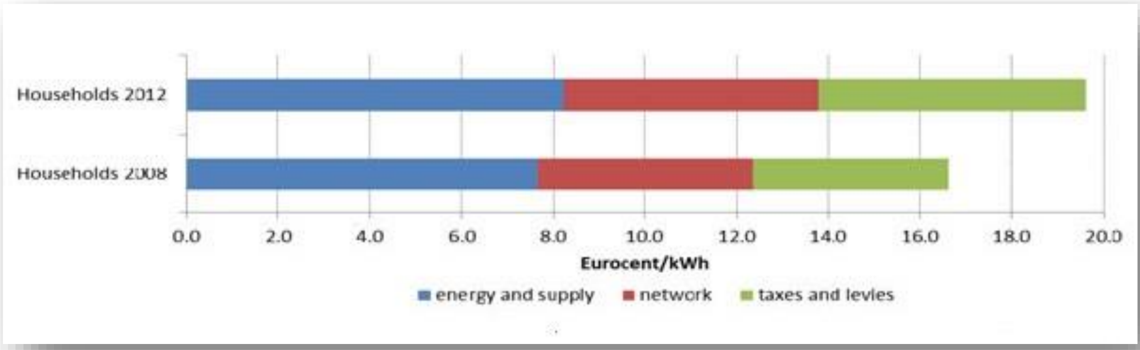

Figure 3. Electricity Price Evolution by component

After the study of the electricity price increment in Europe, it is needed to evaluate if the income of the European citizens have increase in the same level. It is evaluated taking in account the same period analysed in the last Figure 4, between 2008 and 2012.

The EU-SILC (EU Statistics on income and living conditions) published in 2013 a study where it is possible to obtain the changes in the incomes across the 28 Member States, Iceland, Norway and Switzerland. Figure 4, shows the change per year in each country and the cumulative change in these four years (2008-2012). To analyse these results, it is needed to appreciate the cumulative change in these four years. If this value is negative, it means that the median equalised disposable income between the years 2008-2012 has decreased in that country. However, if the value is positive, it means that the median equalised disposable income between2008-2012 has increased in that country.

The overview of the table shows that the incomes have decreased in most of the countries during this period. To be exact the cumulative change in the median income over between 2008 and 2012 shows that the living standards have fallen in 21 Member States and Iceland.[7]

[7] EU-SILC (EU Statistics on income and living conditions) (2013)

	Currency	Change in real terms 2008-2009	Change in real terms 2009-2010	Change in real terms 2010-2011	Change in real terms 2012-2011	Cumulative change in four years
Belgium	EUR	0.8	0.5	-2.0	3.2	2.5
Bulgaria	BGN	4.1	-6.2	-5.1	-0.2	-7.5
Czech Republic	CZK	1.9	-0.2	-0.4	-2.4	-1.2
Denmark	DKK	1.3	0.6	-1.9	-1.3	-1.3
Germany	EUR	0.9	0.1	0.4	-2.1	-0.7
Estonia	EEK	-7.9	-4.8	1.8	5.5	-6.0
Ireland	EUR	-7.0	-2.3	-4.4	-1.9	-14.8
Greece	EUR	2.7	-12.3	-16.0	-12.9	-34.1
Spain	EUR	-1.1	-6.5	-3.4	-4.8	-14.9
France	EUR	1.5	-1.5	0.7	-0.5	0.2
Croatia	HRK	0.0	-5.7	-3.8	-7.7	-16.2
Italy	EUR	1.1	-1.4	-2.5	-5.0	-7.6
Cyprus	EUR	-1.8	2.3	-3.7	-9.0	-12.0
Latvia	LVL	-18.9	-5.4	1.8	2.5	-19.9
Lithuania	LTL	-18.0	-5.4	8.0	5.0	-12.0
Luxembourg	EUR	1.8	-2.1	-2.9	-1.3	-4.4
Hungary	HUF	-4.1	0.4	2.3	-6.7	-8.1
Malta	EUR	-2.4	2.1	2.8	2.3	4.8
Netherlands	EUR	-0.3	-0.8	-1.2	-1.4	-3.7
Austria	EUR	2.5	0.2	-1.9	-1.3	-0.6
Poland	PLN	2.4	2.5	0.0	0.0	4.9
Portugal	EUR	5.7	-4.4	-4.5	-4.4	-7.7
Romania	RON	2.7	-2.7	-4.9	-0.7	-5.6
Slovenia	EUR	-2.0	0.1	-1.1	-4.9	-7.6
Slovakia	EUR	6.9	2.4	5.5	-6.2	8.3
Finland	EUR	0.2	0.5	0.7	-0.7	0.8
Sweden	SEK	0.5	0.6	2.6	2.1	5.9
United Kingdom	GBP	-0.9	-1.9	0.0	-0.6	-3.4
Iceland	ISK	-15.4	-9.7	-2.4	3.0	-23.2
Norway	NOK	-0.4	0.9	5.9	2.2	8.7
Switzerland	CHF	1.4	0.6	3.6	1.9	7.7

Figure 4. Change in median equalised disposable income, 2008-2012

The figure shows how countries such as Greece, Cyprus, Portugal, Slovenia, Italy, Croatia, Spain, Ireland and Hungary have all experienced a decrease in their median equalised disposable income over the four-year period. In the other hand, other countries such as Luxembourg, the Netherlands, Romania, Austria, Denmark, Germany, Bulgaria and the Czech Republic have suffered a total decrease average in the four years There are some countries that during this period have an increased in their median equalised disposable income, but this increase is not equivalent to the increase of the household electricity price.

2.2.2. Accessing cheaper fuel prices by using another supply systems

The second factor for the development of the energy poverty by Preston is the access to cheaper fuel prices by using other supply systems. The householders have the option to select the best alternative for their houses in to access another most profitable supply system.

However there are different barriers, which will be explained in the next paragraphs, for them to choose a better alternative for their homes.

The access to the energy market in order to compare prices and select the best alternative for them is dependent to have different abilities as internet access and knowledge in the energy sector. In Europe there is a 17% of the citizens[8] without internet access in their homes and it is use to be linked to the low-income households. The fuel type is another reason which has implications for the cost of energy in the home because households living in more rural areas have to use more expensive heating systems as oil.

Another important barrier for the householders to choose a cheaper option is because sometimes they do not have the facilities to do it. The main reason of this is because some countries or areas do not have the same facilities than others. In the next paragraphs the percentage of heating systems used by each EU Country will be analysed in order to evaluate how the systems available in each place is affecting the fuel and energy poverty. The first step is to define the different heating systems that operate in Europe. After this, a comparison between the percentages of the heating systems used per country will be made. Furthermore, a brief definition of the different heating systems, which will be evaluated in this section, is needed in order to know their main characteristics. These definitions are shortly mentioned in the following section:

- The first type of heating systems is the individual central heating. This heating system is a centralized heating appliance to heat the whole dwelling.
- The second type of heating system is the collective central heating which does not include the district heating. The central heating included more than a house or apartments and it is controlled from one central point in the building where there will be a specific date during the year when the system is turned on for the winter and off for the summer.
- The third system studied is the district heating which is a system for distributing heat generated in a centralized location.
- The last heating system is the room heating, which consists of a non-centralised heating appliances used to heat separate premises in the dwelling.

After the definition of the four types of heating systems, it will be analysed how these systems are implemented in each country. The Table 1 shows the percentage of households by heating system and share of households with central heating in EU. As it was explained in the section 2.2.1, the countries with the highest energy and fuel poverty rates in Europe are Romania, Hungary, Croatia, Cyprus, Latvia, Lithuania, Ireland, Greece, Poland, Italy, Malta, Spain, Portugal, Estonia, Slovakia, Belgium and the United Kingdom. Most of these countries have as the main heating system individual central heating and room heating. These heating systems have higher consumption than the collective central and too much higher than the new district heating systems.[9] Some of the European countries have been using the district heating systems from several years ago. These systems have efficiency lower than the new systems. This situation can explain why countries as Lithuania or Poland are using a high percentage of district

[8] Share of households with internet access in the European Union (EU28) (Statista 2016)

[9] Euroheat & Power (District Heating in Buildings, 2011)

heating but the energy poverty in these countries is between 20-40%, as it is explained in the chapter 2.1.

It is not a coincidence that the EU countries where the rates of fuel and energy poverty have a lower value than the countries mentioned before are using a higher percentage of district heating. As it is studied in this report, there are different factors for the development of the energy and fuel poverty. However, the type of heating system used is one of the most important and as it is possible to appreciate in the table 1, the most developed countries in Europe, talking about energy and fuel poverty, are improving their system in order to implement the district heating systems.

Heating Systems in Europe	Individual central heating (%)	Collective central (%)	District heating (%)	Room heating (%)
Austria	61.97	14.20	18.51	5.32
Bulgaria	38.09	1.61	16.40	43.90
Cyprus	37.80	0.00	0.00	62.20
Czech Rep.	48.41	20.11	25.11	6.38
Denmark	31.78	3.14	57.56	7.52
Finland	8.72	17.88	40.39	33.00
France	79.45	14.47	4.12	1.96
Germany	38.74	36.79	15.89	8.58
Greece	22.64	47.25	1.25	28.85
Hungary	33.90	3.15	17.25	45.70
Ireland	98.15	0.00	0.00	1.85
Italy	72.65	0.03	24.35	2.97
Latvia	19.20	56.50	0.00	24.30
Lithuania	11.83	21.65	57.63	8.89
Luxembourg	75.43	20.87	0.00	3.71
Malta	0.67	0.00	0.00	99.33
Netherlands	62.36	17.67	11.39	8.59
Poland	21.00	26.00	40.00	13.00
Romania	19.00	0.43	22.89	57.68
Slovakia	30.13	30.86	26.70	12.31
Slovenia	85.76	0.00	0.00	14.24
Spain	48.75	23.75	0.00	27.50
Sweden	49.30	50.69	0.00	0.01
UK	90.58	1.52	0.90	7.00
Serbia	6.46	19.13	15.44	58.98
Croatia	44.69	0.00	0.00	55.31

Table 1. Share of households by heating system and share of households with central heating in the EU[10]

These reasons make more difficult the access to a cheaper alternative system for the householders. Sometimes is because the householders cannot access to the different alternatives but also as it is explained above they don't have the possibility.

[10] (ENTRANZE,2015) Policies to Enforce the Transition to nearly Zero-Energy Buildings in the EU-27 http://www.entranze.eu/

2.2.3. Energy needs

The third factor for the development of the energy poverty is the energy need. It exist different groups of persons, such as older people, those with disabilities and families with very young children who requires a highest consumption in heating.

To develop an consumer vulnerability strategy a definition combines consumer's personal circumstances and characteristics with aspects of the energy market .This definition identifies five key characteristics that it considers central to a consumer being 'at risk' of being vulnerable, namely: consumers of pensionable age; with a disability; chronically sick; with a low income; or that live in rural areas.[11]

The vulnerability of the different consumers is relevant to understand the highest consumption between different groups. This report is focused in the average of heating and cooling needs per country in Europe.

2.2.4. Energy efficiency

The third factor that is responsible of the development of the fuel and energy poverty is the energy efficiency of the dwelling. The installation of energy efficiency measure in the households is relevant to reduce the fuel used and the expenditure linked to have a warmer home. Although, this is an important factor, it is not a direct comparison between the European countries because the colder climates will need more insulated buildings.

The energy efficiency of the different materials which are applied at building construction is measured by the U-Value (W/m^2K). The U-Value is measure from the heat transmission through a building part; this means that the higher the U value the worst the thermal performance of the building envelope will be. A low U value usually indicates high levels of insulation. In the Table 2 is possible to appreciate the top ten EU countries with the highest U-Value per part of the building. Some of the countries might appear in all of the sections or in a high part of them, the reason of this is because the U-Value of the materials used in the dwelling are really high and the energy efficiency is really low. A high percentage of the countries which appear in the Table 2 are part of the highest rate of fuel and energy poverty in the European Union, as it is explained in the section 2.2.1. It is not a direct reasons as it is explained in the

beginning but the difference is so high that it make a factor to take in account. The colder countries have lower u-values but as it is possible to appreciate in the next table some of these countries have not too low values.

[11] Smith, K. (2013a) Consumer Vulnerability Strategy. Final decision.

Highest U-Values per part of the dwelling (W/m²K)							
Floor		**Wall**		**Ceiling**		**Window**	
Netherlands	3.67	Malta	2.23	Cyprus	3.30	Cyprus	6.00
Malta	2.61	Spain	1.82	Portugal	2.58	Malta	5.80
Cyprus	2.00	France	1.73	Malta	1.96	Italy	5.20
Portugal	1.95	Belgium	1.64	Italy	1.79	Spain	4.64
Italy	1.75	Romania	1.58	France	1.61	Portugal	4.09
Spain	1.73	Italy	1.52	Belgium	1.57	Belgium	3.65
Slovakia	1.68	Portugal	1.44	Netherlands	1.42	France	3.55
Romania	1.46	Cyprus	1.4	UK	1.38	Ireland	3.48
France	1.44	Serbia	1.36	Slovakia	1.36	Netherlands	3.36
UK	1.13	Bulgaria	1.28	Romania	1.31	UK	3.35

Table 2. EU Countries with the highest U-Values per part of the household[12]

A thermally-efficient dwelling does not eliminate the risk of its occupants facing unaffordable energy costs having as a consequence the experience of a cold home.[13] The high energy and fuel expenditures cannot be costed if the incomes are not enough although the households will have different energy efficiency measures.

2.2.5. Policy impacts

The last factor for the development of the energy and fuel poverty which will be explained in a brief mode is the policy impacts. This report is not going to be focused in the legislation applied by each country because it has been developed per each country without any common guidelines. As it is explained in the Section 2.1 the European Commission advised to the State Members of this problem in order to protect the vulnerable consumers and reduce this situation. However, these advices from the EC did not give any guidance for the Governments.

The Governments of the State Members have worked to reduce the energy and fuel poverty in Europe during the last years because as it is shown before it is an important issue to improve the quality life of the European Citizens. Each country has developed their own legislation in order to try to reduce the problem with their vulnerable consumers. Different legislations across Europe have been applied, during the last years, to reduce the energy and fuel poverty[14]. The governments have tried to reduce the impact of these factors but for different reasons, explained in the last points, the situation is worsening in Europe.

[12] (ENTRANZE,2015) Policies to Enforce the Transition to nearly Zero-Energy Buildings in the EU-27 http://www.entranze.enerdata.eu/#/floor-u-values.html

[13] Anderson, W., White, V. & Finney, A. (2010) "You just have to get by" Coping with low incomes and cold homes, Bristol.

[14] Energy poverty and vulnerable consumers in the energy sector across the EUOverview of European energy poverty research initiatives - Steve Pye (UCL), Audrey Dobbins (USTUTT) (May, 2015)

2.3. MSW treatments

The management of the municipal solid waste (MSW) is one of the highest expenses in the municipalities around the world. The waste treatment used around Europe is changing during the last decades but the boost of waste treatment systems to generate other raw materials could help to reduce the landfill waste treatment.

There are some countries as Germany and Netherlands, where less than 2% of waste is landfilled because the waste is used for other applications. Unfortunately, it is not a gradual result for all Europe. The Figure 6 shows how the average waste treatment is changing in the last decades from the landfill to other processes as the recycling, composting and incineration with energy recovery.

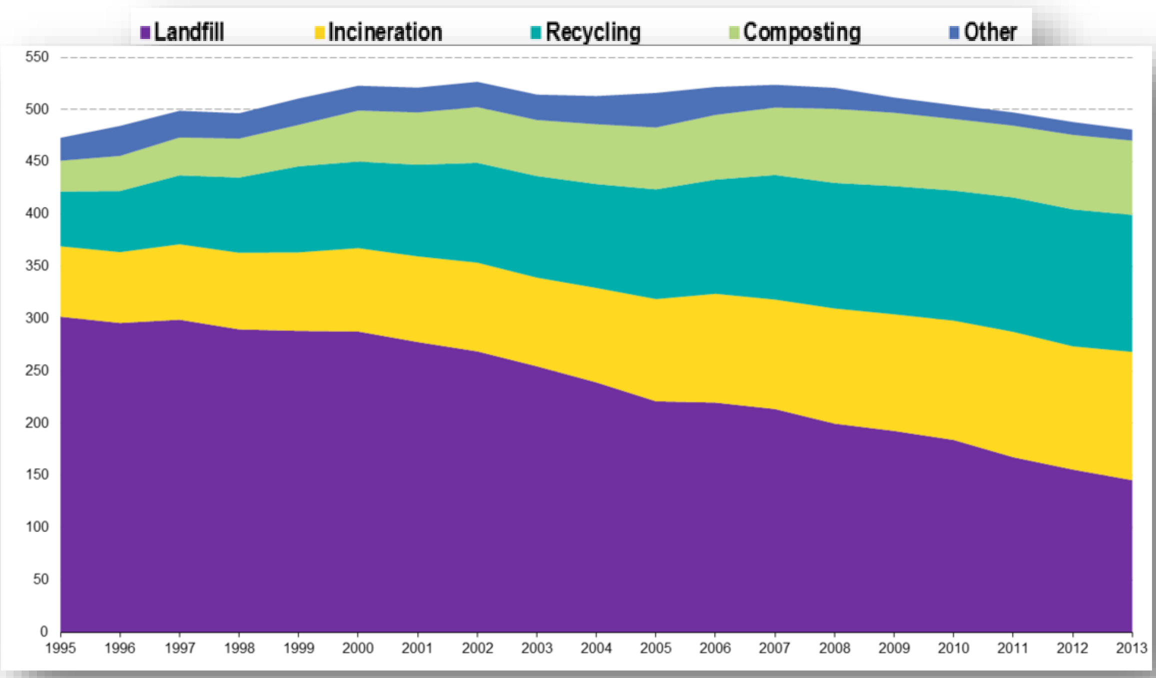

Figure 5. European Municipal Solid Waste Methods (kg per capita) (EC,2015)

As it is explained before, the landfill methods are decreasing gradually during the last years but most of the implementation is happening in some European Countries.

Some municipalities are spending a high amount of their budgets in the waste treatment without any incomes. The energy consultancies development of the decentralised energy systems will study the use of the MSW as raw materials.

As it is possible to see, the energy consultancy studies needed for the implementation of these decentralised energy systems have a high cost because it is needed to take in account so many factors to evaluate the viability of the investment.

2.4. Systematic Approach

The last section has analysed how the different factors are affecting the fuel and poverty situation in Europe. As we have seen, some of these factors are more relevant than others for this situation.

One of the most important factors is the rise of the energy prices relative to income growth because it affects to most of the EU countries. To increase the average incomes of the citizens there are different economic factors which are not linked with the aim of this project. The other key part of this factor is the rising of the energy prices in Europe because as it is defined in the section 2.2.2 a high part of the European Union continues using room heating or central heating and some of these devices work with electricity. It is needed to reduce the high cost of the electricity or the systems used for the heating in order to reduce the energy and fuel poverty.

The second most important factor is the energy needs and it is explained before that it is really difficult to reduce the vulnerability of some collectives as older people.

The implementation of individual actions to reduce the energy poverty could link two of these factors because the householders have to make an investment if they want to improve their systems. These three factors are the access to a cheaper fuel price and the energy efficiency measures. The investment by the householders sometimes is really difficult because they cannot make this effort in order to improve their systems or dwellings. However, it is possible to give them more options but the investments have to be done by Public Authorities or Private Funds.

As it is studied in the section 2.2.2, some of the most developed countries where the district heating systems are more common, the energy and fuel poverty rate is lower. To boost the implementation of the district heating systems in more areas, it is needed to analyse what are the main barriers for the implementation of the district heating systems.

As it said before, the investment for district heating could be done by public authorities as Municipalities, Regional Governments, etc... or by private companies or associations.

The main focus for the public authorities to make a decision investment in a specific activity for the private fund is the economic area. The reason for this is that the private funds only will invest their money in specific activity or in this case in district heating systems, if they will have a highest income than a deposit in a bank or another activity. However in order to avoid the risk of monopoly of the heat providers utilizing this for their own benefit, Denmark has the “heat supply law” saying that DH providers are not allowed to earn a profit. To be sure about the profitability of their investment, the private funds need to develop a techno-economic analysis in order to define the return of the investment.

When the exact investment and the return of this is defined, the companies can then take a better decision to invest in these systems. However, in some of the cases and for different technical reasons, it is difficult to define the return of the investment. These technical reasons need the development of an energy consultancy of the system and the city in order to study different technical parameters. The development of these energy consultancies, used to analyse if the investment is profitable, are mostly expected as high cost and they cannot warranty that the study will be positive.

Regarding the public funds, in addition to the economic reasons of the energy consultancy studies, another reason which makes more difficult the investment in the district heating systems is the political issues.

This project will not study these political issues but the political issues are relevant for the Public Authorities. The return of the investment for the district heating systems will not be so short to show to the citizens that it has been an improvement for them. In order to show the improvement developed by politicians, they like to show how they are improving the quality life of their citizens. Most of the time, the implementation of these consultancy systems studies, are evaluated as a waste of money and it is not a social point for them. However, as it is explained in the section 2.3 the MSW could be treated and generate some outputs in order to reduce the fuel and energy poverty.

According to the evaluation of the five risk factors for the energy and fuel poverty and the use of the MSW,   the next chapter, will state the research question used in the project in order to find the most accurate method to this issue.

3. Research Question

The energy and fuel poverty is one relevant issue in Europe as it is explained in the section 2.1. It has been analysed which are the main factors in Europe which are boosting the energy and fuel poverty. As it is explained before these factors are:

- The impact of rising energy prices relative to income growth.
- Accessing cheaper fuel prices.
- Energy needs.
- Energy efficiency.
- Policy impacts.

After the study of these factors in Europe, it is possible to appreciate some of the improvements which could be implemented in each factor. An example is that there are some installations which could be implemented in order to improve the insulations capabilities of the dwellings. However, it is explained in the sections above that the investment by the households in some countries is more difficult by the economic difficulties that Europe is living in the last years.

On the other hand, the investment in new heating systems by public and private funds also is having some barriers in order to boost these kinds of heating systems. The behaviour change of both funds is needed for the improvement of the life quality of the European citizens. The main reason which has been analysed in the section 2.3 is the unknown investment the investors need to do in district heating systems so they can evaluate the profitability of the inversion. To have this information, it is needed a techno-economic energy study which will evaluate if the inversion is profitable.

After the analysis developed in the Chapter 2, which check the factors for the development of the energy and fuel poverty in the European dwellings through the MSW treatment, this report will focus in how make more attractive the investment in new supply heat systems for the different stakeholders in order to improve the life quality of the European citizens.

What are the barriers for municipalities and private funds to improve the current energy supply systems and how can these be removed or reduced through the MSW treatment?

4. Methodology

The last two chapters provided an overview of the whole background of the project, were the problem analysis landed in a research question that makes possible to define a methodology in order to get a solution for the problem statement. The main purpose of this chapter is to introduce the eleven different chapters that comprise the project structure of this report as well as the methods used to develop the main analysis of the research question.

4.1. Project structure

After the first chapters where it is explained the Problem Analysis and it is developed the Research Question, it is needed a chapter 4 for the definition of the methodology which will be follow during the report. This section explains all the methods used during the report to carry out each section.

Chapter 5 is divided in two main sub chapters. The first one is a general definition of the technologies which are presented as the solution in order to carry out the Research Question of the Chapter 3. This technology is explained from a general point of view to make easier the compression of the solutions and the development of the rest of the chapters.

The second part of this chapter is the technical details of the supply energy systems in the two real cases. These study cases show to the reader the barriers which the main stakeholders will find in the implementation of the solutions proposed.

The chapter 6 ,7 and 8 are the results obtained from the evaluation of the two real cases. The chapter 6 is the environmental assessment of the solution proposed. The next chapter is the business economy analysis which takes in account the different benefits from an economic perspective. The last chapter of them evaluates the externalities linked to the development of these solutions or implementations. These measures provide by themselves the different economic barriers which the municipalities or external investors use to find in order to develop these kind of solutions.

Chapter 9 is developed in order to detect some general political barriers for the development of these solutions. The difficulty of the evaluation of the different legislation available in each country makes this report focus in one of the most cost-effective energy planning systems in the world, Denmark. After this political evaluation chapter 10 summarizes the economic and political barriers. The economic barriers are obtained from the real cases evaluated during the chapters 6, 7 and 8 and the political barriers detected in the chapter 9. The last chapter is the number 11 which is the conclusion of the report. This chapter gives the final answer obtained during the report in order to solve the problem planned in the main research question of the chapter 3.

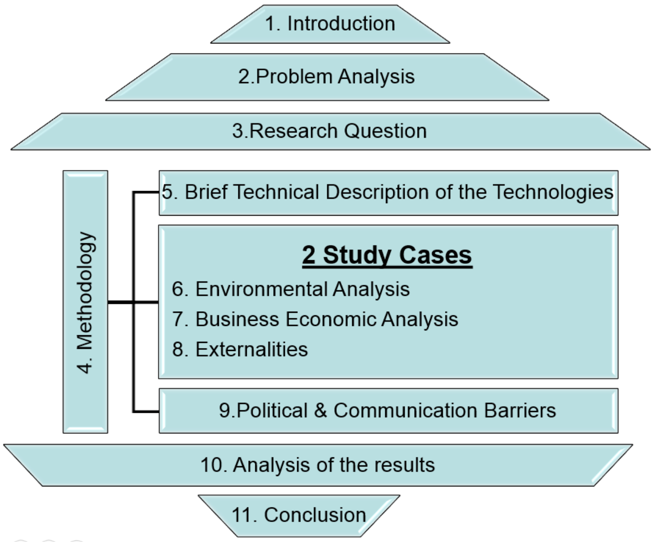

Figure 6. Project Structure

4.2. Methods of the report

The following section illustrates how the different aspects addressed by the research question will be dealt with and what methods will be used to approach these issues. The methods used in the report are summarised by chapter as is it possible to detect in the Table 3.

4. METHODOLOGY

Contents

- Localization of barriers
- Study Cases
- Excel Datasheet Tool
- Theoretical background on the economic assessment

5. TECNICAL DESCRIPTION

Contents

- MSW treatments, Backup and distribution Systems
- Details of the supply energy systems in the two real cases.

Methods

- Excel Datasheet Tool
- Literature review

6. ENVIRONMENTAL EFFECTS

Contents

- Environmental emissions in each scenario before and after the implementation.
- The difference between the amount of emissions before and after the implementation

Methods

- Excel Tool Model & Reference system to evaluate the results
- Literature review

7. CONSUMER ECONOMY & BUSINESS ECONOMIC ANALYSIS

Contents

- Consumer economy
- Capital cost: investment & Net present value calculation
- Operation costs in each scenario before and after the implementation

Methods

- Excel Tool Model & Reference system to evaluate the results
- Literature review

8. EXTERNALITIES

Contents

- Definition of externalities
- Identification and analysis of the related externalities

Methods

- Literature review

9. POLITICAL & COMMUNICATION BARRIERS

Contents

- Danish Heat Planning Powers and Responsibilities as framework
- Policy Advice

Methods

- Literature review

10. Analysis of the economic and political barriers

Contents

- All the economic and political barriers localized during the report are analyzed in order to reduce or skip them.

Methods

- Excel Tool Model
- Barriers localized in chapter 7 and 9
- Literature review

11. CONCLUSION

Table 3. Methods of the report

Table 3 shows in detail each method linked to the different sections. The chapter 4 shows the contests where it is explained the Excel Datasheet tool and the different economic processes which will be developed.

The next chapter explains the technologies which are presented as the solution for the energy and fuel poverty. The principal methods applied in this section are literature review in order to explain all the details of the technologies in general. Also, this chapter has another section where it is explained all the technical details for the new supply energy systems proposed with the Excel Tool. The next two chapter, number 6 and 7, applied the same methods because they use the Excel Datasheet Tool in order to obtain an economic and environmental assessment of the specific real cases. Both of them also use the literature review for different information.

The chapter number 8, externalities, shows how the implementation of these projects could affect to the rest of the sectors and it is based on the literature review. The chapter 9 is use as the main method literature review, in order to detect the main politic barriers that make the implementation of these technologies more difficult than in others countries like Denmark.

4.2.1. Study Cases

The Excel Datasheet tool is tested with the choice of two real cases. The choice of two real cases is regarding the use of this tool in two different weathers to check the impact in both places.

One of them is developed in Córdoba, a city in the south of Spain which will have different needs than the second case which is in Coventry, UK.

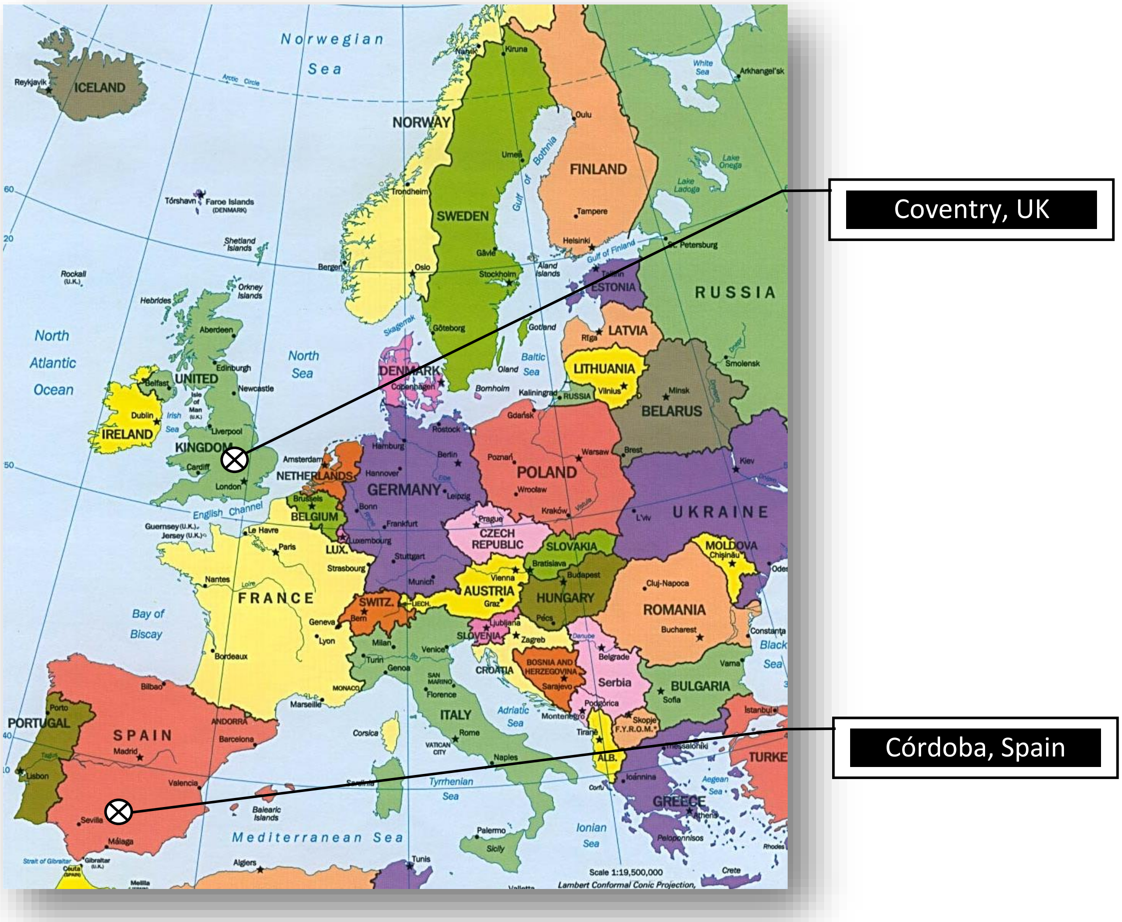

Figure 7. Study Cases

The choice of these cities is because it will be tested the tool for the development of a CHP and a CCHP. As it is explained in the section 2.1, Spain and UK have between 20-30% of their citizens with fuel and energy poverty issues. The study of these two cases will show the main economic barriers and how could be improved their energy supply systems.

As it is explained in the next section Excel Datasheet tool, the cooling systems in dwelling will be used in some specific countries. For this reason, it is selected Córdoba, a city in the south of Spain. This city needs district heating during the winter months and district cooling for the rest of the months. The study of the implementation of a CCHP in Córdoba will carry out an economic and environmental assessment and some economic barriers will be detected.

Córdoba, Spain	
	**Population:** 328.773 **Heating Consumption per dwelling:** 4797 Kwh/a **Primary Energy for Heating:** Electricity **Cooling Consumption per dwelling:** 4230 Kwh/a **Primary Energy for Cooling:** Electricity **Main type of dwellings:** Low Rise Flats

Table 4. Real Case 1. Córdoba, Spain

The second study case is in Coventry, a city in the hearth of UK where the heating consumption will be the main output for the citizens which will be studied with the development of this project.

Coventry, England	
	**Population:** 316.900 **Heating Consumption per dwelling:** 12677 Kwh/a **Primary Energy for Heating:** Natural Gas **Main type of dwellings:** Small terraced

Table 5. Real Case 2. Coventry, UK

Both cases will be compared with a reference system in order to evaluate the results obtained.

4.2.2. Excel Datasheet Tool

The main purpose of this Excel tool is to obtain a first economic and environmental consultancy study to improve the current energy supply system of different countries in Europe. These types of measurements will boost different options to make easier for the user to have their dwellings in a more comfortable temperature according the needs.

The reason why this first consultancy study is necessary for the municipality and external investors is because they can have it in a fastest and reduced costs way. They have the power to take decisions and the money for the investment in order to improve the current energy and fuel poverty.

The research question of this project is focused in the analysis of the different barriers that currently make the district heating systems have not been implemented in many municipalities or cities or they don’t have a cost effective operation. There are different barriers but this tool is focused in the economic aspects because it is one of the most important points for municipalities and external investors. This tool is useful for the municipalities in order to show to their citizens that their account is going in positive numbers and that the external investors can recover the high investment and obtain more percentage than the deposit in a bank without risk.

As the results of getting an energy consultancy study is expansive and with risks of negative results, many companies and municipalities interested in this technology do not choose to invest in them because they don't know if the technical study will be favourable.

This application will make anyone interested in the improvement of the energy supply system of their city evaluate if their city can improve in a cost effective way with the use of the MSW in CHP or CCHP. For this reason, the municipalities and external investors can check if it is feasible to make an investment in a detailed energy consultancy study, eliminating quickly the first economic barrier of these studies. The Excel tool is focused on two fundamental aspects; increase the use of district heating and district cooling systems and the use of MSW as the primary fuel in order to solve two different municipality issues at the same time.

The first step to fill in the tool is regarding some general questions to set up different parameters depending on the country where you want to perform the study. These parameters are defined by themselves with the information of implementation place[15]:

- MSW produced per inhabitant and country (kg): it is used as data base the information obtained from the Eurostat Statistics studies where it is possible to obtain the kg generated per country and person (Eurostat, 2014)
- Average heating consumption per dwelling in each country (Kwh/a) (2014)
- Average cooling consumption in each country (Kwh/m^2 a): it is taken in account the countries where the cooling consumption is more than the 5% of the dwellings use to have air conditioning. (2014) [16]
- Average dwelling size per country (m^2)[17]: it is needed the average size of each dwelling per country in order to obtain the cooling consumption.
- European electricity price for households and industry per country (€/kwh) (2014)
- European natural gas price per country (€/kwh) (2014)
- European average end users costs of others fuel price (€/kwh) (2013)
- Grid Distribution, Costs of district heating networks: for this reference is taken in account the district heating infrastructure and connection costs by built form. It is relevant that the Excel users will fill the sheets with the type of houses that they would like to supply. The infrastructure costs of a converted flats is not the same that a semi-detached. [18]
- Average CO_2 emissions for each fuel type (CO_2/kwh) (2013)

The next step to fill the Excel sheet are the heating and cooling consumption which it is needed to cover with the new energy supply system. Both consumptions are divided in residential demand and non-residential demand. To compare the system which will be proposed by the

[15] European Statistics – Eurostat http://ec.europa.eu/eurostat

[16] (ENTRANZE,2015) Policies to Enforce the Transition to nearly Zero-Energy Buildings in the EU-27 http://www.entranze.eu/

[17] (ENTRANZE,2015) Policies to Enforce the Transition to nearly Zero-Energy Buildings in the EU-27 http://www.entranze.eu/

[18] The potential and costs of district heating networks, Pöyry energy (oxford) limited (April, 2009)

Excel tool using the MSW is needed to have a reference system. The two alternative systems which will be proposed are a CHP or a CCHP to use the current MSW. Also, these systems will have a backup system which will supply the network if it is needed.

To introduce these demands it is needed to fill which kind of heating or cooling fuel are currently using. It is needed in order to compare the operation and maintenance costs and the environmental emissions of each technology compare with the new energy supply system. The different options are electricity, oil, natural gas, biomass, district heating and others.

Once the total demand for heating and cooling is completely filled, the system capacity could be designed with the current MSW available in the area. This system will supply a percentage of the demand and a second system (To be defined) will supply the rest. It is needed to explain some assumptions which have been used for the development of the plants and their operation & maintenance:

- The MSW has different heating Value. For the design of the plant is used a MSW heating value of 9,5 MJ/kg.[19]
- The investment linked to the CHP plants is around 5,75 M€/t/h of capacity.[20]
- The lifetime used for the distribution system used is 40 years.
- For the O&M linked for these technologies is used the next amount 53€/t. [21]

The outputs obtained from the tool after the design of plant and the comparison with the demand needed, are these two analyses:

- Business Economic Analysis
- Environmental Analysis

Both analyses are defined in the report in the next sections. However, it is needed to know that these two analyses will be the final documents for the stakeholders in order to take in account this technology for the improvement of the current energy supply system.

In the figure number 5, it is possible to observe the methodology explained above. In this structure, it is applied the assumptions and data explained before which are needed for the development of the final economic and environmental analysis.

The key point to know that this technology will supply a real case is the calculation of demand for both heat and cold. In this section, it is needed to specify if the demand is for residential or non-residential uses.

After the demand is completely defined, the system will be designed by the MSW available. In order to supply all the heating and cooling demand, another second system could be designed as complement of the CHP or CCHP from the MSW. It is possible to obtain an economic and environmental analysis with the information introduced about the different fuel type uses before the improvement of the energy supply system.

---

[19] Incineration of Municipal Solid Waste – Department for Environment Food & Rural Affairs UK Government (February, 2013)
[20] Technology data for Energy plants. Generation of Electricity and District Heating, Energy Storage and Energy Carrier Generation and Conversion (May, 2012)
[21] Technology data for Energy plants. Generation of Electricity and District Heating, Energy Storage and Energy Carrier Generation and Conversion (May, 2012)

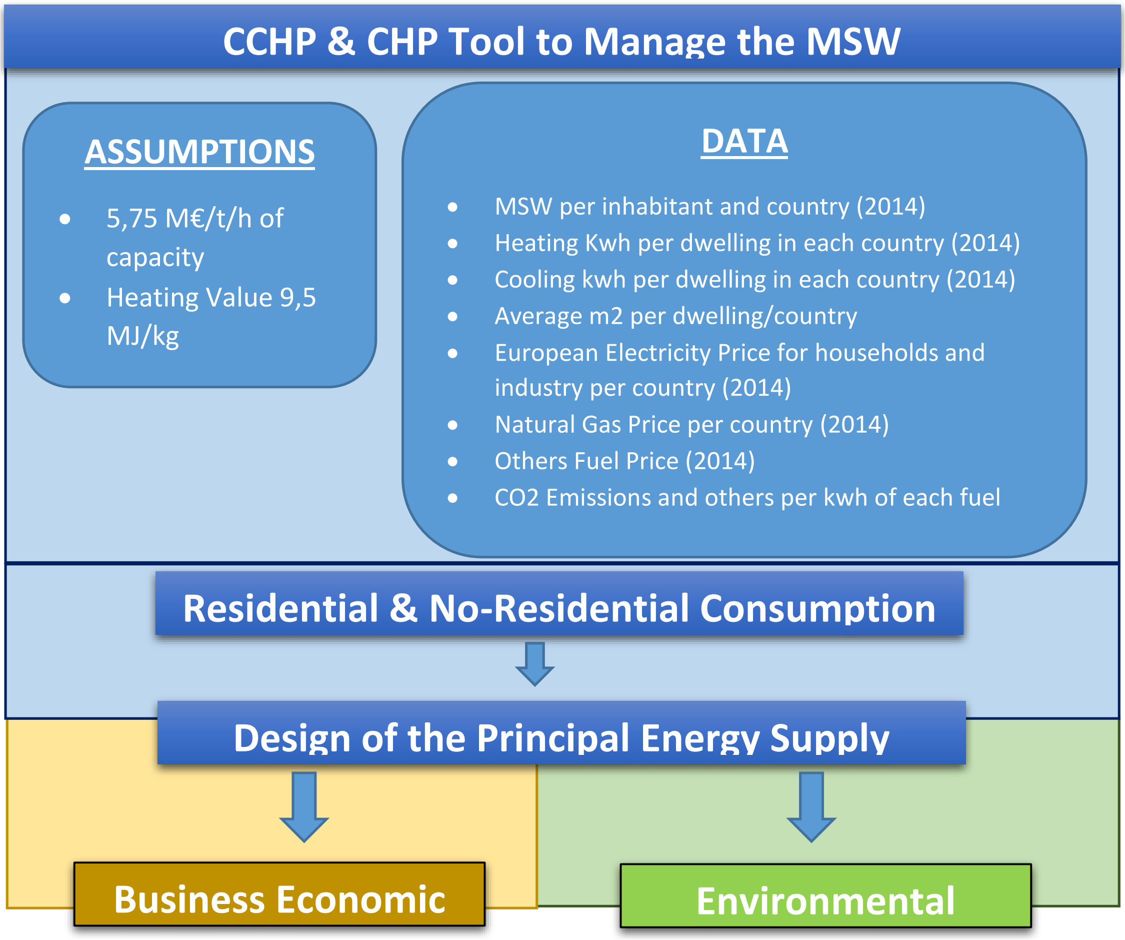

Table 6. Excel Tool Methodology

4.2.3. Economic assessment

Net present value

In this project the economic assessments is calculated by a cost-benefit-analysis that results in a present value of an investment. The net present value gives the discounted value of future costs and benefits in the period of the project and is given by the formula:

$$Net\ present\ value\ (NPV) = \text{capital cost} + \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

Capital cost: the initial one-time cost of developing the infrastructure needed (the pipes needed for the district heating is not included in this first energy consultancy study)

T: timeframe of the investment

r: discount rate

t: specific year (1, 2, 3 … 19, 20) of the cash flow

Bt: the operation benefits in the specific year, t.

Ct: the operation costs in the specific year, t.

The cost-benefit-analysis is often used as a part of evaluating the feasibility of an investment. The yearly costs in a cost-benefit-analysis are defined as operation costs in the project and these can embody fuel prices and operation and maintenance costs among other things. The yearly benefits of a cost-benefit-analysis are defined as operation benefits in the project and these can embody saved operation costs among other things.

Discount rate

In the calculation of an investment´s net present value a discount rate is used to equate future receipts and payments that do not fall at the same time, because the money does not have the same value in the future. The discount rate makes sure that future cash flows are attributed less value. It is among other things an expression of lost opportunity for alternative return on other investments. It is also an expression of the uncertainty about whether the future payments will be paid or not. (Lund & Østergaard, 2010)

The size of the discount rate can have huge impacts on the economic result, especially for projects with longer time frames. For private investments the discount rate is often at least matching the interest rate on a bank loan. According to Fundamental Investment Theory it is possible to borrow at about 10% for companies in Denmark for which reason this could be used as a discount rate. However, the interest rates have been lower during the last couple of years, so a lower discount rate ought to be used for companies. In the case of municipalities in Denmark a lower discount rate is used, since it is a public company. The ministry of Finance in Denmark estimated that a discount rate of 6% must be used for all public investments. (Lund & Østergaard, 2010) However, they have changed this recommendation to 4% and the Danish Energy Agency also recommends using the same for a lifetime of up to 35 years (The Danish Energy Agency, 2013). In this project a discount rate of 4% is used, nonetheless, due to the fact that it has a crucial impact on the calculated net present value, a sensitivity analysis of the discount rate is also carried out.

Taxes, levies and subsidies

The taxes and subsidies in Europe depend on each country. The landfill of the MSW has higher taxes in some countries than others in order to reduce these methods.

The business economic analysis does include taxes and possible subsidies. Socio-economic theory distinguishes between two different methods of calculating the socio-economic value of a given investment i.e. the method of including taxes, levies and subsidies and the method of excluding taxes, levies and subsidies.

Including the taxes, levies and subsidies, the socio-economic value is calculated on the prerequisite of the citizen´s payment willingness in this method. This method states the socio-economic value in consumer prices which includes taxes and levies. (Trafikministeriet, 2003)

Excluding the taxes, levies and subsidies, this method calculates the socio-economic value from a resource-based approach based on the costs of a given investment. Taxes and levies are considered as redistribution within the society and are thereby not considered as an actual cost in an investment. Therefore, taxes and levies are not included in the calculation in this method. (Trafikministeriet, 2003)

The current system of the taxes and subsidies has big influence on the profitability of the investment. The socio-economic calculation in this project is based on the latter described method and therefore determines the socio-economic value without considering the distribution of taxes, levies and subsidies. Consequently, the result of the calculation is not dependant on the current system of the taxes and subsidies as well as the future changes in the system.

Tax distortion loss

The Danish Ministry of Finance recommends using a tax distortion loss when calculating socio-economic net present values of investments with a net cost for public finances, as this net cost has to be financed through additional taxation of other activities. This additional taxation of other activities is thus defined as a distortion entailing a so-called tax distortion loss. The Ministry of Finance argues that this distortion loss has to be accounted for by adding 20% of the needed tax borrowing requirement to the cost of an investment. For every 1 DKK of additional tax, that the investment will entail, a cost of 0.2 DKK thus needs to be included in the calculation.

In the report “Varmeplan Danmark 2010” by Rambøll Danmark and Aalborg University it is argued that the use of a tax distortion loss is problematic, since the assumption and prerequisite behind it are based on a perfect market model, saying that in the situation before the increased taxation all costs were reflected in the market price, meaning that there are no externalities. However, from an institutional economic understanding, tax structures are an effect of political decisions and compromises and are thus defined for purposes other than purely economic optimization. For that reason, it is argued that the situation is not optimal before the tax distortion and that the use of 20% is therefore problematic. Besides, it is argued that there are no economic analyses performed in depth that can describe how the current tax system influences the national political goals. Such analyses are necessary in order to be able determine the influence of a change in the tax system. (Rambøll Danmark & Aalborg Universitet, 2010) Because of these arguments, the tax distortion loss of 20% is not included in the socio-economic calculation.

5. Technological Descriptions

5.1. General Technical Description

In this section, it is described the different technologies from MSW. In this case, the input used in these technologies is the Municipal Solid Waste (MSW) because it is possible to solve another of the municipal issues as the waste treatment. After the first part, it will be explained the benefits and why one of these technologies will be analysed in this section. There are technologies that are able to produce energy from waste and other fuels.

- Gasification: the treatment of the MSW produces combustible gas, hydrogen, synthetic fuels.
- Thermal depolymerisation: the treatment of the MSW produces synthetic crude oil, which can be further refined.
- Pyrolysis: This process produces combustible tar/bio oil and chars
- Plasma arc gasification or plasma gasification process (PGP): produces rich syngas including hydrogen and carbon monoxide usable for fuel cells or generating electricity to drive the plasma arch, usable vitrified silicate and metal ingots, salt and sulphur
- Anaerobic digestion: the output of this treatment is biogas rich in methane
- Fermentation production: examples of the outputs are ethanol, lactic acid, hydrogen
- Mechanical biological treatment (MBT)
    - MBT + Anaerobic digestion
    - MBT to refuse derived fuel
- Combustion: Waste to Energy CHP & CCHP

However, this report is focused in the technology CHP and CCHP for different benefits explained in this section. Also as it is possible to appreciate most of the outputs from the other technologies explained above doesn't contribute directly to reduce the energy and fuel poverty. There are different inputs as primary fuel for the CHP and CHP plants. In this case it is studied the MSW and another materials as combustible wastes, water and chemicals for flue gas treatment, gasoil or natural gas for auxiliary burners (if installed), and in some cases biomass for starting and closing down.

The composition of municipal solid waste varies greatly from municipality to municipality (country to country) and changes significantly with time. It is going to be explained the case of Copenhagen, to have an idea regarding the heating values of the MSW. The heating value for MSW in the Waste-Energy CHP plant in Copenhagen has increased in the last year to 10.5 MJ/kg in 2008 and in the upcoming years it is expected that it will be increased to 11.5-12 MJ/kg by 2025.

The CHP plant is defined as Combined Heat and Power. As it is explained before, the plant is designed to incineration of MSW and another non-hazards residues from the industry. Some types of hazardous waste can also be incinerated. The MSW is delivered by the recollection system and is normally incinerated in the state it arrives but bulky items are crushed before being fed into the waste bunker. The main components of the CHP plant are:

- Waste reception area
- Feeding system
- A grate fired furnace interconnected with a steam boiler
- A back pressure steam turbine
- A generator
- Extensive flue gas cleaning system
- Systems for handling of combustion and flue gas treatment residues. [22]

The CHP plants as his name said is the co-generation of useful thermal energy and electricity from the MSW. The design and operation of CHP plants is variable depending on the needs for the development of the plants. The most modern CHP plants reach efficiencies of 90% or more. CHP plants also reduce network losses because they are sited near the end user.[23]

The definition of CCHP plant is the Trigeneration or combined cooling, heat and power. It means to the simultaneous generation of electricity and useful heating and cooling from the MSW as the principal fuel in this case. The main difference between the CHP plant systems and the CCHP is the equipment of an adsorption or absorption chiller to provide water chilling.

The chilled water can then be used in refrigeration or air conditioning systems. Typically about 38% of the energy supplied as fuel to the engine is converted to electrical energy. The rest of the energy leaves the engine as heat via the hot exhaust gases, the coolant system and the oil system. After the use of this percentage in the generator for the electricity production, a large amount of the waste heat can be recovered through heat exchangers and can be used to different utilities as heating or cooling.

The efficiency of the CCHP plant depends if it is used in a heating mode or in a chilling mode because the efficiency with the cooling system decrease the efficiency. The efficiency in the heating mode could arrive until 85% while the cooling system could have an efficiency around the 67%.[24]

5.1.1. Benefits of the CHP &CCHP:

The main benefits that the municipalities or private funds can see in the investment of these platas could be appreciated in the Figure 6 [25]. The benefits are divided in three main groups which are economic, environmental and social.

[22] Technology data for Energy plants. Generation of Electricity and District Heating, Energy Storage and Energy Carrier Generation and Conversion (May, 2012)

[23] Intergovernmental Panel on Climate Change (IPCC) (2007), *Climate Change 2007 - Mitigation of Climate Change: Working Group III contribution to the Fourth Assessment Report of the IPCC (Climate Change 2007)*, IPCC, Cambridge University Press.

[24] http://www.wartsila.com

[25] United States Environmental Protection Agency

The fist benefit it is the economic group which has the following four main points :

- <u>Reduced energy costs:</u> the higher efficiency of the CHP (around 80%) compare with the conventional systems (around 50%) reduces energy bills. Basically you need less fuel for a given energy production unit. In addition, because cogeneration systems typically use natural gas, which is often cheaper than purchased electricity, CHP can help reduce electricity bills. Invoices are further reduced because the CHP output reduces electricity purchases.
- <u>Avoid refurbishment capital:</u> when it is needed a replacement of the heating equipment sometimes the CHP can often reduce the cost.
- <u>Protection of revenue streams:</u> Using in situ generation and improved reliability, CHP can allow the facility to continue operating in the event of a disaster or interruption of the mains supplied.
- <u>Less exposure to rate increases:</u> Because less purchasing network facilities have less exposure to rate increases. Therefore, a facility could be built in the ability to fuel switch to protect against high fuel prices.

The second benefit is the environmental aspect which needed to take in account that CHP systems offer considerable environmental benefits compared with purchased electricity and thermal energy produced on site. By capturing and using heat which otherwise would be wasted electricity production, cogeneration systems require less fuel to produce the same amount of energy. Because it burns less fuel, emissions of greenhouse gases such as carbon dioxide (CO2) and other pollutants such as nitrogen oxides (NOx) and sulphur dioxide (SO2) emissions are reduced.

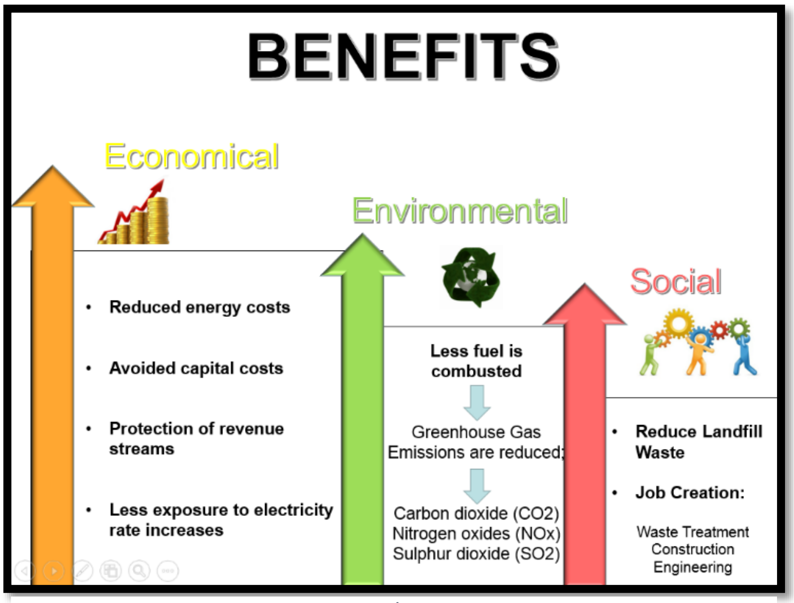

Figure 8. Benefits of CHPC/CHP which runs with MSW

The last benefit is the social aspect which will improve with the results of the implementation of CHPs or CCHPs. The environmental benefits also are part of the improvement than the society will obtain directly. However, there are different externalities which could be affected for the implementation of these technologies. The use of the MSW as primary fuel will reduce the landfill of the waste using this issue as the primary fuel for the plants. The other main point which could be improved is the job creation. The development of these energy supply systems will create jobs in different areas which are explained in the Chapter 8, Externalities. The energy consultancy study needed for the implementation of these projects will generate more renewable energy jobs. The average time for the construction of the plant use to be around three years and also the creation of a new grid network will generate many jobs. During the operation of the plant some different jobs will be created as long term as waste treatment, maintenance engineer and another person needed for the operation processes.

5.1.2. Backup System

The heat supply is a need of first order. This means that the energy supply system must have a secondary system to the CHP or CCHP explained above. The backup system is not required to be combined with electricity production as these systems have a much higher cost. [26]

These backup systems will only be used in specific cases and it is not advisable to make such a large investment for a punctual use.

These backup systems are boilers which can run with different resources as oil, natural gas or biomass. In this report, the primary fuel which is taken in account in order to use a non-fossil fuel is the biomass. The backup system proposed is a boiler fired by wood-chips from forestry and/or from wood industry, wood pellets or straw. Wood chips are wood pieces of 5-50 mm in the fibre direction, longer twigs (slivers), and a fine fraction (fines).

The system will be designed to cover the maximum heating consumption so this system could cover the heating consumption in any month of the year.

The biomass boiler will use the same distribution system designed for the primary energy supply system, so it is not needed an extra investment.

5.1.3. Distribution Systems

The outputs produced by the CHP or CCHP plants are focused in two main areas, electricity and thermal production. The efficiency of these plants regarding the electricity produced depends on the design and needs of each system. This electricity generated could be directly inserted to the grid in order to sell it or used in another facilities which could reduce their costs as water treatment. After the electricity production by the generator, the heating or cooling is distributed to the end users through a network of insulated pipes. District heating or cooling systems consist of feed and return lines. The network uses to be installed underground but it could be also over ground.

The common medium used for heat distribution is water or pressurized hot water, but steam is also used. Also, for cold distribution is used the chilled water. The steam in the heating mode could be used in industrial processes but the losses are higher because the temperature is higher also. The network at customer level is usually connected to the plant via heat exchangers (substations).

The nature of the housing stock has a significant impact on the economic potential of district heating since the cost of connection varies materially across built forms. It is represented in the next Figure 7 the distribution in pounds of the average costs for these works. This data has been used as is explained in the Chapter 4 as the representative costs for the distribution systems per housing stock.

The costs are divided in infrastructure and connections needed in the different dwellings. The different housing stocks available in the market have a different cost linked because the distribution are different. Also, the dense of the houses is relevant regarding both costs as it is

[26] Technology data for Energy plants. WASTE-TO-ENERGY CHP PLANT and DISTRICT HEATING BOILER, BIOMASS FIRED (May, 2012)

possible to see in the Figure 7. It is possible to appreciate that the converted flats need less investment in infrastructure because they have been improved but the connection costs are similar for this type of dwelling.

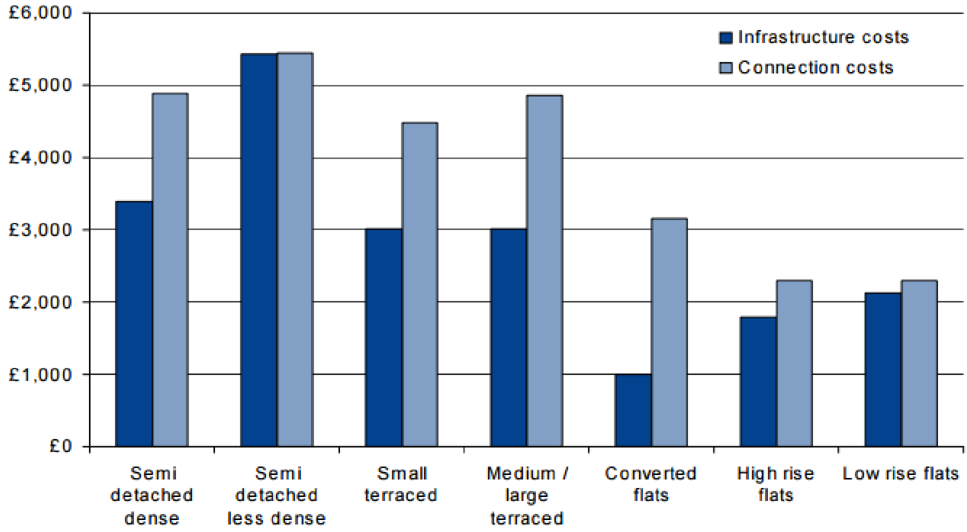

Figure 9 District Heating infrastructure and connection costs by built form

5.2. General Technical Description

This section explains which are the technical details of the two different study cases developed. It is explained all the technical aspects regarding the primary and the backup energy supply systems. These systems will be designed in order to use the MSW and cover the maximum consumption possible with this MSW. The economic and environmental aspects are analysed in the Chapter 6 and 7.

5.2.1. Technical Description Real Case 1

The real case 1, it is the study case of Córdoba and the use of the MSW generated. First step, the choice of Spain and the population of the city gives us different information which will be used during all the design.

Detailed Information for Córdoba, Spain	
MSW generated per person (kg)	435
Tonnes of waste into energy per year	143,016
Heating Consumption per dwelling (kwh)	4,797
Cooling Consumption per dwelling (kwh)	4,230

Table 7. Real Case 1, General Information

The total MSW will give directly the size of the new energy supply system. With these cooling and heating consumptions, the Tool will select the option of a CCHP for this case because the cooling is also needed in the dwellings. The next step in the Excel is the calculation of the needs that the new system, we would like to supply. The CCHP will cover only part of the total demand of the city because it is designed by the MSW generated in the city. It is introduced the residential and non-residential heating and cooling consumption. The tool will select the total number of dwelling which could be supplied. The number of houses is selected by the worst case between the heating and cooling consumption. To know the worst scenario, the tool will generate a heating and cooling percentage in order to divide the annual consumption by month. In the Córdoba case, the tool will supply 6396 dwellings with cooling and heating during all the year. Also, it has been included a non-residential building which will have heating and cooling consumption during all the year in order to supply also these kind of buildings.

The primary energy supply system will be a CCHP with the next characteristics:

CCHP Details	
CCHP Max Capacity (t/h)	16.33
CCHP plant Max Production (Heating Mode) (MW)	36.62
CCHP plant Max Production (Chilling Mode) (MW)	28.82
CCHP plant Max Production- Electricity (MW)	17.84
CCHP plant Max Production- Heating (MW)	18.78
CCHP plant Max Production - Cooling (MW)	11
Dwellings Supplied (nº)	6,389

Table 8. Real Case 1, CCHP Details

In order to ensure the heating in this system is added a backup system as it is explained in the section 5.1.4. However, this system will be used only in punctual cases and it is not feasible to have a CHP or CCHP only for these cases. As it is explained in the other section, the backup system is a biomass boiler with the next characteristics:

Biomass Boiler	
Capacity Backup System (MW)	0.93
Maximum Heating Capacity Needed (MWh)	7,969
Heating Efficiency	98%

Table 9. Real Case 1, Backup System

To check if the results obtained for the CCHP in Córdoba are similar or close to another plant of the same characteristics there are more issues than the case in Coventry. The CCHP technologies are not some implemented in the cities as the CHP and the information available is more difficult. However, the efficiency range used for the design of the plant has to different modes. The first one is the heating mode where the overall efficiency is 85% where the electricity has an efficiency of 41% and the heating 44%. The second case is the chilling mode where the total efficiency is 66,9% where the electricity has the same 41% and the cooling only a 26%.[27]

5.2.2. Technical Description Real Case 2

The second study case is Coventry and the use of the MSW generated to improve the costly-efficiency their energy supply system. As in the last case the first step, is to select UK as the country where the system will be implemented. The tool will supply us with the same information as in the above study case and it will be used during all the design.

Detailed Information for Coventry, UK	
MSW generated per person (kg)	482
Tonnes of waste into energy per year	152,746
Heating Consumption per dwelling (kwh)	12,677

Table 10. Real Case 2, General Information

[27] Sankey diagram showing energy balance for a high efficiency tri-generation plant

As happened before with the first case study, the total MSW will give directly the size of the new energy supply system. For UK it is planned only heating consumption and the tool will select the option of a CHP for this case because the cooling is not considered for the British dwellings.

The next step in the Excel is the calculation of the needs that the new system, we would like to supply. The CHP will cover only part of the total demand of the city because it is designed by the MSW generated in the city. It is introduced the residential and non-residential heating and cooling consumption. The tool will select the total number of dwelling which could be supplied. The number of houses is selected by the worst month case of the heating consumption.

In the Coventry case, the tool will supply 7,702 dwellings with heating during the months needed. The primary energy supply system will be a CHP with the next characteristics:

CHP Details	
CHP Max Capacity (t/h)	17.44
CHP plant Max Production (MW)	45
Max Electricity Production (MW)	11
Max Heating Production (MW)	34
Dwellings Supplied (nº)	7,702

Table 11. Real Case 2, CHP Details

Also, in this case in order to ensure the heating, it is added a backup system. Furthermore, the backup system is again a biomass boiler with the next characteristics:

Biomass Boiler	
Capacity Backup System (MW)	2.93
Maximum Heating Capacity Needed (MWh)	25,625.31
Heating Efficiency	97%

Table 12. Real Case 2, Backup System

In order to compare the results obtained with a real case, it is compared the Coventry CHP which with the Sheffield's CHP Facility. This other case in UK transforms 225,000 tonnes of waste into energy, producing up to 60 MW of thermal energy and up to and 19 MW of electrical energy. As it is possible to appreciate the percentage of generation are around 76% of heating and 23% of electricity. [28]These values are close to the system designed for Coventry the efficiencies developed are 74% for heating and 24% for electricity production.[29]

[28] ADE: The Association for Decentralised Energy: **District heating across Sheffield**

[29] Technology data for Energy plants. WASTE-TO-ENERGY CHP PLANT (May, 2012)

6. Environmental Effects

In this chapter, the environmental effects of investing in the implementation of the CHP and CCHP technologies using MSW will be analysed by describing and calculating the emissions. The emissions are calculated in two scenarios in each real case. The first scenario will be the current supply energy systems situation for heating and cooling consumption. The second scenario will be the situation if the solution proposed will be carried out.

There are different environmental effects of investing in CHP and CCHP technologies using MSW instead of the current energy supply systems. The incineration of MSW involves the generation of climate-relevant emissions. These are mainly emissions of CO2 as well as N2O, NOx and NH3. CH4 is not generated in waste incineration during normal operation. Waste is a mixture of CO2 neutral biomass and products of fossil origin, such as plastics. The CO2 emission factor used in the Excel Datasheet Tool is 37.0 kg/GJ.

Ecological footprints are: air and water emissions including dioxins as well as solid residues to be disposed of. In order to evaluate the exact reduction of CO_2 emissions as a result of implementing Cogeneration or Trigeneration technologies with MSW, the emissions from both the scenarios need to be accounted. The studies are focused only in CO_2 because one of the main objectives of the European Union is the reduction of the emissions a 20% for 2020. The CO2 values used for the heating and cooling emissions comparison between the different systems are the next table:[30]

CO2 Factors	kgCO2/kWh
Electricity	0.590
Natural Gas	0.227
Heating Oil	0.314
Biomass	0.091

Table 13. CO2 Emissions per heating system

6.1. Environmental Emissions Assessment, Córdoba.

6.1.1. Current CO_2, Environmental emissions from the energy supply system

The emissions analysed in this chapter are linked with the electricity, heating and cooling consumption which will be supplied by the new system. For the evaluation of the current environmental emissions, there is a sheet in the Excel Tool which needs the current heating and cooling system for the dwellings which will be covered with the new system. The dwellings are divided by the heating fuel type and different type of houses in order to evaluate the investment needed in each house in order to implement the infrastructure and connection costs. The next Table 14 shows the CO2 emissions for the heating and cooling consumption of the 6389 dwellings supplied and also the average emissions for the electricity production from the CCHP which is inserted on the grid. The total emissions for the heating and cooling consumption and the electricity production with the current systems available in this area will produce 124,658,019kg of CO2 per year.

[30] Biomass Energy Center, UK Government (http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163182&_dad=portal&_schema=PORTAL)

CURRENT CO2 EMISSIONS FOR HEATING/COOLING AND ELECTRICITY PRODUCTION							
Heating & Cooling System Emissions							
	KgCO2/ kwh	% dwellings per fuel type for heating	Heating kwh Supplied	% dwellings per fuel type for cooling	Cooling kwh Supplied	Total	KgCO2
Electricity	0.59	86%	26,295,033	100%	27,056,256	53,351,289	31,477,260
Natural Gas	0.227	14%	4,387,912	0%		4,387,912	996,056
Heating Oil	0.314	0%	0	0%			
Biomass	0.091	0%	0	0%			
Electricity System Emissions							
Electricity Production	156,245,260 KWh						
KgCO2/kwh	0.59 kg/Kwh						
	92,184,703 kgCO2						92,184,703
Total KgCO2							124,658,019

Table 14. CURRENT CO2 EMISSIONS FOR HEATING/COOLING AND ELECTRICITY PRODUCTION in Córdoba

6.1.2. Estimated CO_2 Environmental emissions from the new proposed energy supply system.

In the study case which is developed in Córdoba the CCHP will produce CO2 for the production of the heating, cooling and electricity. The heating and cooling will supplied, 6389 houses and the electricity produced will be inserted in the grid. As it is explained in the beginning of this chapter the CO2 value for the operation of the new energy supply system is 37.0 kg/GJ. The next table shows the total production per year and the CO2 emissions linked. After this chapter the emissions will be compare with the current energy supply system in order to know the saved CO2 emissions during the lifetime. The total emissions for one year are 28,446,604 kg of CO2.

CO2 EMISSIONS FOR HEATING/COOLING AND ELECTRICITY PRODUCTION						
Electricity	156,245.26	MWh	156,245,259	kWh	kg of CO2	20,811,702
Heating	29,846.62	MWh	29,846,620	kWh	kg of CO2	3,975,538
Cooling	27,472.92	MWh	27,472,923	kWh	kg of CO2	3,659,364
Total						28,446,604

Table 15. CO2 EMISSIONS FOR HEATING/COOLING AND ELECTRICITY PRODUCTION in Córdoba

6.1.3. Difference between current and proposed energy supply system

The comparison between the current CO2 emissions and the CCHP system designed will decrease the CO2 emissions per year in 96,211,415 kg of CO2. It means that the CO2 emissions will be decreased in a 77% per year. Taking in account that the lifetime for these technologies are close 20 years, the total amount of CO2 saved is 1,924,228 tonnes of CO2. The reduction is significantly high because the current systems for heating and cooling are mostly electricity. Also, the production of electricity from the MSW will decrease the use of other more contaminant methods. The implementation of this CCHP in Córdoba during its estimated lifetime the CCHP plant will be saved 1,924,228 tons of CO2, which is equal to the amount of CO2 absorbed by a forest with 698 million of trees over 20 years.

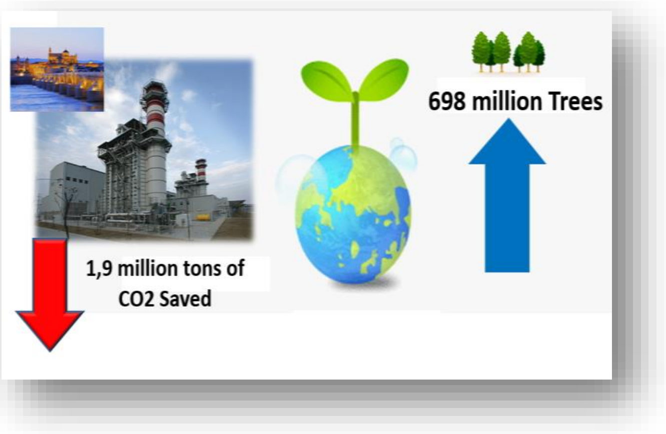

Figure 10. CO2 equivalent to the implementation of the CCHP in Córdoba

6.2. Environmental Emissions Assessment, Coventry.

6.2.1. Current CO_2 Environmental emissions from the energy supply system

In this study case the emissions analysed are linked only with the electricity and heating production from the CHP. The methodology applied is the same like the first study case. The dwellings are divided by the heating fuel type and different type of houses in order to evaluate the investment needed in each house in order to implement the infrastructure and connection costs. The next Table 16 shows the CO2 emissions for the heating consumption of the 5,196 dwellings supplied and also the average emissions for the electricity production from the CHP which is inserted on the grid. The total emissions for the heating consumption and the electricity production with the current systems available in this area will produce 71,211,547 Kg of CO2 per year.

CURRENT CO2 EMISSIONS FOR HEATING AND ELECTRICITY PRODUCTION							
Heating & Cooling System Emissions							
	KgCO2/ kwh	% dwellings per fuel type for heating	Heating kwh Supplied	% dwellings per fuel type for cooling	Cooling kwh Supplied	Total	KgCO2
Electricity	0.59	30%	19,932,748	100%	0	19,932,748	11,760,321
Natural Gas	0.227	62%	40,520,430	0%	0	40,520,430	9,198,138
Heating Oil	0.314	8%	5,410,317	0%	0	5,410,317	1,698,839
Biomass	0.091	0%	0	0%	0	0	
Electricity System Emissions							
Electricity Production	82,295,340 KWh						
KgCO2/kwh	0.59 kg/Kwh						
	48,554,248 kgCO2						48,554,248
Total KgCO2							71,211,547

Table 16. CURRENT CO2 EMISSIONS FOR HEATING AND ELECTRICITY PRODUCTION in Coventry

6.2.2. Estimated CO_2 Environmental emissions from the new proposed energy supply system.

The CHP proposed in Coventry using the MSW will produce CO2 for the production of the heating and electricity. The heating will supplied 5,196 houses and the electricity produced will be inserted in the grid. As it is explained in the beginning of this chapter the CO2 value for the operation of the new energy supply system is 37.0 kg/GJ. The next table shows the total production per year and the CO2 emissions linked. After this chapter the emissions will be compare with the current energy supply system in order to know the saved CO2 emissions during the lifetime. The total emissions for one year are 19,406,385 kg of CO2.

CO2 EMISSIONS FOR HEATING ELECTRICITY PRODUCTION						
Electricity	82,295,34	MWh	82,295,336	kWh	kg of CO2	10,961,651
Heating	63,399.41	MWh	63,399,413	kWh	kg of CO2	8,444,734
Total						19,406,385

Table 17. CO2 EMISSIONS FOR HEATING ELECTRICITY PRODUCTION in Coventry

6.2.3. Difference between current and proposed energy supply system

In this case, the reduction is also significantly high because the current systems for heating is mostly focused in boiler of natural gas, oil or electricity. These energy supply systems are the most pollutants, as it is defined in this chapter. Also, the production of electricity from the MSW will decrease the use of other more contaminant methods.

The CHP placed in Coventry will save in their lifetime a total of 1,036,103 tons of CO2 which is equal to 625,515 trips around the Earth in a family car.

Figure 11. CO2 equivalent to the implementation of the CHP in Coventry

6.3. Reflections on the environmental effects

As mentioned in this chapter the European Union has a goal to reduce the CO2 emissions in a 20% until 2020. The implementation of these methods will reduce the emissions in these three fields. As it is explained in the Chapter 2, most of the countries with fuel and energy poverty are using heating systems from some decades ago and the primary fuel used is more pollutants than the current fuel possibilities. In the first study case, it is possible to detect that there are not current energy supply systems for heating or cooling and they used to have individual central or room heating. The implementation of these systems could reduce the emissions significantly. Regarding the second case, in UK, the main supply system for heating is the natural gas, oil or electricity. These fuel are really pollutants and the supply by CHP will reduce also the emissions as it is explained above. The electricity production in both study cases are really important to decrease the emissions as it is possible to appreciate in the two cases.

7. Business Economic Analysis & Consumer Economy

7.1. Business Economic Analysis

The business economic analysis consists of a comparative analysis on the costs and benefits associated with each of the two scenarios, i.e. current energy supply system in Córdoba (heating, cooling and electricity) and the CCHP proposes in this report.

As described in the section 4.2.3, a business economic calculation should contain a calculation of the net present value of the investment in the CHP/CCHP and the distribution network system, and thus discount future operation costs and benefits for the lifetime of the project.

Due to lack of data on operation costs for the CCHP using MSW to run, the operation and maintenance costs are equal to use of a CHP which primary fuel consumption is MSW.

7.1.1. Capital cost: Investment in main plants and distribution networks

The investment has been chosen to consist as main investment the construction of the CCHP in the study case of Córdoba and the CHP for the study case in Coventry. The other investment which is taking in account as capital costs is in both cases the connection and infrastructure costs. The distribution network is explained in detail in the section 5.1.5.

As it is explained above, due to lack of data regarding the CCHP technologies. It is needed an assumption regarding the costs of the CCHP, it is increased in a 25% from a CHP of the same dimension which works with MSW. Also, for the maintenance and operation costs are used the same as a waste to energy CHP. The investment used for the Waste to Energy CHP plants is 5.7 M€ per tonne/hour of capacity[31]. The costs used for the CCHP in Córdoba is 7,125 M€ per tonne/hour of capacity.

In order to obtain an approximate investment cost for the district heating and cooling network, it has been used the infrastructure and connection costs per type of dwelling supplied. The type of dwellings have been analysed depending the type of dwellings per city. A more specific study has to be developed if these projects will be carried out in order to obtain more economic details.[32]

In the Table 18, it is possible to check the capital costs for both study cases. Both study cases include the investment of the plant and the network needed for the heating and cooling distribution. The grid investment will be carried out in both study cases by the future investors, municipalities or district companies. The capacities of both facilities are similar and the costs linked are close. However, as it is possible to appreciate the network costs in the Coventry case are higher than in Córdoba. The main reason for this situation is main type of dwellings in each case. In the Spanish case, the main type of dwellings are flats and in the British case are semi-

[31] Technology data for Energy plants. WASTE-TO-ENERGY CHP PLANT (May, 2012)

[32] (ENTRANZE,2015) Policies to Enforce the Transition to nearly Zero-Energy Buildings in the EU-27 http://www.entranze.enerdata.eu/#/share-of-single-family-dwellings-in-total-stock.html

detached or terrace houses. The total investment in Córdoba is 128.38 M€ and in Coventry 175.3 M€.

In order to secure the heating system in both places is developed the backup system explained in section 5. As it is explained in the chapter 5, the backup system in Córdoba needs a capacity system of 0.93 MWh. The cost for this system is 0.5 M€/MW[33] and the total cost is 463,009€. The second study case in Coventry needs a capacity of 2.93 MW and the cost linked is 1,462,6312€. The operation and maintenance are not considered in this report because this system will be used only in punctual cases.

CAPITAL COSTS								
CCHP & CHP Investment								
	Córdoba (CCHP)				Coventry (CHP)			
Capacity t/h	16.33				17.44			
Investment	**93,874,825**				**100,261,227**			
District Heating and Cooling Network								
	Córdoba (CCHP)				Coventry (CHP)			
Type of dwellings	Nº Dwgs	Infract Costs €	Connect Costs €	Total €	Nº Dwgs	Infract Costs €	Connect Costs €	Total €
Semi-detached dense	19	4,288	6,272	195,988	622	4,288	6,272	6,569,908
Semi-detached less dense	13	6,720	6,656	180,547	2,758	6,720	6,656	36,895,048
Small Terraced	37	3,840	5,632	351,591	1,195	3,840	5,632	11,321,543
Medium/Large Terraced	51	3,840	6,208	508,598	766	3,840	6,208	7,698,727
Converted Flats	4,049	1,280	3,968	21,250,963	1,349	1,280	3,968	7,076,945
High rise flats	371	2,304	2,816	1,900,493	92	2,304	2,816	470,750
Low rise flats	1,856	2,688	2,752	10,096,367	919	2,688	2,752	5,001,721
Total € (40 years lifetime)				**46,974,149**				**79,112,810**
Total € (20 years lifetime)				**23,487,074**				**39,556,405**
TOTAL								
	Córdoba (CCHP)				Coventry (CHP)			
M€	**117.36**				**139.82**			

Table 18. Capital Costs in Córdoba and Coventry

7.1.2. Operation & Maintenance Costs and Benefits

Costs of operation and maintenance needed for the production of the heating, cooling and electricity from these plants are calculated and discussed in this section. As it is explained in the beginning of this chapter, due the lack of data regarding the CCHP operation and maintenance, it is used the same operation and maintenance information from waste to energy of the CHP.

Operation costs

The operation costs of the CCHP and CHP running by MSW are more expensive than the biomass, natural gas or another boilers because are needed more treatment steps. As it is explained above, the operation costs used will be the same for both plants. In this case the operation and maintenance costs will be 53 €/tonne treated. The Table 19 shows the operation and maintenance costs per year because. As it is possible to appreciate in the Spanish case, it will be

[33] Technology data for Energy plants. DISTRICT HEATING BOILER, BIOMASS FIRED (May, 2012)

higher because the plant will be working all the year in order to supply the heating and cooling demand. On the other hand, the CHP in Coventry will work only during the heat demand.

	Córdoba	Coventry
Kg of waste treated	143,016	89,102
O&M costs	7.579.862	4,722,391

Table 19. O&M Costs

Periodic taxes

The MSW treatment has different taxes depending the methods used and each country has their own taxes. For the different taxes and legislation applied in each country, it is decided not include the taxes of each MSW treatment. Also, during the lifetime of the plants could increase the taxes for some conventional methods in order to reduce them as the case of the landfill.

However in the next section, it is explained the average which will be saved regarding the actual methods used for the MSW treatment.

Municipal Solid Waste Treatment

The current MSW treatment has a high cost for the municipalities and citizens. The high budget used to treat these waste can be used to cover the operation and maintenance costs of the CHP and CCHP proposed in this report.

The budget which will be saved from the waste treatment needs to be taken in account. The different methods and taxes linked makes difficult to take in account the periodic taxes as it is explained in the section above. For this reason, the average waste treatment price used to calculate the savings in this aspects is £ 9 per tonne treated.[34]

The Table 20 shows the annual savings in both study cases. In the case of Córdoba is higher because the plant is working all the year in order to produce heat during the winter and cold during the summer. In the second case, it is not needed the use of the plant during summer and the savings in this aspects are reduced.

	Córdoba	Coventry
Kg of waste treated	143,016	89,102
Savings per year	1,647,547	1,026,451

Table 20. Waste Treatment Savings

[34] Comparing the cost of alternative waste treatment options WRAP's (Waste and Resources Action Programme) (2012)

Benefits from CCHP and CHP Production

For the business economic calculation are needed the operation benefits in each specific year. For this reason, it is calculated the heating, cooling and electricity produced in each case in order to compare with the current situation. As it is explained in the investment costs, it is needed to determinate the heating and cooling fuel type per dwelling type which will be supplied. It is needed in order to specify the exactly savings because each fuel has a specific cost. In the next Table 21 and 22, it is possible to compare the savings from heating and cooling for residential and non-residential buildings.

Heating and Cooling Benefits in Córdoba CCHP Study Case							
		€/kwh	Heating	Savings	Cooling	Savings	Total
Residencial	Electricity	0.2370	86%	5,858,952	100%	6,274,083	12,133,035
	Wood Pellet	0.0618	14%	254,939	0%	-	254,939
	Natural Gas	0.0731	0%	-	0%	-	-
	Heating Oil	0.1892	0%	-	0%	-	-
	DH	0.1023	0%	-	0%	-	
	Others	0.0618	0%	-	0%	-	
Industrial	Electricity	0.1170	100%	117,000	100%	117,000	234,000
	Wood Pellet	0.0618	0%	-	0%	-	-
	Natural Gas	0.0731	0%	-	0%	-	-
	Heating Oil	0.1892	0%	-	0%	-	-
	DH	0.1023	0%	-	0%	-	
	Others	0.0618	0%	-	0%	-	
Total €				6,230,891		6,391,083	12,621,974

Table 21. Heating and Cooling Benefits in Córdoba CCHP Study Case

Heating Benefits in Coventry CHP Study Case				
		€/kwh	**Heating**	**Savings**
Residencial	Electricity	0.2370	86%	5,858,952
	Wood Pellet	0.0618	14%	254,939
	Natural Gas	0.0731	0%	-
	Heating Oil	0.1892	0%	-
	DH	0.1023	0%	-
	Others	0.0618	0%	-
Industrial	Electricity	0.1170	100%	117,000
	Wood Pellet	**0.0618**	**0%**	**-**
	Natural Gas	**0.0731**	**0%**	**-**
	Heating Oil	**0.1892**	**0%**	**-**
	DH	**0.1023**	**0%**	**-**
	Others	**0.0618**	**0%**	**-**

Table 22. Heating Benefits in Coventry CHP Study Case

Regarding the real electricity production the case is easier than the benefits from the heating and cooling because it will be sell it directly to the grid. The exact amount used to sell the electricity to the grid is an average of Europe and the amount taken is around 35 €/MWh.[35]

	Córdoba	Coventry
Real Electricity Produced MWh	156,245	56,431
Savings per year €	5,468,584	1,975,088

Table 23. Electricity Benefits

7.1.3. The business economic calculations

As described in section 4.2.3, a net present value calculation could provide useful insights into the business economic perspective of investing in these two solutions proposed for the energy supply system of Córdoba and Coventry. As it is explained in the methodology, the equation for calculating the net present value for the main business economic analysis is the following:

$$Córdoba\ CCHP\_\_\_\_\ Net\ present\ value\ (NPV) = \text{capital cost} + \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

The capital costs of the CCHP case are 117.36 M€ and it includes the CCHP plant, the distribution network and the backup system. The operation costs are 7.58 M€ and the benefits are 23.5 M€ per year. The lifetime is 20 years and the discount rate the 4%.

The total NPV will be 86 M€.

$$Coventry\ \ CHP\_\_Net\ present\ value\ (NPV) = \text{capital cost} + \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

The capital costs of the CHP case are 139.8 M€ and it includes the CHP plant, the distribution network and the backup system. The operation costs are 4.72 M€ and the benefits are 13.47 M€ per year. The lifetime is 20 years and the discount rate the 4%.

The total NPV will be -28.4 M€.

The net present value for the investment in the CHP case in Coventry is negative due to the use of the small savings in heating in comparison with the situation in Córdoba. The main heating fuel type is natural gas and it is cheaper than the electricity like the Spanish case. Also, the network investment is higher in the British case because the density is lower than in Córdoba.

7.2. Consumer Economy

The report is focused in the energy and fuel poverty and how the solutions proposed could affect in a positive way the consumer economy. Both study cases will try to reduce the energy bills of the end users. In order to reduce the bills from the first year, the total benefits during the lifetime of the plants (20 years) is divided per year. The return of the investment will be the total lifetime and the benefits will help the economy of the end user from the first year of operation.

This section is focused only in the study case of Spain because the NPV is positive and the total benefits are divided between all the dwellings supplied per year. The heating and cooling

[35] Infigen Energy: Where to from here? David Leitch on 6 May 2016

monthly bills will be reduced in order to avoid the difficulties to maintain the same temperature of the dwellings during the different seasons of the year.

The annual consumption in Córdoba per dwelling for heating is 4,797 Kwh and for cooling 4,230 Kwh. Taking in account than the highest percentage of the dwellings are supplied by electricity, the total consumption needed to cover is 9,027 Kwh per year. The price per Kwh used in the Excel for Spain is 0.237 €/Kwh and the annual total cost is 2,139 € and the reduction of the costs is close to the 60%, with an annual cost of 853 €.

The real return of the investment needed to obtain results for the end user from the first year is 20 years. The end users will obtain benefits from this first year of operation and the economic barriers for the end users to maintain the dwellings at the same temperature.

7.3. Economic Barriers

The development of the business economic assessment is needed in order to detect the main economic barriers that the investors can find in order to carry out these projects. That is the reason that this chapter is developed in order to see what could be the main barriers. In chapter 10, it is analysed all the economic barriers that this report has detected.

The first economic barriers which is explained in some sections above is the <u>high cost of the energy consultancy studies</u>. For this reason the Excel tool was developed in order to obtain a first business economic and environmental assessment.

The costs and benefits from the operation processes of both projects are analysed in this section. To detect some economic barriers which are direct or indirectly responsible of not to boost the investment in these solutions.

Regarding the initial investment is easily detectable that the higher costs are the development of the plant, the secondary system and the distribution network. The cost of plants is similar at both sites because the capabilities are similar. The high <u>costs of the CHP and CCHP plants</u> could be a barrier when the municipalities doesn't have funds to build these systems.

The cost of the backup systems is lower in both cases because it is not needed electricity production, it is going to be used only in punctual cases. However, <u>the cost of distribution networks</u> can be one of the highest barriers. It is necessary to detect that in the case of Cordoba is much lower because the density is higher than in Coventry.

Currently the municipalities spend part of their budgets in the waste treatment of their cities. These budget will be reduced if the MSW will be used in CHP or CCHP facilities. If the MSW is used for the plants proposed, the plants will be take care of part of these treatments. The plants will have an extra cost for the use of MSW as primary fuel than other resources.

Also, it must be noted that in recent decades prices for some waste treatments have increased significantly. The main reason of this increase is the objective of the European Union and the countries to reduce the most pollutants methods as the landfill.

If this trend continues during the next years, it is expected that the costs for the waste treatment for the municipalities will be increased. Different legislative measures are being carried out in some countries and to increase the taxes in some methods. These increases make more profitable the investments in the cogeneration and trigeneration plants which work with MSW.

Some of the countries that have issues with the energy and fuel poverty between their inhabitants, explained in the section 2, don't apply these high taxes to the pollutant methods of waste treatment. A barrier that can be found, is that there are not motivations or necessities to invest in these projects because currently, it is not expensive the treatment of the waste with conventional methods.

Another economic barrier that could appear during the execution or planning of the project is the refusal of the end users to develop these projects in their facilities.

For the end users, it is needed to see a reduction in their monthly heating bills compared with their current situations in order to have them interesting in the project. For this reason could be an economic barrier the municipal incentives or to reduce the price for the users.

8. Externalities

Not all effects of an investment are included in the market price. However, these still have a value for people and society. In economic theory these effects are called externalities and can, depending on their effect, be both positive and negative. This chapter explains how externalities are defined in this project. This Chapter explains some of the externalities which should be taken in account if a social economic assessment will be developed. However, this report is focus on the economic and political barriers and how to reduce or delete them.

8.1. Definition of externalities

An externality is defined as a cost or benefit of an economic transaction which affects external people without influence on a transaction, i.e. when an economic activity has an impact on external people and when this impact is not fully included in the market price or is not compensated in a different manner by the ones directly involved in the activity.[36]

An example of a negative externality in an energy context is a power station burning fossil fuels to generate electricity. This process emits e.g. SO2, which is harmful to human health and also causes acid rain which has a negative impact on e.g. houses. The cost of the consequences of the process of generating electricity is not included in the market price of electricity. However, burning fossil fuels to generate electricity instead of using fluctuating renewable energy sources also has a positive impact since the electricity supply is often more reliable, i.e. the production can match the consumption and thereby avoid shortages of energy.

From a societal perspective, the market is inefficient in these situations since the market price is either too high or too low, as the monetary values of positive or negative effects on society are not incorporated in the price. In the next section, it will be described how externalities are defined in this project by a description of the economic transaction.

8.2. Environmental impacts

Both emission of greenhouse gases and air pollutants are environmental impacts which from a socio-economic perspective are considered negative externalities. Córdoba and Coventry plants proposed will result in the municipality or district heating and cooling companies to use MSW instead of another more pollutants fuels.

Also the electricity production by using these plants will save emissions. Since the price of the harming effect is not fully included in the market price, the emissions are considered as externalities.

8.3. Employment

The CCHP job creation information will use the same data as the CHP due the lack of data. The use of CHP and CCHP systems generates direct jobs in manufacturing, engineering, installation, operation and ongoing maintenance, and many other areas. In addition, cogeneration projects create indirect jobs in the supply chain industry cogeneration and other supporting industries.

Workers employed as a result of these direct and indirect jobs can spend their income received in other goods and services, and businesses and consumers can reinvest the savings-energy bill

[36] Definition of Externalities, European Commission (2003).

they receive from cogeneration systems in other projects, goods and services. All this activity creates and maintains jobs and economic growth induces local communities.

Each GW of installed capacity cogeneration network may reasonably be expected to create and maintain between 2,000 and 3,000 jobs time equivalents full throughout the lifetime of the system. These jobs include direct jobs in manufacturing, construction, operation and maintenance as well as other indirect jobs and induced (net of losses in other sectors), both of the redirection costs of industrial energy and energy-bill savings business and home.

Direct jobs in the industry cogeneration energy efficiency like many industries, are often more labor intensive than those in other sectors of the economy are joined locally, and cannot be outsourced. For example, engineering, installation, operation and maintenance should be performed in situ.

The direct jobs created for a long term as operators and maintenance in the CHP or CCHP running with MSW depends on the tons treated. In the case of Córdoba the plant will be running all the year and in Coventry half of the year. Typical employment for an incineration plant of 50,000tpa capacity would be 2-6 workers per shift. The plant usually operate on a three shift system, to allow for 24-hour operations.37

Both study cases will treat around 150,000 tpa and the needed direct workers per shift is around 18 workers. The total workers needed are 54 full time employees. There are another employees during the construction and design phases. However, the report is focused in the long term needs for the plant.

New facilities are often built with a visitor centre in order to disseminate these facilities to another municipalities. These visitor centre will generate also some jobs.

[37] Department for environment food & rural affairs. Incineration of Municipal Solid Waste (February, 2013)

9. Political & Communication Barriers

The technical aspects of the CHP and CCHP technology has been tested in different countries, but in some countries has been more successful than in others.[38] This means that there are some countries that have implemented measures to promote such technologies.

The evaluation of energy policy measures in different countries is complicated because it depends on the needs of each country. As it is explained in the section 4, several energy analysts said that the Danish heat planning system is the most cost-effective district heating system. For this reason, this section is focused in the study of the Danish energy policy measures.

Following this study of the measures that are being implemented in the last decades in Denmark. It will be carried out a summary of some advices to implement the Danish system abroad. Also, many political barriers appear in order to implement some energy policies which are part of the current Danish heat planning situation.

9.1. Danish Heat Planning Powers and Responsibilities as framework

The aim of study the Danish approach in the planning aspects is to select the relevant characteristics and try to check if it is possible to apply them in another countries beyond Denmark.

To understand the highly cost-effective district heating systems in Denmark, it is needed to know that there is a high effort in the heat planning legislation from 1976 continually until our days. It started after the oil shocks of the 1970s which specially affected households. The main policies that have been developed in Denmark in order to arrive to this situation are:

- **1976:** The Electricity Supply Act of 1976 stipulated that all new electricity production must be CHP.
- **1979**: The Heat Supply Act of 1979, regulated the heating sector for the first time
- **1980s:** Energy policies that identified the importance of full accounting of energy projects´ costs and benefits emerged.
- **1990:** The national government issued an energy plan specifically indicating the role that a full socio-economic accounting of costs and benefits should play in any energy project planning.
- **1990 and 2000:** Heat Supply Acts in 1990 and 2000 loosened the rigid situation of the structure of municipal heat plans.
- **2000**: The plans were no longer required as outlined in the 1979 Heat Supply Act. Plans today are developed by municipalities and DH companies.
- **2011**: Official goal of being 100% reliant on renewable energy resources across all sectors by 2050.

[38] European Environment Agency (April,2012) http://www.eea.europa.eu/data-and-maps/indicators/combined-heat-and-power-chp-1/combined-heat-and-power-chp-2

The key of the Danish success is a stable energy policy since 1976, municipal planning, and a tradition for co-operation in the society (Rand, 2009). Political consensus is found at all levels of government and heat planning is not regulatory subject to changing political whims, and developers and consumers can be fairly confident that investments made in DH infrastructure.

It is important to understand how the policy and regulatory assessment work in Denmark, highlighting in particular the European Union, the Danish national government, municipal agencies, councils, heating companies, and individual heat consumers. In the figure 6, it is possible to appreciate all the different levels of government and heat system users in Danish heat planning. In the next paragraph is explained the different tasks in each level of government involved in order to understand the good communication and collaboration. The European Union has a global tasks which are to develop binding and non-binding energy goals and to require national heat plans for each government. The Danish National Government has several tasks which have change during the last decades but at the moment they are focused to establish national legislative framework, frame socio-economic cost-benefit test and to determine which costs can be recovered in DH prices. One of the more important roles and make the Danish system be a framework for the rest of the countries is the high relevant role of the municipalities.

They are responsible for planning local heat projects that promote local interest and they have the power to approve or reject proposed changes to heat infrastructure. The District Heating companies are non-profit companies and it make the end consumers trust them because if they will have benefits, they will reduce the costs of the periodic invoices to compensate it. The main tasks of the district heating companies are to assign cost to specific users, share benefits among all applicable consumers and respond to request made by municipalities. The last level of government are the individual consumers whose role is relevant as they are the end users. They are directly or indirectly influence investment decisions of local DH companies and may contest requirement to connect.

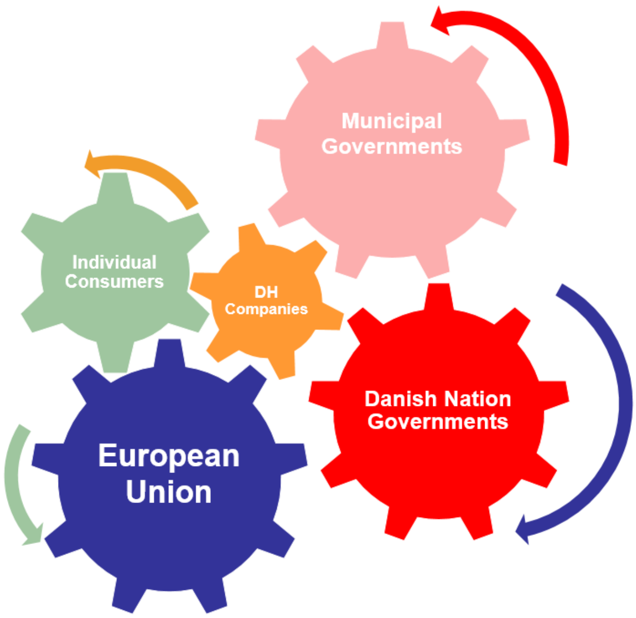

Figure 12 Critical Heat Planning Powers and Responsibilities in Denmark

It is taken in account the Danish critical heat planning powers and responsibilities in order to check if this system could be integrated in other countries.

9.2. Taking the Danish Model to skip the current political and communication barriers.

In order to achieve the EU goal of 20 % reduction in GHGs, an independent analysis found that DH is a prerequisite for the EU to cost-effectively it. After the study of the Danish heat planning, it is needed to evaluate the political barriers that other countries could find in their way to simulate the Danish heat planning. This section explains some advices in order to implement the Danish heat planning in other countries. Also, these advices show the main barriers for the countries to implement them.

- **Systematically cost-effectiveness tests of the heat & cold planning**: In order to evaluate the costs and benefits of the heating and cooling systems of each country, it is needed the development of some cost-effectiveness tests. These tests are used to detect the points which could be improved of the systems. Some barriers appear in order to develop these systematically studies. The development of these tests need the investment of public funds and many countries does not invest high amount in the planning. The development of these tests need also a collaboration between different levels in order to collect all the information needed.

- **The Danish national government gives high importance to the cities in the energy planning decisions.** However, to give this importance to the cities, it is needed some investments linked in order to facilitate them all the tools needed. The governments should support to cities which are interested in sustainable energy planning. Also, the municipalities can apply for credit with low-cost loans for large infrastructure projects. This measures could be replicable in other countries but it is needed some policy measures to increase the loans from banks to the municipalities. In some countries, it will be needed some policies which make the banks invest in infrastructures and projects carry out by the municipalities.

- **Encourage holistic energy planning.** The Danish heat planning system stipulated from 1976 that all new electricity production must be CHP, this kind of measures has provided Denmark´s DH systems with highly efficient and low-cost heat nationwide. The national governments should move these policies in order to make that different energy systems could work together. However, the fault of energy planning in some countries and the inefficiency of other policies which were developed in other countries have done impossible the connection between different systems.

- **Consider the impact and design of state energy targets.** The European Union has a goal of 20 % reduction in GHGs. The main barrier if that the development of these goals doesn´t include specific planning target for countries or cities which will be the most feasible in order to offer the most cost-effective emissions reductions or enhanced grid resiliency. Energy efficiency targets do not consider system-wide efficiency.
  These standards are important tools to achieve an energy system toward a cleaner and more economically resilient future, but alone they fail to address system-wide opportunities.

In the next section, it will be analysed all the political barriers linked to the advices explained in this section which have been analysed in order to apply the Danish energy planning system abroad.

10. Analysis of the economic and political barriers

The chapter 10 shows the different economic and political barriers which are the responsible of the current energy and fuel poverty of some European citizens. Also, this chapter will be focused in the possible solutions or measures to remove or reduce them.

The two study cases developed in this report are part of the methods suggested in order to detect the main costs and the main expenses that the investors and end users can find. It is possible to check all the economic and political barriers in the Figure 14 and the possible solutions to remove or reduce them.

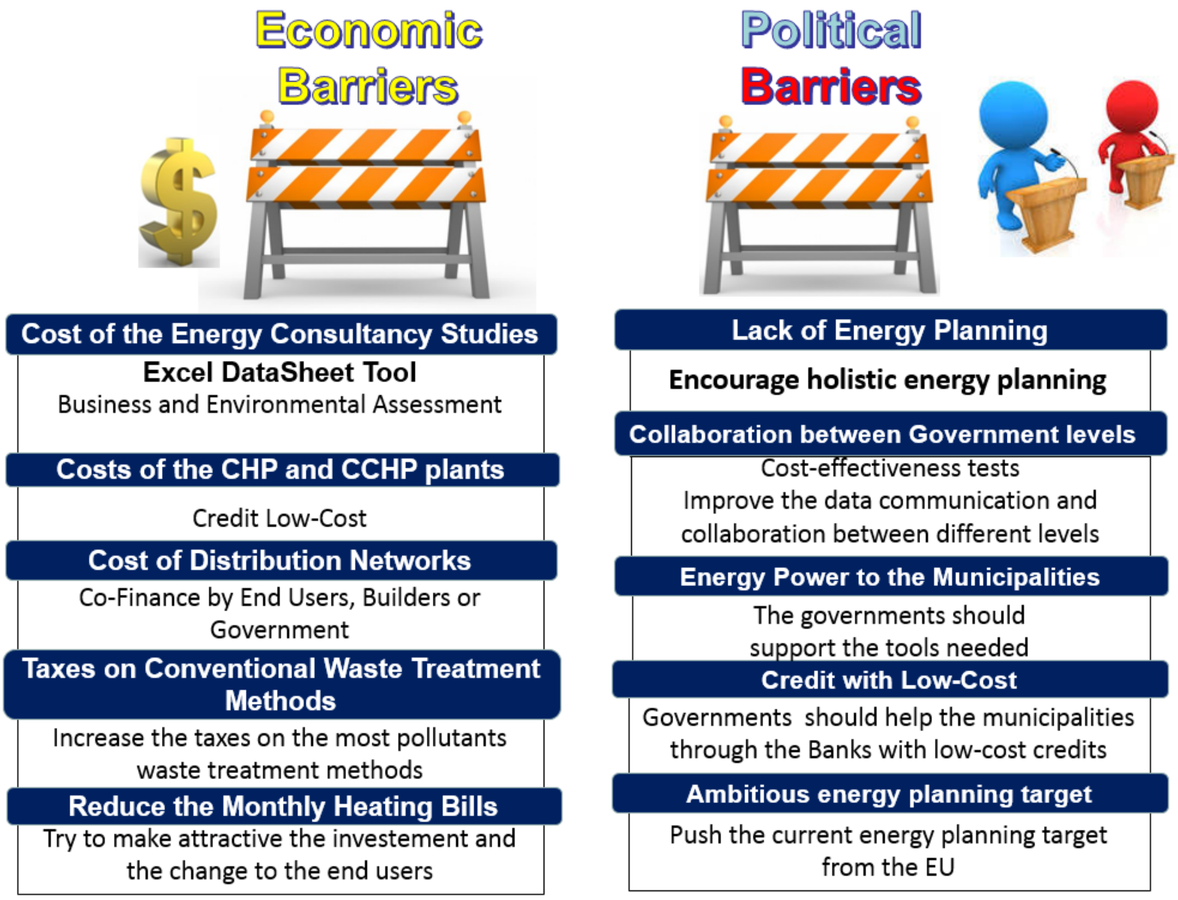

Figure 13. Economic and Political Barriers

All the main economic barriers are detected in the Chapter 7 and this report tries to give different advices in order to reduce them:

- **Cost of the energy consultancy studies**

The costs of the energy consultancy studies to analyse the energy flows of the cities is one of the main barriers for the municipalities. The development of the tool which has been explained during all the report will make easier the knowledge of this solutions for municipalities and interested investors. The business and environmental assessments obtained from this tool will give a first economic evaluation of the implementation of the CHP or CCHP technology in each city in order to involve step by step the main investors in this technology.

- **Cost of the CHP and CCHP plants**

The investments to build a CHP or a CCHP is the highest percentage of the implementation of this solution. It is needed credits to affront these high costs by the municipalities or private funds. In some countries, the banks give credits low-cost in order to make them easier the implementation of these technologies. To boost these investments by the banks, it is needed some legislations or some incentives for them in order to increase the loans with low interest rate.

- **Cost of distribution networks**

The distribution networks is also an expensive cost of the total installation. There are different solutions to cover this cost but in order to reduce the energy and fuel poverty these costs should be cover by the municipality or the investors. However, if new buildings are going to be connected to the grid, the building construction company will add this cost in the total budget.

- **Taxes on conventional waste treatment methods**

In the last decades as it is explained in the chapter 2, the most conventional and pollutants methods for the treatment of the municipal solid waste have higher taxes. The faster implementation of less pollutant methods for the MSW treatment in other countries have different reasons. However, if the municipalities have to pay more for the conventional methods, they will be more interested in new solutions which will produce energy outputs at the same time that it will reduce the cost of the MSW treatment.

- **Reduce the monthly heating and cooling bills to the end users:**

To involve the end users in this technology, it is needed to give them an incentive in order to reduce the energy and fuel poverty in the dwellings. The reduction of the bills depends on the characteristics of the plants and the benefits per year. The case of Córdoba will reduce the energy bills in more than the 60% of the total and the reduction has to be significantly because they have to agree on the installation of these systems in their dwellings.

In the Chapter 9, the political barriers are detected and described to suggest some advices in order to increase the implementation of these technologies. The Figure 14 summaries the main political barriers and some advices to try to reduce or avoid them.

11. Conclusion

The energy and fuel poverty is an issue which affect a high percentage of the European citizens. However, these percentages affect in a high level in some countries for five main reasons which are showed in the Chapter 2. These countries, where the percentage of energy and fuel poverty is higher than the average, have individual energy supply systems or systems with a low efficiency.

In this report, it is analysed the main barriers to improve the current energy supply systems in order to remove or reduce them through the MSW treatment. The MSW treatments to obtain different outputs are a technology which is working in several European countries. However, these systems have more economic and political barriers which are analysed during the report.

The technologies analysed during the report for the treatment of the MSW is the CHP and CCHP. Two real cases are analysed in this report in order to evaluate the investment, the maintenance and operation costs and benefits. The economic and environmental assessment has been developed through the Excel tool to give a fast overview of the main points. The tool explained in this report has an objective and it is to involve municipalities or investors in the different benefits that they could obtain from the implementation of these technologies.

The results obtained are relevant to involve the municipalities but there are other barriers, such as the political, which are relevant in order to implement these technologies. The governments and municipalities should work in the political barriers and the advices which has been analysed in this report because the technologies are working with success in many countries. It is needed to replace the current energy systems and look for the benefits of the citizens. The energy and fuel poverty is increasing in the last years and the governments have to take decisions and apply some legislation from other countries in order to try to reproduce their political and technical systems.

All in all, governments and political institutions have to reduce or remove the barriers and try to remove the energy and fuel poverty in their citizens. If the implementations by the countries of this legislation have some difficulties, the European Union will have to develop some guidelines or recommendations in order to boost the change.