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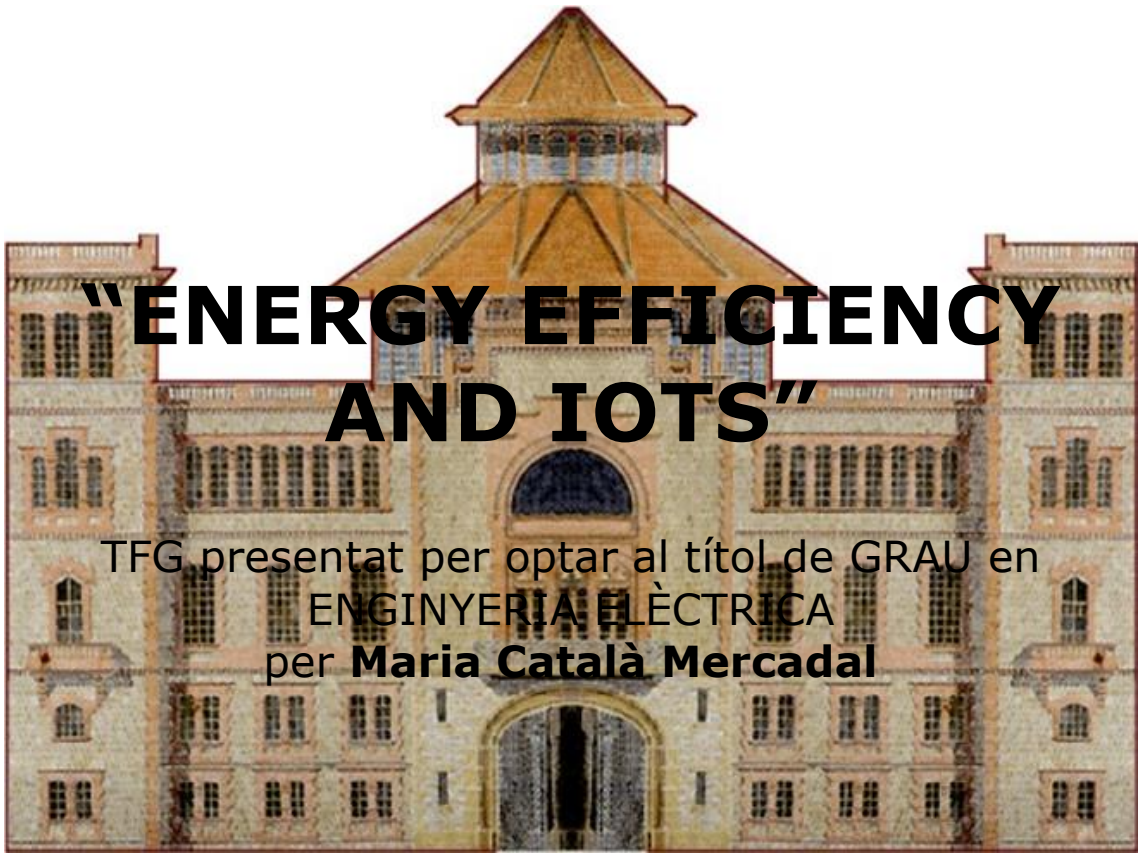

"ENERGY EFFICIENCY AND IOTS"

TFG presentat per optar al títol de GRAU en
ENGINYERIA ELÈCTRICA
per **Maria Català Mercadal**

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RESUM

El present projecte consisteix amb la realització de l'anàlisi de consums energètics en l'àmbit d'una casa ja existent. Es pretén realitzar la substitució de sistemes actuals de la manera més eficient possible i introduint tant com es pugui sistemes de tecnologia Internet de les Coses. S'analitzaran les diferents solucions para poder fer la casa energèticament més eficient.

Els sistemes Smart Home que es poden relacionar directament amb la eficiència energètica son la il·luminació i el control de temperatura. Son importants per assegurar un estalvi energètic. Altres sistemes com la detecció d'incendis la seguretat podem dir que no estan directament relacionats amb l'eficiència energètica. Pel que fa als electrodomèstics son aparells que contenen un al consum en les factures elèctriques, pel que l'estudi de la seva substitució serà un punt clau.

RESUMEN

El presente proyecto consiste en la realización de un análisis de consumos energéticos en el ámbito de una casa ya existente. Se pretende realizarlo de la manera más eficiente introduciendo tanto como sea posibles sistemas de Internet of Things. Se comparan diferentes soluciones para hace la casa energéticamente más eficiente.

Los sistemas Smart Home que podemos relacionar directamente con la eficiencia energética son la iluminación y la gestión de temperatura. Son importantes para asegurar el ahorro de energía. Otros sistemas como detección de incendios, seguridad, no están directamente relacionados con eficiencia energética. Los electrodomésticos son otros aparatos que tienen que ser reemplazados por su alto consumo en las facturas eléctricas.

ABSTRACT

It has been analysed the electrical consumption from an existing house to make it more efficient introducing as much as possible IoT applications. It has been compared different solutions to make the house more efficient.

The Smart Home applications that are directly linked with energy efficiency are clearly the lighting and the temperature monitoring. They are therefore important to ensure the energy saving. The other Smart Home systems, like Fire Detection, Security, are not directly related with the energy efficiency. The households are another important factor to be replaced because of their high power consumption at electrical bills.

CHAPTER 1: INTRODUCCION

This section explains the motivation how I made the Project. As well as the objectives and the scopes.

1.1 Objectives

The objective of this report is to realize an energetic study of a house. The objective is to analyse the possible energy efficient solutions. Specifically the solutions will analyse the power consumption of lighting, conditioning and also household appliances.

1.2 Scope

The report has three sections clearly separated. The first three chapters are referenced to the documentation and legislation from; Smart Home, Energy efficiency and Internet of Things.

After analysing the systems of the house that consume more it proceed to make a study to replace there items to another more efficient. The solution that has been studied to another possible solution has been compared with different types and brands. The systems that will be replaced are the appliances, lighting and conditioning because they are the ones that are related to energy efficiency and Internet of Things and also have higher power consumption.

1.3 Motivation

The motivation of this project is given to me with the need to save energy consumption at homes and also the necessity to investigate at Internet of Things world. The evident climate changes that the planet suffers make me study home improvements using efficiency technology.

The study of energy efficiency solutions causes power consumption and economic savings.

CHAPTER 2: SMART HOME

In this sections there are explained the idea of Smart Home and all the applications that you can control it. To regulate the automation world there are the Protocols explained below.

2.1 Definition

A Smart Home is a home that incorporates advanced automation systems to provide the inhabitants with sophisticated monitoring and control over the buildings functions. A Smart Home can control the temperature, security, lighting, multi-media, doors and windows operations, as well as many other functions. [9] All systems are connected to each other to ensure the best operation and to obtain an energy efficiency result.

In 2003 the UK Department of Trade Industry (DTI) defined smart home as: "A dwelling incorporation a communications network that connects the key electrical appliances and services, and allows them to be remotely controlled, monitored or accessed". [6]

The three things that a home needs to make it smart are an internal network (wire, cable and wireless), an intelligent control (gateway to manage the systems) and also a home automation (products within the homes and links to services and systems outside the home). [6]

It is true that nowadays many new homes are being built with the additional wiring and controls which are required to run advanced home automation systems. This is an advance because the owners can make the house smarter. The problem is when you want to add smart home technologies to an existing house. The cost is higher than a new building. Adding routing

wires and placing sensors in appropriate places is a complex task. Despite the cost if higher for an existing property many people opt for introducing smart home systems.

The different types of Smart Homes increase over the years, new technological advances developed in computer controls and sensors made it rapidly expanded. Smart Homes change completely the way to see the live, controlling form anywhere all the building functions, and at the same time it reduce the energy consumption. It is not necessary to make all the house smart, you can chose the parts of the house that you want and control it. The substitution to the smart home technology could be gradual, made by parts.

As I said a Smart Home can be an existing property or a new building it can control all the following applications:

2.1.1. Home security – Access control

Integrating security and access control system into your home adds into it a new level of convenience to your lifestyle. You can feel safety at home and can be notified from any fault or accident.

It can integrate security systems in the connected home, allowing the alarm and closed circuit cameras to be managed from a single control panel.

The system is dedicated to delivering home security with the utmost in convenience, control and complete awareness for security system users.

2.1.2. Lighting control

Smart lighting allows you to control the floodlights and lamps. The lights can be connected by wirelessly via Wi-Fi or any other existing wireless network to allow users to access them remotely.

This smart system can turn on /off the lights from across the house, integrate the lights, change the colour of the lights, and create profiles (party, cinema, romantic) depending on your mood. Using this system you reduce the power consumption because it is lower than the conventional floodlight. The electrical bill will be also reduced.

2.1.3. Temperature monitoring and HVAC control

Control the temperature of the house is an important thing because it is a big focus of energy consumption. Try to regulated the temperature is a good solution.

Using Wi-Fi , or any other wireless systems, enabled thermostats that allow users to connect directly. The temperature can also set while at home, while on the way home or on the way away from home. It can control the temperature for every room apart and also if there are people or not. Introducing temperature sensors that transform the temperature detection to an electrical signal is a solution to keep the temperature constant and connected if is needed. The thermostat sends the information from all the devices to control the temperature.

2.1.4. Fire detection – Leak detection

There exist a system that detects water leaks, fire, high winds and more, and it will alert you immediately to prevent any further damage. You can get advantage of it because the alert helps you to act as far as you can.

2.1.5. Solar panel monitoring and control

The introduction of solar panels at home promotes the green energies. There are two types of solar panels; the photovoltaic panels and thermic panels. The photovoltaic panels are the responsible to generate electricity form solar radiation and the thermic panels use free heater from the sun to warm domestic hot water. Renewable energy reduces the carbon dioxide emissions and also the electrical bill. A building where the energy consumption provides by renewable recourses is known as zero energy.

2.1.6. Energy efficiency

Optimise the energy consumption is a good solution to save energy. An example could be to maximise your energy efficiency using dishwasher or washing machine only when the electricity is being produced form the photovoltaic system.

2.1.7. Energy Management

All the systems that you control it separately you can get control it all together. An energy management system allows you to monitor and control your energy consumption of the air conditioner, the lights, electronics, and some large appliances giving you a detailed history as well as an accurate real time analysis so you know exactly what to expect the next time you get the bill. You can also monitor the energy that is being created by the solar power, solar thermal or hydrogen fuel cell.

2.2 Legislation

There isn't Smart Home legislation. By my point of view I think that is important to regulate the Smart Home technology even though there are Protocols that regulate it.

2.3 Protocol

The Protocols that are related with the automation and as a result of the smart home too, are the following ones:

a) **Protocol X10:** It is one of the oldest protocols that people use at automation applications. It was designed in Scotland to transmit data throw the low voltage line with a low speed.

b) **Protocol A10:** It was created by Eaton to improve the reliability of the X10 signal. It included improvements of the automation modules.

c) **Protocol KNX:** It was an initiative of three European associations. (EIBA (European Installation Bus Association), Batibus Club International and EHSA (European Home Systems Association)). The main objective was to develop standardization for the European automation houses.

d) **Protocol LONWORKS:** It developed at USA for the company Echelon at the end of 80. Lonworks use different means for transmitting data to braiding, grid, radio, fibre, etc. It has a topology with decentralized

architecture, which allows disturbing signals between the actuators and sensors of the network.

e) **Protocol ZIG-BEE:** It is a short-rang wireless technology and low power consumption. It uses the bands of 868 MHz in Europe and 915 MHz in USA. A Zig-Bee network can consist of u to 255 nodes; the modules are powered by battery. It operates in Master-Slave mode in which any device can connect to another device using others as a signal repeater.

f) **Protocol Z-WAVE**: It is a wireless technology for home automation signed by more than 200 manufacturers. It operates in the 900 MHz band. Each network component acts as a signal propitiating a long reach technology.

g) **Protocol INSTEON:** It was created in 2000 by the firm "Smart Labs" to improve the X10 Protocol. The main objectives for the system were: simple, easy, robust, use at three-phase houses, fast, economic and safely.

   This Protocol is based on a dual system of communication, PLC signals through the electrical cable and radio frequency signals.

h) **Programmable controllers:** The objective is to copy the machines automation systems and implemented to the houses through programmable logic controllers. [1]

CHAPTER 3: ENERGY EFFICIENCY

In this chapter I introduce the definition of energy efficiency. This term comes from the Kyoto Protocol (1997) and followed by de COP conferences. Over the world there are issues about the climate changes and the importance of take care of the environment. The energy efficiency is a suitable solution to reduce the power consumption.

3.1 Definition

Energy efficiency consists on reducing the energy consumption, keeping the same energy services but using sustainable methods that protect the environment. Those ones come from renewable resources.

The energy efficiency can be implemented in all the energy source, electricity, gasoil, gas, steam.

The energy and environment benefits of the energy efficiency implementation are the CO_2 reduction in the atmosphere. It is important to be conscious with the use of resources and to contribute towards sustainability. Boost the renewable energy and the importance of making use of it.

The socio-economic factors that are related with the energy efficiency are clearly the saving on the energy bill, reducing of climate change impact and also the reduction of the external energy dependency.

The IEA (International Energy Agency) promotes energy efficiency policy and technology in buildings, transport, appliances and industry and at lighting applications. They developed the document "25 energy efficiency

policy recommendations" which identify best-practice, for energy efficiency improvements and realise a full potential of it in each sectors. [26]

IEA is an autonomous organisation founded in 1974 which works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. It has four main areas of focus:

1) Energy security: Promoting diversity, efficiency and flexibility within all energy sectors.
2) Environmental awareness: Analysing policy options to offset the impact of energy production and use on the environment, especially for tackling climate change.
3) Economic development: Supporting free markets to foster economic growth and eliminate energy poverty.
4) Engagement worldwide: Working closely with partner countries, especially major economies, to find solutions to share energy and environmental concerns.

3.2 Legislation

The energy efficiency legislation starts in an international agreement in 1997, it called Kyoto Protocol. The importance to make it legal forced it to take place at European and Local legislation to take control of energy situation.

3.2.1. Global

The Kioto Protocol is an international agreement negotiated in Kyoto, Japan, on 11 December 1997 and come into force on 16 February 2005. The detailed rules for the Protocol were adopted at COP7 in Marrakesh, Morocco, in 2001.

Recognizing the developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activities.

It is a legally binding agreement under which industrialized countries will reduces their collective emissions of greenhouse gases by 5,2% compared to the year 1990. The goal is to lower overall emissions form six greenhouse gases – carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, HFCs and PFCs. During the second commitment period industrializes counties committed to reduce GHG emissions by eighty percent below 1990 in the period between 2013 and 2020. [11]

3.2.2. European

In 2002 was published the European Directive 2002/91/CE of Energy efficiency buildings, but it was been modified in 2010 to 2010/31/UE.

In those legislations two clear objectives were consolidated:

On 31 December 2020 all new buildings will have zero energy.

On 31 December 2018 public buildings will consume zero energy.

Zero energy is the energy that comes from renewable sources. [17]

3.2.3. Local

2006: Basic Energy Saving Document (HE) and Technical Building Code (CTE)

It seeks to achieve a rational use of energy required for the use of buildings, reducing consumption to sustainable limits. An also it want to make that all consumption comes from renewable energy sources. These two objectives are specified in five basic requirements in the Document Basic Energy Saving (DB-HE):

a) Limitation of demand
b) Performance of thermal installations
c) Energy efficiency at lighting installations
d) Minimum solar contribution in the production of hot water
e) Minimum photovoltaic contribution of electrical energy

2007: RD47/2007: Basic procedure for certifying energy efficiency in new buildings.

The main objective is to establish the basic procedure that has to comply with the calculation methodology of the energy efficiency qualification. After all the certification process begins.

This certification process takes account the factors that have got more impact on energy consumption in new buildings or renovated.

2010: Saving plan and energy efficiency 2011-2020

The European Board on 17th of June 2010 set an objective for the 2020 to save the 20% of the primary energy consumption.

As a result of this obligations the Minister of Industry, Tourism and Trade and also the IDEA Institute make an Action plan and Efficiency savings 2011-2020.

It includes the quantification of energy savings in 2010 compared with 2004 and 2007.

21/2006, 14th of February

This is a Spanish legislation that regulates the adoption of environmental criteria and eco-efficiency in buildings. It also continue the process of social changes in the way we conceive, design, build and use buildings, from the perspective based on environmental sustainability.

In Catalonia de building and de use of buildings produce more than 40% emissions of CO_2 to the atmosphere. Currently it is found that lot of buildings has a growing trend towards the consumption of primary energy sources of non-renewable origin. It is a problematic situation that has to be solved using renewables energies.

The objective of this decree is the incorporation of environmental parameters and eco-efficiency in new buildings construction, existing property and public buildings.

The eco-efficiency parameters are: water, energy, materials and construction systems and waste. Those are the ones that people have to use it by renewables energies.

To sum up, the energy efficiency legislation want to reduce the worldwide pollution a solution can be using renewables energies as much as possible.

Public buildings are the focus of the problem, so they must work by 'Zero energy' by 2018 and the new buildings by 2020.

3.3 Currently Situation

In 2015 took place the COP21 in Paris, known as the 2015 Paris Climate Conference. It was the first time in over 20 years of UN negotiations; aim to achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2ºC.

The next meeting will be the COP22 in Marrakech, Morocco. The Forum will convene cross-sector participants form business, Government, finance, UN, NGO and civil society to create an unparalleled opportunity to bolster business innovation and bring scale to the emerging green economy.

The COP movement starts with the international political response to climate change. It began at the Rio Earth Summit in 1992, where the 'Rio Convention' included the adoption of the UN Framework on Climate Change (UNFCCC). Now it has a near-universal membership of 195 parties.

The main objective of the annual Conference of Parties (COP) is to review the Convention's implementation.

The first COP took place in Berlin in 1995 and significant meetings since then have included COP3 where the Kyoto Protocol was adopted, COP11 where the Montreal Action Plan was produced, COP15 in Copenhagen where an agreement to success Kyoto Protocol was unfortunately not realised and COP17 in Durban where the Green Climate Fund was created. [4]

CHAPTER 4: INTERNET OF THINGS

In this chapter there are the definition of Internet of Things, the potential areas that it wants to expand and also the roles that regulate this technology.

4.1 Definition

The internet of things is the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. The IoTs have been associated with machine-to-machine (M2M) communications; they are often referred to as being smart. The concept may also be referred as the Internet of Everything.

It can be explained as a scene where animals, personas and objects are connected or have an IP address and provided with the ability to transfer data over a network. Anyone can access to the data and interact with them. The relationship will be between people-people, people-things, and things-things. [10]

In 1999 Kevin Ashton was the first person that has mentioned the term of "Internet of Things" in a presentation that he made to Procter & Gamble. He described the concept like the network that connects objects with the physical world and the Internet. Although the concept wasn't named until 1999, the Internet of Things has been in development for decades. The first Internet appliance was a Coke machine at Carnegie Melon University in the early 1980s. The machine could connect to the Internet and check the status of the machine. [27] [10]

The IoT includes over 25 billion connected devices worldwide, including fitness trackers, Wi-Fi connected appliances, and more, and this number is only growing. CISCO estimated that by 2020 there will exist between 50 billion and 75 billion devices. [19]

4.2 Potential areas

It is true that the IoT technology is not developed as the investigators expect. The initial cost and the lack of precedents does not favour the development.

According to Rachel Kalmar, during a conference of TedxSF in San Francisco, she said that there are 5 challenges that we can found at the ecosystem of IoTs. They are:

a) The lack of shared infrastructures: The hardware and software constitute a platform for developers and companies. The vertical nature of this platform has contributed to the fragmentation of this infrastructure.
b) Lack of standards: There is no global organization to standardize protocols, hardware, and software. (Nowadays FTC is making a Protocol).
c) Battery life: It is estimated that there will be 25 billion devices connected to 2020. Actually many battery operated has a limited shelf life.
d) Data Control: It is who has access to your data.
e) Exchanging information: Companies offer a free service or with a normal price in exchange of consumer personal data. [7]

Despite those challenges many sectors are working to introduce the internet of things technology to their areas. The following areas are some technologies that take importance:

a) Vehicle: Increasing the safety and the intelligence of the vehicles.
b) E-Health: Solutions of preventive medicine, diagnosis and monitoring.
c) Industry: Monitoring, management and connectivity in production processes.
d) Smart Cites: improve efficiency and the sustainability of cities.
e) Shops: Monitoring and intelligence at the point of sale.
f) Smart Houses: It is the area that has more investigation and more products.

In the following image there are other areas that investigators think that will expand the Internet of Thing technology.

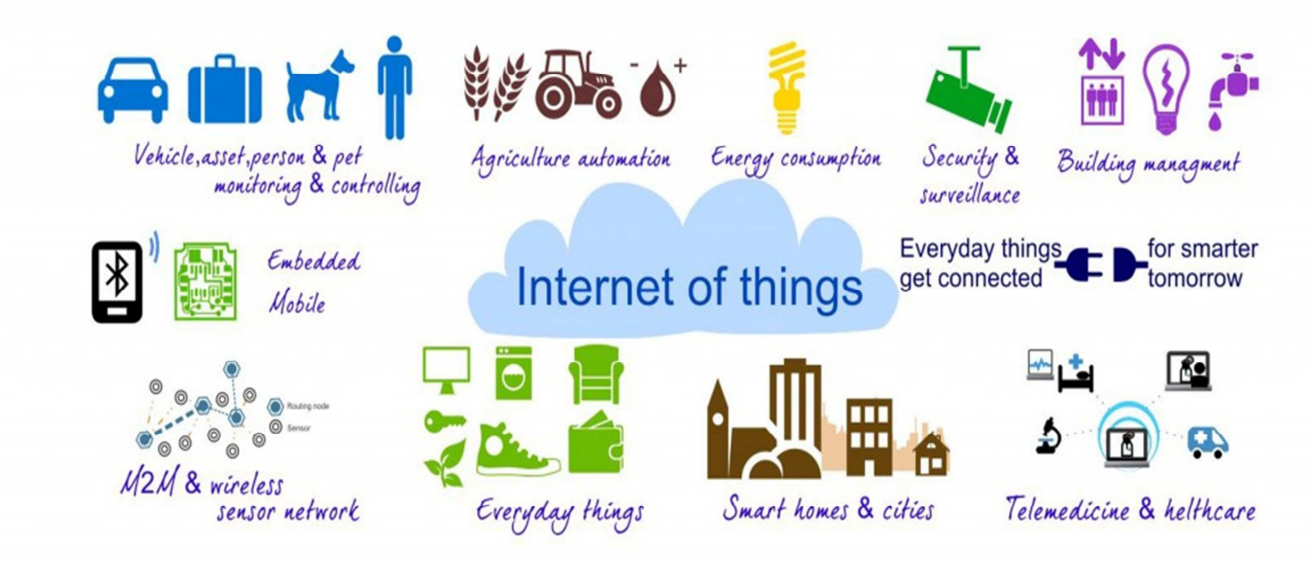

Figure 1. *Potential Internet of Things Areas.[8]*

4.3 Legislation

Nowadays exist a recommendation document of Internet of things; there isn't any legislation that you can base on it.

On January 27, 2015 the Federal Trade Commission (FTC) issued a 71-page report on the Internet of Things.

The FTC makes a Best Practice that recommends devices manufactures take concrete steps to protect the security of information collected by and available through the device. There isn't a legislation that regulates it.

In that report they said that additional legislation isn't necessary because FTC's current Section 5 authority to prohibit unfair and deceptive acts or practices already requires notice and choice for collecting sensitive personally identifiable information and protects against uses of consumer information likely to cause substantial consumer harm. [24]

The lack of unanimity underscores the complexity of the legal and policy issues of Internet of Things. So the legislation in the Internet of Things does not exist, there just exist some recommendations reports.

CHAPTER 5: ENERGY EFFICIENCY & IOTS IN A SMART HOME

In this chapter is pretend to encompass the three terms; Smart Home, Internet of Things and Efficiency Energetic.

5.1 Concepts

Energy Efficiency, Internet of Things and Smart Home are three terms clearly related. In a Smart Home the Energy Efficiency and the Internet of Thing technology is clearly evident. A Smart Home can be controlled by the internet and the importance of energy saving is increasingly important.

With the development of the availability of more and more appliances that have been presented in a smart house. It comes out a problem that how to manage and control these increasing various appliances efficiently and conveniently so as to achieve more comfortable, security and healthy space at home.

In this paper, a smart control system is based on the technologies of internet of things has been proposed to solve the above problem. The smart home control system uses a smart central controller to set up a radio frequency, wireless sensor and actuator network.

The main objective in a Smart Home is to reduce power consumption and consequently the electrical bill is cheaper. You can get it introducing the appliances and devices to control all house. [R.5]

An automation home is “The internet of things”. The way that all devices and appliances will be networked together to provide control over all items of our home makes the house automated. Introducing Internet of Thing at home you have a full control of your home from anywhere. You can manage how a device should react, when it should react, and why it should react.

As I told in the Chapter 2 a Smart Home is a home that incorporates advances automations systems to make the building more functionality. To obtain best result of communication, the Internet of Things ensures a good management of the house appliances. You can take advantage of it and reduce power consumption at same time and also provide a benefit at the environment.

After seeing that the benefits of join the three concepts are good the environment in the following chapter I will make a study of the main house power consumption and how can I replace to another technology more efficient.

The Smart Home applications that I can be directly linked with energy efficiency are clearly the lighting and the temperature monitoring. Are therefore important to ensure the energy saving. The other Smart Home systems, like Fire Detection, Security, are not directly related with the energy efficiency. The households are another important factor to be replaced because of their high power consumption at electrical bills.

Conditioning and lighting are controlled by IOT systems, so we ensure a connection between all the devices that make up the network. It is being able to connect directly to each other.

A correct temperature regulation is directly related to electrical consumption reducing. If the conditioning is centralized the outside temperature could provide an optimal temperature at any time of the day, we adjust to the needs of every moment (If there are people or not, If is at night or not). The use of the sunlight during the day and the lighting management in absence of people ensure an electrical consumption saving. Open the shutter to take advantage of sunlight is a suitable solution for managing home efficiently.

At the following chapters there will be the Lighting, household appliances and conditioning study of how to reduce the electric consumption of the current devices and how to change for ones more efficient.

CHAPTER 6: HOUSEHOLD

The household appliances are important to be replaced for ones that are efficient because the power consumption is very high if the household are not efficient. The Energy Label control and classify the different appliances in each category. The IDAE institute make a study of the Spanish residential consumptions.

6.1 Study Object

This project is related to an existing two-storey one-family house located in Menorca. The surface distribution is attached at the tables 1, 2 and 3. The drawings that help to get an idea of the distribution are attached at annex document Chapter 2.

Actually the house has incandescent bulbs and fluorescents, old household appliances and also central air conditioning installation. The necessity of remove the current installation and make it more efficient get me to do this studies.

Table 1. Surface Ground Floor

Ground Floor - Surfaces	
Zone	m^2
Bedroom 1	11,74
Bathroom 1	6,55
Bedroom 2	11,81
Bathroom 2	4,11
Bedroom 3	14,34
Dressing Room	5,2
Reading Room	7,73
Kichen	20,56
Dinning Room	27,79
Hall 1	10,23
Aisle 1	10,84
Pantry	5,7
Terrace 1	31,42
Garage	23,41
Total Surface	191,43

Table 2. Surface First Floor

First Floor - Surfaces	
Zone	m^2
Bedroom 4	15,12
Bathroom 3	7,28
Laundry	7,73
Office	11,34
Gym & Sauna	27,26
Locker Room	10,03
Games Room	39,18
Aisle 2	5,37
Hall 2	11,46
Terrace 2	25,34
Total Surface	160,11

Table 3. Total Surface

Total Surface	
Zone	m^2
Ground Floor	191,43
First Floor	160,11
Total Surface	351,54

6.2 Consumptions

The following chart contains the proportion of total consumption related to the services.

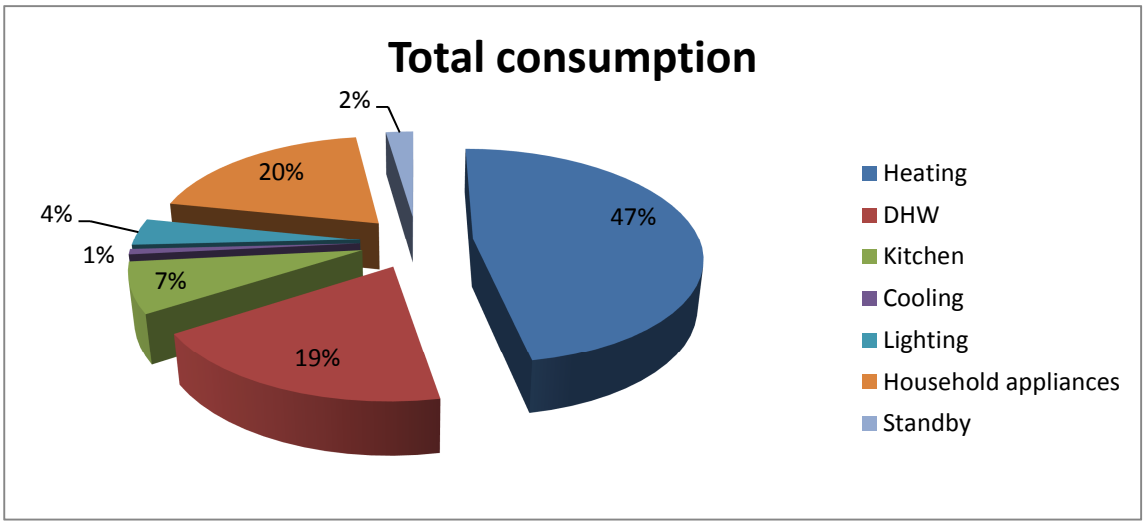

Figure 2. Spanish total consumption.

As I can extract from the Figure 2, the heating, domestic hot eater and household appliances are the three important power consumption services. The heating consume around 47%, household appliances 20% and domestic hot water 19%. The other 14% are the lighting, kitchen, cooling and stand by devices.

Furthermore at the figure 3 there is the power consumption related to the services.

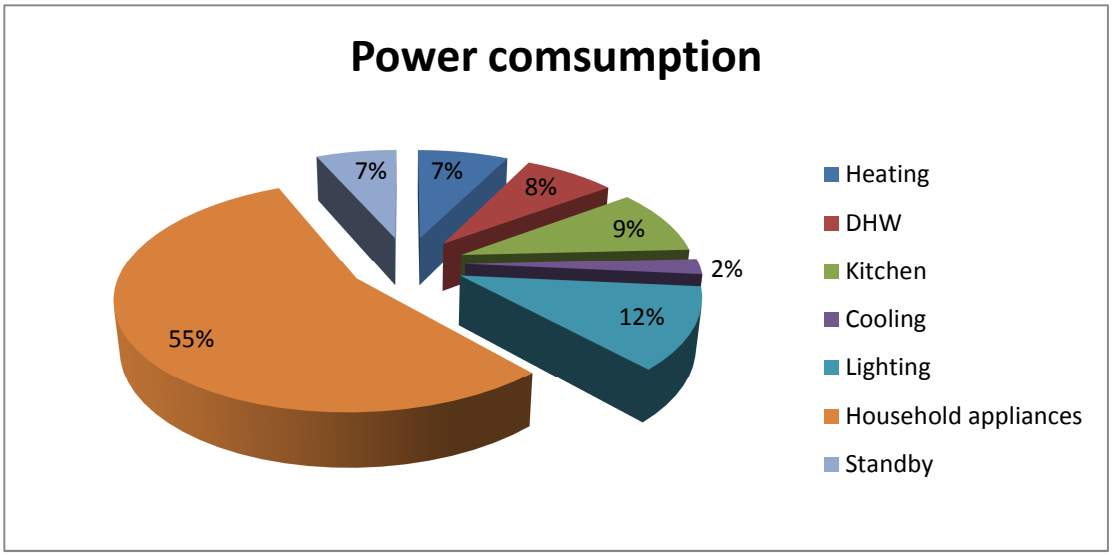

Figure 3. *Total power consumption.*

As you can see at the Figure 3 the household appliances consumption are above more than 50 % of the whole power house. So it is very important to reduce the power as much as possible. Introducing household appliances with high energy efficiency or regulating the time slot of using are some ideas to reduce their consumption.

The following system that has high power consumption is the lighting with a 12% of the power consumption. It is followed by heating, DHW, Kitchen and stand by all of them with a percentage around 8%. The service that consumes less is the cooling with a 2 percent.

The household appliances are important devices to reduce, thanks to IDEA document I can classify they by their power consumption:

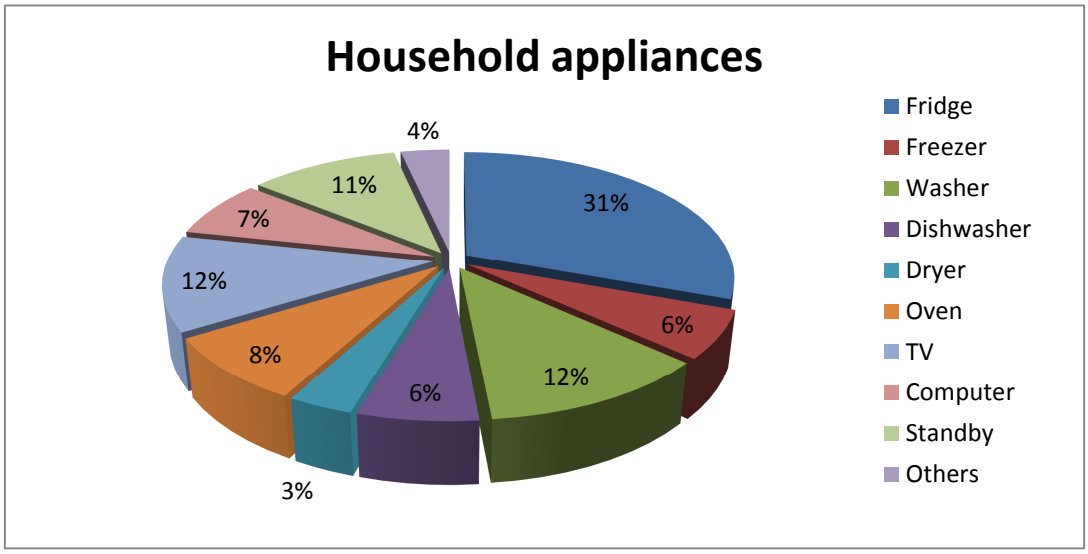

Figure 4. *Household appliances consumption.*

In the Figure 4 you can see the different household appliances that there could be in a house with their respective consumption average.

Most new devices have an energy label that indicates the power, the consumption and also the efficiency. Thanks of this label people can quickly identity the features of the devices and their consumptions. They are classified form A+++ (the most efficient) to D (the less efficient).

As is evident, the cost of an efficiency household appliance is higher than another that isn't efficient. Remove the current households to another more efficient causes an initial investment even the power consumption is lower.

The household appliances that I will replace are: Refrigerator-Freezer, washing machine, dishwasher and oven because they are the devices that consume more, you can see at the Figure 3. The main brands are Bosch, Miele, Samsung, Balay, LG. I know that there are more brands but the best related to the technology, functionality, good quality-to-price ratio and also energy savings are those mentioned.

From all the brands I compare the same capacity in different energy categories A+++, A++ and A+ as much the brand produce and I also compare how the power increase or decrease and also the cost. From there I choose the best solution to replace at households. All the values are from the brands websites.

6.3 Refrigerator

Table 4. Refrigerator

	Energy Efficiency	Consummation kWh/ year	Cost €	Useful Capacity Litres
Bosch	A+++	172	1.080,00 €	320
	A++	239	1.050,00 €	319
	A+	305	720,00 €	319
Siemens	A+++	172	1.080,00 €	320
	A++	239	1.050,00 €	319
	A+	286	1.000,00 €	309
Miele	A+++	x	x	x
	A++	242	1.299,00 €	322
	A+	338	1.249,00 €	348
LG	A+++	167	1.249,00 €	377
	A++	224	950,00 €	377
	A+	317	799,00 €	377
Balay	A+++	179	1.080,00 €	355
	A++	268	960,00 €	355
	A+	319	720,00 €	354

From the Table 4 I clearly extract that the solution must be an A+++ refrigerator although the price is higher but no too much if I compare with the other energy categories. If you compare the kWh per year of consumption at an A+ refrigerator and at an A+++ you can see that the difference is that the energy savings are between 140 kWh per year. The final solution will be the refrigerator that consumes less and have more capacity.

I can see that Miele doesn’t have refrigerators with A+++ category, so it is not as much efficient as I need.

The cost of A+++ Bosch, Siemens and Balay refrigerators have the same features but Balay has more capacity and of course more consumption. Otherwise Bosch and Siemens have the same features for power and capacity.

LG have the refrigerator with the lowest power consumption 167 kW/ year and have the most capacity refrigerator consequently has a higher price.

After analysing the brands with their features the solution is the A+++ LG refrigerator because it has the less power consumption and the higher capacity refrigerator. It cost 1249€. See Annex Chapter 4 for more information.

6.4 Wash Machine

Table 5. Wash Machine

	Energy Efficiency	Consume kWh/ year	Cost €	Capacity kg
Bosch	A+++-20%	139	680,00 €	7
	A+++	165	635,00 €	7
	A+	198	880,00 €	7
Siemens	A+++	135	805,00 €	8
	A+++	135	695,00 €	8
	A+++	137	1.030,00 €	8
Miele	A+++	176	1.299,00 €	8
	A+++	176	1.099,00 €	8
	A+++	156	1.499,00 €	8
LG	A+++	137	599,00 €	8
	A+++-30%	137	599,00 €	8
	A+++	x	x	x
Balay	A+++-20%	139	645,00 €	7
	A+++	165	480,00 €	7

All the brands have the category A+++ or more, there not exist wash machines with less efficiency this focus the importance of energy saving. This means that the difference between them is the capacity and the power consumption. But nearly all brands have got more or less the same features; the lower power consumption is around 135 and 139 kWh/year and is at capacity and cost where there are changes.

As you can see in the Table 5 Miele is the expensive brand and also the one that consume more, so I rule out this solution.

Siemens wash machine has the less consumption in an 8 kg capacity while Balay and Bosch consume 4 kWh more per year but in the capacity is 7kg.

The best option is the Siemens wash machine with a A+++ category with a consumption of 135 kWh/year, a capacity of 8 kg and a cost of 695€.

See Annex Chapter 4 for more information.

6.5 Dishwasher

Table 6. Dishwashers

	Energy Efficiency	Consume kWh/ year	Cost €	Litres Consumption litres / year
Bosch	A+++	237	1.045,00 €	2660
	A++	266	960,00 €	2660
	A+	294	645,00 €	3360
Siemens	A+++	234	1.045,00 €	2660
	A++	266	805,00 €	2660
	A+	294	660,00 €	3360
Miele	A+++	237	1.049,00 €	2716
	A++	266	999,00 €	2772
	A+	295	849,00 €	3780
LG	A+++	235	899,00 €	2600
	A++	235	729,00 €	2600
	A+	235	689,00 €	2600
Balay	A+++	266	805,00 €	2660
	A++	294	575,00 €	3360
	A+	249	550,00 €	3220

The Dishwashers features that are directly related with the energy savings are the litres consumption per year and the power consumption. The best solution is to consume less power and water.

Bosch, Miele consume 237 kWh per year if the best efficient device, but Miele consume more litres per year (2716) it has automatically refused for the final solution. Siemens consume 234 kWh/year and LG 235 kWh/year with A+++ category and 2660 litres consumption. Furthermore Balay is the brand with more power consumption 266 kWh per year and a litres consumption of 2660.

The gadget that fulfils the specifications is the Siemens's dishwasher A+++ because consume less than the other brands, 234 kW/year and 2660 litres /year and cost 1045 €. Bosch, Miele and LG have been eliminated because they consume a bite more.

See Annex Chapter 4 for more information.

6.6 Oven

Table 7. Ovens

	Energy Efficiency	Consume kWh/ cycle	Cost €	Efficiency Index %
Bosch	A+	0,87	815	81,2
	A	0,93	720	90,1
Siemens	A+	0,87	815	81,2
	A	0,90	670	88,6
Miele	A+	1,10	1199	81,9
	A+	1,10	999	81,9
LG	A+	x	x	x
	A+	x	x	x
Balay	A	0,93	765	90,1
	A	0,90	669	88,6

As you can see at the Table 7 only exists ovens with energy efficiency category A or A+ this means that they haven't got the maximum efficiency that the Energy Label have.

First of all, the LG brand does not manufacture ovens. So the resolution will be between Bosch, Siemens, Miele and Balay.

If I compare the efficiency index with the power consumption I can extract that the best efficiency index is around 80% (from Bosch A+, Siemens A+ and Miele A). Balay and Bosch have got an efficiency index around 90%, but the energy efficiency is just A. Now if I compare the different power consumptions I can see that Bosch, Siemens and Balay are the brands with less consumption, with a value around 0,87 and 0,9 kWh per cycle.

If I compare the three ovens that consume less and the efficiency index that they have. The best solution is the A Balay oven because it has the best efficiency index (88,6%) and a power consumption of 0,9. Despite that the category is A is the one that have more efficiency index and less consumption.

See Annex Chapter 4 for more information.

6.7 Final solution

Table 8. Household Appliances

	Brand	Energy Efficiency	Consume kWh/ year	Cost €
Refrigerator	LG	A+++	167	1.249,00 €
Wash Machine	Siemens	A+++	135	695,00 €
Dish Washer	Siemens	A+++	234	1.045,00 €
Oven	Balay	A	0,9 cycles	660

The Table 8 show as a summary the household appliances that I finally choose. All the data sheets are attached at annexes document chapter 4.

6.8 Intelligent Plugs

Another way to control the household appliances is to introduce an intelligent plug that allows you to control the devices. This plug allows you to switch on and off the electric appliances remotely, consequently the electric bill is cheaper. You can also program the switch off and on of the domestic appliances. It can control the spending in the light so you can manage the saving consumption at the electrical bill.

Mixing systems, buying more efficient household appliances and introduce intelligent plugs at their switches you can reduce the energy consumption.

Some brands that offer this product are Dlink, Edimax, Fibaro, Belkin.

Table 9. Intelligent Plugs

D-LINK	EDIMAX	FIBARO	BELKIN
Switch on/off the appliances	Switch on/off		Switch on/off the appliances form anyway
Programming the plug	Hands control or programming	Needs panel to control automatically	You can program the use
Protect the devices			Use app to control
Control the light expending	Control the light expending	Real time energy monitoring	Control the expending's
	Notifications by email or sms		Notifications by email or message
Easy installation	Wireless installation	Easy installation	Easy installation
		Z-Wave network	Wi-Fi network
48,66 €	54,60 €	64,99 €	59,99 €

At the table 9 there are the different features form intelligent plugs. The Fibaro intelligent plug needs a brain to control the appliances; you cannot switch on/off the plug without this system. So FIBARO plug has to be excluded.

The other brands have more or less the same features. Edimax and Belkin notify you with a message or email if there are an incidence this could be useful if you want to know for example when the wash machine was finished.

The best solution is the BELKIN intelligent plug because of all its features and the easy installation; it the one that allows you to control the lamps and appliances via app form anywhere just programming it or at the moment. You can get also the control of the expending.

The introduction of an intelligent plug reduces the electric bill. In the economic and energetic chapter it will be calculate the saving that produce the introduction.

CHAPTER 7: LIGHTING

As the Figure 2 shows, the second service that has a higher consumption after the household appliances is the lighting with a value of 12%, so the importance of making a study to replace the current home lighting is evident with it I can save in the electricity bill.

I replace the lights to LED's technology and also to LED 's controlled by wireless network. Some of the brands related to lighting are Philips, Osram, LG, Samsung, Sylvania, Bridgelux and Toshiba. The main lighting brands are Osram and Philips because of the innovation, functionality, good quality-to-price ratio and also for the innovation of controlling the floodlight.

Implement a LED solution is a good idea because it consume less than the conventional lights. In the case of LEDS + IoTs is an expensive solution but can achieve more saving energy in a year because of the controlling lights by an wireless network.

Over the years LEDs technology has been growing and nowadays is the technology that offers more light and less consumption. Moreover their service life is disproportionally higher if you compare with the traditional lighting. Introducing a LED + IOT technology allowed making an adjustment of the lighting control like the costumer want. Osram Smart Home lighting technology is LIGHTIFY and for Philips is called Hue in each paragraph it will be explain.

For the two brands, Osram and Philips I make a study to replace the current lighting to a more efficient one.

7.1 The current lightings

The house electrical distribution is calculated by the ITC-BT and is like the following table but the drawings that show you more clearly are in the Annex document chapter 2.

Table 10. House lighting distribution.

		Ground floor	First Floor	Total
Light	Light simple point	20	15	35
	Simple fluorescent	5	1	6
	Double fluorescent	3	2	5
Switch	Crossing Switch	15	7	22
	Switching	7	0	7
	Switch	7	10	17
Plug	Mono-phase 16 A	28	22	50
	Mono-phase 25A	2	0	2

As you can see at the Table 10 there are 35 Lights simple points (incandescent bulbs), 6 Simple fluorescent and 5 double fluorescent at home.

7.2 OSRAM

The two technologies that I compare are the LED and the LIGHTIFY with the current floodlight.

Osram LIGHTIFY is a wireless system to control the lighting. There are two options Lightify Pro and Lightify Home. It is a Smart connected lighting controlled via mobile app. You can control networked Led products individually or grouped in any room.

Lightify Pro is an application focus on professional installations that has got a medium size (like offices) that allows to enter more applications and make the installation more efficient. With this information the Pro system has to be refused because my analysis is related to a private house.

Lightify Home is intended to small installations with not more than 50 light points (private home) this provide a simple solution type plug-and-play with lamps and floodlights. The benefits that have got this system are: easy

installation, electrical consumption information, and smartphone or tablet control. This is the final solution that I implement at the house.

In the Table 11 there are the technical qualities in front of the different types of bulbs.

Table 11. OSRAM floodlight

		Currently		LED		LIGHTIFY
		Incandescent Bulb	Fluorescent	Bulb	Fluorescent	Bulb
Nominal power	W	60	10	6	8,4	9,5
Nominal voltage	V	230		220-240	220-240	220-240
Nominal luminous flux	lm	505	650	470	840	810
Colour Temperature	K	2700	2700	2700	4000	2700-6500
Lamp service life	h	1000	16000	25000	30000	20000
Power consumption	Kwh/h	60/1000	13/1000	6/1000	11/1000	10/1000
Energy efficiency		E	A	A+	A+	A+
Cost	€	2,06 €	8,00 €	10,85 €	20,45 €	44,00 €

At the Table 11 there are the current lights, the LED technology bulbs and also the Ligtify technology from Osram.

From the current bulb you can see that the price is lower than the other technologies, otherwise the power consumption are importantly higher so do the energy efficiency. The energy efficiency category from incandescent bulbs is E and from fluorescent is A. It is important to highlight that their service life is very lower if you compare with LED technology. Incandescent bulbs have got a service life of 1000 hours.

On the other hand LEDs technology has a higher initial cost if you compare with the current floodlight, but the energy efficiency is category A+.

The evidences that the initial cost is higher at Led bulbs than the conventional lights are obvious, the improvement of service life and power consumptions confirm that. If I compare the bulbs the cost of the Led bulbs is 5 times higher than the conventional light price and the service life is significantly increased in the Led technology (from 1000 hours for incandescent and 25000 hours for Led bulb).

The Retrofit fluorescent has more or less the same features of the current fluorescent, the retrofit ones consume a bit more, has got more nominal luminous and an energy efficiency of A+ and also the service life doubles the hours from 16000 to 30000 hours.

This comparative shows that at first sight the LED technology has got better features than the current technology. The power consumption savings is evident and also the service life. The only drawback is the price.

In the following sections I make a comparative each current floodlight with the LED technology.

7.2.1. Incandescent vs LED bulb

The incandescent bulb has got a nominal power of 60 W while the LED one just 6 W, both with the same or better features. The luminous are almost the same, around 480 lm, LED 470 lm and 505 lm incandescent. The big differences are in the power consumption, energy efficiency and in the service life in which the LED technology is clearly better. It is an energy efficiency of A+ and has a service life of 25000h and a power consumption of 6 kWh/ 1000 hours. The Incandescent bulb has got a service life of 1000h and a power consumption of 60 kWh/ 1000 hours and also an energy efficiency of E (one of the worst category). The cost of the fluorescent bulb is 2,06 € while the LED is 10,85€.

7.2.2. Fluorescent vs LED Retrofit Fluorescent

If I compare the fluorescent with the LED Retrofit fluorescent there are some differences. The nominal power from the Retrofit fluorescent is 8,4 W and from the fluorescent is 10 W, there is not a big difference. As regards the fluorescent has 650 luminous and service lives of 16.000 hours while the LED 840 luminous and 30.000h, almost twice the value of the service life. The energy efficiency has a value of A for the fluorescent and for the LED fluorescent A+. The price is clearly the difference, in the conventional one the cost is 8€ while the LED cost 20,45€.

7.2.3. LIGHTIFY

To get with the Lightify technology at home is not enough to get the lightify bulbs. You also need a Starter Kit (Gateway + Blub) that cost 122€ and also you can get the Gateway and the Blub separately they cost 56 € and 44€ respectively.

This technology consumes more or less the same as LED technology. It consumes 9,5W of nominal power, has 810 luminous a durability of 20.000 hours, a power consumption of 10 kWh/1000 hours and an energy efficiency of A+.

The advantage of this technology is that you can program the floodlight and you can control form any smartphone or table. Even if you forgot to switch off any light you can turn it off. The possibility of controlling your floodlight allowed owner to reduce the power consumption over the 30% additionally of the power savings that the LED technology gives you. [2]

7.2.4. Service Life

The floodlight in a house has been turned on 7 hours per day. The service life is the days and years that the lights must be replaced. Dividing the lamp services life with the 7 hours per day I obtain the days and years that I have to change the floodlight.

Table 12. OSRAM services life

	Useful days	Useful years
Incandescent	143	0,39
Fluorescent	2286	6
Bulb LED	3571	10
Retrofit Fluorescent	4286	12
LED + IOT	2857	8

You can see at the Table 12 that the conventional floodlight has to be replaced more than ones annually while the LEDs proximately every 10 years. This is an evidence that the even the price is higher in the LED technologies the usable life is clearly better. While the retrofit fluorescent has to be replace nearly every 12 years, the fluorescent very 6 years. The LIGHTIFY technology is similar with the LEDs, every 8 years. Incandescent bulbs have to be replaced 5 bulbs every 2 years.

Table 13. Osram Cost

	Incandescent	Fluorescent	LED Bulb	Retrofit Fluorescent	Lightify
2016	6,18 €	8,00 €	10,85	20,45 €	44,00 €
2017	4,12 €	0,00 €	0,00 €	0,00 €	0,00 €
2018	6,18 €	0,00 €	0,00 €	0,00 €	0,00 €
2019	4,12 €	0,00 €	0,00 €	0,00 €	0,00 €
2020	6,18 €	0,00 €	0,00 €	0,00 €	0,00 €
2021	4,12 €	0,00 €	0,00 €	0,00 €	0,00 €
2022	6,18 €	8,00 €	0,00 €	0,00 €	0,00 €
2023	4,12 €	0,00 €	0,00 €	0,00 €	0,00 €
2024	6,18 €	0,00 €	0,00 €	0,00 €	44,00 €
2025	4,12 €	0,00 €	0,00 €	0,00 €	0,00 €
2026	6,18 €	0,00 €	10,85	0,00 €	0,00 €
2027	4,12 €	8,00 €	0,00 €	0,00 €	0,00 €
2028	6,18 €	0,00 €	0,00 €	20,45 €	0,00 €
2029	4,12 €	0,00 €	0,00 €	0,00 €	0,00 €
2030	6,18 €	0,00 €	0,00 €	0,00 €	0,00 €
Total	**78,28 €**	**24,00 €**	**21,70 €**	**40,90 €**	**88,00 €**

In the Table 13 there are the costs from now to 2030 that a single bulb cost related with the times that it has to be replaced.

In the Incandescent bulb the total price is higher than the LED bulb because they has to be replace more than ones a year while the LED bulb has to be changed every 10 years. The LED technology is a good choice for the energy saving features and also for the price.

In the fluorescents technology the Retrofit fluorescent tube is expensive than the fluorescent even if it has to be replace twice a year and the conventional fluorescent three times annually.

The Lightify technology is the one of LED technology with a huge cost, for only two replaces.

7.2.5. Power Consumption saving

It is true that the first thing that I think when I replace the current floodlight with the LED technology is the power consumption saving that I obtain with the replacement. This estimate shows you the truest energy saving.

Table 14. Power consumption Osram

	Power kW	Power Consumption kWh / year
Incandescent Bulb	0,06	153,30
Fluorescent	0,01	33,22
Bulb LED	0,01	15,33
Fluorescent LED	0,01	28,11
LED + IOT	0,01	25,55

With the power consumption value that the manufacturer gives me in the Data Sheets I make a relation kWh/h to obtain the kWh that each floodlight consumes. I calculate for every year consumption, so then I make the relation with the current floodlight and the new one and compare who many kWh I could save in a year.

The Table 15 shows you the kWh that I could save making the appropriate changes.

Table 15. Power saving Osram

	Bulb LED kWh /year	Fluorescent LED kWh /year	LED + IOT kWh /year
Incandescent Bulb	137,97		127,75
Fluorescent		5,11	

It is evident that the most energy saving is between the incandescent bulb and the LED bulb and also with the LIGHTIFY technology; it is because of the higher power consumption of the incandescent bulbs.

The less significant power consumption saving are between the fluorescent technologies that the only save 5,11 kWh/years because of the similar features.

The technology that save more energy consumption is the substitution of the incandescent bulb with the Led bulb with a saving value of 137,97 kWh per year. Even the Lightify technology save around 10 kWh per year less than LED technology could be a good solution too.

7.3 PHILIPS

The two technologies that I compare are the LED and the HUE with the current lighting. In the following tables there are the technical qualities in front of the different types of bulbs.

Philips Hue is a personal lighting system that people can control the lights with a bridge. The bridge is the heart of the system and it connects the smart devices to the Philips Hue lights. It can be added up to 50 lights and accessories to one bridge. Linked to Wi-Fi via router, it can be controlled form any device and even out-of-home just with Philips app.

Table 16. PHILIPS floodlight

		Currently		LED		LED + IoT
		Incandescent Bulb	Fluorescent	Bulb	Fluorescent	Bulb
Nominal power	W	40	15	6	9	9,5
Nominal voltage	V	230		220-240	220-240	230
Nominal luminous flux	lm	390	930	470	800	800
Colour Temperature	K	2700	6500	4000	6500	2700
Lamp service life	h	1000	20000	15000	20000	25000
Power consumption	Kwh/h	40/1000	19/1000	6/1000	9/1000	10/1000
Energy efficiency		E	B	A+	A	A+
Cost	€	1,20 €	4,24 €	7,99 €	26,99 €	19,47 €

The Table 16 compares all the different lights from Philips. The features between them are at the following paragraphs.

7.3.1. Incandescent vs LED bulb

The incandescent bulb has got a nominal power of 40 W while the LED just 6 W. The luminous that has the incandescent is 390 and the LED is 470. The big differences are in the power consumption, energy efficiency and in the service life in which the LED technology is clearly better. It is an energy efficiency of A+ and has a service life of 15000h and a power consumption of 6 kWh/ 1000 hours. The Incandescent has got a service life of 1000h and a power consumption of 40 kWh/ 1000 hours and also an energy efficiency of E. The cost of the fluorescent bulb is 1,20€ while the LED is 7,99€.

7.3.2. Fluorescent vs LED Retrofit Fluorescent

Related with the fluorescents, the current fluorescent consumes 15 W while the Retrofit tube 9W. In connection with luminous from each bulb, the fluorescent has 930 luminous and the LED 800 luminous. Another important feature is the energy efficiency, in the Fluorescent is B and in the LED is A+. The service life for both fluorescents is the same, 20000 hours. The price is also a difference, the fluorescent that consume 15 W cost 4,24€ and the Retrofit fluorescent 26,99€ there are a huge difference of price, this is because of the energy efficiency category.

7.3.3. HUE

To get use of the HUE technology you need a Starter Kits that includes light bulbs and a bridge, or you can get a separate bridge. There are some starter kits but I choose the Basic KIT 3x9W E27 Edison Screw Bulbs (that include 3 bulbs 9W each one and the bridge), it cost 183,5 €. To get one the bridge is 61€ and only the blub is 19,5€.

The advantage of this technology is that you can program the floodlight and control it form any smartphone or table. Even if you forgot to switch off any light you can turn it off. As I said at Osram technology the possibility to control your floodlight reduce apart of the energy savings because of the category A+, exist a reduction of the power consumption over the 30%. [G.7]

7.3.4. Service Life

If it supposed that in a house the average of hours that the lights are on is about 7 hours per day. With this value I calculate the days and years that a bulb needs to be replaced. With the value of the lamp service life divided by the 7 hours per day that a house consumes, I obtain the replaced time. Since that times fly I need to replace the floodlights.

Table 17. Philips services life

	Useful days	Useful years
Incandescent	143	0,39
Fluorescent	2857	8
Bulb LED	2143	6
Fluorescent LED	2857	8
LED + IOT	3571	10

In the Table 17 you can see that the conventional floodlight has to be replaced more than ones annually while the LED technology between 6 and 10 years depends on the type of floodlight.

The bulbs have a service life of 6 years (with a functionality of 7 hours per day), the Retrofit fluorescent 8 years of durability and the use of internet of things 10 years. This is an evidence that the even the price is higher in the LED technologies the usable life is clearly better. The technology that has a long service life is the HUE, introducing the control of the floodlight extends the service life.

If you compare the Philips technology with the OSRAM (Table 12) there exist a decrease of the Philips service life. Osram floodlight have better service life.

Table 18. Philips Cost

	Incandescent	Fluorescent	LED Bulb	Retrofit Fluorescent	HUE
2016	3,60 €	4,24 €	7,99 €	26,99 €	19,47 €
2017	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2018	3,60 €	0,00 €	0,00 €	0,00 €	0,00 €
2019	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2020	3,60 €	0,00 €	0,00 €	0,00 €	0,00 €
2021	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2022	3,60 €	0,00 €	7,99 €	0,00 €	0,00 €
2023	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2024	3,60 €	4,24 €	0,00 €	26,99 €	0,00 €
2025	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2026	3,60 €	0,00 €	0,00 €	0,00 €	19,47 €
2027	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2028	3,60 €	0,00 €	7,99 €	0,00 €	0,00 €
2029	2,40 €	0,00 €	0,00 €	0,00 €	0,00 €
2030	3,60 €	0,00 €	0,00 €	0,00 €	0,00 €
Cost	**45,60 €**	**8,48 €**	**23,97 €**	**53,98 €**	**38,94 €**

In the Table 18 there are the costs from now to 2030 of the entire floodlight.

It I compare the LED bulb with the incandescent I can see that the cost over the year between them is very high. This is because the current lights have to be replaced more than ones a year while the LED bulbs 6 a year. Even the initial cost is higher for LED technology over the years the cost decrease.

The fluorescent tubes have the same service life and consequently the same time to be replaced. The difference between them is the cost of the tubes;

the current tube has less cost if you compared with the retrofit fluorescent. So the retrofit replaced is higher.

Changing the floodlight to the LED technology over the years you achieved more cost saving with the Bulbs but not with the retrofit fluorescents tubes. HUE technology has a cheaper price than the Osram technology.

7.3.5. Power Consumption

The power consumption savings that I obtain with the replacement is an important factor that I should to consider. This estimate show you the truest energy saving.

Table 19. Power consumption Philips

	Power kW	Power Consumption kWh / year
Incandescent Bulb	0,04	102,20
Fluorescent	0,02	48,55
Bulb LED	0,01	15,33
Fluorescent LED	0,01	23,00
LED + IOT	0,01	25,55

With the power consumption value of each floodlight I make a relation kWh/h to obtain the kW that each floodlight consumes. I calculate for every year which is the power consumption, so then I make the relation with the actual floodlight and the new one and compare who many kWh I could save in a year. The Table 20 shows you the kWh that I could save if I replace the current light with LED's technology.

Table 20. Power saving Philips

	Bulb LED	Fluorescent LED	LED + IOT
Incandescent Bulb	86,87		76,65
Fluorescent		25,55	

As you can see in the Table 20 you save 86,87 kWh per year if you replace the incandescent bulbs with the LED technology.

The energy saving that you have replacing the fluorescent to a retrofit fluorescent tube is about 25,55 kWh per year.

As you can see in the Table 20 the saving energy between the LED technology and the LED + IoT is above 76,65 kWh, 10kWh per year bellow the LED technology.

7.4 Final Solution

After analysing both brands with the features and cost I can extract the best solution to replace the current light as you can see throw the chapter 7 the solution will be LED technology. But at Table 21 there will be the main features and cost of the final solution an also which brand.

Table 21. Floodlights

		Bulb		Retrofit Fluorescent		LED + IOT	
		Philips	Osram	Philips	Osram	Philips	Osram
Nominal power	W	6	6	9	8,4	9,5	9,5
Nominal voltage	V	220-240	220-240	220-240	220-240	230	220-240
Nominal luminous flux	lm	470	470	800	840	800	810
Colour Temperature	K	4000	2700	6500	4000	2700	2700-6500
Lamp service life	h	15000	25000	20000	30000	25000	20000
Power consumption	Kwh/h	6/1000	6/1000	9/1000	11/1000	10/1000	10/1000
Energy efficiency		A+	A+	A	A+	A+	A+
Cost	€	7,99 €	10,85 €	26,99 €	20,45 €	19,47 €	44,00 €

The final lights that I replace with the current lights are:

From the substitution of the incandescent tubes I get the Osram bulb instead of the Philips bulbs. Even if the nominal power is the same in both bulbs (6W) Osram has more service life. The price is higher but has to be replaced less times.

It I compare the Philip and Osram Retrofit fluorescents I can get that the nominal power of the Philips one is higher than the Osram. Related with the luminous Osram has got 40 more luminous. The solution is Osram because of their energy efficiency of A+ and for its higher service life, 30000 hours; even the power consumption is a bit higher between Philips technologies.

The Internet of things technology is better at Philips because has higher service life and a cheaper price. Other features are the same from Osram lights.

The final floodlight will be finally like the table 22.

Table 22. Final solution

		LED bulb Osram	Retrofit Fluorescent Osram	HUE Philips
Nominal power	W	6	8,4	9,5
Nominal voltage	V	220-240	220-240	230
Nominal luminous flux	lm	470	840	800
Colour Temperature	K	2700	4000	2700
Lamp service life	h	25000	30000	25000
Power consumption	Kwh/h	6/1000	11/1000	10/1000
Energy efficiency		A+	A+	A+
Cost	€	10,85 €	20,45 €	19,47 €

7.5 Other systems

Other systems that can make the house more efficient could be the introducing of detectors to control light at the corridor and stairs. Moreover it could be good to open the blinds if the outside light is enough, so I can take advantage to use the sunlight to illuminate inside. For this I need some detectors that can control switch on the blinds if the light outside enough.

7.5.1. Detectors

Introducing movement or motion detectors at the stairs or the corridor of the house could be a solution to saving more energy because at these places people don’t remember to turn off the lights.

The detector records the thermal radiation from its surroundings or its detection zone. If recorded thermal radiation detector transforms it into a measurable electrical signal and the light switch on. If you do not record any movement and exceeded the luminosity value defined, the detector turns the light off automatically.

The most common detectors are the movement and the presence detector. The movement can also evaluate the brightness at the time it detect movement. In contrast the motion detector is constantly evaluating the luminosity.

For a private house the best solution is a movement detector because is enough to evaluate the brightness only when there are someone. Is not necessary to evaluate the luminosity at all time.

7.5.2. Shutters

Loxone is one of the brands that offer the possibility of control the shutters intelligently so lets you to have a full control over them.

You can automatically control the shutters. The room temperature is controlled and if necessary solar radiation to heat the rooms or keep cool in summer is used. All movements are performed optimally and automatically.

It can also include the option to make the correct movements of the shutters throughout the day. In the morning, they will be uploaded at the same time the alarm goes off and during the day if you want to use solar energy to heat the room increases will remain. In case of storms, the shutters will get off automatically for safety. And when it starts to get dark, its position will also be closed to maintain privacy at home.

CHAPTER 8: TEMPERATURE CONTROL

Control the temperature of the house is another factor that is regulated, because a good management could save electrical consumption. Adjust the temperature introducing a remote control programmable thermostat that controls the house conditioning no matter where you are.

8.1 Introduction

As [5] said the percentage of power consumption that is related to the temperature is for cooling 2% and heating 7%. It also said that the average consumption of Spanish house is 3487 kWh. Getting this I can get the consumption of the heating and cooling systems.

For the cooling the consumption is 69,74 kWh and for heating 244,09 kWh so the introduction of a programmable thermostat can help to reduce the power consumption.

Introduce a remote control programmable thermostat is a good option because you don't need to make a new installation, just introduce a remote control in your current installation. It will help you to control the conditioning.

There are lots of brands that offer that kind of services. The ISSUU magazine show me same of them. [X.8]

The main brands that have different kind of thermostats are Venstar, Honeywell, 2GIG, Ecobee, RCS, Aprlaire, Jackson systems. In the following sections there are explained by their features.

8.2 Venstar

Venstar thermostats have different types of thermostats depending of the necessity. They allow you to control your comfort and save money on energy using from anywhere.

8.2.1. Touchscreen

The Venstar ColorTouch Series Thermostat is a multi-functional, simple-to-use, programmable touchscreen thermostat in which the user can customize their own backgrounds. This thermostat is compatible with most heating and air conditioning equipment and control gas/electric or heat pump equipment, which up to 4 heating and 2 cooling stages. It is also dual-fuel capable. ColorTouch is able to intelligently control your HVAC system and displays the proper equipment status, in terms of heating and cooling stages turned on. It is compatible with Wi-Fi accessories.

8.2.2. Voyager

The Voyager model is a good solution for a residential home. It controls gas/ electric or heat pump equipment. You can programme or non-programme and also choose the option of 7 days, 5+2 days or 1 day programming. This thermostat notifies you of any alert. Optionally you can choose the wireless modules Wi-Fi, Z-Wave or Zig-Bee as you prefer.

8.2.3. Wireless

It is a thermostat able to move it; you can put it by your bedside at night, or even control your heating and air conditioning a system from two different places, such as upstairs and downstairs. It can be programmable for 7 days with 4 time periods per day and also it use two AA lithium batteries.

8.3 Ecobee

The Ecobee thermostat is a Zigbee compatible Wi-Fi enabled, energy saving solution that gives users total control over their home's heating and air conditioning form anywhere with an internet connection. It has a remote sensor that delivers the right temperature at different rooms, for every room you want to control the temperature you need a remote sensor.

It is constantly monitoring your equipment performance and will send you an alert if anything is not working or working sub-optimally. Similarly, Ecobee can send you service reminders to help you maintain your equipment.

8.4 2GIG

2GIGI has different types of thermostat but the two that fit with a private house are the following ones.

8.4.1. GC-TBZ48 Z-Wave

This Programmable Thermostat model GC-TBZ48 is a battery powered Z-Wave thermostat that connects to all Z-Wave hubs, it giving you control over your home's comfort wherever you are. This model is designed to be incredibly easy to install and includes a front loading battery compartment to hold 4 "AA" batteries to power the thermostat for two full years, or it can be powered by the HVAC systems 24 VAC "C" wire. The GC-TBZ48 works with most contemporary Central HVAC systems, whether standard or heat pump.

Features

a) Large, easy-to-read LED backlit display
b) Battery powered design runs on 4 "AA" batteries
c) Can be powered by 24 VAC "C" wire form HVAC system
d) Z-Wave compatible – Ver. 4.5.5
e) Supports Z-Wave FLiRS functionality
f) Works on standard HVAC systems: 2 stage heat/ 2 stage cool
g) Works on heat pump HVAC systems: 3 stage heat/ 2 stage cool
h) Simplified installation
i) USB firmware upgrade ability
j) Wall mount or mounts on single-gang unction box

8.4.2. Z-CT100

This remote management option allows full control over a home's heating and cooling at all times while home or away with a valid internet connection. This feature can help to reduce energy consumption by allowing users to turn their thermostat off, or alter the temperature, while no one is at home and still activate it to your optimal settings prior to coming home.

Features

a) Ultra slim from factor
b) Two year battery life
c) 4 stage heat
d) Bright display with Touch Screen
e) Improved Z-Wave range
f) Auto mode
g) Improved user experience.

8.5 Lock State Connect

The Lock State thermostat is able to control remotely via the internet. You can have further control by setting heating and cooling programs that will save energy. The Wi-Fi Touch Screen Thermostat can also be setup to send alerts to notify when specified settings are either met or exceeded for further control. This will let you know if the device is being adjusted when it shouldn't be or if there is a problem.

The LS-90i model Touch Screen Thermostat is compatible with nearly all HVAC systems which include traditional furnaces and heat pumps, external air baffles, humidifiers and de-humidifiers. This model controls up to 3 stages of heating and 2 stages of cooling as well as 7-day programming for further customizing.

8.6 Honeywell

Honeywell is a brand that has many kind of thermostats all of them

8.6.1. LYRIC RCH9310WF5003

The Honeywell Lyric was designed with your dynamic schedule in mind. They moved the thermostat controls to your smart devices, so you stay connected no matter where the days take you. You come and go at different times each day. Lyric automatically adjusts comfort when you are home and savings when you are away.

Features:

a) Location based on/off - uses your smartphone's location to know when you're away and saves you energy; it senses your return and helps make you comfortable upon arrival.
b) Smart alerts - push notifications remind you of filter changes and warn you of extreme indoor temperatures.
c) Save energy and maintain comfort from anywhere
d) Comfort – view and adjust humidity levels of your Indoor Air Quality system.
e) Custom shortcuts - create custom shortcuts for recurring events and change settings with 1 touch

8.6.2. RTH9580

The RTH9580 Honeywell thermostat is an ideally suited for the connected home and today's smartphones. It's packed with smart features, a customizable Touch screen and a simple setup, is very easy their programming.

Features:

a) Wi-Fi enabled - control from anywhere
b) Full-colour, bright and customizable screen
c) Smart response technology for the precise temp when you want it
d) Automatic energy-saving settings that fit your life
e) Customizable colour settings to match your decor
f) Auto alerts ensure on-time filter changes; know about extreme temps
g) Local weather conditions including temperature and humidity
h) Simple set up
i) Reliable app backed by Honeywell's dependable network

j) Peace of mind - control energy use, ensures safe temps for pets, or keeps tabs on a vacation home
k) Auto-updates for daylight savings; adjusts for 12/24-hour and multi-language needs
l) Quick schedule changes - update your settings for temporary holds or vacations; restore everyday settings in a snap
m) Help on demand - onscreen help button answers questions as you go

8.6.3. RTH9580WF

The Honeywell Wi-Fi Smart Thermostat connects to your home Wi-Fi network which gives you the ability to control it remotely form a smartphone, tablet or computer. This convenience means you can easily keep your home at a comfortable temperature without having to get up and walk over to the thermostat each time the temperature needs to be adjusted. Additionally there is a free app available for iOS and Android operating systems to provide quick-access to the Wi-Fi Programmable Touchscreen Thermostat from a compatible smartphone or tablet.

Features:

a) Wi-Fi enabled thermostat allows for remote access via smartphone or computer
b) Free smartphone app for iPhone, iPad and Android operating systems
c) Precise temperature control - thermostat holds +/-1 degree F accuracy to maximize comfort
d) 7 day programming with 4 program periods per day can be configured to meet almost any scheduling scenario for ultimate flexibility
e) Pre-programmed with energy savings schedule.
f) Universal compatibility - works with virtually any system type (C-wire required)
g) Intelligent alerts - high/low temperature notifications of unusual temperature sing and loss of connection to Wi-Fi network alert
h) Filter change indicator
i) Ability to view local weather from web portal or app
j) Smart Response Technology - continually learns when to pre-heat/cool your home so you are comfortable at your programmed times
k) Auto change from heat to cool - automatically determines if your home needs heating or cooling so you are comfortable at your programmed times
l) Vacation hold - adjusts programming and have it automatically resume the normal settings in time for your return
m) Display options - degree F or C temperature display; 12 or 24 hour clock
n) Wink App Ready - No Wink Hub Required

8.7 Aprilaire

Aprilaire thermostats reduce energy costs and achieve total comfort. Most of them are designed around your heating and cooling system. From the basic to all-inclusive, they have a thermostat that you can program and control based on your lifestyle and comfort needs.

The manufacturer recommends a programmable thermostat to save up to 30% on heating and cooling bills. The thermostat automatically set the temperature based on your personalized program.

8.7.1. 8910W

The Aprilaire Model 8910W Wi-Fi Thermostat with IAQ (Indoor Air Quality) control is for homeowners who want total comfort and control over all aspects of indoor air quality. As the most comprehensive controller Apriaire offers, it goes beyond simple temperature management to include humidity, air purity and air freshness control. All of their indoor air essentials come into perfect balance with one, easy-to-operate touchscreen control.

8.7.2. 8620

You can get a total comfort and control it the 8620 touchscreen thermostat. Along with precision temperature accuracy and effortless programmability, it gives you options for controlling the remaining aspects of indoor quality – humidity, fresh air and air purity.

8.8 RCS

The TZ45 is a Z-Wave wireless digital thermostat, designed to control the majority of HVAC systems. It contains a robust thermostat interface and is designed for use with communicating systems where remote monitoring and /or remote control are desired. It can be programmable 4 x 7 days standard or Heat Pump HVAC Systems it has an operational remote sensor to control the temperature at the rooms.

8.9 Jackson Systems

This brand has different types of programmable thermostats, each one adapts to customer's needs.

8.9.1. T-32-P

The Comfort System T-32-P universal thermostat is compatible with most commercial HVAC systems and is ideally suited for use with the Comfort System zoning panels.

Its features are:

a) Up to 3H/2C conventional and heat pump systems
b) 7 day programmable
c) Large backlit display
d) Auto or manual changeover
e) Keypad and/or set point lockout
f) Smart fan logic for commercial control
g) Adaptive recovery
h) Optional indoor sensor or outdoor sensor
i) Outdoor temperature display with optional outdoor sensor
j) Available with integrated Modbus communications
k) Hardwired
l) 5-year warranty

8.9.2. T-32-TS

The Comfort System 3ed generator T-32-Ts is a universal, low-cost touchscreen thermostat. It can be battery powered or hardwired. It operate in a high temperature, 150 degrees, that makes it ideally suited for use in residential and light commercial applications.

a) Up to 2H/2C conventional
b) Up to 3H/2C heat pump or dual fuel
c) 7 day programmable, 4 events per day
d) High operating temperature makes it ideal for hot yoga rooms
e) Low-cost, universal touchscreen thermostat
f) Auto or manual changeover
g) Keypad lockout

h) Adaptive recovery
i) Assignable auxiliary rely for economizer or IAQ products
j) Adjustable heating and cooling set point limits
k) Optional indoor sensor or outdoor sensor
l) Outdoor temperature display with optional outdoor sensor
m) Hardwired or battery powered
n) 4 assignable dip switches that will bypass setup
o) 5-year warranty

8.9.3. WCTT-32

The WCT-32 is a wireless 7-day programmable, battery-powered thermostat. It can communicate via RF data link to a relay control module located near the HVAC equipment. This thermostat can control single-stage, multi-stage and heat pump equipment with up to 3 stages of heating and 2 stage of cooling.

a) Up to 3H/2C conventional and heat pump systems
b) 7 day programmable, 4 events per day
c) Eliminates installation of wiring a thermostat to the HVAC equipment
d) Exclusive memory back-up ensures reliable performance in the event of a communications interruption
e) Wireless 915MHz proprietary protocol
f) 100’ transmission range
g) Easy-access, front-loading battery compartment
h) Battery powered
i) 5-year warranty

8.10 Saving

The introduction of a programming thermostat, as recommended manufacturer Aprilaire, saved up to 30% on heating and cooling bills. So the power consumption can be reduced. The power consumption can be implemented to all other brands because they offer similar features. It is also because it is an Internet of Things device and I have an extra power saving.

In the chapter 10 there will be the costs and power reductions that have a thermostat programmable.

8.11 Final Solution

The functionality of the thermostat is to regulate the temperature over the house. Most of them just control the temperature on one point. It is not useful because there could be different temperatures in each room.

The best solution is a thermostat that could control the temperature of different rooms. They are the Ecobee, RCS and Jackson Systems that get sensors to control it. So I make the following tables to compare the thermostats.

Table 23. *Thermostats features I*

	ECOBEE	RCS
Sensors	Remote Sensors	2 Indoor Remote Sensors
Standard gas /electric HVAC	2 heating - 2 cooling stage	2 heating - 2 cooling stage
Heat Pump HVAC	4 heating - 2 cooling stage	3 heating - 2 cooling stage
Programming	7 days / Any period	7 days / 4 periods
Wireless	Zig-Bee	Z-Wave Zig-Bee Wi-Fi
Alerts	Yes	No
Battery	No	No
Cost	218,54 €	160,18 €

Table 24. *Thermostats features II*

	JACKSON SYSTEMS - T-32-P	JACKSON SYSTEMS - T-32-TS	JACKSON SYSTEMS - WCT-32
Sensors	2 Remote Sensors (Outdoor - Indoor)	2 Remote Sensors (Outdoor - Indoor)	2 Remote Sensors (1Outdoor - 1Indoor)
Standard gas /electric HVAC	3 heating - 2 cooling stage	3 heating - 2 cooling stage	3 heating - 2 cooling stage
Heat Pump HVAC	3 heating - 2 cooling stage	3 heating - 2 cooling stage	3 heating - 2 cooling stage
Programming	7 days	7 days / 4 periods	7 days
Wireless	No info.	No info.	915 MHz proprietaryprotocol
Alerts	No	No	No
Battery	No	No	2 AA Alkalin Batteries
Cost	96,54 €	121,12 €	157,82 €

In the Tables 23 and 24 there are the features from the thermostats that have sensors. From them I can extract that the best solution for the home is Ecobee thermostat because is the only one that allows you to install as many sensors as you want. This allows you to control and adjust the temperature over the rooms. And also it can alter you if the consumption programming is overtaking or there is any incidence.

This thermostat can be programming day by day, putting when you are out of home and automatically it reduce the temperature. It has a vacation mode

CHAPTER 9:

DATA CENTER

9.1 What is a Data Center?

A Data Center is a part of a Company where the information is processed. All the information that includes a DC is extremely important so it must always have energy supplied. Because of the importance of this equipment they are called "critical equipment". If a DC doesn't work correctly the information and the interests of the company will decrease.

The essential elements that include a DC are: computers, communication networks and also intern and external networks services of the company. The important aspects that must have a data center are: Power supply, cooling, access control, internet access, automated fire extinguishers.

Since 2005 exist an American regulation ANSI/TIA 942 that classified the different types of Data Center by Tier1, Tier 2, Tier 3 and Tier 4. This regulation collected all the experiences and incidences that happened all the past years in different DC all over the world. The Uptime Institute is the only one that can classify the Tier's.

9.2 IoT a Data Center Impact?

The development and the growth of the Internet of Things technology cause directly an increase in the Data Centres capacity. This will involve a renewal in terms of capacity and technologies used and the needs of companies will increase. [38]

The data required to run a Smart home will be stored in a Data Center. As indirectly the use of Smart Home is not only an evident energy saving, the storage at a Data Center produces consumption.

9.3 Real Smart Home Savings

IoT systems installed in a home is closely related to energy saving. This technology and the energy from natural sources allow us to saving on electricity bills. Although we are not fully aware that the introduction of this technology also causes energy consumption, not directly at home but in a Data Center yes.

The use of IoT systems needs to storage the data in a Data Center. The storage of information has cost and therefore consumption.

Each Mega necessary for the use of Internet of Things systems has a kW power consumption in a Data Center that is stored. For this you have to note that the current consumption of energy is not the really one that people expect when they install IoT technologies at home.

I can calculate the energy savings with the introduction of energy efficient systems and the Internet of Things technology calculating the consumption of the Mega Bytes needed to control a Smart Home.

The questions that I have to answer to make the calculation of the current energy saving are:

a) How megabytes IoT systems consume a Smart Home in a day?

As [23] explained Stacey Higginbotham in July 2014 said that a Smart Home generates 1 GB in a week. This statement involves in my case 52 GB per year.

b) Which is the cost of store Megas in a Data Center?

Microsoft Azure has the possibility of storage your Data in their Data Centers, actually they have the possibility of storage Terabytes but on the June 2016 there will be the possibility of storage Gigabytes.

There are two types of storage: [14]

1) LRS: Locally Redundant Storage

It makes 3 synchronous copies of your data within a single Data Center. This is the best option for an economical storage of data governance compliance. The availability is SLA 99.9$ red/white.

2) GRS: Geographically redundant storage

It makes 3 synchronous copies in a data center and also 3 more copies asynchronous copies to a second data center hundreds of miles away. It is a good solution for protection against a major Data Center outage or disaster. The availability is SLA 99.9$ red/white.

The cost of storage is for LRS 0,0675€ per GB and for GRS 0,0843 € per GB. In this case the first solution the locally redundant storage is enough because the information is not critical.

So for the 52 GB per year that needs a Smart Home, the cost will be 0,0675 € per GB per 52 GB per year a total of 3,51€ per year.

c) How many kWh consume the storage of GB?

As [12] said that the power estimate yields is 5,12 kWh per GB. This cause for the 52 GB per year a total power consumption of 266,24 kWh per year.

9.4 Final Solution

The additional cost of storing of data is not included to the economic and energetic study because its cost is very little and not enough for the final price. This is because nowadays the storage of data in cheaper than years ago.

This cost has to be added at the additional saving of internet of things technologies. So real reduction won't have the value of the energy savings, but it has to be account the value of 3,15 € from Data Center storage.

CHAPTER 10: ECONOMIC AND ENERGETIC STUDY

To make the energy and economic study of the systems introduced in the previous chapters I need to compare the old systems with the introduction of the more energy efficient systems. The annual consumption and the cost of the different systems substituted are calculated. The study is conducted for household appliances, lighting and conditioning.

In this study it has to take into account the initial investment required to perform the substitution and also the economical and power consumption savings.

In order to analyse the profitability of the project I calculate the amortization of this. This allows me to calculate how many years I recover the initial investment and also if the investment is profitable.

The cost of the power consumption saving will be calculated with a value of an electrical bill. In this case the cost of 0,071852 €/kWh.

Form the technologies that have internet of things systems have an additional save. It can be around 30% but I made a sensibility study of easy technology saving 10%, 20% and 30%.

10.1 HOUSEHOLD

The replacement of appliances is given by the high consumption at home. The necessity of introducing more efficient appliances allows me to calculate the energy savings that get me making the replacement.

The values of the old devices are getting from the reference [3]. They said that refrigerators power consumption depends on the energy type. A device with an energy efficiency type C has a power consumption of 676 kWh per year and for AAA+ category 175 kWh per year. By the same token for the other devices I made a relation so the old devices have a power consumption factor of 3,6 more than the new appliances.

Table 25. Appliances consume and cost savings

	OLD		NEW		SAVING	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Refrigerator	601,2	43,20 €	167	12,00 €	434,2	31,20 €
Wash Machine	486	34,92 €	135	9,70 €	351	25,22 €
Dish Washer	842,4	60,53 €	234	16,81 €	608,4	43,71 €
Oven	591,3	42,49 €	164,25	11,80 €	427,05	30,68 €
TOTAL	2520,9	181,13 €	700,25	50,31 €	1820,65	130,82 €

As you can see in the Table 25 the power savings from all appliances are 1820,65 kWh per year and the cost of this energy saving is 130,82€ per year.

10.2 LIGHTING

In the table 22 there are the summary of the final lights to be replaced at home.

To analyse the savings that I get with the floodlight substitution I have two options, A and B. The option A is the one that introduce LED lights in the substitution and the option B is the one that control the lights by Wi-Fi.

In the following table I analyse which of the two options gives more energy and cost savings will be the solution that I implement.

Table 26. *Option A. Consume and cost*

	OLD		OPTION A		SAVING A	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Bulb	5365,5	385,52 €	536,55	38,55 €	4828,95	346,97 €
Fluorescent	825,35	59,30 €	477,87	34,34 €	347,48	24,97 €
TOTAL	6190,85	444,82 €	1014,42	72,89 €	5176,43	371,94 €

Table 27. *Option B. Consume and cost*

	OLD		OPTION B		SAVING B	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Bulb	5365,5	385,52 €	894,25	64,25 €	4471,25	321,27 €
Fluorescent	825,35	59,30 €	477,87	34,34 €	347,48	24,97 €
TOTAL	6190,85	444,82 €	1372,12	98,59 €	4818,73	346,24 €

Table 28. *Summary lighting consumes and cost*

	Consume kWh/ year	Cost €/year
OPTION A	5176,43	371,94 €
OPTION B	4818,73	346,24 €

As you can see in the Table 28 the option that generate more power consumption saving is the Option A, the substitution of the current floodlight to LED lights. Even the contrast between the option A and B is not too much and here doesn't take to account the additional power saving that you can get with Internet of Things technology.

10.3 TEMPERATURE CONTROL

The introduction of a thermostat capable of regulating the temperature in the house is the best choice for energy saving in air conditioning system. The introduction of it can reduce around 30% of the conditioning system. At the section 10.6 there will be a sensible study comparing different saving rates.

Table 29. Temperature consume and savings

	CONDITIONING		THERMOSTAT		SAVING	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Cooling	69,74	5,01 €	48,818	3,51 €	20,922	1,50 €
Heating	244,09	17,54 €	170,86	12,28 €	73,23	5,26 €
TOTAL	313,83	22,55 €	219,678	15,78 €	94,152	6,77 €

10.4 TOTAL SAVING

The total power savings that all the systems got to the house are the following ones. Here there are the two lighting options.

Table 30. Total saving Option A

	OLD		NEW		SAVING	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Household	2520,9	181,13 €	700,25	50,31 €	1820,65	130,82 €
Thermostat	313,83	22,55 €	219,678	15,78 €	94,152	6,77 €
Floodlight A	6190,85	444,82 €	1014,42	72,89 €	5176,43	371,94 €
TOTAL	9025,58	648,51 €	1934,348	138,99 €	7091,232	509,52 €

Table 31. Total saving Option B

	OLD		NEW		SAVING	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Household	2520,9	181,13 €	700,25	50,31 €	1820,65	130,82 €
Floodlight B	6190,85	444,82 €	1372,12	98,59 €	4818,73	346,24 €
Thermostat	313,83	22,55 €	219,678	15,78 €	94,152	6,77 €
TOTAL	8711,75	625,96 €	2072,37	148,90 €	6639,38	477,05 €

At the table 30 you can see the total power consumption with the fight light option that you save if you change the current devices to the new ones, more efficient. The total power saving in a year is 7091,23 kWh per year and the saving cost is 509,52€ per year. And at the table 31 you can see the total saving with the lighting option B, the total power saving is 6639,38 kWh per year and supposed a saving cost of 477,05€. The economical savings between each option is 32,47€.

10.5 AMORTIZATION

The amortization calculation shows if the substitution of all the systems is profitable. So I calculate in how many years the initial investment is recovered. For this I made the following table where I calculate the years of recovering for each option, A and B.

Table 32. Amortization Option A

	Initial Investment Euros (€)	Saving €/year	Amortization Years
Household	3.649,00 €	130,82 €	27,89
Floodlight Option A	727,40 €	371,94 €	1,96
Thermostat	218,54 €	6,77 €	32,30
TOTAL	4.594,94 €	509,52 €	9,02

Table 33. Amortization Option B

	Initial Investment Euros (€)	Saving €/year	Amortization Years
Household	3.649,00 €	130,82 €	27,89
Floodlight B	1.090,10 €	346,24 €	3,15
Thermostat	218,54 €	6,77 €	32,30
TOTAL	4.957,64 €	483,82 €	10,25

In these tables you can see in how many years I recover the initial investment.

For the option A the household appliances recover the initial investment in nearly 28 years, the Floodlight in 2 years and the thermostat in 32 years. The total amortization of the new installation is 9 years. To show it more clearly chart the amortization in the figures 5, 6, 8 and 9.

For the option B the floodlight B recover the initial investment in more than 3 years, so the total amortization is above 10 years. This is because the initial investment for the IoT floodlight is expensive than Led's. In the figure 7 you can see the representation of the amortization.

10.5.1. Household appliances

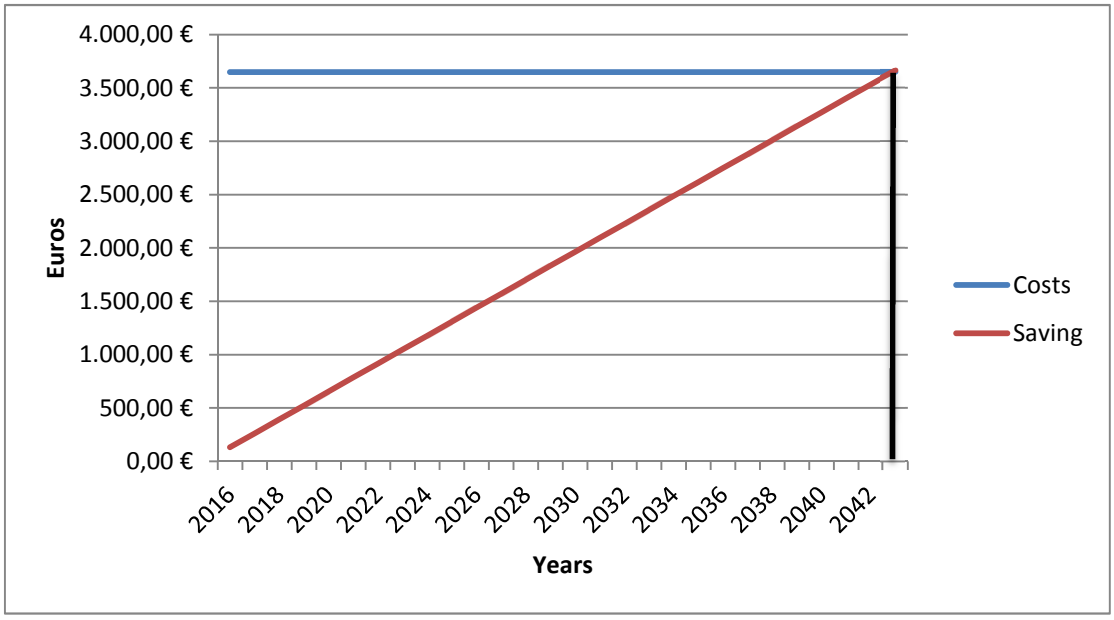

Figure 5. *Total power consumption.*

As you can see in the table 32 the years to get the initial investment is 32 years. In the figure 5 you can see clearly. In 15 years I only save around

500€ while the initial cost is 3649€. By 2043 you recover the initial investment.

10.5.2. Lighting

a) Option A

To calculate the amortization form the floodlight I just need to divide the initial cost with the power saving. In the table 31 said that in 2 years I get the initial investment. In the figure 6 you can see than representation of the costs.

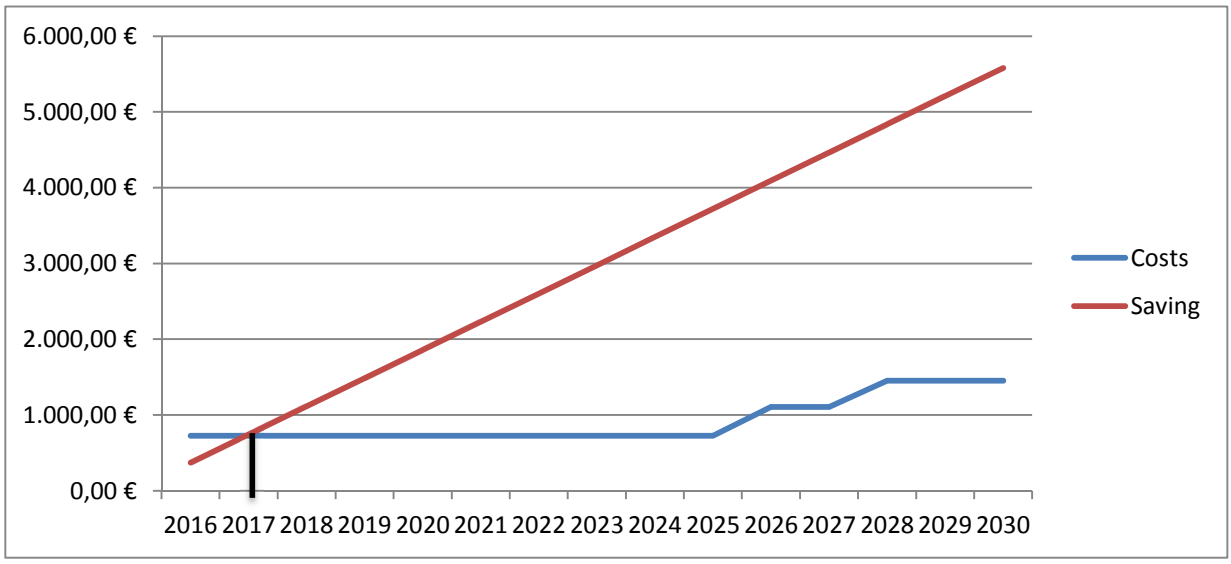

Figure 6. *Lighting Option A Amortization.*

b) Option B

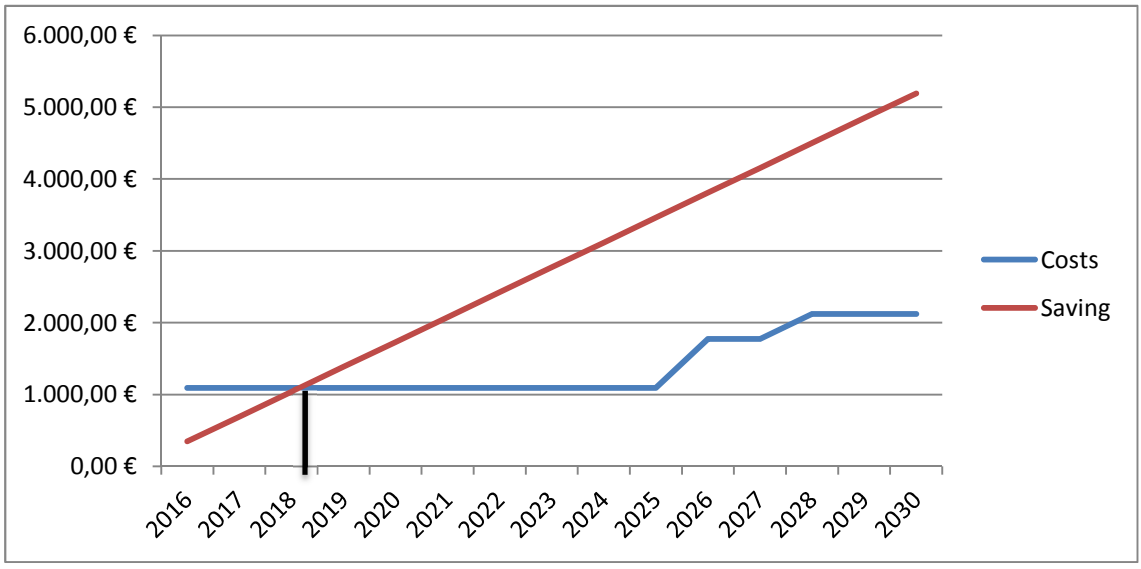

Figure 7. *Lighting Option B Amortization.*

In the figure 6 you can see that the initial investment is recovered in nearly 2 years. And in the figure 7, 3 years.

10.5.3. Temperature control

In the figure 8 you have that the introduction of the thermostat that cost 218,54 € is recovered (at table 28) in 32 years. By 2030 you can only save 100€ of power consumption. Is by 2048 that you have save the initial investment.

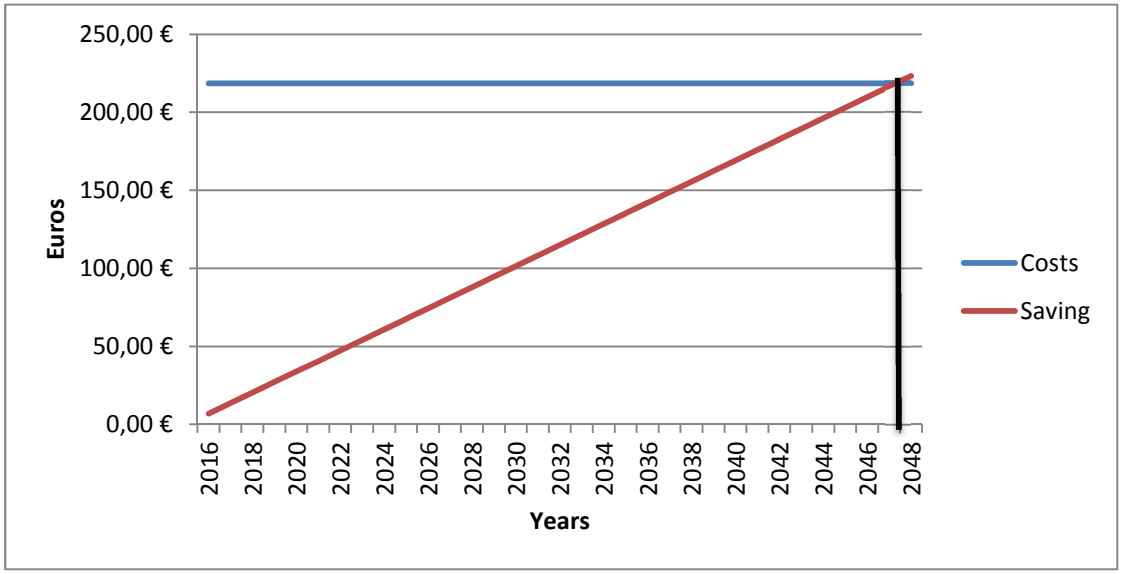

Figure 8. *Temperature amortization.*

10.5.4. Total Amortization

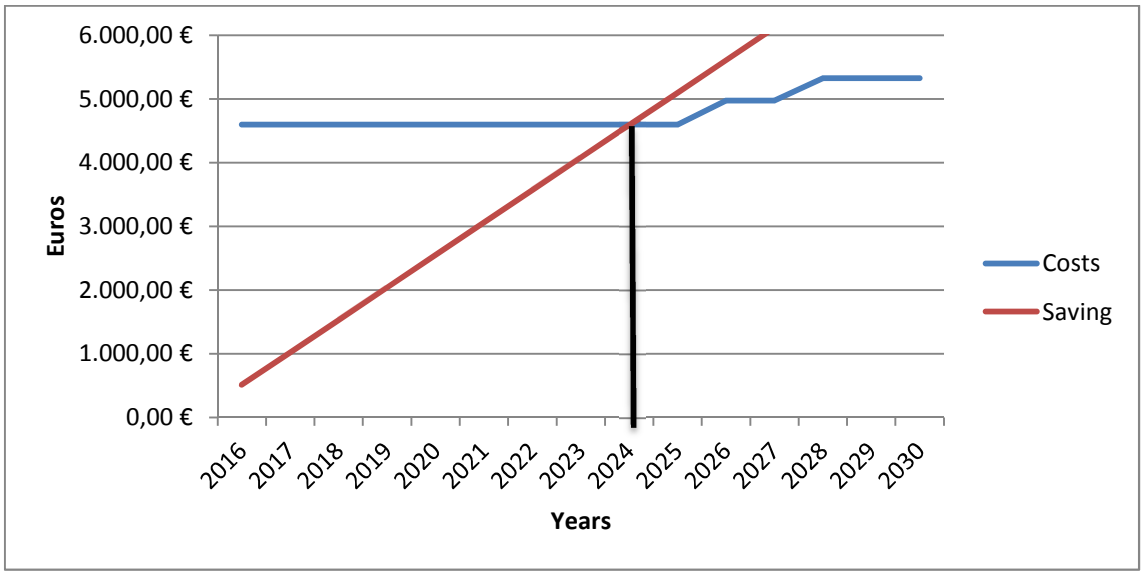

Figure 9. *Total Amortization.*

In the figure 9 there are represented the amortization of the total investment; floodlight, household appliances and temperature control.

As the table 28 said all the installation will be recovered in 9 years. In the figure 9 I clearly appreciate it, by 2025 the initial investment is recover.

10.6 SENSIBILITY STUDY

After seeing that the introduction of internet of things reduce the power consumption but also have an extra cost because of the data storage at a Data Center I calculate the real saves.

From the project the systems that got IoT technology are the Intelligent Plug, HUE floodlight, and also Programmable Thermostat customers want to reduce the consumption using that.

Knowing that the customers have the habits and the awareness of the importance of saving energy consumption the IoT solutions helps to reduce it.

The power saving is around 30% of the actually consume but I make a sensibility study with the rates 10%, 20% and 30%. [2]

The cost of storage the Smart Home Data is 3,15€ per year so this cost has to be added in the saving study.

10.6.1. Intelligent Plug

Table 34. Appliances IoT consumption

	NEW		NEW-10%		NEW-20%		NEW-30%	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Refrigerator	167	12,00 €	150,3	10,80 €	133,6	9,60 €	116,9	8,40 €
Wash Machine	135	9,70 €	121,5	8,73 €	108	7,76 €	94,5	6,79 €
Dish Washer	234	16,81 €	210,6	15,13 €	187,2	13,45 €	163,8	11,77 €
Oven	164,25	11,80 €	147,825	10,62 €	131,4	9,44 €	114,975	8,26 €
Storage		3,15 €		3,15 €		3,15 €		3,15 €
TOTAL	700,25	53,46 €	630,225	48,43 €	560,2	43,40 €	490,175	38,37 €

10.6.2. HUE

Table 35. HUE IoT consumptions

	NEW		NEW-10%		NEW-20%		NEW-30%	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Bulb	894,25	64,25 €	804,825	57,83 €	715,4	51,40 €	625,975	44,98 €
Fluorescent	477,87	34,34 €	430,083	30,90 €	382,296	27,47 €	334,509	24,04 €
Storage		3,15 €		3,15 €		3,15 €		3,15 €
TOTAL	1372,12	101,74 €	1234,908	91,88 €	1097,696	82,02 €	960,484	72,16 €

10.6.3. Thermostat

Table 36. Thermostat IoT consumption

	NEW		NEW-10%		NEW-20%		NEW-30%	
	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year	Consume kWh/ year	Cost €/year
Cooling	48,818	3,51 €	43,9362	3,16 €	39,0544	2,81 €	34,1726	2,46 €
Heating	170,86	12,28 €	153,774	11,05 €	136,688	9,82 €	119,602	8,59 €
Storage		3,15 €		3,15 €		3,15 €		3,15 €
TOTAL	219,678	18,93 €	197,7102	17,36 €	175,7424	15,78 €	153,7746	14,20 €

In the tables 34 – 35 - 36 there are the energy consumptions that supposed to have internet of things technology. By rates 10%, 20% and 30% saving. The power consumption of the introduction of all the new systems is reducing depending on the rates, so the cost of it is cheaper if the savings are higher.

The use of intelligent plug at best you save around 200 kWh per year that supposed a saving of 15€ per year. In the case of the Intelligent floodlight installation the power savings at best are around 415 kWh per year with a saving cost of 30€. Finally for the thermostat the saving is around 65 kWh per year with a saving cost of 4,73.

Table 37. Real savings

	Initial Investment €	Saving €/year	Amortization Years
Household	3.948,95 €	330,82 €	11,76
Floodlight B	1.090,10 €	761,24 €	1,43
Thermostat	218,54 €	71,77 €	3,05
TOTAL	4.957,64 €	1.163,82 €	4,47

I have to introduce the cost of the four intelligent plugs at initial household investment.

Having all this saving the new installation is profitable, in more than 4 years and a half the total investment is recovered.

10.7 CONCLUSIONS

As a conclusion the amortization of the replacement is profitable on the whole. If I analyses one by one the only substitution that will works is the floodlight substitution because of their quickly amortization. The thermostat and the household appliances spend 30 years to returns the initial investment, so by themselves aren't profitable.

The sensitive study shows that the best solution for the lighting is the B because of the introduction of internet of thing technology have an extra power consumption saving. With this study the power consumption is reducing significantly, the total amortization around 4 years while without this considerations is around 9 years. Definitely the use of intelligent plugs, programmable thermostat and also HUE technology are the best solution.

CHAPTER 11: BUDGET

It intended to reflect the economic study of the implementation of this Project. Engineering costs, documentation and costs associated with the project are recorded.

This budget has a validity period of one month since 26/04/2016.

11.1. Engineering Costs

Engineering costs are derived from works done by the engineer.

Table 38. Engineering Costs

Task	Cost €/h	Hours h	Total Cost €
Initial Information	32	90	2880
Lighting Study	32	90	2880
Appliances Study	32	60	1920
Temperature control Study	32	60	1920
Plots and Final Conclusions	32	100	3200
TOTAL			12800

11.2. Documentation Costs

Documentation costs are the ones costs associated with typing job. The implementation of the project as a document its review and printing.

Table 39. Documentation Costs

	Cost €/h	Hours h	Total Cost €
Typing	20	100	2000
Revision	27	24	648
Printing	27	5	135
TOTAL			2783

11.3. Total Costs

The total cost of the report is the sum of the engineering costs and the documentation cost.

Table 40. Total Costs

Concept	Cost €
Engineering Costs	12800
Documentation Costs	2783
Subtotal	15583
IVA (21%)	3272,43
Total	18855,43

CHAPTER 12: CONCLUSIONS

After analysing the different solutions there could be three possible solutions to be implemented. The first one that is to leave the installation as they are I don't recommended because of their high power consumption.

The second one is the introduction of energy efficiency solution that has decrees the power consumption of the current installation. And the other option is the introduction at energy efficiency solutions the internet of thing technology that have an additional power saving that decrees the amortization.

Globally the substitution is profitable, but individually with the savings that generates the Internet of things systems the introduction of new floodlight system and a thermostat that regulate the temperature of the house are profitable.

The introduction of internet of things technologies produce an extra power consumption saving because of their management. Even their initial investment is higher than other technologies. Over the years their cost will decrees and these systems will be easier to implement.

CHAPTER 13: BIBLIOGRAPHY

The bibliography is divided into two parts. The first are the References which are those that correspond to the citations appeared in the text. On the other hand there is the Bibliography Consultation that served me as a basis or consulting.

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