NOVIA
UNIVERSITY OF APPLIED SCIENCES

RENOVATION CENTER

A Nordic center for energy efficient renovations

FINAL REPORT

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This present work has been elaborated with the purpose of gathering information about building renovations from different parts of Europe, focusing on methods and techniques, which can be applied in Nordic countries building projects.

In order to achieve this mission it has written a series of definitions of fundamental techniques aspects about building covers, building installations, indoor environment, material specification and case studies.

In addition, to get an overview about how the building renovation sector and the legislations in Europe are currently, the project also includes research information about European Union, Austrian, French, German and Spanish policies, local laws and measures.

All information has been presented in a simple way so that the different stakeholders are able to access directly without complications and easy understanding.

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1 Introduction

During the last years the climate change is a permanent guest in the mass media all over the world. Almost everyone is discussing this topic and searching for the best solutions to stop it. The interested party is not just the average world population, but there are quite a lot interested people from the high society too and of course the specialists from the sectors science, economy, politics and culture. Nowadays, the majority of the population has recognized, that something is changing on our planet and it is not controversial anymore.

The technique to save energy is already developed and we also have the skills to implement it to our life. However, all these information are not gathered in a simple or efficient way, therefore it is necessary to encompass and share them that everyone can understand it, thus the present project was born in order to achieve this goal.

European Union with the member states agreed, to decrease all the energy waste and also to save the environment and beat the climate change. The next set objectives for all members are the 20-20-20 goals, which has to be realized until 2020. After this, the European Union already set the next goals for 2050 and to prohibit the climate change the greenhouse gas production has to be neutral in the second half of this century.

The building sector is one of the biggest energy consumer in Europe, especially the residential buildings needs more than 1/3 of the whole end energy. Therefore, it was established in this report how the different stakeholders could renovate their houses or buildings to reduce their consumption.

Besides it is important to stand out that the present project is a part of a big already ongoing project, which takes part in the Nordic countries (Finland, Sweden and Norway). The main sponsor of this project is Interreg [1], as well as some other companies and universities from the Nordic countries. The main task is to inform stakeholders how they could renovate their buildings in a sustainable way. The quality of the building should of course increase after the renovation, but not just in one aspect to save energy, also to improve the quality of living. The report includes the necessary information about renovation and an idea how an online sharing platform could look like.

1.1 European Project Semester

The European Project Semester is a program offered by seventeen European universities in twelve countries throughout Europe, created with engineering students in mind, but other students are also welcome.

Dr. Arvid Andersen was the originator of the EPS concept. He developed the program in Helsingør, Denmark [2]. EPS grew constantly and it is crafted to address the design requirements of the degree and prepare engineering students with all the necessary skills to face the challenges of world economy nowadays. International student teams work on interdisciplinary projects with commercial businesses and industries, selected to match the students' specializations and capabilities as well as to develop their inter-cultural communication and teamwork skills.

The whole EPS program is composed by different courses and activities, for instance: project management, teambuilding, integration week, Survival Swedish, English lessons, energy week and supporting technical courses.

The main objective is to train students from different countries and different disciplines to work together in multi-cultural and multi-disciplinary groups. The students work together to execute an integrated engineering-design-and business project, focusing on:

- The development of personal competences, especially the ability to work and communicate within cross-cultural groups.
- The interrelated work of several disciplines like civil, mechanical & electrical engineering, information technology, business & management, etc.

Figure 1: Isologo of EPS

1.2 Project group

1.2.1 Team members

The team is formed by five students from different countries of Europe. Our international and intercultural project group consists of Austrian, German, French and Spanish students. Because of the intercultural mix, everyone is used to different working techniques and that can be challenging in some situations. Each of us come from different universities and our field of studies are also mostly different.

The fact that all team members presents different backgrounds, which are in our opinion a positive aspect, which might affect the results of our project positively. To conclude the team was composed by the results obtained at a Belbin test, which gives us an overview about the different personal qualities of each team member.

All team members are represented on the following page with basic information.

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Mechanical engineering
Ecole nationale d'Ingénieurs de Tarbes

Ceylan Munar
Int. sales and purchasing in engineering
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2 The project

2.1 Summary

These days almost everyone has recognized, that the climate on the earth is already changing and this change is caused by human's behavior. Especially in the last century, when the big industrializations begun, a lot of new inventions rises which are not the environmental friendliest. In the past almost nobody recognized that fossil fuels are causing climate change and so a lot of engines and machines were working with this type of energy source. However, now the civilization has realized that our behavior has to change and we must try to use as much as possible from renewable energy sources to stop/reduce this change.

The building sector consume about 40% of the total final energy and this can be prevented. But to reduce or stop this consumption a renovation is essential. So the European Union created the 20/20/20 targets, which has to be realized by 2020.

Thus in the Nordic countries of Europe, therefore was started a big project (also called Renovation Center) which is sponsored by Interreg. The members of this big project are Finland, Sweden and Norway and this project should be realized from 01.04.2015 to 31.03.2018 [4]. The main aim of this project is focused on renovations in the building sector.

Our EPS group is involved into this big project and our task is to help the stakeholders to realize a sustainable renovation. We collected information from all Europe, especially from our own countries. We are focused on information which can be implemented in the Nordic area to improve the buildings. The specialization is set energy savings, which means to upgrade the building cover like outer walls, roof, windows etc., but we are also looking for special materials which are able to resist this hard climate conditions in the north of Europe. In the end we want to inform stakeholders the following:

- How to renovate their buildings in a sustainable way.
- How to save energy.
- Which materials to use for a renovation.
- How to prevent building damages like mold, moisture damage, etc.

2.2 Mission and vision

In these times where the human being is experiencing an important global warming in the climate due to the accumulation of greenhouse gas in the atmosphere, it is extremely important to make aware people of the opportunity which we have to change this situation by the energy reduction in our style of live.

With this project, it pretends to inform of the different existing ways, which are known so far, that reduce this energy consumption in the building sector by the renovation of old buildings in Nordic Countries.

With the purpose to achieve this mission, it has set a series of goals in this project.

- Gathering enough information and tools in energy efficient and sustainable renovations for buildings.
- Analyzing of politic from European Union countries with the aim to know the current situation on energy efficiency in Europe.
- Analyzing of techniques and materials in order to share this information in a simple way with all people, such as companies in the building sector, municipalities, owners, tenants, etc.
- Searching of successful cases and their subsequent study in order to demonstrate that renovations get their objectives.

Thus, the team hope to contribute to make the world a better place where to live in the future and where our children can enjoy of a healthy and long life in a natural environment.

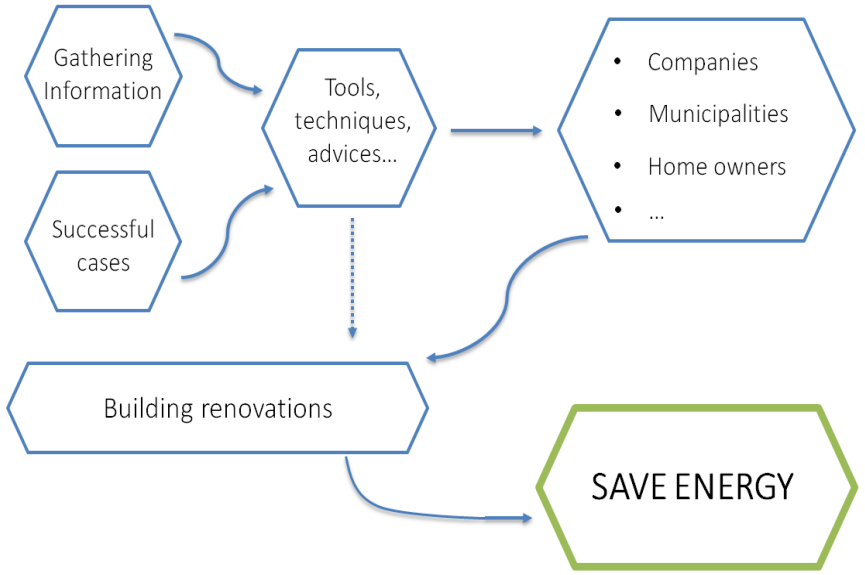


Figure 2: Mission and vison of the project

3 Research

3.1 The European Union 20-20-20 Goals

In these days almost everybody is talking about climate change and global warming and also this topic is very relevant and important in the whole European Union. Therefore the EU government set a goal for stopping this change until 2020. The main idea is to reduce the greenhouse gases by 20 % in comparison with 2005[5]. The amount of renewable energy should increase by 20 % and the energy should be used in a 20 % more efficient way (figure 4).

Figure 4: Illustration of the EU goals from Remake electric.

To conclude it has to be also said that the EU has proposed in January 2014 a new framework which goal is to save 30 % of the used energy by 2017. But nowadays it has not been decided if this will be binding for all member states of the EU or if this will be an individual country basis. Instead the 20-20-20 goals are general in force for all EU member states. In the following figure 18 there can be seen the different projections and current trend of the 20-20-20 from all 27EU members (figure 3):

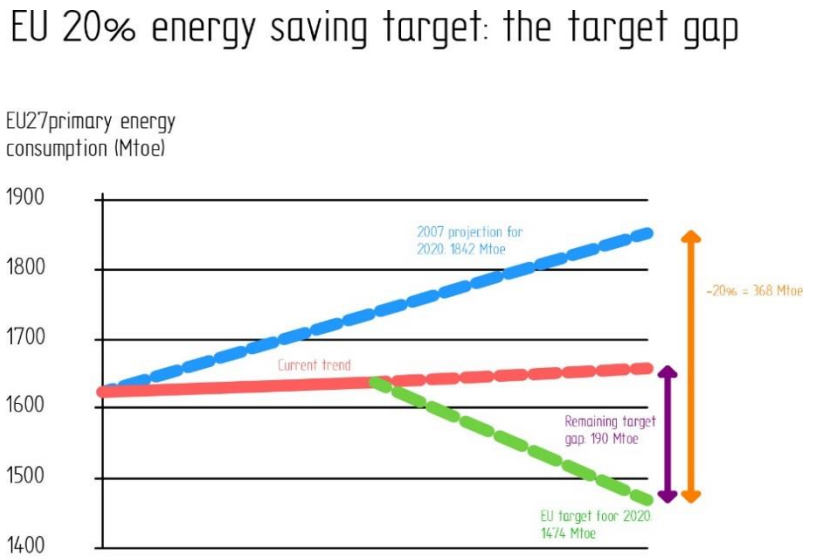


Figure 3: The world green building council. Energy efficiency directive.2012

It is very important to stand out that for the study the and analysis of the different tools and techniques and the achievement of objectives on the present project, the team decided to gather and analyze information concerning the laws and politics of belonging countries of the Union European. With this, it pretends to clarify the motivations and objectives of these countries in order to obtain information about techniques which are used to achieve thereof.

Due to the characteristics of the team, it decided to analyze the policies and goals of the countries of each member (in this case: Germany, Austria, Spain and France), making easier the collection of information as well as resolving problems because of language and/or lack of awareness about policies of other countries, which could be unknown for the students.

Besides, it is interesting to highlight the interests that these countries have in matters of energy efficiency and renovation of buildings. Considering that, this information provide us a lot of data about how these countries contribute for their respective citizens to have enough tools and advice, with which to be able to face: expenses, ignorance on the matter, steps to follow in a renovation, etc.

3.2 Local policies

3.2.1 Austria

Vision and goals: For the reduction of greenhouse gas (GHG) emissions every EU country got different objectives, which were evaluated in a “Burden Sharing”-Process. The industrial facilities and power plants, which are seen as the big greenhouse gas producers must reduce their emission by 21 % until 2020 in comparison to 2005. The rest in Austria caused emissions should be reduced by 16 % and these regards for the building sector, transport sector and small/ medium scale companies.

Also for expansion of renewable energy carrier each EU country has own objectives. In Austria the set contribution is to increase the renewables from 23.3 % in 2005 to 34 % in 2020. And the energy use in a more efficient way is the same for the whole EU members. To reach this goals it is very important to implement the building sector, because the energy consumption of this sector is approximately 40 % of the whole consumption. Therefore, Austria becomes a member of “build up skills”. In this project the important stakeholders of Austria

created a roadmap to achieve the 20.20.20 targets. The objective of the national strategy for capacity buildings is [6]:

- Contribution to the achievement of the EU energy objectives
- Reduction of construction deficiencies and damages, especially of defects in terms of missing the value indicated in the energy performance certificates
- Ensure the required number of appropriately qualified personal under special consideration of young trainees
- Structural improvements in the education sector so that lifelong learning in the target area gets more attractive and strengthened

As mentioned above, the building sector has a central role to reduce the actual energy waste, because more than 1/3 of the whole energy consumption is consumed for heating, hot water processing and cooling. To realize this EU goals, the standards of new buildings and the on-going renovations has to upgrade. For this reason the new build buildings have to be "nearly zero energy buildings" and this can be realized by high quality materials and renewable energy systems. To make the new system for the stakeholders more attractive the government will offer subsidies.

To reach the goal in the building sector of "10 % end energy reduction" the renovation has to increase by 2.1 % from 2009 to 2020 and not just in the residential buildings but also in the not residential buildings. The heat supply has to move from the fossil fuels to renewable energy sources or to district heating.

Explications of the policies: In Austria there is a main construction policy and guideline for buildings, which is provided by OIB (Austrian construction technology institute) [7]. In this guide are 6 directives:

1. Mechanical resistance and stability
2. Fire protection
3. Hygienic, health and environmental protection
4. Safety in use and accessibility
5. Noise protection
6. Energy savings and heat retention

For this EPS project especially the sixth rule is important, because this contains:

- Requirements to the net energy demand
- Requirements to the final energy demand
- Domestic and commercial power requirement
- Primary energy demand
- Carbon dioxide emissions
- Overall energy efficiency factor
- Requirements for components (heat transmitting components)
- Requirements for components of the technical building system (heating distribution, -storage, -recovery; ventilation systems)
- Further requirements (prevention of thermal bridges; air and wind density; summer overheating protection; central heat supply; electrical resistance heating; use of highly efficient alternative energy systems (Combined Heat and Power Plants – CHP, district – or block heating or cooling systems, heat pumps, fuel cells))
- Energy Performance Certificate: Issued by qualified and authorized persons; mandatory information for residential and non- residential as well as other conditioned buildings
- Reference facilities (Heat transfer and heat distribution systems, heat storage- and heat supply system)

Conclusion: Austria is on a good way to reach their targets, for sure it can be done more to convince the citizens more to decrease their energy consumption. In Austria there are very good guidelines and policies, how to improve buildings in an energy efficient way and also a lot of specialized companies which are able to realize a renovation.

3.2.2 France

Vision and goals: In France there are 12 million detached houses built before the year 2000, which represent 1 billion square meters of accommodation. Moreover 50 % of the houses were built before 1974 without thermic rules; consequently they have a really bad insulation and consume a lot of energy.

The building sector is one of the most important energy consumer. It represents every years more than 40 % of the French energy consumption and close to 25 % of the greenhouse gas emission [8].

The state has as objective to renovate 500.000 accommodations until 2017, which the half are mainly owned by modest income people, and this in order to reduce 15 % of the energy demand from now until 2020. Moreover during the "Grenelle de l'Environnement in 2007" the government wanted to reduce the energy consumption of the existing buildings of 38 % before 2020.

The French government organized a lot of concrete measures in order to fight against the energy demand, improve the building consumption, improve the life quality and support the economy.

Legalization: According to the French law: "the energy transition and green development: concrete measures to promote energy renovation of buildings (2015)" the government took some measures to reach the 2020 goals.

- Measures for energy demand and life quality:
  - Creation of "Energy Cheque" to help the most modest people (4 million beneficiary).
  - Creation of electricity/ gas/ water smart meter. In order to have a good command of energy consumption.
  - Creation of renovation platform. To advice people with craftsperson, energy diagnosis or building work organization.
  - Fight against unworthy houses.
- Measures in order to permit modest income people to renovate:
  - Creation of "Eco-prêt à taux zero" (Zero rate loan).
  - Discount tax credit. Which can save a maximum of 30 % of the costs of a thermic renovation under 16.000€.

- Measures to increase the energy performance of buildings:
  - Serious renovations (Roof restoration, Building Facade restoration, Area extension, Attic transformation) should respect energy performance up to the region and building.
  - Establishing of a waste area grid for construction industry. In order to improve the recycling of construction materials.

Conclusion: The French state has set important goals regarding of the greenhouse emission and the building renovation sector is an important point to reach these goals.

3.2.3 Germany

Vision and goals: The aim of the energy concept that Germany is following is to make the existing buildings almost climate neutral by 2050. The primary requirement is to reduce the combination of energy efficiency and the use of renewable energy sources till this date, 80 % compared to the data in 2008.

Moreover the ambitious EU 2020 climate targets announced in 2007 constitute also a starting point. These seek a 20% cut in greenhouse gas (GHG) emissions, a 20 % improvement in energy efficiency and 20 % share of renewables in EU energy consumption by 2020 [9].

To achieve this goal it's generally determined on the proven energy efficiency measures and sources of renewable energy for heating purposes and these are improved and expanded. All this resolutions will reduces heating costs and make them more independent of energy price increases. Even an increase in value of the Property success by the energetic quality.

Actually there can be found around 19 million residential buildings with approximately 40 million apartments where more than the half needs to be rehabilitate and renovate in the coming 20 years. This corresponds to approximately one million apartments to remedial. Since the renovation cycles are approximately 30 to 40 years in the building envelope, the chance for energetic exercise should be used.

To get in the situation of energy consumption it has to be known that 40 % of the whole energy in Germany is used in the building area.

Residential buildings contribute more than the half, followed by the sector trade, commerce, services and the industrial buildings.

To complete this information, in the following figure 5 it can be seen that the biggest savings would be made in the buildings of the model year 1749 to 1978[10], because these have the largest areal consumptions. The graphic is about the distribution of area-related final energy consumption of the building stock by year of construction in kWh / m2, located in Germany.

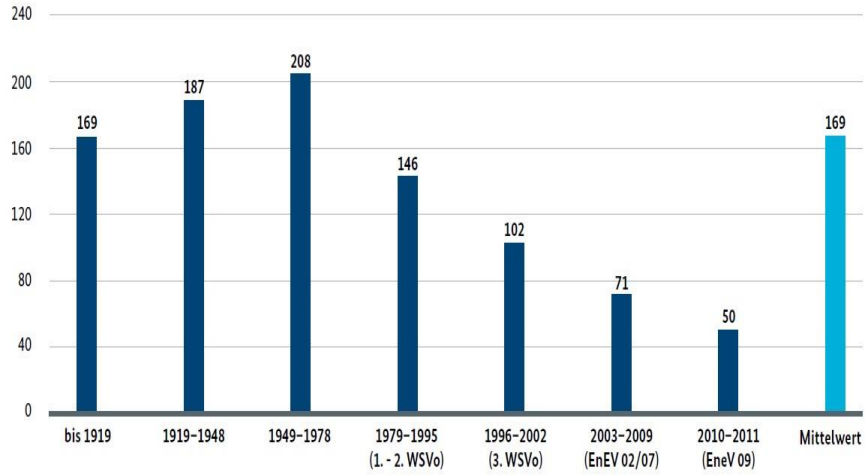


Figure 5: Energy consumption of the building stock by year in kWh/m2 in Germany,

Current Legislation: Nowadays there can be found two legal bases for energy efficiency in Germany, which manage and systematize all the different aspects comprehensive:

- Energy Saving Regulation (EnEV): It regulates the technical requirements for new buildings and refurbishments of old buildings. Especially what structural requirements take into account the energy consumption of the building that owner must fulfill. This applies not only to new buildings but also for renovating old buildings or expansion of the building by more than 50 m2. The ordinance applies to residential buildings, office buildings and certain operational building.
- Renewable Energies Heat Act (EEWärmeG): This law entered into force on 1 January 2009 to increase the share of renewable energy in final energy consumption for heat (space, cooling and process heat and hot water).

Conclusion: Even before the EU Directive on the energy performance of buildings had actually been adopted, Germany had already gone ahead and revised its EnEV and EEWärmeG. However to achieve the goal of the energy concept to acquire a carbon-neutral building stock by 2050, a reduction of the energy consumption of existing buildings is totally necessary, increasing more the efficiency in the building envelope and the building as well as the changes of the power supply on sources of renewable energy. To conclude Germany is one of the overriding countries in these aspects and they are on the right track to succeed in their future and current endeavors.

3.2.4 Spain

Vision and goals: The construction sector has a huge influence on the evolution of energy consumption and greenhouse gases emissions in Spain. Houses and buildings of the tertiary sector represent 26 % of final energy consumption, 17 % and 9 %, respectively. In addition, only energy use in homes represents a fifth of emissions of greenhouse gases in the country. Moreover if it also adds the emissions, which are originated in building construction process, it is concluded that the residential sector accounts for a third of the total national emissions of greenhouse gases.

The goals and actions on energy efficiency in Spain are part of the set objectives and regulatory advances by the Community institutions in European Union. Thus, in addition the objectives of reducing emissions of greenhouse gases and use of renewables, which were adopted at the European Council in spring 2007, it also was included a target which consists of improving energy efficiency by 20 % by 2020 in the EU, which has been commented previously.

In line with the European objective, the Plan of Action 2011-2020 Energy Saving and Efficiency considers a series of actions aimed at reducing consumption and energy costs in all economic sectors through energy efficiency actions for the purpose of confront the goals set by UE. 0.8 % from 2010 and a reduction by 1.5 % of energy intensity. This Plan considers a target of primary energy consumption of 142213 kt in 2020, which can be achieved with an annual increase of energy efficiency of 0.8% since 2010 and a reduction of 1.5% intensity primary energy between these two dates [11].

Moreover, in the National Reform Program 2013 is highlighted how energy intensity has been reduced in recent years, which equates to energy efficiency improvement due to that these indicative are inversely proportional, with annual rates of 3% and accumulated 18.5% since 2005, which indicates a substantial improvement in the energy efficiency sector.

The mechanisms of action, which support the sought objectives in the Action Plan 2011-2020 and Energy Efficiency to the building sector in Spain, are:

1. Certification of energy efficiency in buildings (RD47/2007) updated with the RD235/2013.

This document is a requirement under the Directive 2002/91/EC, transposed into Spanish law by Royal Decree 47/2007, which approves the Basic Procedure for the certification of energy efficiency of new construction buildings.

On February 2nd 2012 the Royal Decree Draft has been subjected to a hearing procedure and subsequent approval where the basic procedure for the Energy Efficiency Certification of existing buildings is approved. As with the new buildings, the ultimate goal of this decree is that every existing building has an Energy Efficiency Certificate that provides objective information to buyers and users in general.

2. The Technical Building Code, CTE (RD 314/2006, 17/03/2006).

It is about a regulatory framework that establishes the requirements to be met by buildings in relation to the basic requirements of safety and habitability. It has a series of Basic Quality Requirements to be met by the buildings, HE Basic Requirement, such as:

- HE Basic Requirement 1: Limiting energy demand
- HE Basic Requirement 2: Thermal installations output
- HE Basic Requirement 3: Energy efficiency of lighting installations
- HE Basic Requirement 4: Minimum solar contribution to DHW
- HE Basic Requirement 5: Minimum photovoltaic contribution of electrical energy

3. Regulation of Thermal Installations in Buildings, RITE (RD 1027/2007, 20/07/2007).

RITE sets out the conditions to be complied with by the facilities designed to meet the demand for thermal comfort and hygiene through heating, air-conditioning and sanitary hot water installations; to achieve a rational use of energy.

4. Energy Efficiency and Renewable Energy Bill

This Bill seeks to provide certainty to private investors, encourage the continued development of technologies intended for the utilization of renewable energies and create a market for companies involved in energy efficiency. It seeks to meet the goal of reaching 20 % of energy consumption from renewable sources by 2020 boosting its implementation, improving energy efficiency and increasing the use of biofuels.

As well as these actions, the different local governments support the people, who are interested about renovating their houses or building, with economical contributions, tax reduction, or any type of help that they need it, provided that the refurbishment is focused on the energy efficiency [12].

Conclusion: Spain, like other countries of the European Union, has proposed fulfil with emission reduction and reduce energy consumption in the building sector. Therefore, it has implemented a series of policies and tools in order to achieve the goal. Besides, it has always been a pioneer in the use of renewable energies, which added to the warm weather, could provide to the country a great opportunity in order to reduce its dependency on fossil fuels, improving the environment, quality of life off citizens and increase of employment.

3.3 Fundamental technical definitions

It is important to define some important concepts, which have been used in this report constantly:

- Heat transfer: it is the exchange of thermal energy between physical systems. The rate depends on the temperatures of the systems and the properties of the intervening medium through which the heat is transferred. There are three fundamental mechanisms of transfer: see table 1[13]:

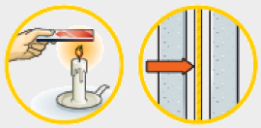
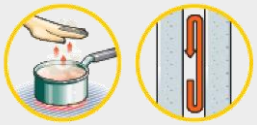
Conduction	Convection	Radiation (infrared)
		
Solid body **Transfer of energy through matter from particle to particle**	**Liquids and gases** Transfer of heat by the actual movement of the warmed matter	**All objects** give out and take in thermal radiation Electromagnetic waves that directly transport ENERGY through space

Table 1 : Heat transfer mechanisms. Picture source: Isover 2016

In a building, all ways of heat transfer are present at the same time but with more or less important, but the conduction transfer mechanisms is the most important in a building. Insulate means to get rid of the three transfer mode. In fact, to work only on one transfer mechanisms would not be enough. Also some properties about heat transfer are:

- Thermal conductivity λ (W/ (mK)): the property of a material to conduct heat. The Smaller this value is, the more the material will insulate for the same thickness of material.

- Thermal resistance or R-value [15] R (m2K/W): Thermal resistance is a heat property and a measurement of a temperature difference by which an object or material resists a heat flow. The higher the thermal resistance is, the higher the insulation will be, for the same thermal conductivity (λ).

Figure 6: Equivalence between thickness and thermal resistance of different materials. MWNG. SA 2015

As it can be seen in the previous figure 6, regarding thermal resistance it can be observed for example that 12 cm of fiberglass is like 1400cm of granite due to the difference of thermal conductivity. This shows the importance of the material to use [14].

- Thermal Resistance of a wall:

In order to obtain the thermal resistance of a wall you need to add all the resistance of the different part of the wall and also the indoors and outdoors surface resistance (figure 7):

$$R = \frac{e}{\lambda}$$

R = Thermal resistance (m^2 K/W)

e = Material thickness (m)

λ = Lambda (W/ (mk))

$$R = R_{Wall} + R_{Insulation} + R_{Facing} + \sum r_{si}\ r_{se}$$

$R_{Wall} = \frac{\text{Wall thickness}}{\lambda \text{ Wall (according to material nature)}}$

$R_{Insulation} = \frac{\text{Insulation thickness}}{\lambda \text{ Insulation (according to material nature)}}$

$R_{Facing} = \frac{\text{Facing thickness}}{\lambda \text{ Facing (according to material nature)}}$

$\sum r_{si}\ r_{se}$ Indoors and Outdoors surface resistance (according to material nature)

Figure 7: Formulation and explication of thermal resistance and its

Thereupon, the values of indoor (r_{si}) and outdoor (r_{se}) surface resistance are explained graphically according to different cases depending on the orientation of the wall/floor/roof (table 2):

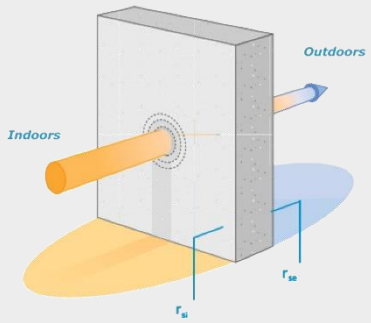
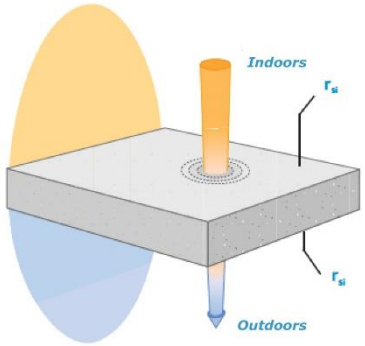
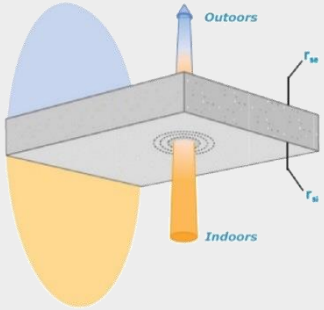
PANEL /WALL GIVE ONTO: ○ Outdoor ○ Unheated room ○ Open premises	r_{si}	r_{se}	$r_{si} + r_{se}$
Vertical panel 	0.13	0.04	0.17
Horizontal panel (ascending flow) 	0.17	0.04	0.21
Horizontal panel (downward flow) 	0.10	0.04	0.21

Table 2: Surface resistance. Picture source: Isover 2016

- Heat transfer coefficient/film coefficient/U-Value Uc W/(m²K)

  The film coefficient is the amount of heat which passes through a unit area in a unit time when the temperature difference between the boundaries of the system is 1 degree. The higher the value of

heat transfer is, the higher the heat loss will be. By definition The U-Value is the inverse of the R-Value:

$$Uc = \frac{1}{R(total\ thermal\ resistance\ of\ the\ wall)}$$

Thermal bridge /Heat Bridge/Cold Bridge: is an area where there is a higher heat transfer than the others materials around. Thermal bridges reduce energy efficiency and can allow condensation (moisture) and indoor environment problems. Thermal bridges occur in three ways [15]: Structural connections, One-off thermal bridge and linear thermal bridge, all of them are explained in the following table 3:

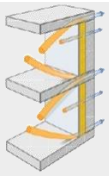
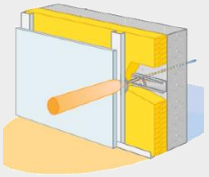
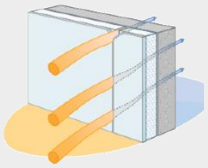
STRUCTURAL CONNECTIONS	ONE-OFF THERMAL BRIDGE	LINEAR THERMAL BRIDGE
		
Materials with higher thermal conductivity than the materials around	Discontinuities or gaps in the insulation material	Penetrations of the thermal envelope due to linear connecting element

Table 3: Thermal bridges classifications. Picture source: Isover 2016

3.4 Renovation tools and methods

3.4.1 Improve building cover

The first objective in a building renovation should always be to improve the building cover in order to reduce the heat losses. The thermal building cover consist of outer walls, base plate, basement ceiling, windows, outer doors, ceiling and roof. There are different methodologies which are used to improve the thermal cover. One of the most common technique is to improve the outer walls by upgrading the insulation which is situated on the outside of walls, but there are also other system which can be realized like the indoor insulation or the insulation between to walls. Every technique has its own pros and cons and this should be discussed before the renovation starts well. Another very important aspect in a renovation would be: the windows and doors. Windows are important to be of high quality and not just because of heat loses protection, but also responsible for the solar heat earnings. Regarding roofs and ceilings are also one of the main critical areas, in order to save heat energy, because hot air rise and therefore the insulation should be of high quality. In the end to realize a good renovation with new technics, the air tightness of

the building is an important part. It is not just important for a successful implementation of ventilation system with heat recovery, but also for the hot air losses through the walls and other parts of the building. Techniques for energy-efficient renovation are available and tested adequately from a technical perspective. From the structural point of view, there are a lot a components to improve which can bring the house owners economic efficiency in energy issues [16].

Insulation

Thermal insulation is a very important energy-saving measure for buildings, because well insulated buildings envelopes cut down the energy losses and that will help to reduce the energy consumption.

For an average house the heat losses can be reduced by reduced at least half. The problems that arise by installing adequate amounts of insulation in existing buildings vary enormously. The question is no longer whether to insulate, but costumers simply need to find the most efficient way of insulating each part of the home to the highest that can be afforded. The purpose of this part in the project is to give the necessary background to approach this task with confidence.

There are many positive benefits, which can be reached from insulated buildings, as well as a few pitfalls to watch out for. Besides the environmental benefit of reduced carbon dioxide emissions, there will be increased comfort, and a more even temperature around the house. Also, the heating system can be scaled down and radiators can be more freely placed anywhere in the room and, in some cases, dispensed with altogether.

The main pitfalls by adding insulation is that of creating cold bridges, where the original construction remains uninsulated and cold whereas the newly insulated surroundings are now warm. This can sometimes result in condensation, however there are solutions for most of the problems. There are very few principles to understand with insulation, and there is one concept that is worth bearing in mind:

All that insulation does is to slow down the rate of heat loss, so that less heat is required to maintain the same internal temperature. When we insulate our houses to a high standard, we not only conserve the heat from our heating appliances but also all the other sources of heat, such as from cooking and lighting, play a more important role.

Condensation: This occurs when warm air meets a cold surface: the moisture in the air cools and condenses on the surface in tiny droplets of water. Most commonly, condensation occurs on the inside of single glazed windows, but it can also occur on walls and within the fabric of buildings.

Condensation is a problem that has a number of causes:

- It can be an indication of the internal temperature being too low for the internal humidity level. This can happen in an unheated room that is not being used. The insulation of the whole building helps to solve this problem by evening out the temperatures internally, making it easier to keep the extremities of the house warm.
- It can also be an indication that humidity levels are too high and that water vapor produced elsewhere in the home is not being vented. The simplest way of avoiding this problem is to use mechanical extract fans connected to a humidistat, in both the bathroom and the kitchen. The humidistat will switch on when humidity levels exceed a predetermined limit. It is also a good idea to keep closed the door of a room where there is a source of water vapor, this aspects will be explained in a more extended way in the ventilation section.
- Condensation in an insulated house can also be an indication of cold bridging: where a non-insulated part of the construction protrudes through the well-insulated part and causes a surface in the interior to be at a much lower temperature than its surroundings. If the humidity level is high enough, condensation will form on this cold surface, possibly causing problems of deterioration. Cold bridging occurs most commonly at windows and where brick partition walls meet internally insulated externals walls.

3.4.1.1 Walls insulation

In a building more or less insulate, around 25% of heat losses take place through the walls. Insulation of the walls has to fulfil many essential functions in order to promote a good comfort for the owners.

Beyond the most evident like thermal comfort or acoustic protection, it is also with a good insulation that users can remove the “cold wall sensation or effect” (Sensation of cold feel when the difference between the ambient air and the wall surface is superior to 3°C) or also it is like that users are able to have a good durability of the damp room facing like the bathroom.

Insulation of the walls is an effective way to contribute to save energy and to improve the indoor environment. There is tree principals way to insulate walls building, from inside and from outside and cavity insulation [17].

3.4.1.1.1 Interior insulation

Thermal insulation from inside consists of putting the insulation material, as the name says on the inside face of the wall.

Advantages: For a renovation case it is often a good solution used when users want to preserve an outwards appearance and it is also the best option regarding to the ration Performance/Price.

It permits to works more easily with junctions, with joinery and with the roof insulation.

Disadvantages: Costumers have to remove the radiators and the electrical facility, the technique does not solve the problem of thermal bridge on the floor and on the interior load-bearing wall. It also prevents the natural wall inertia. Moreover the insulation will be effective only if the envelope is airtight [18]. So users must put a vapor barrier in order to prevent moisture through wall and interstitial condensation, which can destroy the insulation fiber.

There are two principal techniques of interior insulation: by doubling on frame and glued doubling.

Doubling on frame: Insert insulation material in an area created by a frame (figure 8 & 9). Finalize last layer by screwing plasterboards on the frames. Insulation material can have different natures and thickness, regarding the expected performances [19].

Advantages: This technique permits to obtain regular finish even if the existing wall has some irregularities. Insulating fibers are very common and stakeholders have a large choice of insulating materials (see the part of insulation materials).

Disadvantages: During the renovations users have to clear out the room because the technique need to remove the existing wall cover and make dust and waste.

Glued doubling: The prefabricated assembly of plasterboard and insulation is glued on the wall (figure 10 & 11). The most used materials are expanded polystyrene (EPS) which have the best ration Performance-Price and Polyurethane (PUR) for thin application in order to save indoors space.

Advantages: It is easy and quick to install this is why this technique is competitive. Insulation materials are always in constant evolution and they are really efficient regarding to the durability, moreover the materials which are used have one of the best lambda (λ) on the market (EPS until 0.030 W/ (mK), PUR until 0.022 W/ (mK)).

Figure 8: Example doubling on frame by Isolver 2016.

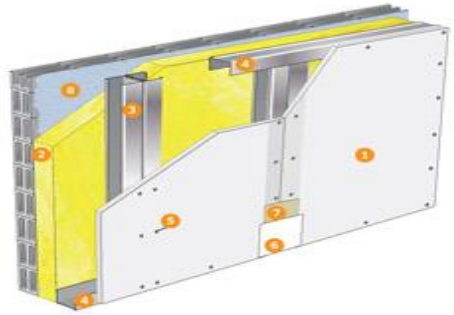


Figure 9: Example doubling on frame by Placo saint-Gobain. 2016

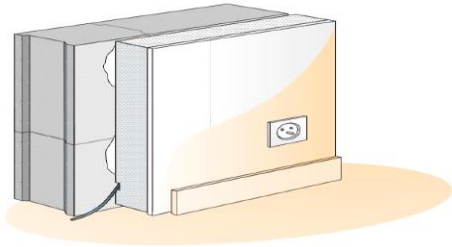


Figure 10: Example glued Doubling by Isolver 2. 2016

Disadvantages: This type of insulation has two serious confines. The planeness of the walls is an obligation, when the prefabricated panels should be glued. Contrary to the previous technique, if the wall has some irregularities users can not have a better finish as the existing wall.

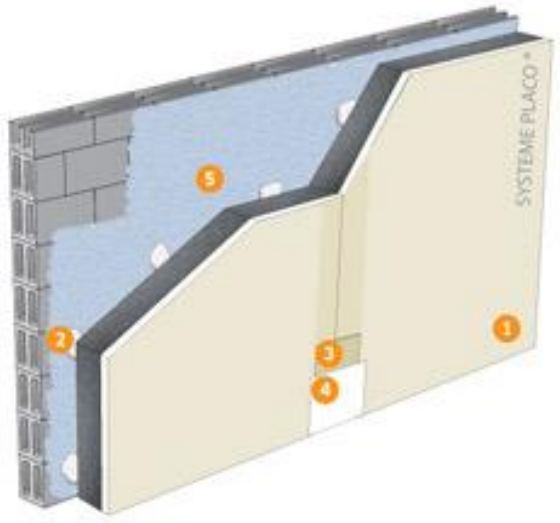


Figure 11: Example glued doubling by Placo saint-Gobain 2. 2016

3.4.1.1.2 External insulation

Thermal insulation from outside (figure 12) consists of putting the insulation material on the outside face of the building walls [20].

Advantages: This solution is very efficient and interesting for almost every type of detached houses. It permits to enjoy of the inertia of the walls and delete thermal bridges at the level of the transitional floors and the interior load-bearing walls. There is no reduction of the living area and inhabitants have not to change the indoor decoration. Moreover the appearance of the facade is modernized and costumers do not have to leave their house during the construction work.

Figure 12: Wedge-Dowelled insulation "Loprobat 2011"

Disadvantages: This solution can increase thermal bridges, especially junctions between ceiling and walls, at the level of windows; in order to reduce them it require a specific implementation. It increases the building density of the site. Moreover costumers have to change all the locking system like shutters. And to finish the cost of this technique is more expensive than the interior insulation. There are three principal techniques of interior insulation: glued insulation, wedge-dowelled insulation and Under Cladding insulation.

Glued Insulation, Wedge-dowelled insulation: Glued insulation and Wedge-dowelled insulation are quite similar, at first a starting rail close to the floor has to be installed and then the insulation panels with glue on the back can be added; and for the second costumers follow the same basis but the insulation panels are screwed or dowelled on the wall. In both case you need a primer and a protection layer [21].

Advantage: This system is compatible with all types of external insulation however the nature of the insulation material (Wood fiber, EPS, rock wood etc.) and the nature of the shelf. For the wedge-dowelled insulation it can be installed even if the wall is not perfectly flat.

Disadvantages: for the glued insulation users need a perfect flat wall.

Under Cladding: Insert insulation material in an area created by a frame (metallic /wood) and finalize the last layer by putting the structure material, what users want (figure 13).

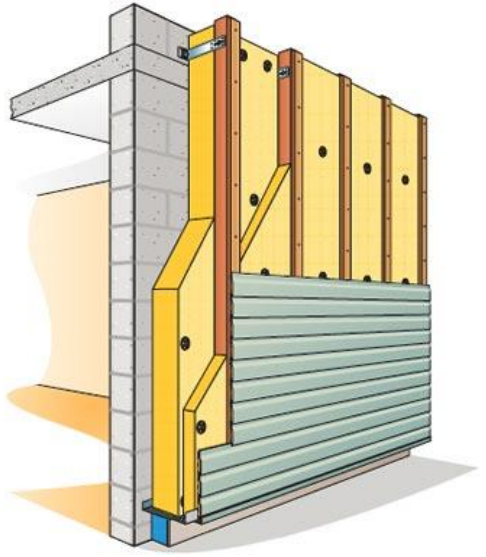


Figure 13: Under Cladding illustration “MaisonBrico.com” 2016.

Advantages: The implementation of the frame permit to the creation of a ventilated air gap essential for the resolution of moisture problems.

Disadvantages: The disadvantage of this technique is that the installation and the materials costs are from the most expensive methods.

3.4.1.1.3 Cavity wall insulation

Cavity wall insulation (figure 14) is used to reduce heat losses through a cavity wall by filling the air space with material that inhibits heat transfer. This immobilizes the air within the cavity (air is still the actual insulator), preventing convection, and can substantially reduce space heating costs [22].

Cavity wall insulation also helps to prevent convection and can keep a house warm by making sure that less heat is lost through walls; this can also thus be a more cost-efficient way of heating one's house. The insulation can be installed quite easily by drilling holes through the external outer leaf of the wall and pumping mineral glass/wool fiber, foam or polystyrene beads or similar into the cavity. The holes are drilled at regular intervals in the wall and are patched up in matching mortar afterwards. A good point to note here is that the mortar or substance used to patch the holes up afterwards will need to be waterproof in nature or sealed. By drilling a hole in the outer cavity

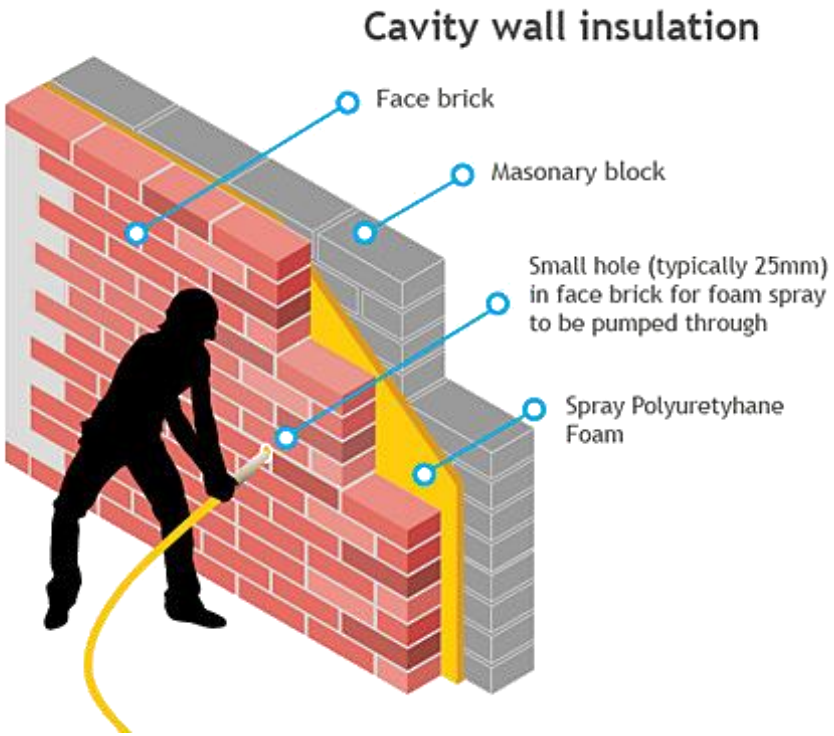


Figure 14: Cavity wall insulation procedure. Works IMBG, 2014.

wall costumers are effectively compromising its repellent qualities so whatever is used to fill the holes needs to be of the same standard.

The size of the house determines how long the process takes but a standard three-bedroom detached house should take about three to four hours, if the building presents the necessary characteristics and the professionals approve it [23].

Advantages:

- Cheaper than external or interior wall insulation.
- Maintains existing wall thickness.
- Minimal disruption to install
- Can reduce condensation

Disadvantages:

- Thermal bridging problems.
- Thickness of insulation is restricted by width of cavity.
- Significant number of buildings are unsuitable due to their exposure.
- Settlement and saturation of cavity-fill leading to cold bridging

3.4.1.1.4 Comparison tables

In the following table 4 there can be seen which the differences between the different insulation techniques explained before are [24] [25] [26] [27] [28] [29]:

All the costs and thermal resistance depends on the material that is used, its thickness and also on the insulation company, which install the systems.

WALLS	EXTERNAL INSULATION	INTERNAL INSULATION	CAVITY INSULATION
COSTS (€/M2)	100 - 230	60 - 90	5 - 15
IMPLEMENTATION	INTERMEDIATE	INTERMEDIATE	EASY
LIFE DURING THE RENOVATION	DON'T NEED TO MOVE OUT	NEED TO MOVE OUT	DON'T NEED TO MOVE OUT
BUILDING DENSITY	INCREASE	NO DIFFERENCE	NO DIFFERENCE
LIVING SPACE	NO DIFFERENCE	REDUCED	NO DIFFERENCE
THERMAL EFFICIENCY (R = M2.K/W)	1 – 7.9	1.5 - 5	1 – 2.8
APPEARENCE	FACADE RENEWED	INTERIOR RENEWED	NO DIFFERENCE

Table 4: Comparison of walls insulation.

In the table below (table 5) the comparison gets more specific, here there can be seen which the differences between external walls insulation techniques are.

And just after (table 6) there can be seen which the differences between interior walls insulation are [30] [31].

EXTERNAL WALLS INSULATION	GLUED INSULATION	WEDGE-DOWELLED INSULATION	UNDER CLADDING
COST (€/M2)	100 - 150	120 - 190	180 - 230
IMPLEMENTATION	INTERMEDIATE	EASY	EASY
THERMAL RESISTANCE (R = M2.K/W)	1 – 7.9	1 - 7.9	2 – 7.5
CONDITION NEEDED	PERFECTLY FLAT (NEED TO SAND THE SURFACE)	DON'T NEED TO SAND THE SURFACE	DON'T NEED TO SAND THE SURFACE

Table 5: Comparison external walls insulation.

INTERIOR WALLS INSULATION	DOUBLING ON FRAME	GLUED DOUBLING
COST (€/M2)	60-90	40
IMPLEMENTATION	EASY	INTERMEDIATE
THERMAL RESISTANCE (R = M2.K/W)	1.85 - 5	1.5 - 4
CONDITION NEEDED	PERFECTLY FLAT (NEED TO SAND THE SURFACE)	NO ONE

Table 6: Comparison interior walls insulation.

3.4.1.2 Roof insulation

In this part it has to be said that the heat losses are also very important in a building to take into consideration. During summer it is also here that happens uncomfortable heat peaks. Approximately 30% of heat losses of a building are passing through the roof, in fact the roof usually have one of the most important part regarding to the surface in contact with the exterior. Moreover because the heat naturally goes up, thus goes in direction of the roof. There it is two main way to insulate the roof, by the interior or by the exterior [32].

3.4.1.2.1 Interior insulation

First of all, users must remember that there are two possible types of attics in a house, habitable attics or uninhabitable attics.

Habitable attics: are the attics where the space under the roof is not congested by the framework of the building. Usually they are 180cm of height under the framework and the angle of the roof slope is superior to 30 % for a real comfortable attics.

Uninhabitable attics: are not habitable this is generally due to the low height under ceiling or/and by a framework that is too cumbersome (table 7).

ADVANTAGES	DISADVANTAGE
EASY TO IMPLEMENT LIMITED COST	DECREASES THE LIVING SPACE CAN HIDE WOOD BEAM LESS EFFICIENT THAN EXTERNAL INSULATION

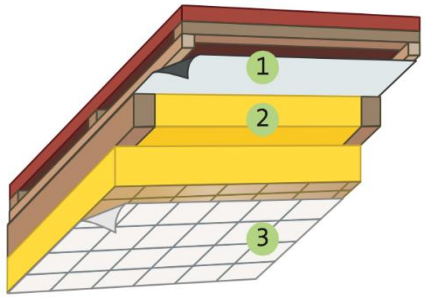
Table 7: Advantages and disadvantages comparison table interior insulation

The insulation of the attics is the most economical and the most efficient operation: it's an operation of retrofit very relevant on an economical plan; that requires a small investment and produce big effects.

Costs: Regarding to the costs of an interior insulation with the workforce, the customer will have to count between 40 and 90 euros/m^2 for a habitable attic and between 20 and 30 euros/m^2 for uninhabitable attic. But the cost of the insulation varies a lot depending on the materials [33].

Insulation of traditional attic with simple or double layer principle: According to the performance that users need, they will choose simple or double layer techniques (figure 15 & 17), the first one consist in just putting the insulation between purlins and the second one is to add one more layer after this.

For the double layer technique: The first layer of insulation is wedged between the purlins and the second layer of insulation, as well as all the other elements are retained by a rod (figure 16) (Suspension system). This rod also maintains a metal framework where users can screw the plasterboard.



1 Vapor barrier

2 Insulation layer between rafters

3 Air sealing membrane

Figure 15: Layers of Double layer insulation. Isover Saint-Gobain 2016

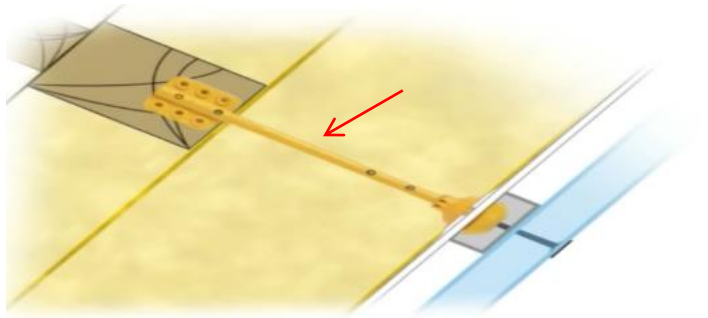


Figure 16: Rod (suspension system). Isover Saint-Gobain 2016

Advantages:

- A lot of decorative finishes (Plasterboard, paneling, customers can also let the purlins visible, etc.).
- A lot of choices for thermal and acoustic performance, depending on the insulation material.
- Decrease considerably thermal bridges.
- The fixing system (metal framework and suspension system) permits a good draught proofing of the insulation and an easy screwing of the facing layer.

Disadvantages:

- Users must clear out the room of the attic in order to make the renovation. The use of this technique caused a lot of dust and trash inside the building.

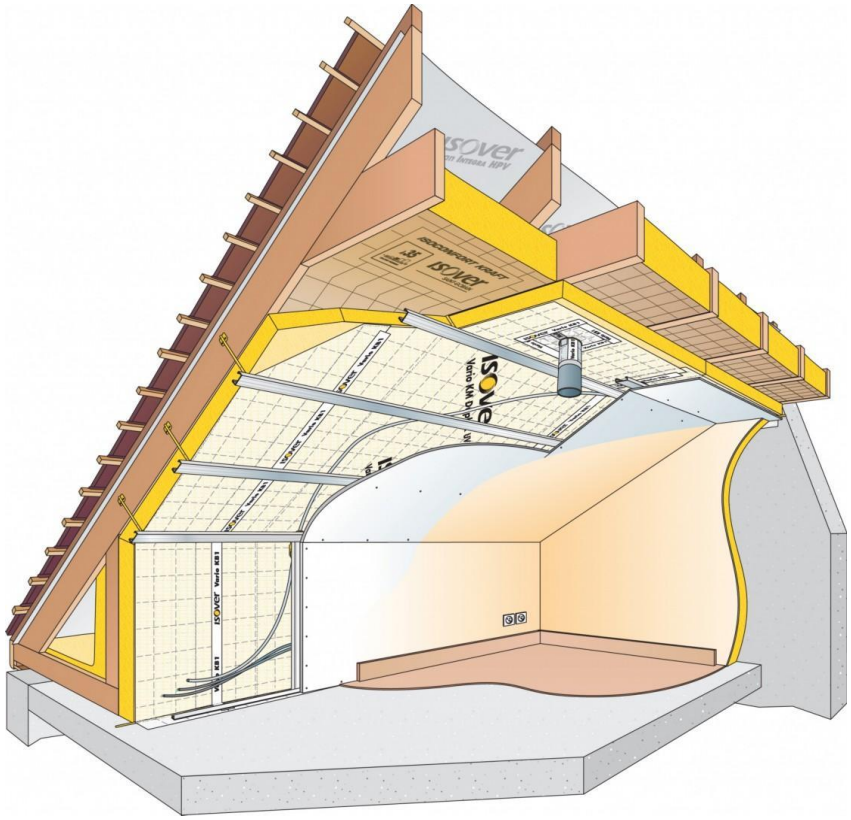


Figure 17: Double layer insulation. Isover Saint-Gobain 2016

Blowing insulation principle: This method consist in blowing insulate material (figure 19 & 18) (like mineral wool or cellulose insulation) on the floorboard of the loft [34]. This is in order to create a mattress of insulation which keep the heat from the house; a height of 30 to 35cm is recommended in order to safeguard a good insulation. Moreover with an eye to prevent against condensation and moisture problems, the technique put also in place a vapor barrier in contact with the floorboard. The blowing of the insulation materials is doing by a compressor and a mechanic blowing machine.

Figure 19: Blowing insulation 1. Isover Saint-Gobain 2016

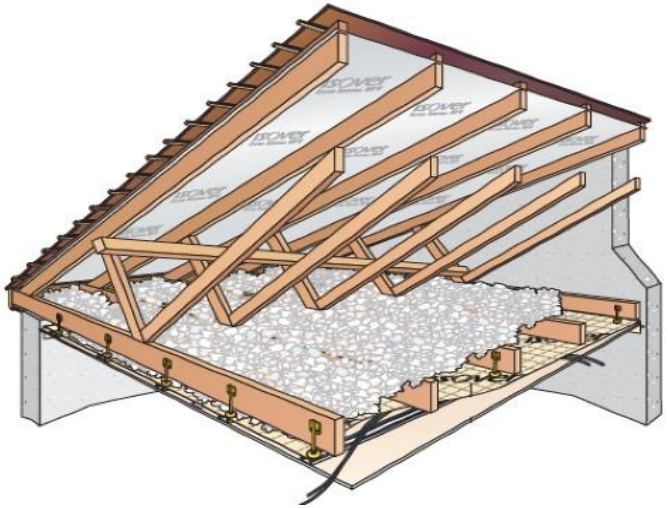


Figure 18: Blowing insulation 1. Isover Saint-Gobain 2016

Advantages: Insulation by blowing is the easiest way for inhabitable attics. In fact it is adaptable at all the configuration of buildings roofs, even in case of an inaccessible attics, the blowing may be carry out by interior or by exterior of the building. More than the easiest solution it is also the fastest, the most efficient and also the most economic (20 - 25 €/m^2). An average of 3h is necessary in order to insulate 100m^2 with more than 30cm of height. By the homogeneity of the structure it delete thermal bridges and guaranty a good insulation

quality. Moreover the feeble weight of the material is ideal for a renovation, it do not overload the structure [35].

Disadvantages: First of all this method needs mechanic blowing machines, which are often expensive. And secondly, the insulation by blowing is not adaptable for a habitable attic or a shed; it is only for inhabitable attic.

Blanket insulation principle: This method (figure 20 & 21) just consists in rolling out an insulation roll on the floorboard of the attic (for a better insulation add a second layer above the first one). Or if there is no flat floorboard like a succession of beam, the user will cut and roll out the insulating material between each beam and also add a second layer for better performance. Moreover with an eye to prevent against condensation and moisture problems, the technique put also in place a vapor barrier in contact with the floorboard.

Advantages: This system is quick and easy to put in place. The users are not limited by the height for the realization of the insulation, a thickness of 30 to 40 cm is advised for the best performance.

Figure 20: Blanket insulation between beams. Isover Saint-Gobain 2016

Figure 21: Blanket insulation. Isover Saint-Gobain 2016

Disadvantages: In this case a good accessibility to the attic is needed, contrary to the blowing insulation that can be made from the floor under or above the attic thank to a sheath [36].

3.4.1.2.2 External insulation

The external insulation consists in putting insulation material on the exterior part of the roof [37].

Advantages: During a renovation, it is not necessary to clear out the habitable rooms of the attic, and it is also not necessary to leave the building during the renovation. Moreover there is no dust or waste inside the building and the user do not need to make the interior decoration again, there is a possibility to bring out the framework which can add character to the house. The ceiling height is maintained and the habitable square meters are keeping, updating the building aspects. Finally, it has to be said, that an external insulation is more efficient than an interior insulation.

Disadvantages: This type of renovation needs an expert (roofer) who will make a diagnosis of the existing framework, and a load calculation.

Moreover it have more disadvantages, especially regarding the general aspect of the building. In fact it modify all the exterior decoration like the opening of the roofs and also for the water disposal system which need to be changed. The insulation of the opening part like roof windows limits, the rays of the sun and the aeration [38].

And finally, the square meters cost is up to each project but it will be always more expensive to insulate from the exterior than the interior.

Cost: Regarding to the cost of an external insulation with the workforce, the customer will have to count between 90 and 180 euros/m2. But the cost of the insulation varies a lot depending on the materials.

Sarking technique principle: Sarking (figure 22) is an exterior insulation technique. The idea is to make an insulation thank to a “Second Roof”. In reality the Sarking raise the roofing by placing the insulation material under the new layer roof. More precisely it consists in the realization of a floorboard on the rafters in order to receive an insulating material.

Steps of Sarking insulation: First of all it is important to remove all the old elements of the roof.

- **1&2** In order to avoid thermal bridges it is necessary to install wood insulating panels and also a second insulating material.
- **3.** After that comes the installation of the rafters that permit a ventilation of the roof.
- **4.** Now it's the turn of the roofing battens (long piece of wood that maintain the last layer of the roof).
- **5**. To finish it all that is remains to fix the roof sheathing.

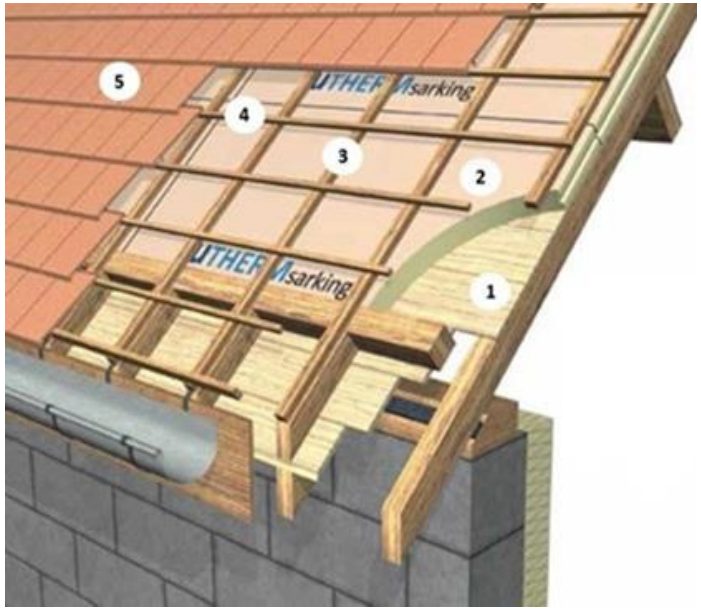


Figure 22: Sarking components. Utherm Sarking on Unilin 2013

In the Sarking method there are different types to renovate:

- Simple layer or double layer (figure 23)

Figure 23; Simple layer installation (Left) or Double layer insulation (Right). Utherm sarking on Unilin 2013

- With or without screen (figure 24)

Figure 24: Lay without screen (Left) lay with screen roof underlayment and vapor barrier (Right). Utherm sarking on Unilin 2013

- With the existing insulation (figure 25)

Figure 25: Insulation with existing pre-insulation. Utherm sarking on Unilin 2013.

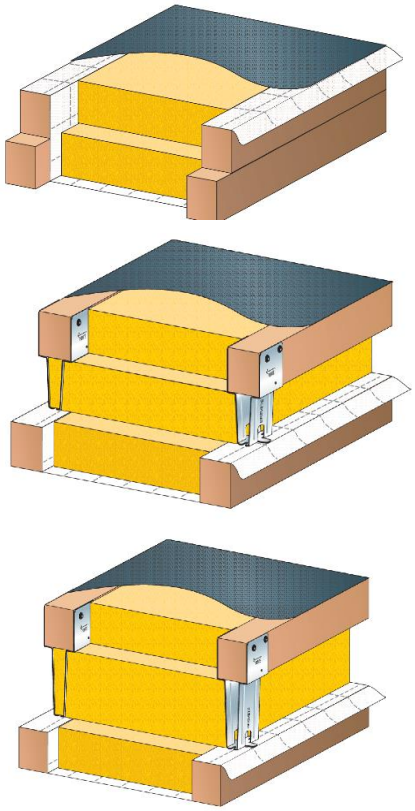
Advantages: This method of Sarking have an aesthetics advantage for the exterior (tile, slate, wood shingles, metal leaf...). Moreover the framework can be visible from the inside and the exposed beams are conserved. Furthermore contrary to an interior insulation system this solution guarantee to save habitable space in the attic. This method of insulation has a main advantage of a continuous insulation that reduces considerably the risks of thermal bridges. And finally this technique permits to reach efficient insulation goals.

Disadvantages: Despite its efficiency the technique is meticulous and quite long and so it is expensive. If a professional install the insulation by Sarking the cost will be approximately 180€/m^2 against 40 to 60€/m^2 [39], if the customer do it by himself. Nevertheless this method requires a real savoir-faire of the roofer because it is fairly complex. According to the implementation, the Sarking technique adds a lot of weight on the framework during a renovation. This means making a diagnosis of the existing framework, a load calculation and a bearing calculation are imperative.

Intégra Réno system principle: The Intégra Réno system use a combination of products:

- Airtight membrane
- An under roof vapor barrier
- Insulating roll material
- Intégra Réno pillar in order to increase considerably the thermal performance.

It is possible to put until 3 layers (figure 27) of insulation in order to reach really efficient thermal resistance.



R = 4.5 m^2.K/W

R = 6.75 m^2.K/W

R = 8 m^2.K/W

Figure 26: Minimal configuration/ Average performance configuration/ high performance configuration with Intégra Réno pillars. Isover 2016

It is also possible to reach other performances with the same configuration, in fact for example with an insulation material which has a lambda of 0.032 (W/Km) and with the high performance configuration the system reach a thermal resistance of 8.4 m2.K/W [40].

In the end the system is present like in the figure 26.

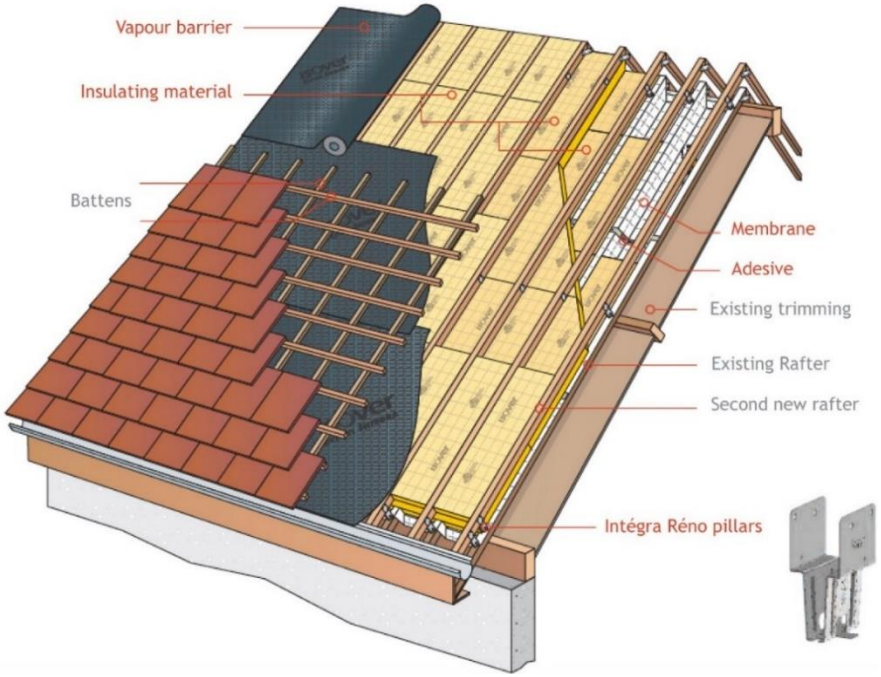


Figure 27: Complete system. Isover 2016

Advantages:

- Strengthening of the quality of the thermal an acoustic insulation of the attic.
- Can fit the existing frame.
- Able to straighten the existing framework.
- Upkeep of the living space of the attic and their facing finish.
- No risk of condensation.
- Promotes drying of the lumber thanks to the membrane.
- Thermal bridges are drastically reduced.

Disadvantages:

- This technique adds a lot of weight to the framework during a renovation. This means that a diagnosis of the existing framework like a load calculation and a bearing calculation are imperative.
- It is a complex technique

Structural insulation panel and Sandwich panel principle: The structural insulation panel (figure 28 & 29) is a freestanding panel which is insulated with polyurethane foam, extended polystyrene or by rock wool. It contains a finish on the underside in order to decorate the ceiling of the habitable room of the attic. Many different finishes are accessible on the market.

Figure 28: Insulating panels. Dessine moi une maison.fr 2016

Advantages: It is a two-in-one solution for the roof, on the one hand it provides the insulation and on the other hand it provide the enclosed of the roof. It is quick and easy to implement in place, thanks to the length of the panels that cover the height of the

Figure 29: Cross-section view of a panel. Bricolage avec Robert

roof with only one length of a panel, and a reduced number of panel in order to cover the width of the roof. Furthermore because the panels are usually made of natural materials the panels are recyclable.

Disadvantages: Because of the weight of the panels, it is better to call an expert for roofing. In fact a lift system is necessary to install the panels over the framework. Moreover this type of renovation needs an expert (roofer) who will make a diagnosis of the existing framework, and a load calculation in order to know if the framework can support the weight. All the solutions that are on the market available nowadays do not permit to reach the best thermal goals. The technic can reach a thermal resistance of 7 m^2.K/W. This type of realization imposed to totally uncover the roof. And it is a risk for the house because if the weather is bad you cannot start the renovation (around 3 days of good weather is preferable). The last negative point is that the wood structure is very bad according to thermal bridges. In order to solve this problem of thermal bridges it exists one similar solution, but without wood frame and a lateral profile which permit to fit together both panels. This solution is called Sandwich panels (figure 30 & 31).

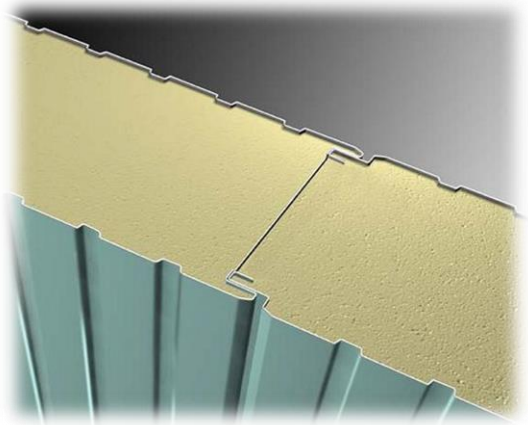


Figure 30: Conjunction between sandwich panels. Top metal isolation 2015.

Figure 31: Sandwich panels roof. Profils Acier Bordelais 2016

3.4.1.2.3 Comparison tables

All the costs and thermal resistance depends on the material that is used, its thickness and also on the insulation company.

In the following table 8 there can be seen all the different characteristics which presents external and internal insulation [41] [42]

ROOF	EXTERNAL INSULATION	INTERNAL INSULATION	
		HABITABLE ATTICS	UNINHABITABLE ATTICS
COSTS (€/M2)	70 - 180	40 - 90	20 - 40
IMPLEMENTATION	DIFFICULT	INTERMEDIATE	EASY
LIVING DURING THE RENOVATION	POSSIBLE	IMPOSSIBLE	POSSIBLE
LIVING SPACE	UNHANGED	REDUCED	X
THERMAL RESISTANCE (R=m^2K/W)	2 - 8.4	2 - 7	4 - 10
APPEARENCE	RENEWED	RENEWED	X

Table 8: Comparison of the different roof insulation

Comparison table 9 of internal insulation of uninhabitable attics techniques:

INTERNAL INSULATION OF UNINHABITABLE ATTICS	BLANKET INSULATION	BLOWING INSULATION
COST (€/M2)	20 - 40	20 - 40
IMPLEMENTATION	EASY	EASY (BUT NEED A BLOWING MACHINE)
THERMAL RESISTANCE (R = M2.K/W)	4 - 10	4 - 7
ATTIC ACCESSIBILITY	GOOD ACCESSIBILITY IS NEEDED	DON'T NEED AN ACCESIBILITY

Table 9: Comparison table. Insulation roof.

Comparison table 10 of external insulation techniques:

EXTERNAL INSULATION	SARKING	*INTÉGRA RÉNO*	INSULATING PANELS	INSULATING SANDWICH PANELS
COSTS (€ / M2)	120 - 180	110 - 160	70 - 90	90 - 100
IMPLEMENTATION	DIFFICULT	DIFFICULT	INTERMEDIATE (WITH A LIFT SYSTEM)	INTERMEDIATE (WITH A LIFT SYSTEM)
THERMAL RESISTANCE (R = M2.K/W)	4 - 8	4.5 - 8.4	2 - 6.5	2 - 8
THERMAL BRIDGES	NO	NO	YES	NO
APPEARENCE	EXTERNAL RENEWED	EXTERNAL RENEWED	EXTERNAL AND INTERNAL RENEWED	EXTERNAL AND INTERNAL RENEWED

Table 10: Comparison table. External roof insulation

3.4.1.3 Floor insulation

A house losses heat through every exterior faces. Losses by the ground can represent 10% of the total amount of the heating bill. By insulating the floor, customers reduce durably energy costs. A homeowner can insulate the floor on the top or on the bottom or between the structures of the flooring elements [43].

Insulation of the floor with the bottom principle: This technique put in place an insulating material in the ceiling of the lower floor (figure 32). If the house contains a crawlspace or a cellar the insulation will be on the bottom.

Crawlspace: Space situated between the floor of the house and the ground, which aims to ventilate the bottom of the dwelling because of the humidity from the ground, which ascend at the surface.

One of the solutions is to choose rigid insulation panels but users can also use higgledy-piggledy material between the ceiling and the false ceiling. Moreover they can choose supple material that fit closely the shape of the support, even if it is irregular. The insulation can be leave bared or coated with a finish (plasterboard or coat). The more classic technique consist in staple the insulating material on the ceiling. In order to avoid thermal bridges, insulation panels have to be jointed, installed continuously and moreover it is necessary to insulate wall corner and the support of the flooring.

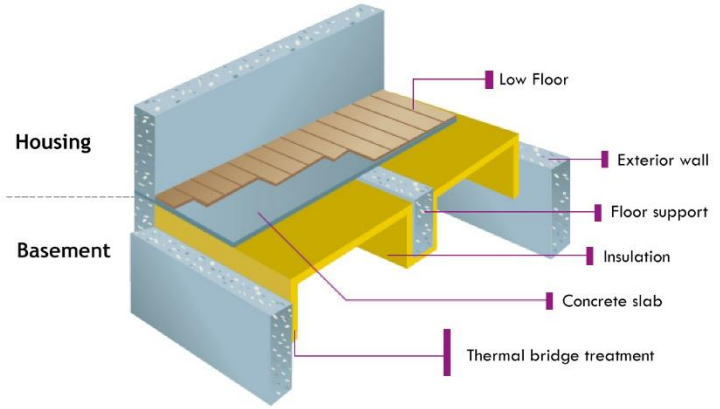


Figure 32: Insulation of the floor by the bottom. ADME 2016

Advantages:

- Easy to put in place
- Quick to put in place
- Cheap

Disadvantages:

- Humidity problems

Insulation of the floor by the top principle: This insulation by the top consists in put in place an insulating material on the floorboard, and bellow the floor covering. Even if the existing floor covering is naturally an insulation, this is not sufficient in order to reach good thermal goal. If the house doesn't have any crawlspace or cellar (the users can't access the bottom of the floor) the user will has to use the technique of insulating the floor by the top [44].

Some steps are necessary in order to insulate the floor by the top. First of all the technique need the measurement of the room to insulate. After that the user has to put in place the insulating material on the floor depending on the technique (panels or supple insulation figure 33 and 34). For example if it is a supple insulation material, the user has to hang over a little bit on the wall a cut the surplus with a box cutter. And if it's a panel insulating material they can fit together thanks to grooves [45].

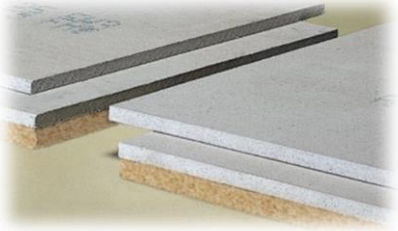


Figure 33: Insulating Panels. Fermacel 2016

Figure 34: Supple insulation. Maisonbrico .com 2016

Advantages:

- During a renovation the appearance of the floor covering is updated.
- It offers the opportunity to rectify levels difference in the floorboard

Disadvantages:

- Can be hard to remove the existing floor covering
- The insulating material can reach 10cm of thickness and can be a problem according to doorway levels and radiators.
- More expensive than the insulation by the bottom because of the extra steps.

3.4.1.3.1 Comparison table

All the costs and thermal resistance depends on the material that is used, its thickness and also on the insulation company.

In the following table 11 there can be seen all the different characteristics which presents external and internal insulation [46] [47].

FLOOR	TOP INSULATION	BOTTOM INSULATION	
		CRAWLSPACE	CELLAR
COSTS (€/M2)	40+	20+	20+
IMPLEMENTATION	INTERMEDIATE	EASY	EASY
LIVING SPACE	REDUCED	X	REDUCED
THERMAL RESISTANCE (R = M2.K/W)	1 - 3	1 - 4.5	1.7 - 6.25
APPEARENCE	RENEWED FLOOR COVERING	X	RENEWED CEILING

Table 11: Comparison table floor

3.4.1.4 Window insulation

General windows comprise about one quarter of the surface area of exterior walls. Windows often help to identify the architectural style, design and give scale to a building. Just as windows define the character of a building, also the visual impact and appearance of new, replacement windows that do not match or replicate features can be dramatic. Problems in the window structure arise from a lack of maintenance, water and condensation damage, and ultra violet light degradation [48].

Casement replacement conserving the frame: Replacement are needed not only to improve the appearance of the house, but also to take advantage of modern energy efficient windows that bring about an overall improvement of the ambiance of the house at low recurring cost of heating and cooling. If costumers want to replace just the casement, the frame need to be in a good condition. The replacement of the windows has to be realized by an expert, in fact it need a real know-how in order to avoid impermeable damage.

Casement replacement and new adaptive frame: In this case (figure 35), the new replaced window is installed within the existing frame. This installation technique is simpler than a full-frame installation, but decreases the size of the window opening due to the nesting of the frames.

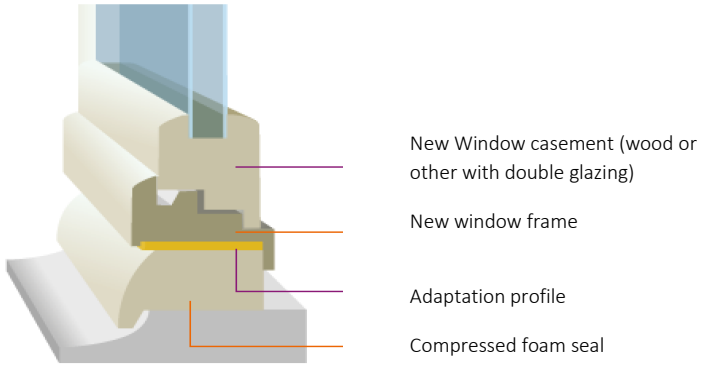


Figure 35: Casement replacement and new adaptive frame. ADME 2014

With this method the final frame is more massive and loose of translucency because the glazed surface is smaller. There also exist some risks to create thermal an acoustic bridges if the window frame is not perfectly adapted and if there is some interstice during the interlocking of the old and new window frame.

Complete window replacement: It is the most powerful technique, and moreover it keep the pre-existing translucency. Windows are designed for a variety of installation situations and techniques. In a full-frame installation, trim around the old window (interior and/or exterior) is removed and the old window frame is removed completely. The new window is secured to the studs surrounding the window opening, and the trim is replaced. This operation is more major and expensive than the last one. This technique have to be use when the window frame is in bad condition, it bring a better thermal and acoustic insulation.

Addition of a second window: In this technique users have to add a second window to the existing window (figure 36). In order to put in place this technique, there must be an adaptable architecture and room configuration. Also in order to have a good ventilation in the building, air inlet have to be created in both windows.

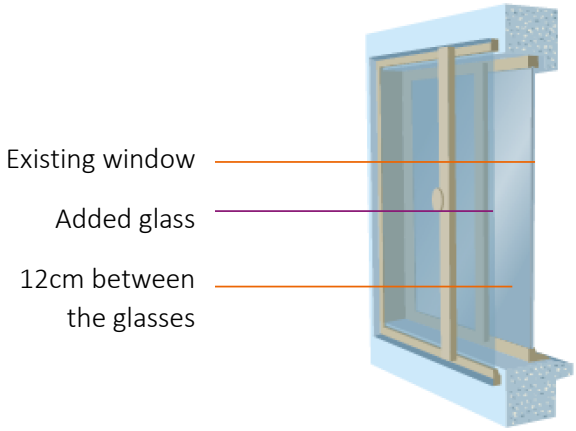


Figure 36: Addition of a second window. ADME 2014

Installation of new triple-glazed windows: Triple-glazed windows will achieve an excellent thermal insulation and high energy efficiency. Windows with triple shift aren't suitable for building, which walls are not sufficiently insulated, since even a well-insulated window in the case of incorrect ventilation conduct to moisture damage or even to mold formation. Therefore house owners, especially in older buildings, make sure that the installation with the facade is combined insulation and in good conditions.

About the construction of the Windows, it has to be know that since gas presents a better insulation than air, the spaces between the three discs are filled with gas argon or the more expensive krypton.

By the additional coating of the glass, once again isolated, it only allows a part of the solar energy to the inside so that unpleasant solar radiation is avoided, so that triple glazed windows provide a good indoor climate. In the following figure 37 it can be seen which the differences between single glazing, two panes insulation glass and triple-glazed are:

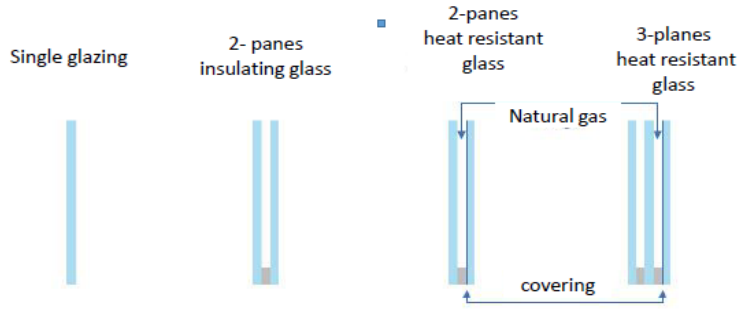


Figure 37: Comparison of different glazing systems. BMWI 2014

A triple-glazed window insulates six times more efficient than single glazing. The lower the U-Value break down, the better are the heat insulation properties of a window.

By good insulation values energy consumes decrease and therefore also the heating costs. In the following figure 38 there can be seen a general buildup of a triple-glazed window and the features it presents.

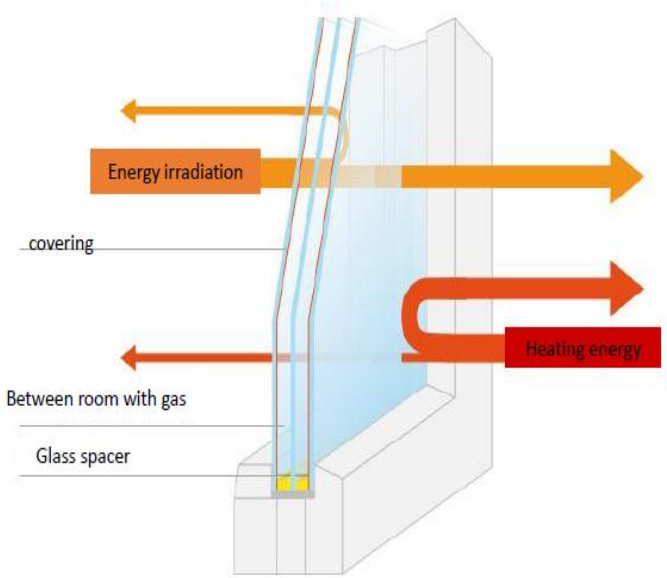


Figure 38: Triple-glazed buildup scheme. BMWI 2014

Other ways to improving the insulating properties: [49] There are many ways that windows can be insulated at night, or when a particular room is not being used in winter:

- Curtains: there are many ways that curtains can be made more effective. Users can use thicker material, or even a quilted material with an insulating filling. Adding a reflective covering to reflect heat back into the room, making sure that escaping down-draughts from between the window and the curtains are reduced by:
    - Using a pelmet which fits well around the top of the curtain.
    - Ensuring that the sides of the curtain connect as well as possible to the sides of the frame and to themselves in the middle.
    - Providing a shelf or sill for the seam of the curtains to lie on.
    - Ensuring that if a radiator does not go up behind the radiator does not go up behind the curtain (either tuck the curtain behind the radiator or fit a shelf).
- Blinds can be made to fit in slides at the side of windows, so they are easier to seal than curtains. The bottom of the blind can simply rest on the still and a simple flap can contain the top. Blinds, being more rigid than curtains, can more easily be treated with special coatings or incorporate a thin insulating film.
- Shutters: these can be designed to be both insulated and tight-fitting, and hinged so that they fold back and to the side when not in use. However these will almost certainly need to be specially made.
- Pop-in insulation panels, these are a cheap and effective solution. A ridged sheet of insulation, preferably one that is a sandwich of aluminum foil and card (in order to protect the foil), is cut to size and fitted to exactly the inside of the frame and the side facing the room covered with fabric. The main disadvantage is the extra work required to place them each time you wish to insulate the

window. One solution is to have them hinged at the top so they can swing up out of the way and be attached to the ceiling by hook.

- External security and insulation blinds. These are made first and foremost for security. However they have the advantage that they are placed on the outside of the house and so do not interfere with internal arrangements of rooms. They would be worth thinking about if costumers are having external insulation fitted, or a real security problem in the neighborhood, or the facade of the house has little aesthetic significance.

3.4.1.5 Air tightness

An air tight building cover is not even necessary to save energy and money, but it is also a fundamental for damage-free constructions and healthy living. Airtightness is a comparable figure for buildings, which describe the tightness of a building cover [50].

However, a tight building is not able to prohibit air movement across a building cover up to 100%, but the amount of the infiltrated air should be within a scope which is set for different types of buildings.

In general the problem is not that the buildings are too air tight. But rather there are leaks through the walls which are the reason for energy loses and structural damage. In the following figure 39 is in a simply way explained the difference between an air tight and non-air tight building.

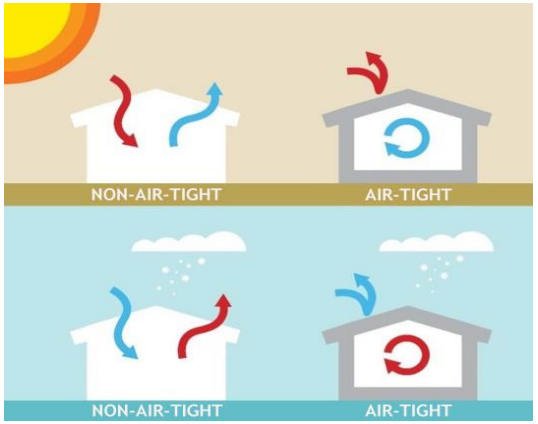


Figure 39: Comparison of air tight and non-air tight buildings

On order to determine the airtightness, a special air tightness measurement (Blower-Door-Measurement) is essential. With this tool it is possible to find leaks during the construction period, and the constructor can prevents of construction damages, raised energy losses and following costs which would be necessary for repairs. So the quality of the construction and the right material selection is deciding about the air tightness [51].

3.4.1.5.1 Blower-Door-Measurement

As mentioned before to determine the air tightness of a building a measurement is absolutely essential. The most common way to realize a successful measurement is the Blower-Door-Measurement (figure 40).

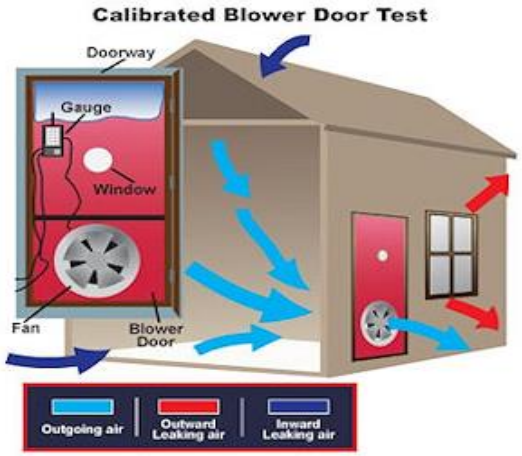


Figure 40: Blower Door Measurement.

During this special measurement, which is split into two parts, every opening part of the building (windows, doors, etc.) had to be closed otherwise it is not possible to realize the test. In the first part of the measurement the blower create a low pressure and then in the second part an over pressure in the building of 50Pa. After the pressure difference was done, the volume velocity (V_{50}) which cross the building cover, in each measured. The average value of these two measurements is the value of the air tightness measurement. To detect the leaks, a fog machine is necessary, or if this is not available it is also possible to find the leaks with a feather, but the second technique needs more experience, because the cover have must be checked with the feather precisely. The value of air tightness n_{50} is determined by the average volume velocity (V_{50}, explained before) divided by volume of the building (V).

$$n_{50} = \frac{V_{50}}{V}$$

The value n_{50} describes the air exchange per hour, by a pressure difference of 50Pa. For example n_{50}=3 means that air volume in the building is exchanged three times per hour. The specific values are written down in the EU-Standard 13829. The maximum n_{50} value for buildings with a ventilation system is 1.5[1/h] and without ventilation 3[1/h].

3.4.1.6 Acoustic protection

The main target of acoustic protection is to increase the quality of living and to make life as much comfortable as possible. Constant noise is not just annoying and disrupting, but it can also have a negative influence on human's health. Therefore the acoustic protection of a building is important and protect the inhabitants.

The sound propagation in construction is split into [52] [53]:

- Airborne noise (figure 42): This kind of noise is caused by people, animals, machinery, etc. and is carried forward with air.

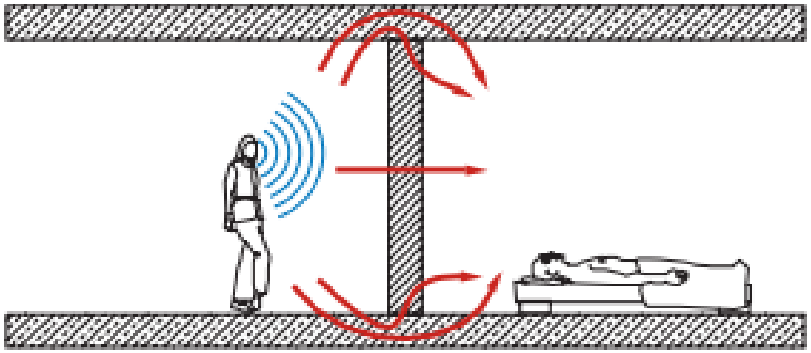


Figure 41: Airborne noise. "klimaaktiv Programm nawaro markt"

- Structure-borne noise (figure 41): People's and machinery's movement are the causer of this noise and are transported across walls or/and floors.

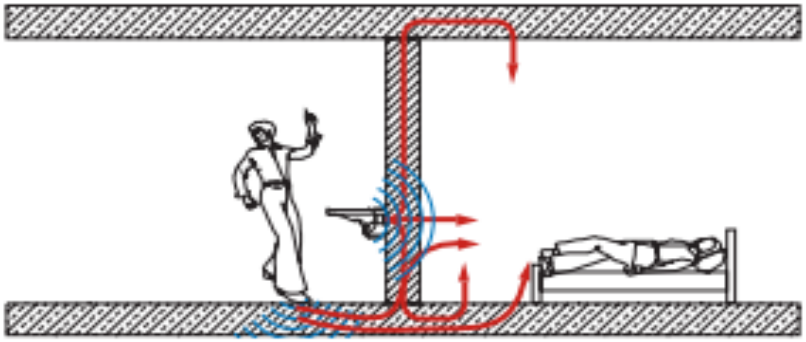


Figure 42: Structure-borne noise. "klimaaktiv Programm nawaro markt"

Arrangements for a good noise protection:

- Massive components: Components with mass ≥350kg/m² are particular suitable for airborne noise protection.
- Multi-walled components: This structure prohibit airborne noise transfer.

- Combination of lightweight and massive construction, for example a massive wall with facing formwork and fiber insulation.
- Floating floor construction, with footstep sound insulation downward and sideward.
- Interior walls, with insulation to ceiling and floor.
- Pipes in brick-walls and ceilings with insulation; big pipes should be laid behind facing formwork
- Use of acoustic absorbing materials (soft goods)

In detached houses the focus is set on noise protection of outer walls and therefore heat composite systems with hemp or mineral wool have advantages in comparison with EPS, because the primarily mentioned are able to absorb low frequencies. Moreover in apartments it is also important to protect the flats of the noise from the neighbors, so here it becomes more important to concentrate on structure borne noise and footstep sound protection [54].

3.4.2 Improve building installations

When the building cover is made of high quality after the renovation it makes sense to improve the technical equipment in a building. Now the cover of the building is good enough to reduce the energy losses and therefore also the heating system can be dimensioned in a small scale. If we are talking about small scale it is much easier to implement heating systems which are not addicted to fossil fuels, but heating system which use renewable energy sources for the energy generation. The same applies for the hot water processing, which has to be determined in the same way and adapted specially for the user's needs. These days the lighting technology makes a big effort and therefore it is easy to implement the new technology in building in a cost efficient way. The ventilation system in a building becomes more and more important, not just because of still constant air quality, but moreover the heat recovery. Nowadays the ventilation systems are able to recover about 80% of the heat which is transported through the air by exchanging with the new cold air from outside. So the ventilation system is recovering heat, which means energy saving and increasing the air quality.

3.4.2.1 Lighting

In the last year the light of energy saving bulbs was criticized because of light quality. However, this has changed in the present and now on the market there are a lot of different types available, there is for almost everybody a suitable light [55].

To precise there is witnessing a revolution in lighting energy efficiency: one that will make lighting a far smaller proportion of the energy requirements if the users use these advances intelligently. Lighting can account for anything from 30-70 % of the total residential electrical consumption, so it is encouraging to know that this is an area where savings can be made much more quickly and easily than in almost any other. There are a number of ways to reduce the energy demand for lighting:

- Using energy-efficient light fittings
- Use sunlight as much as possible
- Adjust the light for user's needs
- Use of automatically controlled light systems
- Clean shiners

The new most common types are compact fluorescent lights (CFLs) and light emitting diodes (LEDs), but in this section there will be also exposed other types. In the past the customers choose their lights according to power, but nowadays choosing the right light the customer has to know how much lumen (unit of luminous flux) are necessary. But there are two more important things, which should be not forgotten. The first, if there is a dimmer switch user should use it for the perfect light strength or just switch the light on/off. In the following figure 43 there can be seen in K-value which are the recommended types of lighting [24]. In the following steps there will be explained, in a more precise way which are the different lightening that are considered as energy efficient models and which can reduce a lot the energy consumption of the building.

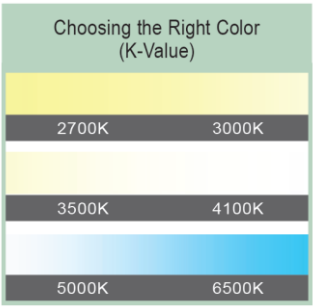


Figure 43: Color variation of the light.. Eco Renovation. Edward Harland 1993

3.4.2.1.1 Quartz halogen lights

These are the latest souped-up models of the tungsten filament lamp. They produce a brighter, whiter light and are more energy efficient because they operate their tungsten filaments at higher temperatures. What is more, the blackening of the filament that occurs in standard bulbs, reducing their output by 25%, has been largely overcome and the light they produce decreases by less than 10% over the lifetime of the fitting [49].

All this has been achieved by enclosing the filament in a quartz envelope which withstands the heat better than glass, and this envelope has been filled with a halogen gas. Where halogen lamps are used with dimmers, these need to be turned on full from time to time to allow this regenerative process to take place. It is important to never touch the quartz envelope with your bare fingers as the natural oils in your hand will react with the quartz glass and cause it to fail. Often this envelope is enclosed in a larger bulb to prevent just such an occurrence.

Tungsten-halogen lamps produce about 50-100% more light per watt than standard tungsten filament bulbs and last longer. Depending on the model this could be from 2.000 to 4.000 hours. Many models of quartz-halogen bulb operate at 12 volts which mean they require a transformer. These are now quite neat and small. The main drawback of these lamps is their energy saving quality makes up for this. They emit a very attractive sparkly light, specialty is that the light source can be focused and directed better than any other light source. This makes them particularly appropriate and efficient for task lighting.

3.4.2.1.2 Long-life bulbs

These bulbs have been around for a long time and are at the moment being advertised as the latest thing. However they are very similar to existing bulbs, except that they have a thicker filament and incorporate a special gas in the bulb which makes them last up to four times longer. The irony is that instead of using less energy they often use more to produce the same amount of light. They have their place perhaps in relatively inaccessible fittings but not in normal domestic circumstances. Because of this, they are not appropriate for detaches houses or multifamily houses [49].

3.4.2.1.3 LED

Led is also known as Light Emitting Diode and is an electronic component, which means that the current is converted directly into light. The current of the diode flows in the forward direction, formed with a dependent on the semiconductor material wavelength ultraviolet radiation or infrared radiation. In the conventional light bulbs, the current is also converted into heat, which leads to a high energy loss, about 95% of emitted light. LED lights use only a fraction of the power what means that the energy is used in a more efficient way.

There are serval advantages by using LED lightning. They present a high sturdy comparing to other lightning lamps, the light is also gentle and in the production the energy consumption is also very little. Other benefits are that they are free of odors, they turn-on without any delay and they present a higher number of switching cycles. It also has to be said that there are some disadvantages: the price is more expensive (at the beginning) than normal lamps, LED emit only in one direction and depending on the model a slightly larger heat generation [49].

3.4.2.1.4 Compact fluorescent lights (CFLs)

In the past fluorescent fittings were confined to long tubes. New technology has shrunk these tubes such that they are now like small protruding cylindrical fingers from a slightly enlarged bulb base. These compact fluorescent `bulbs` are now being developed to replace every tungsten filament application. These electronic waste have several advantages. Standard fluorescent lights flicker at 50 cycles per second, which has proved a problem for some people, producing headaches and nausea in certain situations. They are also a third more efficient than the electromagnetic waste and start almost instantly.

These new lamps present an opportunity to light up buildings with a quarter of the energy required before. Virtually all tungsten fittings should be replaced with compact fluorescent fitting as the opportunity arises. Although they cost more than traditional bulbs, users start making savings in their electricity bill straight away. These lamps fit into the same sockets as normal bulbs and give a warm colored light similar to tungsten fittings; they are generally four to five times as efficient and last five to ten times as long [49].

3.4.2.2 Heating

3.4.2.2.1 Logs gasification boiler

Function: The logs gasification boiler (figure 44) function is different to the other wooden heating systems. The furnace is split into two separate combustors. In the first one the wood get dry and heated, until the gases leave the wood and this gases are sucked of. This resulting gases are led into the second combustion, where they are burned under high temperature. Because of this high temperature the wood can be burned away to almost nothing. The wood carburetor achieve a high efficiency under low emission. This technique save energy, money and is environmental friendly [56].

Filling and burning time: This type of heating system is not working automatically, so it needs a caretaker who load the combustor to guarantee an optimal and efficient combustion of the wood. So if the house owner doesn't like to do this workings, he maybe has to think about another heating system for his building. One load of the combustor has approximately a volume of 90 to 300 liters and among full duty it burns for about 5 hours. The burning time can be extend, but it has a negative aspect on the efficiency and the exactly burning time depends on the wood fuel. To decrease the heating losses and to protect the environment it is important to operate among full duty. To provide the system more efficient and comfortable it is advisable to include a buffer tank, where the heat can be stored.

Figure 44: Logs gasification boiler. [VIESSMANN, Wood boilers, 9449 591 - 6 GB 04/2016]

Which wood fuel is needed?

There are logs gasification boiler on the market available which can burn wood pellets, wood shavings or wood chips, but typically they are used to burn wooden logs. The sort of wood influence the generated heat and produced amount of air pollution. To keep the air pollution as less as possible it is recommended to burn a kind of hard wood like beech wood or oak wood. It is also important to prepare

the wood with the optimal size, so that the easily pieces can be put into the combustor and the wood should be dry for an optimal combustion.

Advantages & disadvantages

One of the biggest advantage of the logs gasification boiler are the costs, the investment costs and the operating costs are in comparison to other systems low. It is also possible to produce the wood fuel on their own, if there is an access to a forest. With a buffer tank this system can be provide high efficient and if the combustion is works well the emission value is low and environmental friendly.

But on the other hand there are some disadvantages too, especially the comfortability is less then by other technologies. It is necessary to purify the combustion and to fill the combustion with wood to produce heat.

In Table 12 are the advantages and disadvantages listed.

ADVANTAGES	DISADVANTAGES
LOW INVESTMENT COSTS	SPACE FOR FUEL STORAGE
HIGH EFFICIENT	NO AUTOMATICALLY RELOAD
CHEAP FUEL	HIGH CLEANING EFFORT
LOW EMISSION VALUE	LESS SUITABLE FOR BIG BUILDINGS

Table 12: Comparison table with advantages and disadvantages

3.4.2.2.2 Pellet heating

This heating system is suitable especially for multi-family houses, because of the higher demand of space. The technology needs a room where the pellets can be stored and a transportation system to the combustor.

Function: Both a pellet heating system (figure 45) and a pellet stove (figure 46) have the same principle of function. The stove more or less used to heat a single room, so the heat which is produced is delivered by natural convection and heat radiation. And by the heating system

the produced heat is delivered to a heating cycle in which water is moving between the radiators and the heat exchanger in tubes [57].

Figure 45: Pellet heating system. ÖkoFEN 2015

Figure 46: Pellet stove. Pelleteer 2006-2015

At first the heat has to be generated and therefore the pellets have to be transported to the combustor, this can be realized in different ways. This transportation can be done automatically by screw-conveyor or pneumatic tubes, but also not automatically then the provider has to fill a storage container near to the combustor. A backfire assurance is necessary to protect the storage from fire. When the transportation is ensured the ignition start, the burning process and a thermostat regulate the heating demand.

To realize an efficiency and a low demand on fuel a buffer tank is necessary, where the heat can be stored if there is no actual demand. In the buffer tank the hot water can be stored for a period and when the hot water is needed it can be taken from the tank and so the heating system can be provide in an efficient way.

A pellet heating system is very comfortable technique, the transportation for fuel can be realized automatically and because of the combustion which is almost without of residues, the owner has not to take care regularly.

Wood pellets: Wood pellets are produced out of the waste from the wood industry, therefore the price of this fuel is stable and attractive for the user of pellet heating systems. But it is not just profitable for the end-user, the environment will be also spared.

Facts of pellets:

- They are produced out of wood, therefore they are a CO2 neutral fuel. The CO2 emissions which get into the atmosphere during the combustion were absorbed nearer the time, so compared to the fossil fuel like oil or gas which is more of hundreds years old, the impact on the climate is low.
- Wood pellets are in general a local product, so they are not addicted on the global price trend and the short transportation saves the environment too.
- For the pellets production wood waste is necessary in form of flavor and small pieces, which can be pressed into the small pellet shape

Advantages & disadvantages

Also a pellet heating system has not just advantages (see Table 13). In general a system like this is for large building where the heat demand is high, in that case the high investment cost will be paid back soon and because of the high space demand it is also not compatible in every building.

ADVANTAGES	DISADVANTAGES
LOW OPERATING COSTS	HIGH INVESTMENT COSTS
ENVIRONMENTAL FRIENDLY HEATING	HIGH SPACE DEMAND
STORAGE PLACE FOR PELLETS CAN BE BUILD BY OWN	ASH HOPPER HAS TO BE EMPTIED REGULARLY

Table 13: Advantages & disadvantages of pellet heating

3.4.2.2.3 Heat pump

If somebody hear heat pump for the first time, maybe he think about a pump in a heating system, but in this content we mean the heat pump which is used to generate heat for a building. This almost new technique is using outside air, ground or the water as energy source.

Function: As mentioned before the energy sources for this type of heating system are available next to our buildings, for example this system can use outside air, ground or water it is up to the location

where the heating system is installed. The heat can be supplied by traditional radiators, floor heating or by ventilation system [48].

In general the heat pump is a “reverse fridge” (figure 47), which drain heat from the environment and deliver it to the building which should be heated. To realize this process a small amount of electricity is necessary, but this are just approximately 25% of the total heat which will be supplied.

And if the electricity which is used is generated by renewable energy sources this system works CO2 neutral. In conjunction with a photovoltaic solar system it is possible to produce almost the whole energy which is for the heating required at home and in the end be independent of the big electricity companies.

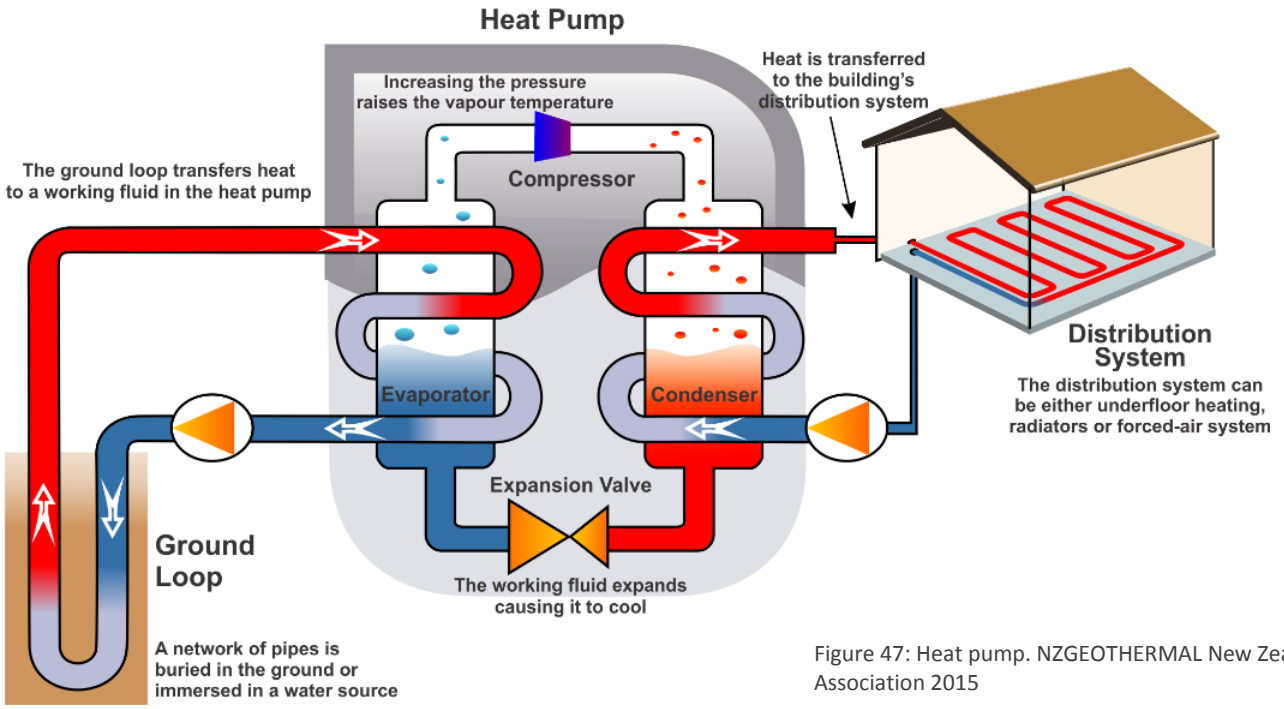


Figure 47: Heat pump. NZGEOTHERMAL New Zealand Geothermal Association 2015

Types of heat pumps

Air to water heat pump: This air to water heat pump type (figure 49) use the outside air to generate heat for the heating in a building. They are easy to install, because they do not need a hole in the ground or water as energy source, but on the other hand they are not that much efficient as the other types.

Figure 49: Air to water heat pump. Renova Retrofit 2015

Another benefit is that this kind do not need a permission under building low [59].

Ground heat pump: In this case there are to general system for the heat pump, both are using the ground as energy source. However, one is using holes (figure 48) which can be deeper than 100 meters to generate heat, they are able to withdraw a high amount of energy of the ground and they are very efficient. But to drill the holes for the probe is very expensive and the system is not possible to implement to every area.

Figure 48: Heat pump with bore hole. Renova Retrofit 2015

On the other hand it is also possible to install surface collectors (figure 50), which are in deep 0.5 meter up to 1.5 meter. It is necessary to audit this deep in the set location, because the surface collectors have to be under the frost limit.

Figure 50: Heat pump with surface collector. Renova Retrofit 2015

Water to water heat pump: A water to water heat pump (figure 51) use the heat energy of a water reservoir and deliver it to the heating system in the building. Typically for this system is that it is connected to the groundwater, because this has a constant average temperature during the year.

Figure 51: Water to water heat pump. Renova Retrofit 2015

A heat pump as a heating system for a building is not in every case the best solution (Table 14). It depends on the application area if it is a good solution to install this technique. The biggest cons are the high investment costs and the increased demand of electricity to run this technology. But in a well-chosen area this cons are deleted by the pros and combined with electricity which is generated by renewable energy sources the heat pump will be a futuristic technology.

ADVANTAGES	DISADVANTAGES
USE OF ENVIRONMENTAL HEAT	HIGH INVESTMENT COSTS
CO2 NEUTRAL OPERATION POSSIBLE	NOT USABLE AT EVERY LOCATION
NO RESERVES ON FUEL NECESSARY	INCREASED ELECTRICITY DEMAND
LOW MAINTANANCE	

Table 14: Advantages & disadvantages heat pump

3.4.2.2.4 Condensing boiler

Condensing boiler are one of the most energy efficient techniques which are nowadays available on the market. In comparison with common heating system, this types can save a lot of energy and the provider profits by low heating costs [59].

Function: This almost new technique use latent heat which is available during condensation of the exhaust gas, old boilers techniques do not use this heat and therefore condensing system are

so much more efficient. The heat which is gettable from the exhaust gas is used to preheat the water and the boiler has just to up heat the water to the heating temperature. So the burner does not need that much gas to reach the necessary temperature for the heating. The condensing boiler (figure 52) reach a high rate of use, more than 110% in comparison to the lower heating value.

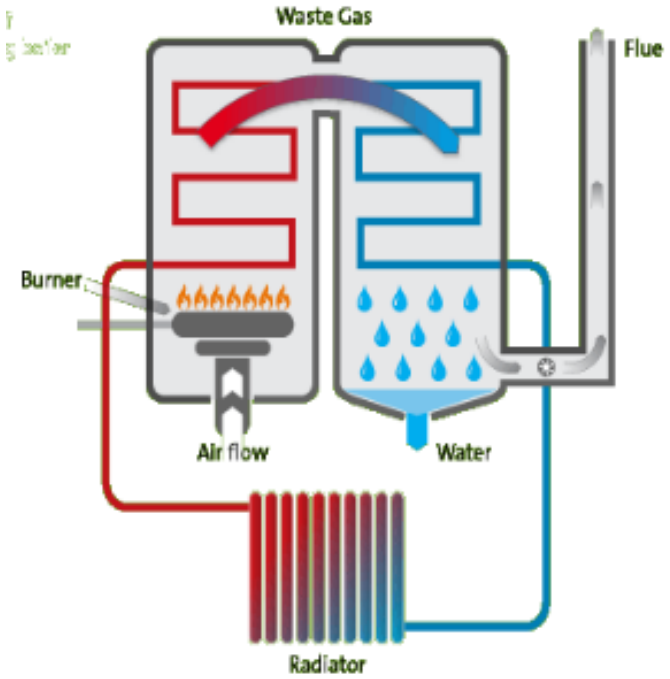


Figure 52: Condensing boiler. SNH Trade 2016

Advantages & disadvantages

The end-user benefits especially from the high efficient and so the low operating costs. However, it is not predictable what will happen in the future with the price or the disposability of fossil fuel. In the next table 14 are the pros and cons listed.

ADVANTAGES	DISADVANTAGES
HIGH ENERGY EFFICIENCY	FOSSIL FUEL
EASY IMPLEMENTATION IN ALMOST EVERY BUILDING	UNPREDICTABLE FUEL PRICES
LOW INVESTMENT	ACIDIC CONDENSATE
CHEAPER THAN OIL (PER KWH)	GAS CONNECTION NECESSARY OR STORAGE TANK (OIL)

Table 15: Pros and cons of gas condensing boiler

Oil & gas condensing boiler: These two types of high efficient heating systems use the same technique, just the burned fossil fuel is different. As the name already disclose one type need gas and the other one oil to create heat. Maybe just the access to the energy

source is different, the gas boiler need a connection to the gas grid and for the oil boiler a tank where the fuel can be stored is necessary.

In the following table there can be seen the comparison of the different heating systems [56] [57] [58] [59]:

3.4.2.2.5 Comparison table

CHARACTERISTICS	WOOD FUEL		HEATPUMP			CONDENSING BOILER	
	LOGS GASIFICATION BOILER	PELLETS	AIR TO WATER	GROUND TO WATER	WATER TO WATER	GAS	OIL
INVESTMENT COSTS (€)	CA. 8000-15000	CA. 17000-25000	CA. 12500	CA. 18000-23000	CA. 25000	CA. 6000-9000	CA. 7000-9000
FUEL PRICES (CENT/KWH)	5.8	5.2	5.0-7.0	5.0-7.0	5.0-7.0	7.0	7.8
IMPLEMENTATION	EASY	INTERMEDIATE	EASY	INTERMEDIATE	INTERMEDIATE	EASY	EASY
ENVIRONMENTAL IMPACT	LOW	LOW	LOW	LOW	LOW	MEDIUM	MEDIUM

Table 16: Comparison table heating systems.

3.4.2.3 Ventilation

An old building, which is not air tight before and the air/moisture can evaporate across the walls and gaps in the building, a ventilation is not necessary. However, if it comes to energy saving and renovation, the building must be air tight otherwise it is not possible to recover the energy which is already in the building or especially in this case in the air. Also the moisture must be carried out by the ventilation system, besides it will create mold or damage the construction and it is unhealthy for the inhabitants if in the building is a too high humidity [60].

3.4.2.3.1 Types of ventilation systems

In general there are two types of ventilation systems on the market available, one of them is the centralized and the second one is the decentralized system. Moreover this types can be split into three subtypes, the exhaust air system, the inlet and exhaust air system and this techniques with or without heat recovery.

Before the house owner decide to implement a ventilation system it should be audited, which type is the best solution for each case.

Decentralized systems: This systems are used in buildings which area already build up, because it is easy to implement them. It is not necessary to install ducts across the building, it just needs a hole preferably close to a window and the system can be installed and start operating.

Decentralized inlet and exhaust ventilation system: This types of ventilation systems will be installed especially in rooms, where it is necessary to provide fresh and suck of the old/used air. This rooms are for example kitchens, bathrooms or smoking rooms, in this cases can be a lot of moister and smell in the air so a decentralized system (figure 53) is a good solution. The installation is also relative smoothly and it is not required to install air ducts through the building.

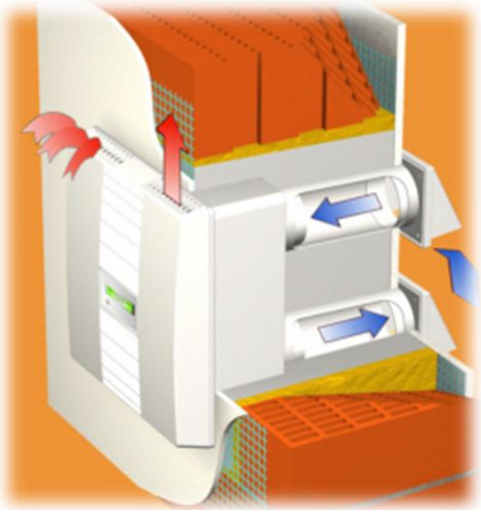


Figure 53: Decentralized inlet and exhaust ventilation. Thermobau ohg 2014

These types of systems are also available with heat recovery, which increase the energy saving immediately. The energy which is transported with the exhaust air will preheat the fresh air which is blown in, saving around 75% of the heat which is already in the heated room.

Decentralized exhaust air unit: This system is a good solution for rooms, in which are produced a lot of smells and humidity. The decentralized exhaust air unit (figure 54) is smoothly to implement to already consisting buildings and the investment for the installation is low. In this case, it is just necessary a duct through on the wall, which connects the inside of the room with the exterior, as well as in each unit there is a ventilator which creates a low pressure so that the "old" air will be sucked to outside. If the ventilation system is not running, the flaps in the duct will be shut and this should reduce the energy losses. The fresh air, which is required for the building, is provided by simple flaps which are situated in the walls or passive where another room is ventilated and under the door which connect this rooms is a gap.

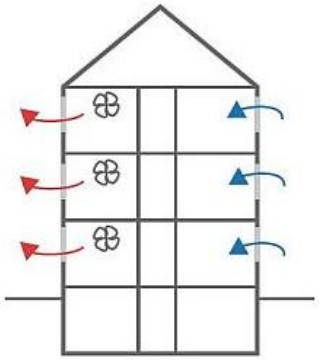


Figure 54: Decentralized inlet and exhaust ventilation. Wiesbaden Umweltamt 2012

Advantages & disadvantages (table 17)

ADVANTAGES	DISADVANTAGES
LOWER INVESTMENT COSTS AS CENTRAL VENTILATION SYSTEMS	HIGH INVESTMENT COSTS, IF NECESSARY FOR EACH ROOM
EASY TO REFIT IN EXISTING BUILDINGS	HIGHER NOISE POLLUTION BY MULTIPLE FACILITIES
LESS STRUCTURAL MEASURES	RISK OF AIR SHORT-CIRCUIT
HEAT RECOVERY POSSIBLE	AIR CONDITION PARTLY REALIZABLE
LOW OPERATING COSTS, BY LOW NUMBER OF FACILITIES	LOWER ENERGY SAVING AS CENTRAL SYSTEMS
INDIVIDUAL AIR CONTROL	

Table 17: Pros and cons of decentral ventilation systems

Centralized ventilation system: A central system is suitable for new buildings, particularly for new types of buildings like Passive Houses, Zero Energy Houses or Plus Energy Houses. With these types of systems, it is possible to save a lot of energy, because a heat exchanger can be included. This system are general in new buildings,

because the installation of ducts, which are necessary afterwards, is very expensive or even not possible, regarding to the construction where the space for the ducts is not available. Therefore the planning for this system is more complex in comparison to the decentralized systems [60].

Centralized exhaust ventilation systems: The exhaust systems (figure 55) are a cheap opportunity to transport the used and moist air out of the building. In comparison to other central system, the structural works are the lowest. Besides, in some special cases these types are realized in already built up buildings.

Exhaust ventilation system consider of a big ventilator, which is strong enough to suck air from all rooms which are connected to the system. In each room there are flaps where the force can be regulated and noise

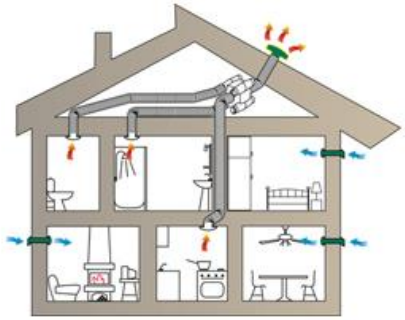


Figure 55: Centralized exhaust ventilation system. ENERGY SAVER 2016

protection utensils, which should guarantee a high comfort.

All the exhaust air flaps are connected to the main duct and with the ventilator system. All flaps can be regulated by sensors or manually. The sensor technology is much more energy efficient, but also more expensive. As opposed to the decentralized system, where the heat recovery system is implemented in the duct directly and can support a heat pump to heat the building.

Centralized exhaust and supply ventilation system: A centralized exhaust and supply ventilation system (figure 56) is used to realize hygienic minimum of air exchange number for separate rooms. This system consists of an exhaust unit and a supply unit, each of the systems have a ventilator which is responsible for the air transportation. With some special equipment it is possible to add an air filtration, regulation of temperature and a control for air humidity.

The exhaust unit is responsible for sucking

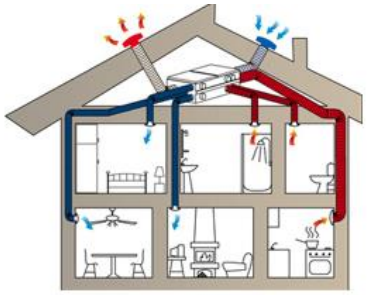


Figure 56: Centralized exhaust and supply ventilation system. ENERGY SAVER 2016

the old/used air and transport it outside. The supply unit will deliver new/fresh air to the rooms and therefore this system is not easy to implement in already built up buildings, because the effort for installation is huge and requires a lot of space, which could be a problem in old buildings. Furthermore it is important that the building is airtight, otherwise it does not make really sense to install this system, when in the construction there are gaps where the air can circulate and the evaporation through the walls is significant high [60].

Centralized exhaust and supply ventilation system with heat recovery:

This system, which also consist of an exhaust and supply unit, is able to save a big amount of energy because the air, which is sucked, will be preheated by the air which is blown in. Nowadays with efficient heat exchangers, it is possible to recover up to 95% of the heat which is in the air and sucked. Without a heat exchanger the heat would be wasted and just delivered to outside. However, it is necessary to implement this system for passive houses, zero energy buildings and plus energy buildings, because otherwise it would not be possible to reach the low energy consumption. For this types of buildings it is also essential to be air tight. This system is recommendable to be operated with sensor which automatically regulate the ventilators.

Advantages & disadvantages (table 18)

ADVANTAGES	DISADVANTAGES
HIGH POTENTIAL TO SAVE ENERGY	HIGH INVESTMENT COSTS
LOW NOISE ANNOYENCE	DIFFICULT IMPLEMENTATION IN ALREADY EXISTING BUILDINGS
NO RISK OF AIR SHORT CIRCUIT	HIGH STRUCTURAL COMPLEXITY
AIR CONDITIONNING POSSIBLE	HIGH MAINTENANCE REQUIRE, ESPECIALLY FOR HYGIENIC OPERATION
ADJUSTABLE FOR SEPARATE ROOMS	

Table 18: Pros and cons of centralized exhaust and supply ventilation system with heat

3.4.3 Improve indoor environment

The indoor environment is becoming more and more important, because the inhabitants of buildings do not like to live under worse conditions after a renovation. And this part is challenging the whole building sector. The new techniques and new materials, which are able to save a lot of energy are not tested well so far. This can be due to the short availability on the market. So, for a successful renovation it is important to use materials and technical equipment which is recommended from building specialists. However, not just the air quality is important to feel comfortable in a building, also acoustic protection should be on a high level, especially in apartments or building which are close to streets with a lot of traffic or other annoying events [61].

The sustainability and energy saving aspects becomes more important and are been the most of the time implemented into new constructions, therefore the indoor environment quality should not be ignored.

New building becomes air tighter and are also able to save energy, but in the optimized buildings new topics come up which are responsible for a high comfort.

Possible weaknesses of optimized buildings:

- Less fresh air
- Overheated in summer
- Odor pollution
- Mold/ moister damage

These weaknesses are easy to manage, if the construction is built in a right way.

3.4.3.1 Guidelines to increase the indoor environment quality

Air quality: Through the targeted and regular entry of fresh outdoor air, the indoor air quality is significantly improved. An hourly outside air intake of 30 m^3 per person leads, depending on apartment size and occupancy, an air exchange rate from 0.4 to 0.8 h^{-1}, as already said before. These data are far from being achieved by manual ventilation,

so mechanical/comfort ventilation is needed. To improve the air quality it is recommended the installation of filters which leak out air pollution like the high efficiency articulate air filter (HEPA) [61].

Prevent toxic substances: Materials which are available on the market can contain toxic substances, therefore it is important to be sure from which substances these used materials are. The constructor should be especially careful by using new products which are not tested or known, they can consist of toxic substances and have a negative impact on the inhabitants. Substances which are already forbidden are Asbestos, artificial mineral fibers, chlorofluorocarbon (CFC), hydro chlorofluorocarbon (HCFC), polycyclical aromatic hydrocarbon (PAH), polychlorinated biphenyls (PCB) and wood preservative like pentachlorophenol (PCP) and Lindane (hexachlorocyclohexane).

Thermal comfort: Comfortable and cozy atmosphere is quite different from person to person, it can be influenced positively or negatively by a variety of factors (e.g. by clothing, acclimatization, color surroundings, air humidity or drafts, etc.). The difference between head and feet in a room should be not higher than 2K to feel cozy and the difference between ambient air and that of the surrounding surfaces of the room should not exceed 2K to 3K. These targets can be achieved with floor heating and well insulated building envelope.

The optimum temperature in a room depends largely on the activity therein. For persons sitting and clad in light clothing, the temperature should not be lower than 20°C and not exceed 23°C (figure 57). In rooms were is more bodily activity than sitting the temperature can be appropriately reduced. Building physics identifies a clearly defined range where human beings feel most comfortable in enclosed rooms – the “optimum comfort range” [62].

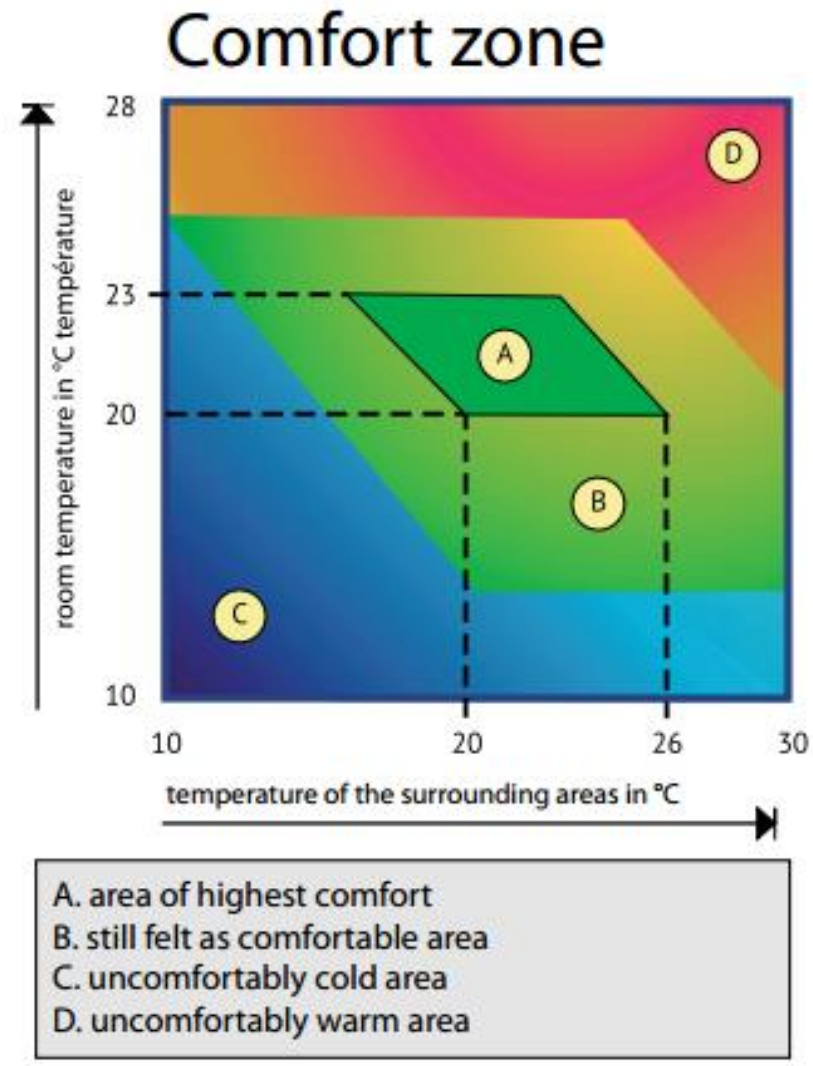


Figure 57: Comfort zone. *Pro-distsucturet, 2014.*

Ventilation: In new constructions it is already standard to implement a ventilation system, but not in renovated buildings. The ventilation system guaranteed fresh air during the whole day and protect the construction of mold, especially after a renovation when the building becomes more air tight it is important to ventilate the rooms. A ventilation system increase the quality of air, with filters it is possible to clean the air before inlet. So the amount of pollen, dust, spores can be reduces significantly and the CO2 concentration can be hold on a constant level which protect from tiredness. A person needs about 30m³/h air by normal activities and for example during sleeping 20-25m³/h, the air supply system is able to deliver exactly the necessary amount of air for each room and this helps also to save energy. And it is also important that the system is silent in rooms where heightened attention is required or where people are sleeping the sound pollution maximum is 25dB (A) [63].

Lighting: Through various light sanctities, light directions and light colors the daylight effect the people in a different way. From an evolutionary point of view the daylight definite our living rhythmus, so when it is dark people know they have to sleep and when the sun rise a new day begins. Outside the level of illumination is in general high, but the difficulty is to yield the daylight into the rooms.

Sufficient daylight is reached, if the proportion between the area which is light transparent (windows, door, walls, etc.) and the room ground area is minimum 1:10. For rooms where more light is necessary a proportion of 1:5 is recommended. If this goal is not reachable artificial light must be used, therefore it is necessary already in the planning stage to focus on daylight.

To measure the daylight there is a daylight factor which is expressed as a percentage, for standard rooms like bedroom, living room or corridors the daylight factor should be min.2%. For rooms where more light is essential the daylight factor should be min.3%. How to calculate the daylight factor is explained in the following Figure (Figure 58) [64].

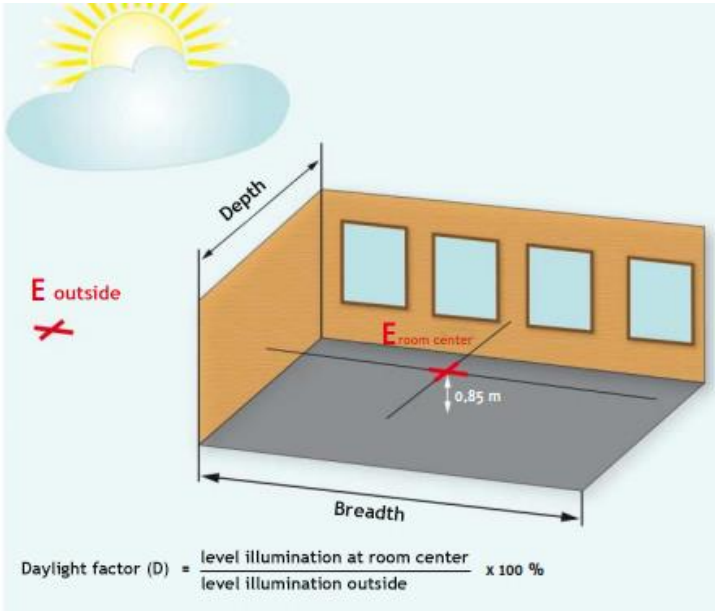


Figure 58: Daylight factor. *Pro-distsucturet, 2014.*

Acoustic protection: A powerful noise protection is also necessary for detached houses, and should be observed in the planning stage. Noise can cause health problems, decrease the living comfortability and in the end it is annoying. More about acoustic protection, how to downscale and details under the point [62] [63] acoustic protection in building covers.

3.5 Materials

3.5.1 Building material classes - assessment of fire behavior

The distinction of the burning behavior of materials is divided between non-combustible, normally combustible and fire resistant. The classification of building products (table 19) at a glance [65] [66]:

BUILDING MATERIAL CLASS	CRITERIA	EXAMPLES
A1 (non-combustible)	without combustible components	Gravel, sand, clay, brick, concrete, steel, cement mortar, glass, building ceramics, calcium silicate boards
	with minor combustible ingredients	Mineral fiber panels with low resin bond
A2 (non-combustible)	incorporating inflatable elements	Plasterboard, gypsum fiber boards, mineral fiber boards with synthetic resin bond
B1 (flame-retardant)		Cork, plastics, PS foam, rigid PVC, wood-wool plates
B2 (normal flammability)		Roofing felts, wood, PU foam
B3 (highly flammable)		Untreated wool, straw, paper, cardboard

Table 19: Building material classes

3.5.2 Insulating materials

In the following specifications there can be seen the different insulation materials which can be used in the already explained techniques for each part of the building.

3.5.2.1 Seagrass

SEAGRASS

Definition: Seagrass is a natural insulation, which insulates well, it is also difficult to burn and it does not attracts vermin. Seagrass grows extensively in the Baltic Sea and the Mediterranean Sea.

Advantages: Sorption material, which means that it can absorb moisture, even a temporary influence of moisture does not lead to the formation of mold. This fact is because of the high salt content which is up to 2%. This materials requires also no chemical additives.

Disadvantages: Seagrass may be comparatively quite durable, but it should not be used in outdoor applications and it is not suitable for compression.

Methods/Techniques: Combinable with almost every technique.

Application: Walls and floor

Thermal conductivity: 0.037 W/mK

Price range: 30-50€/m^2

3.5.2.2 Cellulose fiber

CELLULOSE FIBER

Definition: Fibers made with ether or esters of cellulose, which can be obtained from the bark, wood or leaves of plants, or from a plant-based material. Besides cellulose, these fibers are compound of hemicellulose and lignin, and different percentages of these components are responsible for different mechanical properties observed.

Advantages: Diffusible material, resistant against pests and mold, elastically and easily available in big quantities.

Disadvantages: During the installation the material abrades readily, not suitable for compression, not moisture resistant and it swells even slightly on.

Methods/Techniques: Cavity wall insulation and insulation between rafters.

Application: Walls, roof and floor

Thermal conductivity: 0.030 -0.045 W/mK

Price range: 20-30€/m

3.5.2.3 Sheep wool

SHEEP WOOL

Definition: Sheep Wool Insulation is environmental friendly, a green way to insulate and partially supporting fibers of polyester. Sheep Wool Insulation acts as a buffer between the cold damp weather outside and the warm dry environment inside.

Advantages: It is a sustainable and a renewable resource. As wool is breathable, it absorbs moisture to keep the house warm during winter, and releases moisture in summer by high temperatures, getting a perfect temperature balancing. This material is very elastic, it presents fine dust particles and a high water absorption capacity.

Disadvantages: This material is not suitable for compression and the flammability of it, is in a normal average (B2).

Methods/Techniques: blowing insulation

Application: Roof

Thermal conductivity: 0.035 -0.045 W/mK

Price range: 25-40€/m2

3.5.2.4 Mineral wool

MINERAL WOOL (GLASS WOOL/ROCK WOOL)

Definition: Mineral wool is an insulating material made from fibers arranged using a binder into a texture similar to wool. The process traps many small pockets of air between the glass/rock, and these small air pockets result in high thermal insulation properties.

Advantages: High UV resistant, quite flexible, non-flammable (A1) and resistant against pests as well as to mold and rot.

Disadvantages: Not suitable for compression, it presents high energy costs in the production. Skin irritation are possible during the installation and the firer dust is suspected to be carcinogenic.

Methods/Techniques: Combinable with almost every technique.

Application: Walls, ceiling and roof

Thermal conductivity: 0.030 -0.045 W/mK

Price range: 20-70€/m2

3.5.2.5 Cork

CORK

Definition: Cork is consist of suberin, ahydrophobic substance and, because of its impermeable, buoyant, elastic, and fire retardant properties, it is used in a variety of products.

Advantages: Renewable resource with a good thermal conductivity, good sound insulation and a high ability of compost. It is also breathable attractive, rotting and rot-resistant and it presents a high suitable for compression.

Disadvantages: The flammability of it is in a normal average (B2) and impregnated cork is not compostable.

Methods/Techniques: Combinable with almost every internal insulation technique.

Application: Walls and floor

Thermal conductivity: 0.045 -0.055 W/mK

Price range: 20-50€/m^2

3.5.2.6 Coconut coir

COCONUT COIR

Definition: It is a fibrous material, which is found between the hard internal shell and the outer coat of a coconut. When it is used as an insulation material it is often combined with boron salt or ammonium sulfate as a flame retardant.

Advantages: Permeable, durable, long lasting, pests resistant, break and tear proof as well as moisture proof.

Disadvantages: The flammability of it is in a normal average (B2), it is expensive and this material is not suitable for compression.

Methods/Techniques: Combinable with almost every external insulation technique.

Application: Walls

Thermal conductivity: 0.040 -0.050 W/mK

Price range: 60-90€/m^2

3.5.2.7 Straw

STRAW

Definition: This material is an agricultural by-product, the dry stalks of cereal plants, after the grain and chaff have been removed. For insulation use it is compressed into bales cornstalks combining it with boron salt as fire protection.

Advantages: Permeable, low priced, hardly energy consumption in the production.

Disadvantages: Low flexibility and the flammability of it is in a normal average (B2).

Methods/Techniques: Combinable with almost every technique.

Application: Walls, roof and floor

Thermal conductivity: 0.038 W/mK

Price range: 40-50€/m^2

3.5.2.8 Wood fiber

WOOD FIBER

Definition: Wood fibers are extracted from wood residues such as wood chips or rinds from sawmills. Wood fibers are treated by combining them with other additives. The insulation in wood can be used both indoors and outdoors of the home almost everywhere, except for the perimeter insulation.

Advantages: This material is diffusion open, it absolves swelling processes from the other materials and the humidity control is one of the best.

Disadvantages: The flammability of it is in a normal average (B2) and the installation is very expensive.

Methods/Techniques: Under cladding and other similar.

Application: Walls, roof and floor

Thermal conductivity: 0.040 – 0.0060 W/mK

Price range: 25-40€/m^2

3.5.2.9 Hemp & Flax

HEMP/FLAX

Definition: Commonly used term for high-growing industrial varieties of the cannabis plant and its products. Hemp is not to be confused with the close relative cannabis, which is also a cannabis plant, but is widely used as a recreational drug and medicine. Concrete-like blocks made with hemp and lime have been used as an insulating material for construction. Such blocks are not strong enough to be used for structural elements; they must be supported by a brick, wood, or steel frame

Advantages: Permeable, resistant to mold and pests, good soundproofing, flame retardant (B1), untreated hemp fibers are recyclable and environmental friendly.

Disadvantages: This material is not suitable for compression.

Methods/Techniques: Combinable with almost every technique.

Application: Walls, roof and floor.

Thermal conductivity: 0.030 – 0.0045 W/mK

Price range: 15-35€/m^2

3.5.2.10 Foam (EPS)

FOAM (EPS)

Definition: EPS is a flexible, versatile and economical insulation made of Styrofoam and is referred to as open-cell insulation material made of expanded polystyrene. EPS is most often seen as insulation panels, which are used for the insulation of facades within a heat recycling system (EIFS).

Advantages: Low cost, good thermal insulation properties, simple application/installation, low environmental impact and health burden, moisture resistant and flame retardant (B1).

Disadvantages: Not UV resistant, low flexibility and it can release toxins in case of fire.

Methods/Techniques: Glued doubling and wedge-dowelled

Application: Walls

Thermal conductivity: 0.030 – 0.0045 W/mK

Price range: 15-25€/m2

3.5.2.11 Insulation materials comparison

MATERIAL	SEAGRASS	CELLULOSE FIEBER	SHEEP WOOL	MINERAL WOOL	CORK	COCONUT COIR	STRAW	WOOD FIBER	HEMP FLAX	FOAM (EPS)
CHARACTERISTICS	NATURAL	SYNTHETIC	NATURAL	SYNTHETIC	NATURAL	NATURAL	NATURAL	NATURAL	NATURAL	SYNTHETIC
FLAMMABILITY RANGE	B2	B1	B2	A1	B2	B2	B2	B2	B1	B1
APPLICATION	WALLS FLOOR	WALLS ROOF FLOOR	ROOF	WALLS ROOF	WALLS FLOOR	WALLS	WALLS ROOF FLOOR	WALLS ROOF FLOOR	WALLS ROOF FLOOR	WALLS
TECHNIQUE	INTERNAL & EXTERNAL ISULATION	CAVITY	BLOWING INSULATION	INTERNAL & EXTERNAL ISULATION	INTERNAL ISULATION	INTERNAL ISULATION	INTERNAL & EXTERNAL ISULATION	UNDER CLADDING	INTERNAL & EXTERNAL ISULATION	GLUED DOUBLING WEDGE-DOWELLED
WORK (TIME RANGE)	DIFFICULT	EASY	DIFFICULT	INETRMEDIATE	EASY	DIFFICULT	EASY	EASY	EASY	INETRMEDIATE
THERMAL CONDUCTIVITY (W/MK)	0.037	0.030 0.045	0.035 0.045	0.030 0.045	0.045 0.055	0.040 0.050	0.038	0.040 0.0060	0.030 0.0045	0.030 0.0045
PRICE RANGE (AVARAGE)	30-50€/m^2	20-30 €/m^2	25-40 €/m^2	20-70 €/m^2	20-50 €/m^2	60-90 €/m^2	40-50 €/m^2	25-40 €/m^2	15-35 €/m^2	15-25 €/m^2

Table 20 Insulation materials comparison

3.6 Case studies

In this section it pretends to show some successful cases in refurbishment of buildings, which are focused on reducing energy consumption and improving the comfort of residents, for the inhabitants.

In the following section are four cases represented, which are distributed in different European countries. Two of them are situated in Finland, another one in France and the last one in Sweden; anyway at the end of this section, are several references where it is possible to find information about other cases in other countries with different techniques.

With the inclusion of this cases, the team want to inform about some techniques which has been used in building renovations, as well as showing costs, work periods, materials, and pictures which demonstrate how to carry out some tasks.

Besides, it is important to stand out that these cases try to prove that the energy consumption can be reduced enormously without spending a lot of money, relocating tenants, etc. providing an increase of quality of living for tenants and also reducing greenhouse gases, something very important nowadays in the politics of European Union countries.

It is important to stand out that all the figures which will appear in this section of the report, belong to the authors of each indexed case report, and are free to use.

3.6.1 Apartment block - Riihimäki, Finland

It is about a multi-stories building, which was built in 1975 and contains a total of 38 rental apartments with a total habitable area of 2 834 m^2. The different apartments have sizes ranging from 38 to 97.5 m2. As well as there is a childcare service on the ground floor.

It is located in the Peltosaari area in Riihimäki, Finland and belongs to a rental company. Its renovation was carried out at the beginning of 2010 and lasted approximately 11 months with a cost of 4.3 million €. This project had a financial support by state associations. The project searched for innovative methods and solutions for energy efficiency upgrades of the existing building stock.

Before renovation: The data, which are shown below, were calculated by the company in charge of the renovation based on a series of numerical simulations.

The existing facades of the building (figure 59) were prefabricated concrete sandwich elements, which are very common in the area. Besides they were isolated by a thermal isolation with a thermal conductance between 0.25-0.27 W/m^{2}K (The type of the material is unknown) with 12 cm of thickness. In addition it had an air tightness of 5-7 l/h. The base floors were also isolated by an isolation of 0.46 W/m^{2}K of thermal conductance while the roof had one with 0.22 W/m^{2}K.

Windows were double glazed with 2.9 W/m^{2}K while door had 1.8 W/m^{2}K. It is unknown models and materials. The air conditioning had a district heating system based on radiators with a natural ventilation system. The building did not possess any renewable system in order to produce energy.

Figure 59: Case 1. Before renovation.

According to the following table 21, the building had a total consumption of energy of approximately 594 MWh/year; it is equivalent to 157.5 kW/m^2. Only the heating system consumed 350 MWh/year, which is 92.8 kWh/m^2.

SYSTEM	BEFORE RENOVATION	
	MWH/year	MWH/(M2 year)
HEATING	350.00	92.80
HOT WATER	146.20	38.80
LIGHTING	25.14	6.70
DEVICES	63.95	16.90
OTHERS	8.68	2.30
TOTAL:	**593.97**	**157.50**

Table 21: Case 1. Before renovation.

After renovation: The renovation of the facade (figure 60) involves a change of insulation, which presents a new thermal conductance of 0.088 W/m^{2}K, and the air-tightness was improved, achieving to pass from 5-7 l/h to 0.8 l/h. Furthermore a new facade is installed using prefabricated wood elements in order to integrate the air conditioning with it, so that it removes the external layer of concrete sandwich elements.

Figure 60: Case 1. After renovation.

The following figure 61 shows all elements used on the project for the facade, the materials (from inside to outside) are:

Where:

- The old inner shell.
- Insulation layer of rock wool (PAROC UNM 37 pz) with a thickness of 100 mm.
- Layer Tyvek-kangas, XMW 060.
- Another insulation layer of rock wool (PAROC eXtra plus) of 300 mm.
- Construction panel of cement.
- Insulation layer of rock wool gypsum for facades (PAROC Linio 80) with 50-100 mm of thickness.

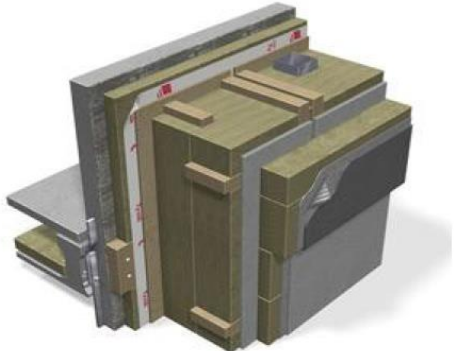


Figure 61: Representation of the materials facade.

The facade present a new U-value of 0.10 W/m^{2}K.

Base floors keep the same structure and materials. For the roof, it only changed the insulation, which has 0.08 W/m^{2}K now. As for the windows, they were changed for other ones, which present a new thermal conductance of 0.66 W/m^{2}K.

It was installed a heat recovery ventilation system with an efficiency of 75 % in order to improve the indoor air quality, as well as a mechanical ventilation system in each apartment (supply and extract) with news ducts. Besides it decided not to install any renewable system in order to provide energy to the different systems, such as the hot water production.

The following table 22 shows the energy consumption after the renovation.

SYSTEM	AFTER RENOVATION	
	MWH/year	MWH/(M2 year)
HEATING	74.30	19.70
HOT WATER	146.20	38.80
LIGHTING	25.14	6.70
DEVICES	63.95	16.90
OTHERS	29.91	7.90
TOTAL:	**339.50**	**90.00**

Table 22: Case 2. After renovation.

Renovation process:

Firstly, both the outer layer of the original facade (figure 62) and the existing insulation were removed. This step lasted around 10 days and allowed owners to stay during the process.

Figure 62: Case 1. Demolition of facade.

After, windows were exchanged (figure 63) and balconies were replaced.

Figure 63: Windows installation.

Once these steps are completed, the insulation layer of rock wool (PAROC UNM 37 pz) of 100 mm thickness is placed (figure 64).

Figure 64: New insulation installation.

Next, all different layers and elements were installed, such as: prefabricated wood elements (figure 65), ventilation ducts, windows, doors and balconies.

Figure 65: Prefabricated wood elements.

Project highlights

- High cost, especially because it was a pilot study. It is understood that the cost could be reduced if the technology became widespread.
- It pretended to achieve an energy reduction of 70%, however it only got 30% in the first year after renovation although it is possible to achieve a 50% in the following years.
- The owners were able to live in their homes during the renovation.
- The comfort in the building was improved highly and the owners save money in their bills.

Figure 66: Installation of the facade 2.

MORE INFORMATION ABOUT THIS CASE

http://www.vtt.fi/inf/pdf/technology/2014/T193.pdf
(Report Innova, in Finnish)
Company: VTT Technology 193
2014
Authors: Tekijä(t) Jyri Nieminen & Riikka Holopainen

http://www.paroc.com/campaigns/innova-project
(English Website)
Company: Paroc Group Oy. Paroc Group
2016
Author: Kimmo Lylykangas

3.6.2 Apartment block – Oulu, Finland

The Building is situated in Virkakatu 8, Oulu, Finland, this case was a pilot project and is owned by PSOAS Student Housing Foundation. The building was built in 1984 and possesses eight apartments, which are split in two floors. Its state before the renovation was not good and outdated, so it needed a complete refurbishment. There is approximately a floor area of 576 m^2 available.

The renovation was accomplished by NCC Construction Finland (NCCFI), which took over of design, retrofitting and so on. The employed building method has replication potential for the retrofit of facades made from concrete sandwich elements.

The renovation began on site in August 2012 and finished in February 2013, so it lasted around 7 months with a cost by 1.4 million of euros. The construction was financed by PSOAS although also counted on Europe Union support.

The following figures 68 and 69 display the building before and after renovation.

Figure 67: Case 2. Before renovation.

Figure 68: Case 2. After renovation.

Although the target has not a big impact, it is about a case with high replication potential due to its building technique and character, typical of standardized suburban construction in Finland.

Before renovation: As a result of a research done previously, PSOAS decided on realizing a building renovation, including a comprehensive refurbishment of indoor spaces and a facade renovation with the TES method based on using timber prefabricated elements for the renewal of the building envelope.

The structure of the building is based on standardized load bearings end and partition walls, with non-load-bearing sandwich elements on the long exterior walls and the upper floor constructed with long precast hollow core slab elements. The main concrete facade elements are faced with face brick. The building has concrete element balconies as free-standing towers, tied back to the facade concrete elements. In addition it had an air tightness of 3.3 l/h. The estimated existing external wall had a U-value of 0.28 W/m^{2}K according to Finnish building regulations with 140mm of mineral wool.

The original ground slab, which had a U-Value of 2.1 W/m^{2}K, consisted of 70 mm reinforced concrete slab insulated with 50 mm polystyrene, while the roof U-Value was 0.22 W/m^{2}K. The windows presented a U-Value of 2.1 W/m^{2}K.

The heating system was connected to the district heating system for the property, shared by all 5 houses and the heating level was estimated to be 148 kWh/m^2 and the target value was set to 30 kWh/m^2. The ventilation system was natural.

The total energy consumption was 115 MWh/year.

After renovation: The building underwent a complete retrofitting of the envelope. The outer facade layers of the existing prefabricated concrete sandwich elements were removed and only the inner concrete layer was left in place.

A new facade was retrofitted, by using prefabricated timber based elements. The old roof was replaced completely by a new timber truss roof and a new thermal insulation layer of 550 mm blown loose fill mineral wool resulting in a U-value of 0.08 W/m^{2}K. Moreover the existing ground floor slab was replaced, with a new in-situ ground

floor slab with 200 mm graphite-enhanced EPS insulation. Special effort was made to improve airtightness in the building envelope, and leaks in the concrete frame were grouted, passing from 3.3 l/h to 0.8 l/h.

The old windows were replaced for other new ones with a U-Value of 0.8 W/m^{2}K. Besides, the lighting was changed to LED in stairwells and apartments.

It was installed, a new district heat circuit and domestic water pipes from the service building as well as a new real-time automatic valve control of the flow of space heating from the district heat exchanger, which had been replaced in 2006 by PSOAS. It was also added, a new thermostatic radiator control of indoor temperature.

The energy performance of the building was improved by adopting apartment-specific, balanced ventilation systems equipped with high efficiency heat recovery.

After renovation, the new consumption passed from 115 MWh/year to 48 MWh/year where only the heating system consumes 23 MWh/year (40 kWh/m^{2}year). In the following figure 70 is the Finnish Energy Certificate for the building before and after the renovation represented.

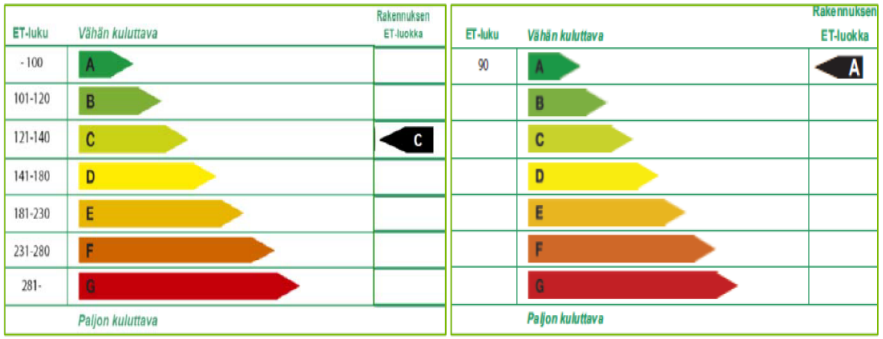


Figure 69: Energy certificate (Before/After renovation)

Costs summary: Next, is shown a table with the different costs of the project, counting a lot of types of costs, such as: design costs, surveys costs or contract general costs, etc.

Overall measures	Cost	%	Cost/m² leasable floor area
design	49 200 €	3 %	85 €
surveys	12 300 €	1 %	21 €
site costs	86 100 €	6 %	149 €
contract general costs	84 200 €	6 %	146 €
∑ overhead costs subtotal	232 000 €	16 %	403 €
TES energy façade*	233 300 €	16 %	405 €
roof replacement	84 400 €	6 %	147 €
ground slab replacement	72 600 €	5 %	126 €
building services	80 000 €	6 %	139 €
monitoring and automation	27 300 €	2 %	47 €
∑ energy renovation measures	497 500 €	35 %	864 €
Interior renovation and balconies	700 500 €	49 %	1 216 €
∑ TOTAL	1 430 000 €	100 %	2 483 €

Table 23: Budget of renovation

It is important to stand out that the table 23 has been gathered from the final report of the project, which explains the following:

"NCCFI cost breakdown for Oulu demonstration project. Facade size: total area approximately 480 m2. Facade cost includes passive house compliant windows, but excludes new roof and balconies. The cost is divided by 576 m2 leasable floor area. As a result of the small size of the demonstration, the overhead site and contract costs were large. This overall cost level was considered comparable with new build market prices for passive house energy performance. As a result, the asset value of the property has been significantly improved for a renewed life expectancy of 50 years. (S. le Roux, 2012)"

Renovation process: Building works began (figure 71) with the removal of the original in-situ ground floor slabs and the external layer of concrete and brickwork from the precast facade elements.

Figure 70: Removal of facade.

The old thermal insulation layer was stripped away. Additional foundation structures were added, widening the existing concrete footing to carry the load of the new facade elements.

The original facades consisted of prefabricated sandwich elements with 80-85 mm external brickwork, 130-140 mm of thermal wool insulation and an 80mm inner layer of concrete on the long facades and a 150 mm inner layer of concrete on the short end facades, which carried the upper floor slabs. Detailed measurements of the existing building were made for the manufacturing of the retrofit facade elements. New facades were manufactured 125 km away from the site, in a northern Finnish factory in Haapavesi, from prefabricated timber based elements. A thin thermal insulation layer was added to the elements on site as an adjustment layer between the elements and the uneven existing concrete surface.

External cladding and windows were assembled on site. The total thickness of new thermal insulation in the completed facade is 300 mm. Inward opening wood aluminum passive house casement windows were installed. The TES Facade (figure 72) comprised of a prefabricated timber element system installed over an existing inner precast concrete shell:

- 7mm corrugated fiber cement facade cladding, color black, and installed in-situ.
- 44 mm air gap (22 + 22x100mm - c600mm sawn timber battens).
- 9 mm gypsum wind barrier.
- 50 + 200mm glass mineral wool thermal insulation (declared Lambda value 0,033 W/m^{2}K).
- 42x48mm c600mm sawn timber horizontal battens.
- 42x198mm c600mm sawn pine vertical load bearing frame.
- 9 mm plywood board.
- 50 mm thermal insulation for adjustment layer, installed in-situ.
- 80mm inner layer of existing precast concrete sandwich element.

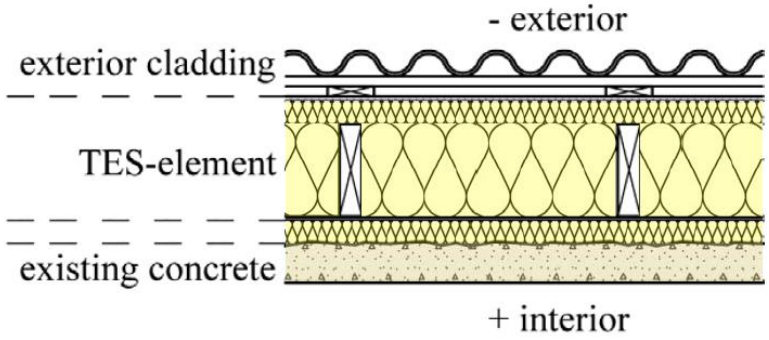


Figure 71: Set of elements of facade.

The following figure 73 shows the completed process of facade renovation. From left: Original precast sandwich element, stripped concrete shell, adjustment layer to receive TES facade, prefabricated elements assembled on concrete shell, cladding applied in situ (M3 Architects, 2012).

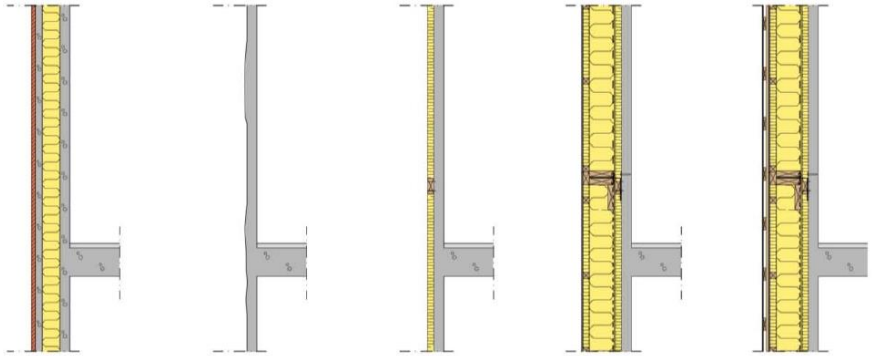


Figure 72: Renovation facade steps.

Project highlights:

- The Finnish BES5 system with standardized precast elements and joint details was widely used for housing projects across Finland, and therefore the findings and solutions used for this demonstration project offers good possibilities for replication in modernization of Finnish housing projects from 1970's onwards.
- Compared to new building, a refurbishment project has good potential to be a safe and dry construction process, so long as the facade is well protected (figure 74) during the building site works.

Figure 73: Protection cover.

- Tenants valued the design and outcomes positively, but they were preoccupied with the disturbances that they suffered during the renovations. Despite of this, there were some positive comments.
- Overall, a strong increase in perceived architectural qualities regarding public spaces within the building but also balcony design and bathroom.

MORE INFORMATION ABOUT THIS CASE

http://www.e2rebuild.eu/en/demos/oulu/Sidor/default.aspx
Company: E2ReBuild
2014
Author: Simon le Roux

http://www.e2rebuild.eu/en/demos/augsburg/Documents/E2ReBuild_D2.2_DemonstratorOulu_Final.pdf
Company: E2ReBuild
2014-06-24
Author: Simon le Roux

http://www.tesenergyfacade.com/
Company: TES EnergyFacade
2011
Author: Dipl.-Ing. Frank Lattke

3.6.3 Brogården Alingsås, Sweden

This case is about 8 blocks of flats which were built between 1971 and 1973. It belongs to AB Alingsåshem which is a municipal housing corporation in the municipality of Alingsås, Sweden. The town is situated in the western part of the country.

These buildings count on 144 apartments and 14860 m2 living area in total. They also have balconies and patios. Works began in August 2011 and finished in September 2014. The total cost is approximately € 36.5 million where there were some grant of € 0.68 million by European Union and € 0.4 million by local government, the rest was paid by a loan.

The aim of renovation was to reduce the very high use of energy, besides there were leaky pipes, lots thermal bridges, annoying air currents, poor soundproofing, and so on.

Before renovation

The envelopes of buildings (figure 74) were formed by gypsum boards on non-loadbearing wooden studs and facade bricks, as well as being insulated by a thermal insulation of 95 mm of thickness. The basement was of concrete walls without any insulation while the roof had an insulation of 300 mm on roof slab. The types of insulations are unknown.

Figure 74: Before renovation.

The buildings presented windows with single pane and supplementary aluminum sash and one additional pane, their U-Value were 3.0 W/m^2K.

The air conditioning was composed for a mechanical ventilation system by air intake through window vents, and a district heating system by radiators. This heating system was renewable to 98 % as well as serving to warm up water too.

The common areas had lighting by incandescent light fittings. The building did not count on any renewable system in order to produce energy.

According to the preliminary studies, the energy consumption was approximately 177 kWh/m^2, where the heating system was 115 kWh/m^2, the hot water 42 kWh/m^2 and the electricity of the building 20 kWh/m^2.

After renovation: It is important to stand out that Brogården is classified as an area of conservation value (figure 75). Therefore the selected material had to be similar to the original buildings.

The envelope had to be demolished in its entirety. The previous wall was replaced by a new wall with several layers of insulation and slotted steel studs; it has 440 mm of insulation in total. Regarding basement a layer of 100 mm expanded polystyrene was installed at 1 meter below ground level as well as 100 mm drainage panels downwards to ground floor. On the roof, it placed 400 mm of a new mineral wool insulation.

Windows were changed for a triple pane system with insulated glass which counts on a U-Value of 0.85 W/m^2K.

With regard to air conditioning, the ventilation system was balanced by a single heat recovery unit for entire building, which also combines with the heating system (district heating). The hot water system continues being the same although solar collectors were installed on the roof in order to support it, moreover water-saving faucets and shower heads have reduced energy used enormously.

As it is usual in these cases, lighting was changed to low energy fittings such as halogen and LED lighting in staircases.

The new energy consumption is 48 kWh/m^2 in total, where only 19 kWh/m^2 belongs to the heating system while the hot water system reduces its consumption to 18 kWh/m^2 due to the new solar collectors. Finally the electricity of the building is 11 kWh/m^2.

Figure 75: Case 3. After renovation.

Renovation process: Due to cold and wet weather during the winter season, it is important to protect (if it is possible) the work in the external part of the building like the facade; in consequence it should cover the facade with a cape after the old brick facade and original balconies are removed.

Figure 78: Picture group of the demolition facade.

After removing the façade (figure 76), it assembles the outer wall with its four layers of insulation (figure 78) (mineral wool), finishing then with the facade tiles installation (figure 77).

Figure 77: Insulation installation.

Figure 76: New tiles installation.

The same as with the facade, it installs the insulation on the roof (figure 80). First, the roof structure has to be reinforced. For that, it rebuilds the wooden roof and connects the eaves with the exterior wall and its insulation.

Figure 79: Roof renovation.

Also, it is important to add an additional 100 mm of insulation in top in order to ensure moisture safety (keeping the relative humidity of the wood well below critical values) and prevent temperature of the wooden layer from dropping too low (figure 81).

Figure 80: Insulation roof renovation.

The work on the roof is especially important as the ventilation ducts will be situated in the attic (figure 82); therefore it has to be insulated perfectly in order to prevent unwanted heat exchange between the air and the attic space.

Figure 81: Heating ducts location.

As it can appreciate in the following figure 84, the attic insulation (300 mm of mineral wool) will fill up towards the sides of the box and the wooden shelves in the middle of the picture are built temporarily in order to enable the insulator to reach to fill every space between the ducts.

Figure 83: Installation steps of the insulation attic.

The holes for windows are made in the prefabricated elements, which will be protected by a plastic foil or a wind barrier from the outside, prior to window assembly (figure 83). During the window assembling, a plastic foil sheet is mounted around the frame which the interior plastic foil of the air barrier later will be joint to.

Figure 82: New windows installation.

The next steps of the windows are: raising and insulating the inner wooden frame of the wall. Around the window, the angled opening is shaped by wooden elements and then to be filled with insulation (figure 85).

Figure 84: New window insulation.

Project highlights

- Big reduction of energy consumption, around 60 %.
- The tenants had to relocate during the project; however Alingsåshem offered them apartments in the same area while the renovation was being carried out.
- After renovation, some tenants (approximately 25 %) did not get back due to the large rent increase (an average of 40 %)
- After refurbishment, electricity and hot water is no longer included in the rent.
- The inclusion of high energetic efficiency equipment in lighting and water achieved a marked reduction in energy consumption in these systems.
- In general, residents were satisfied with the apartments after the upgrade.
- The knowledge developed at Brogården has spread to other projects, through e.g. over 700 study visits and collaborations in national and international energy efficiency programs.

MORE INFORMATION ABOUT THIS CASE

http://beem-up.eu/demostrators.php

Company:Beem-up

BeBo, 2012. Brogården – Miljonhusen blir passive

SINTEF, 2013. Presentasjon av casestudier i REBO

3.6.4 Contentin Falguière, Paris - France

The following case is about a multi-story building built in the 1950s. It is located in the center of Paris, France. The building is composed of 86 dwellings distributed in 7 floors. It was already renovated in 1993, nevertheless it was necessary to upgrade it again in order to achieve less energy consumption and reach the low energy standard for renovated buildings. The renovation began in January 2013 and lasted around 18 months (counting on studies, test, work and so on) and had a cost of € 4 million approximately.

Figure 85: Case 4. Before renovation.

Figure 86: Case 4. After renovation.

Before renovation: The external facade (figure 86) in regards to the street was of concrete with a sandwich thermal insulation of 2 cm thickness, while the back side wall was concrete, but with 2 layers of insulation, one of them was a sandwich thermal insulation of 2 cm and the other one was an ETICS EPS (External Thermal Insulation Composite System of Expanded Polystyrene) of 8 cm. Moreover the basement was made of concrete without insulation. Roof was also of concrete but in this case they counted on an insulation of 5cm.

The windows were 20 years old and made of PVC with double glass. The air conditioning had two collective heating systems (figure 88) with gas boiler, as well as being fed by vertical steel canalization. Temperature was not individual and there were differences among the floors, for example when there was 20°C in the upper apartments, in the lower ones there was 25°C resulting in additional heat losses due to compensatory behaviors from the tenants. There was a natural ventilation system in kitchens, bathrooms and toilets (apparently without problems).

Figure 87: Original heating system.

The production of hot water was realized by individual electric boilers (figure 89), which were installed in 1993. Besides, the building did not have any renewable/recovery energy source.

Figure 88: Electric boiler.

Regarding lighting, the building possessed regular incandescent light bulbs in the public zones (figure 90).

Figure 89: Incandescent bulbs in common areas.

It is estimated that the energy consumption average was 205 kWh/m^2 per year.

After renovation: Now the building counts 82 apartments. The envelope of the building was modified and after refurbishment it presents: an insulation of ETICS EPS of 20 cm and λ= 0.32 W/mK was installed, both on walls street side and on walls back side. Also it was installed on some sections of the facade a new and innovative ETICS with high performance (very low thermal conductivity, λ= 0.018 W/mK, resistance to water-vapor with permeability μ=5, toxicologically safe, fire protection, soundproof, so on). It is about panels with only 5 cm of thickness and 730x730 mm, ensuring the insulation. This material is called BASF MultiTherm Aero and is an ETICS, with coating above fibrous mineral panel and contains silica air gel.

With regard to the basement and the roof, the first one was renovated with a new insulation EPS of 10 cm and λ= 0.32 W/mK below ceiling, while the second one counts on a new insulation of PUR (polyurethane) and λ= 0.24 W/mK on ceiling.

Windows were changed for other new ones, which also are of PVC with double glazing and U-Value 1.5 W/m2KAs for the air conditioning: the heating system is formed for new condensing boilers which moreover also warm up water as well as installing a heat recuperation system from waste water in order to avoid wasting it. Besides the ventilation system is controlled mechanically now.

A bio fluids system was set in order to produce energy (10 kWh/m2 a year). All public spaces are fitting with low-energy light systems and tenants.

It is important to stand out that in each dwelling, videophones were installed which show the energy consumption on their displays (daily, weekly, monthly even annually) (figure 91). With this, the tenants know in every moment their consumption, as well as knowing whether they are saving energy or not with their habits.

Figure 90: Videophones.

According to the measures, the new energy consumption is approximately 50 kWh/m^2 a year per apartment. As a result of the renovation, the building achieved a reduction of 75 % of energy consumption.

Renovation process: Several tests and monitoring deployment in some apartment were carried out before renovation in order to get data to facilitate the evaluation of its impact on energy performances (figure 92) and user comfort. Also they were made after the renovation. Tests like infrared thermography (interior and exterior), blower-door test, windows, or even acoustic test between apartments.

It is important to stand out that 2 test depressurized tests were made in order to measure the airtightness as well as one pressurized test to locate air leakage pathways with artificial smoke.

The same as doors and airtightness, windows were examined with infrared thermography and artificial smoke in order to detect colder areas and air leakage pathways.

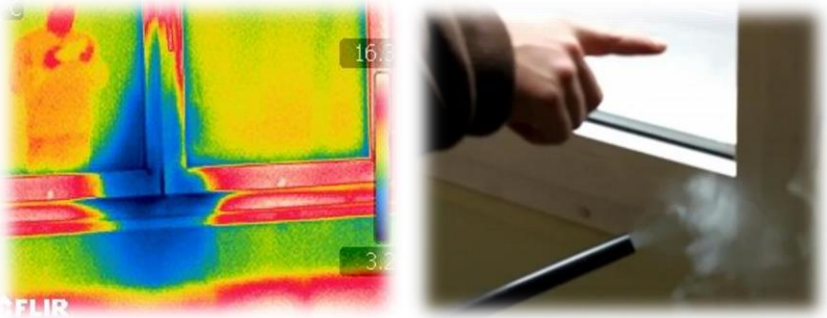


Figure 91: Window test.

Installation of windows and frames (figure 93): During the process, all windows were controlled by thermal camera, showing thermal bridges and poor airtightness, so that the subcontractor had to changed it.

Figure 92: Windows and frames installation.

As it has been commented previously, a new insulation was installed on the roof on it (figure 94).

Figure 93: New roof insolation installation.

As for the facade, the external layer was removed, as well as installing an UV protection sheet (figure 95) in order to avoid that it was damaged by the sun.

Figure 94: Demolition facade and its cover.

18 cm Neopor polystyrene (figure 96) panels (R=5.8 m^2K/W) are pasted on the walls with adhesives. To finish, the material is mechanically fixed with special lag screws, depending on the type of material (grey is polystyrene, and orange is mineral wool, which is set between dwellings in order to stop fire progression). The gaps between panels are filled with PU foam (Polyurethane) to avoid thermal bridges.

Figure 95: Different insulation panels.

Following with the facade, elements of the new and surprising material, BASF MultiTherm Aero, are installed in some sections of itself (figure 97). For this, the panels are pasted on the walls, and then fixed with lag screws. First, a 5 cm thick coating is applied on the panels before adding a glass fiber mesh. Final coating is composed of a 2cm thick hydraulic primer plus two coats of siloxane paint. The system is covered by a total surface of 150 m^2.

Only for this purpose, 2 experts from Germany had to go to Paris for a whole day in order to explain and demonstrate how to install this material to the workers.

When this material was installed in the building, it was not authorized for commercialization in France, so it had to be approved like an experimentation material by French construction authorities.

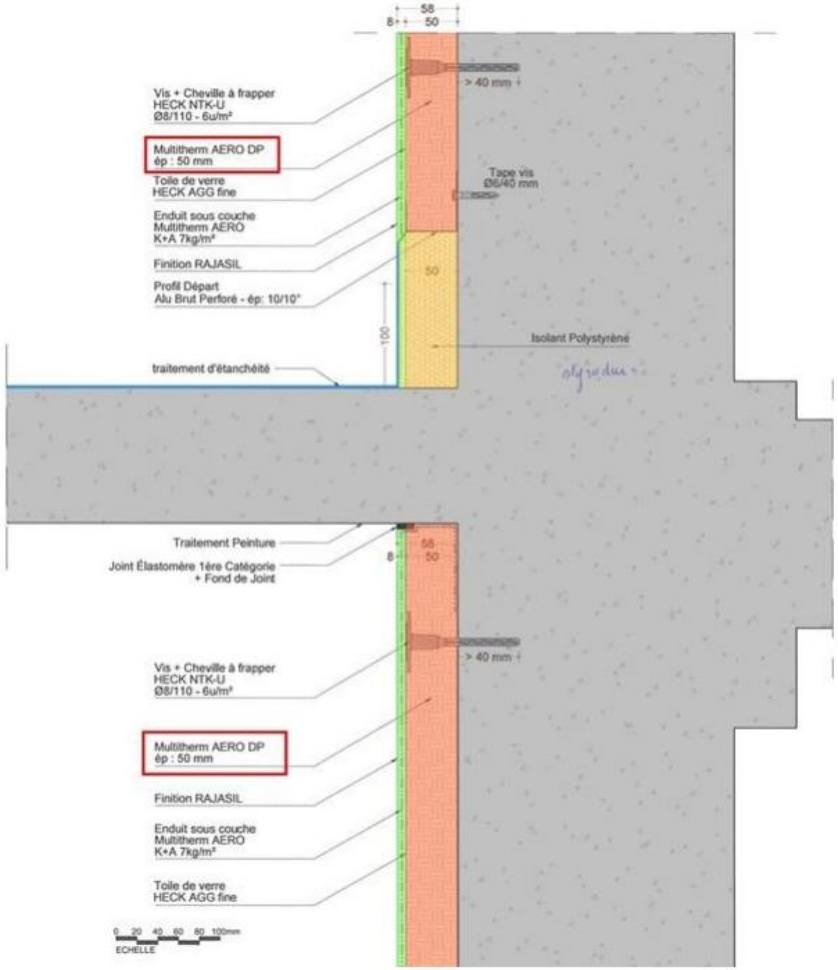


Figure 96: Composition of the facade.

Figure 97: BASF MultiTherm aero installation

It was also installed in the common areas an acoustic insulation on the ceiling in order to prevent noises from these areas to reach first floor dwelling as well as this insulation is useful for thermal loses because common areas will not be heated during the winter season (figure 99 & 98).

Figure 98: Acoustic insulation in common areas.

Project highlights

- There were tenants' complaints due to bad existing conditions in the building before renovation.
- The most tenants did not have to leave their homes during the refurbishment.
- Huge reduction of energy consumption, around 75%.
- The video phones guarantee that tenants know in every moment their consumption and whether their habits are good or not.
- It used a new material which could reach to be very important in order to achieve buildings with very low consumption energy.

MORE INFORMATION ABOUT THIS CASE

http://www.beem-up.eu/demostrators.php#tabs-2
Company: ICF Novedis
2013
Author: Contentin Falguière Paris, France

Conclusions

In general, the most of analyzed cases try to reduce energy consumption in buildings, which were usually built in the 70s or earlier with poor quality materials and without any consideration for energy saving. In addition to pretending to obtain a significant reduction in consumption also it tries to increase the quality of life of tenants, providing greater comfort at home, either by improving air quality, reducing noise or making life easier the tenants.

The observed renovation techniques are very varied from one company to another one, but there are a series of basic principles which are carried out in each described example, as well as in analyzed ones along the project. I could be said that the renovation of a building with the intention of being energetically efficient follows a series of guidelines and steps in order to obtain the desired reduction in consumption while improving the comfort.

According to the analyzed studies of energy consumption, the most of the energy consumption of a building focuses on air-conditioning and hot water production. Therefore, the renovations almost focus on these systems totally.

1. An efficient way to reduce the heating consumption is to prevent heat losses between inside and outside of the building as these cause that he heating system have to work longer and with more power in order to reach the desired temperature. These heat losses usually proceed from thermal bridges, poor airtightness in the rooms, etc.

- Thus as it can be seen in all the refurbishments practically, it is usual to work with the thermal insulation. Many of these buildings do not even have insulations on their walls, especially in buildings which are situated in warm climates such as Southern Europe while in cold climates it is usual to find insulations but these ones are usually insufficient or with poor quality. In all cases which have been analyzed it has observed that insulations play a very important role in the renovations. The ideal is that the original insulations should be changed for new ones with better properties (such as thermal conductivity) on walls, floors and ceilings.

- Another important point is the facade due to it plays a key role in the process as it is the outermost part of the building envelope. The usual practice in these cases is to demolish the outer layer of the old facade and place new prefabricated elements, which are easy to install and inexpensive to produce, providing a low thermal conductivity between inside and outside of the building. In the 4 discussed examples the new facades are usually wooden prefabricated elements which have already an included insulation; also it is possible to see that its installation is very simple. Finally it is covered with tiles in order to get a new and flashy esthetic.
- The inclusion of triple-glazed windows or windows for passive houses, which have fantastic properties to prevent heat transfers, reduces significantly energy losses. As shown in the cases, the renovation of windows is an important factor in order to achieve the objectives of the renovation due to they are sources of appearance of thermal bridges. In its installation it does a special emphasis on their frames and connection with insulations of the walls. It is often the use of plastic covers in order to avoid problems with cold climates.
- As for the airtightness it is important to comment that when a low value of itself is achieved after the renovation. It is advisable to install a mechanical ventilation system which renews the air, avoiding that it spoils. This could cause a sense of discomfort in the tenants.

2. Another way would be to change the air conditioning system for another one which is more modern and based on energy efficiency. Currently, on the market there are a large number of brands which provide these types of systems with high quality and high capacity to save energy.
   - Right now it is normal to install a heat exchanger, so that this can leverage the own energy of tenants, as well as the provided energy by the heating system before. So the system would not need the same energy to heat the air which enter from outside because it has already been warmed up previously.

- The upgrading of radiators is also an element to keep in mind because its technology has increased enormously in the last years. If it adds to this the renovation of heating ducts (hot water too) for other ones with insulation and better materials, the reduction of energy consumption is notable.

Other two important points, which have to be commented, are the cost and working period of the renovation. Along the study, it has been possible to observe that the budget for the different refurbishment varies hugely from a country to another one, for example it is difficult to compare budget between cases in Finland with cases in Bulgaria or Rumania, where the labor is pretty cheaper than in Finland or Sweden. Anyway, the cost goes intrinsically bound with the fixed objectives. Regarding to the work period, the cases vary between them. The experience is an important factor in this case, because experienced workers will finish the work before than a worker with little experience in this kind of techniques. Also there are differences between the cases because some of them work in a building too big or with several buildings on the same project.

MORE INFORMATION

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2016-04-22
Author: Jenny Gode

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4 Conclusion

In our research we found a lot of documents with useful information. Nowadays, on the internet is a lot of data available, for our specific topic as well. For this reason the difficulty is not to collect information but to sort and utilize the different results. In our particular case it was also necessary to cut down information to the Nordic countries.

The basement how to realize a sustainable renovation is done. The report includes information about building cover, building installation and how these new techniques affect the indoor environment quality. Apart from their effect on the living environment, also the criteria which are important to observe during a renovation are included. These collected information we would like to share with stakeholders easily and according to that we created a basis how a webpage should look like. It does not matter what the interested person is looking for, in the end the webpage structure should lead to the end product which the person was searching.

We also have to say, that the technique and the knowledge to reduce the energy demand is available in the European countries. However, now the population must be convinced to start to reduce their own energy demand and this is only possible if the technical equipment and the operation costs are affordable. Therefore, in our opinion the government has the big tasks to support their citizens in a financial way and to lead them to an energy saving behavior.

One of our first tasks in the project was to inform ourselves, what is going on in our home countries, the different roadmaps to reduce the energy consumption. In addition we have to say that in each country there are plans to stop the wastage but every roadmap is quite different. However, in every case it is not easy to follow those maps.

In the and we have to say that not just the average population in their detached houses or apartments have to change their behavior and improve their building to more energy savings but especially the big players like the Industry must contribute and prohibit the climate change.

5 List of figures

6 List of tables

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8 Appendix

8.1.1 Codes of conduct

Communication and information: The team have worked in the EPS room at *Technobothnia,* during the project redaction and all the recollected information were uploaded to Dropbox where all the files will be accessible for team member.

Weekly meetings: The meetings with the Project supervisor was obligatory for all team members. Before every meeting, an "Agenda" had to be done by the chairman, sent out to the supervisor and uploaded to the Dropbox group. The meetings used to open by the chairman and the secretary who had to take notes about what has been said in the meeting. After that, the secretary used to send out the minutes of meeting to the supervisor and also uploaded the document on group Dropbox. Other meetings that were planned had to be attended unless there was a good and acceptable reason for absence.

Working norm: Each member agreed to the quota of 30 work hours a week, except Thomas Kadlec who will just work 15 hours a week because he is a half part EPS student. All the team members keep track of their own working hours in an Excel document which was accessible for all on Dropbox group.

Team rules: If the team members have different opinions about some issue, everyone has the freedom of expression to expose his/her point of view. In case of disagreement, a discussion could be held in order to get all team members behind the same idea or opinion.

Responsibilities: In the group the team has chosen two main roles at the pertinent persons to them:

- Project manager: Antonia Zoë Strunk. Updates the information, keeps a look on the report, verifies the tasks list, contacts with companies and delegates the work.
- Secretary: Théo Echardour. Updates of the planning (Gantt chart), checking if the accomplished work is in accordance to the goals

set for the corresponding task and reporting to the project manager if there are any issues.

8.1.2 Team name & Imagotype

The team began with a Brainstorming where each member writes ten word which he/she relates to the project and to the chosen key words, which where : Renovation center, Innovation and Energy efficiency. From this point the group decides the name of the team which ends to be: EFFICIENT RENOVATORS.

Once we have decided the name, the next step was to design the team logo. In the figure it can be seen that the Beta version of our logo follows a golden ratio, almost perfectly. It also has to be said that the proportion between the isotype (Image) and the logotype (text) creates an accurately harmony and compact element. On one hand this proportion gives our logo an appropriate design and makes it more attractive for our customers. On the other hand it adds fluency and clear structured lines which completes the entire imagotype (combination of the image and the text)

Figure 99: Áuria proportion of the isotype

After deciding the combination of the imagotype we added colors to the complete Beta version. In the figure it can be seen the different Hex color formulations are.

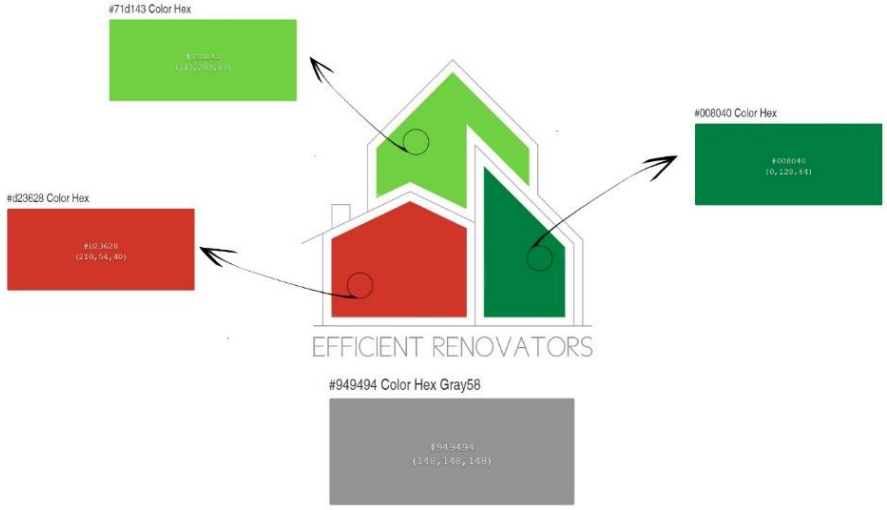
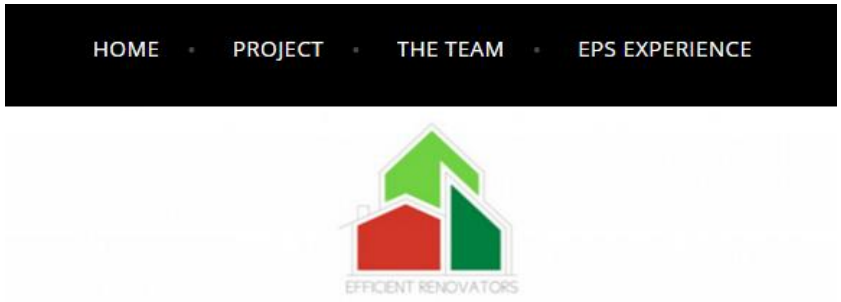


Figure 100: Color Hex formulation from the imagotype

8.1.3 Team website

The EPS project website is a key tool for the project, it has several functions such as: represent the project and show the progress of work on it, etc. The website has to present some characteristics like: user-friendly, clear, informative, useful and representative. The Beta version of the website has been made with WordPress programming and it uses the basic design of Argent, which had been redesigned by the team so that it adapts perfectly to the requirements of the project. The layout allows for a seamless user experience no matter the device or screen size. The Start page of the website shows the different categories that can be found on it and also the latest news or important occurrence, which can be seen at the following figure as well as the website address:



www.renovationcenter.wordpress.com

Figure 101: Start page of the website.

On the Home website there can be found the general information about what users can find on thereof. There are answers to the questions: What, why, who, where and when.

On the next slide, Project, it can find all information about the project like the summary and the objectives. Besides the midterm and final report will be uploaded with their presentations and solutions.

Following, the next slide corresponds to the presentation of the team members, the team. Here the users can find short introductions and information about every group member.

The last slide of the Beta version of the website contains the EPS experience. Here, it can find an introduction and an explication about what the European Project Semester is and the different activities which have been done in it.

8.2 Project specification

The project consist in gathering information, tools and politics from different countries of European Union in matters of energy efficient and sustainable resources in order to renovate buildings within the Botnia-Atlantica region, in Nordic Countries. Then the information will

be shared with stakeholders through different channels and platforms.

8.3 Work breakdown structure

The project has been divided into seven steps, which were controllable because of the different tasks and responsibilities are divided. Thereupon it can be found which the different steps are:

1. Planning
    - Developing project management plan
    - Presentation of the project and its plan
2. Research
    - Gathering information about Nordic Countries
    - Gathering information from European Countries
3. Analysis and classification of the information collected
4. Design of platform to share results (show how it will work)
5. Reporting results
    - Developing results report
    - Period corrections
    - Sharing report with stakeholders
6. Progress meeting
7. Final presentation

8.4 Gantt chart

The main objective of a Gantt chart is to show different activities, tasks or events displayed against time [5]. In project management it is one of the most popular and useful ways to organize the work. Once the Gantt char is elaborated there can be found on the left chart a list of the activities and along the top a suitable time scale. Each activity is represented by a bar and additional information, the position and length of the bar which reflects the start, duration and end date of the activity.

To elaborate correctly our Gantt chart, all team members started identifying the input's and tools & techniques that we had to take in

count. After that we started using MS project which can be seen down below:

- Input:

1. Project charter/brochure.
2. Environmental factors.
3. End user's needs.
4. Information from other countries in relation to energy efficient.
5. Project management plan.

- Tools & Techniques:

1. Expert judgment in order to get a good classification of all analyzed information (coordinators, students, stakeholders, professionals of sector)
2. Used renovation tools (successful examples, so on).
3. Comparison between different projects and methodological inventory methods (energy simulations and performance validation, energy efficiency measures, evaluation of the result...)

Table 24: Project management activities for the Gantt chart.

	Name	Beginning	End	Duration
1	Planning	Mon 15/02/16	Fri 19/02/16	33 hours
1.1	Developing project management plan	Mon 15/02/16	Wed 17/02/16	24 hours
1.2	presentation of the project and its plan	Fri 19/02/16	Fri 19/02/16	1 hours
2	Research	Mon 22/02/16	Mon 14/03/16	90 hours
2.1	Gathering information from Nordic Countries	Mon 22/02/16	Thu 25/02/16	30 hours
2.2	Gathering information from countries in European Union	Thu 25/02/16	Mon 14/03/16	60 hours
2.2.1	Information from Germany	Thu 25/02/16	Mon 14/03/16	60 hours
2.2.2	Information from France	Thu 25/02/16	Mon 14/03/16	60 hours
2.2.3	Information from Spain	Thu 25/02/16	Mon 14/03/16	60 hours
2.2.4	Information from Austria	Thu 25/02/16	Mon 14/03/16	60 hours
3	Analysis of the information collected	Mon 14/03/16	Thu 17/03/16	30 hours
4	Classifying of the information according Tools, Materials, policies...	Fri 18/03/16	Wed 23/03/16	30 hours
5	Comparison of methologies among different countries	Wed 23/03/16	Mon 28/03/16	24 hours
6	Desing of platform to share results	Mon 28/03/16	Fri 01/04/16	30 hours
7	Reporting results	Fri 01/04/16	Tue 26/04/16	90 hours
7.1	Developing results report	Fri 01/04/16	Wed 20/04/16	60 hours
7.2	Period corrections	Thu 21/04/16	Tue 26/04/16	30 hours
7.3	Sharing report with stakeholders	Tue 26/04/16	Tue 26/04/16	0 hours
8	Progress meeting	Mon 15/02/16	Wed 30/03/16	224 hours
8.1	Meeting presentation	Mon 15/02/16	Mon 15/02/16	0 hours
8.2	Meeting nº2	Tue 23/02/16	Tue 23/02/16	0 hours
8.3	Meeting nº3	Tue 08/03/16	Tue 08/03/16	0 hours
8.4	Meeting nº4	Tue 15/03/16	Tue 15/03/16	0 hours
8.5	Meeting nº5	Wed 23/03/16	Wed 23/03/16	0 hours
8.6	Midterms presentations	Wed 30/03/16	Wed 30/03/16	0 hours
9	Others	Tue 23/02/16	Thu 17/03/16	104 hours
9.1	Project Webinar	Tue 23/02/16	Tue 23/02/16	0 hours
9.2	Meeting with differents stakeholders (energy week)	Thu 17/03/16	Thu 17/03/16	0 hours
10	End of the project	Wed 11/05/16	Wed 18/05/16	40 hours
10.1	Preparing presentation	Wed 11/05/16	Mon 16/05/16	30 hours
10.2	Final Presentation	Wed 18/05/16	Wed 18/05/16	0 hours

- Gantt chart of the project:

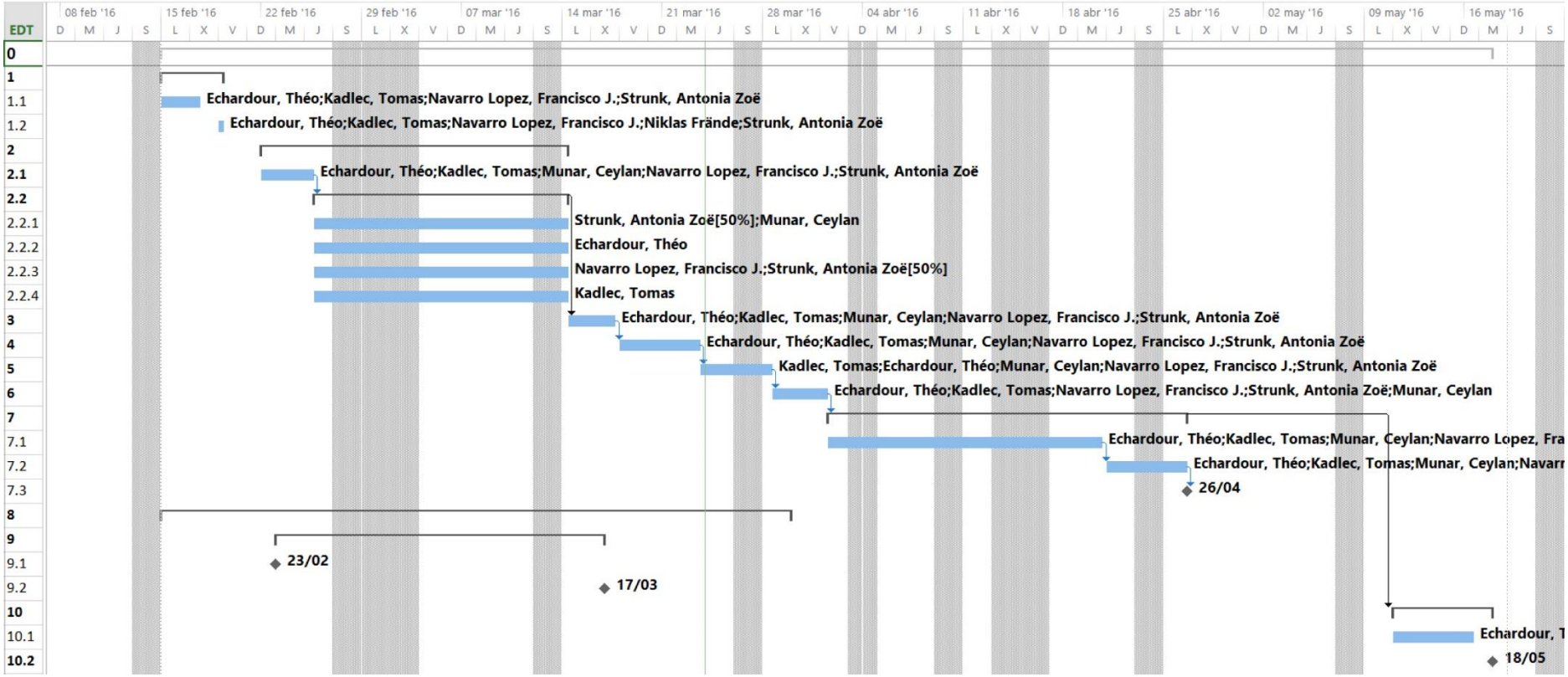


Figure 102: Gantt chart form the Efficient Renovators.

8.5 Responsibility

In the following table there can be seen which different type of responsibilities from each team member are.

1 → Theo Echardour 2→ Tomas Kadlec 3→ Francisco Navarro

4→ Antonia Strunk 5→ Ceylan Munar 6→ Niklas Frände

OBS / WBS	1	2	3	4	5	6
1. Planning						
Developing Project plan	R	R	R	R	S	
Project presentation	R	R	S	R	S	
2. Research						
Gathering information from Nordic countries	R	R	R	R	R	S
Gathering information from Europe						
Information from Spain			R			S
Information from Austria		R				S
Information from France	R					S
Information from Germany				S	R	S
3. Analysis	R	R			R	S
4. Classify			R	R		S
5. Comparison methodologies	R	R	R	R	S	S
6. Design of platforms	S	S	S	R	S	S
7. Reporting results						
Developing results report	R		R	R	R	S
Sharing final report with stakeholders	R	R	R	R	R	S
8. Progress meetings	R	R	R	R	R	S
9. Final Presentation	R	R	R	R	R	S
4. Comparison methodologies	R	R	R	R	S	S
5. Design of platforms	S	S	S	R	S	S
6. Reporting results						
Developing results report	R		R	R	R	S
Sharing final report with stakeholders	R	R	R	R	R	S
7. Progress meetings	R	R	R	R	R	S
8. Final Presentation	R	R	R	R	R	S

Table 25: Responsibility table of Efficient Renovators and their supervisor.

8.6 Basic elements method

The method form part of the project management course and it is used to give an overall view of the project. The main objective is listing all the tasks, who will be involved, the resources, the tools and also the environment that the project will deal with in different parts. Thereupon (figure104) the scheme which the team had developed is:

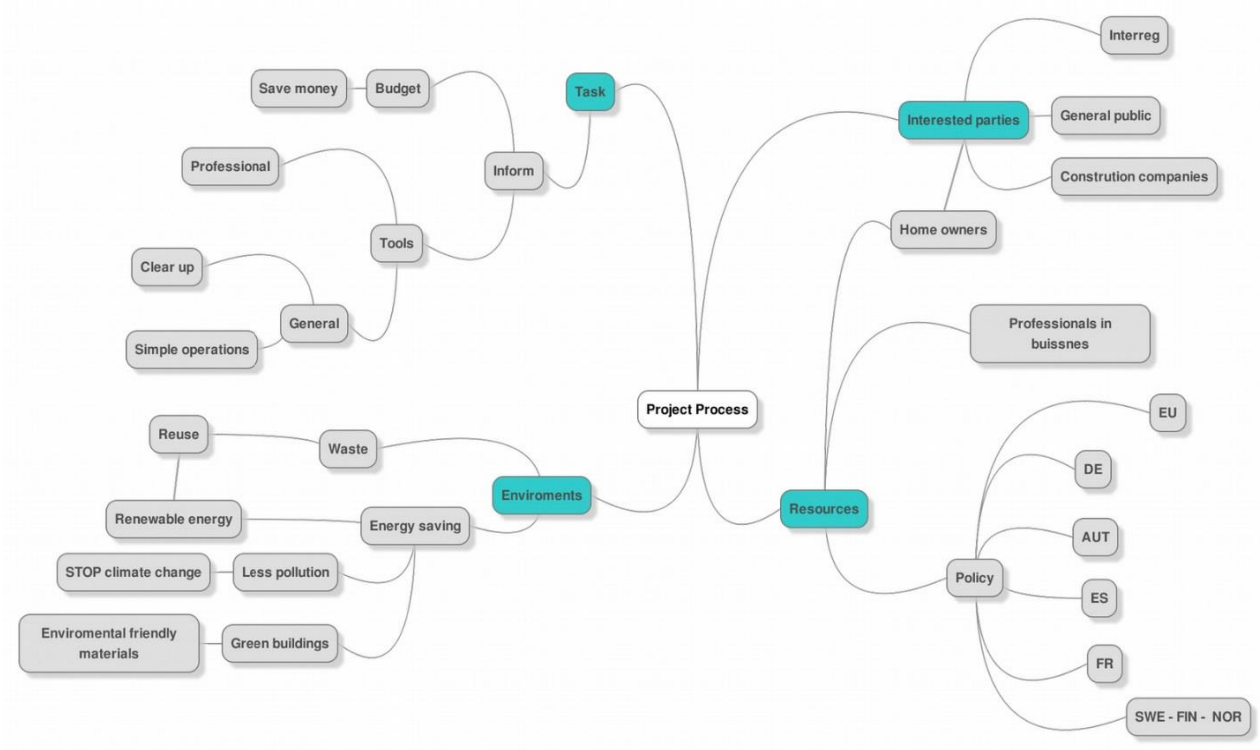


Figure 103: Team mind map to the basic elements method

8.7 Cost management

Expected project budget implementation: the budget for the project implementation can be seen in the following table, which has been broken down by the different tasks that make up the project (table 26):

Name	Expected Cost
Developing project management plan	1.728,00 €
presentation of the project and its plan	97,00 €
Gathering information from Nordic Countries	2.700,00 €
Information from Germany	1.620,00 €
Information from France	1.080,00 €
Information from Spain	1.620,00 €
Information from Austria	1.080,00 €
Analysis of the information collected	2.700,00 €
Classifying of the information according Tools, Materials, policies...	2.700,00 €
Comparison of methologies among different countries	2.160,00 €
Desing of platform to share results	2.700,00 €
Developing results report	5.400,00 €
Period corrections	2.700,00 €
Sharing report with stakeholders	100,00 €
Meeting presentation	100,00 €
Meeting nº2	100,00 €
Meeting nº3	100,00 €
Meeting nº4	100,00 €
Meeting nº5	100,00 €
Midterms presentations	1.000,00 €
Project Webinar	100,00 €
Meeting with differents stakeholders (energy week)	100,00 €
Preparing presentation	2.700,00 €
Final Presentation	1.000,00 €

Table 26 : Project tasks and their cost.

- It estimates that the expected budget amount to 33.785,00 €.

The mainly cost is focused on team member's salary, who earn 18€/h, whereas it has been estimated 100 € per meeting, as well as 1000 € per report delivery, which have been set throughout of the project. Below the different costs have been detailed according to summary tasks (table 28):

Name	Expected cost
Planning	1.825,00 €
Research	8.100,00 €
Analysis of the information collected	2.700,00 €
Classifying of the information according Tools, Materials, policies...	2.700,00 €
Comparison of methologies among different countries	2.160,00 €
Desing of platform to share results	2.700,00 €
Reporting results	8.200,00 €
Progress meeting	1.500,00 €
Others	200,00 €
End of the project	3.700,00 €

Table 28: Expected costs of the tasks of the project.

Monitoring and control costs: the following data on the progress of the project costs have been calculated on the date 24.03.2016, thus it can be observed the estimated cost development of the project so that it reflects the real cost, as in the difference between both (table 27):

Name	Expected cost	Real cost	Remaining cost	Variation
Planning	1.825,00 €	1.922,00 €	0,00 €	97,00 €
Research	8.100,00 €	9.450,00 €	0,00 €	1.350,00 €
Analysis of the information collected	2.700,00 €	1.350,00 €	1.350,00 €	0,00 €
Classifying of the information according Tools, Materials, policies...	2.700,00 €	0,00 €	2.700,00 €	0,00 €
Comparison of methologies among different countries	2.160,00 €	0,00 €	2.160,00 €	0,00 €
Desing of platform to share results	2.700,00 €	0,00 €	2.700,00 €	0,00 €
Reporting results	8.200,00 €	0,00 €	8.200,00 €	0,00 €
Progress meeting	1.500,00 €	500,00 €	1.000,00 €	0,00 €
Others	200,00 €	200,00 €	0,00 €	0,00 €
End of the project	3.700,00 €	0,00 €	3.700,00 €	0,00 €

Table 27: Monitoring and control costs table and specifications.

Monitoring and control costs: the following data on the progress of the project costs have been calculated on the date 12/03/2016, thus it can be observed the estimated cost development of the project so that it reflects the real cost, as in the difference between both:

Name	Expected cost	Real cost	Remaining cost	Variation
Reporting results	8.200,00 €	8.200,00 €	0,00 €	0,00 €
Research	8.100,00 €	9.450,00 €	0,00 €	1.350,00 €
End of the project	3.700,00 €	1.900,00 €	0,00 €	-1.800,00 €
Analysis of the information collected	2.700,00 €	2.700,00 €	0,00 €	0,00 €
Classifying of the information according Tools, Materials, policies...	2.700,00 €	4.500,00 €	0,00 €	1.800,00 €
Desing of platform to share results	2.700,00 €	1.350,00 €	0,00 €	-1.350,00 €
Comparison of methologies among different countries	2.160,00 €	1.800,00 €	0,00 €	-360,00 €
Planning	1.825,00 €	1.922,00 €	0,00 €	97,00 €
Progress meeting	1.500,00 €	1.500,00 €	1.000,00 €	0,00 €
Others	200,00 €	200,00 €	0,00 €	0,00 €

Table 29: Monitoring and control costs table and specifications.

The Project have had a final variation of -263 €, that is that the final cost has been less, saving money (table 29).

According to the data, it concludes that the project has overruns in some tasks due to delay in them. These delays increase the number of hours that team members have to work, thus it increases the costs.

The following figure 8 shows the Earned value, where it can be seen the Budgeted Cost of Work Scheduled (BCWS), the Budgeted Cost of Work Performed (BCWP) and the Actual Cost of Work Performed (ACWP) so on (figure 104).

Considering that ACWP is superior to BCWP, it can be affirmed that the project has overruns, as well as BCWS is superior to BCWP too, thus the project is delayed respect to the estimated plan (figure105).

According to the data, it concludes that the project has an overruns in some tasks due to delay in them. These delays increase the number

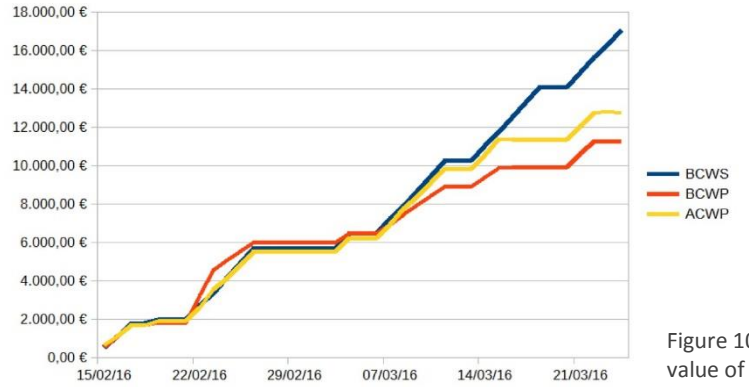


Figure 104: Earned value of the project.

of hours that team members have to work, thus it increases the costs. Anyway this overruns have been balanced out with the savings of another task.

The following figure 105 shows the Earned value, where it can be seen the Budgeted Cost of Work Scheduled (BCWS), the Budgeted Cost of Work Performed (BCWP) and the Actual Cost of Work Performed (ACWP) so on.

Considering that BCWP is superior to ACWP at the end of the project, it can be affirmed that the project has fulfilled with the budget cost, even there is a savings, as well as BCWS is inferior to BCWP too, thus the project has not had a delay respect to the estimated plan.

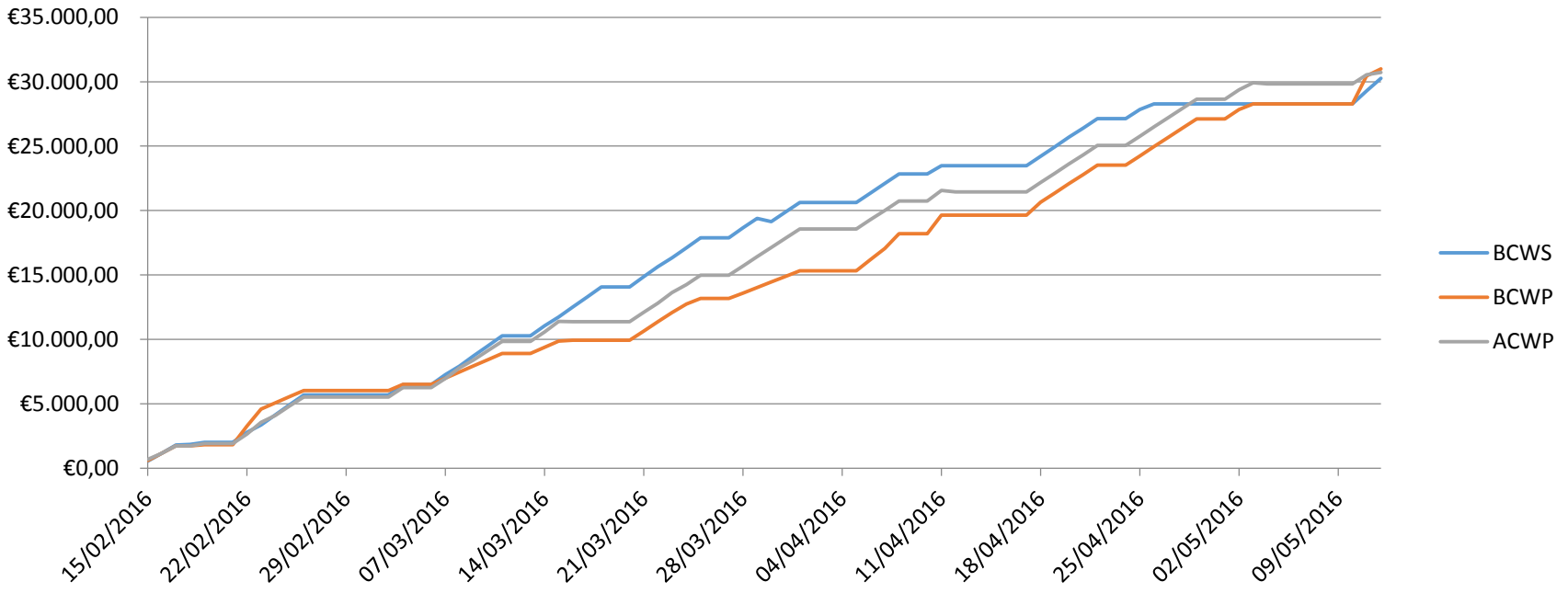


Figure 105: Earned final value of the project

8.8 Risk management

The risk management plan includes the processes with which it is possible to carry out the management planning, identification, analysis and response planning of existing risks on a project; as well as monitoring and control. These processes interact witch each other and with the processes of the other areas of knowledge such as Project Integration Management, Project Quality Management, Project Cost Management, so on. Its main objectives are increase the probability and impact of positive events (opportunities) and decrease them in negative events (risks) by coordinated and economical application of resources. Risk management's objective is to assure that uncertainty does not deflect the endeavor from the business goals. Risks can come from diverse sources such as uncertainty in financial markets, threats from project failures, credit risk, illnesses, etc. These risks are always placed in the future; moreover they can have one or more causes and impacts. For the realization of the risk management plan, it has been used a software called Risky Project which allow users to perform Monte Carlo simulations (algorithm of calculation) of project cost and schedule using discrete risk event and uncertainties.

On the present project, the identified risks are been set in the following figure 106.

	Risk Name	Threat/...	Risk Assigned To
1	Lack of project management knowledge	Threat	All tasks (global)
2	Too much useless information	Threat	Assigned to 6 tasks/res
3	Bad communication among members team	Threat	All tasks (global)
4	Too much information	Threat	Assigned to 8 tasks/res
5	Translation problems	Threat	All tasks (global)
6	Bad teamwork	Threat	All tasks (global)
7	Loss of information	Threat	All tasks (global)
8	Forget information	Threat	All tasks (global)
9	Unclear goals and objectives	Threat	All tasks (global)
10	Sick leave	Threat	All tasks (global)
11	Problems with classification of information	Threat	Task 12: Classifying of tl
12	Problem with languages of Nordic Countries	Threat	Task 5: Gathering inform
13	Misunderstanding of information	Threat	Task 11: Analysis of the
14	Wrong way and lost track and objetives	Threat	Assigned to 2 tasks/res
15	Impossibility to share realized details of projects by companies	Threat	Assigned to 5 tasks/res
16	Double information	Threat	Task 12: Classifying of tl

Pre-Mitigation						Post-Mitigation			
Pro...	Imp...	Sco...	Score	Cost (Pre...	Cost (Miti...	Pro...	Imp...	Sco...	Cost (Po...
50,0%	86,6%	43,3%		0,00 €	450,00 €	0,0%	20,7%	0,0%	0,00 €
77,3%	49,4%	38,2%		0,00 €	0,00 €	37,3%	38,4%	14,3%	0,00 €
50,0%	73,9%	37,0%		0,00 €	0,00 €	10,0%	34,5%	3,4%	0,00 €
76,4%	47,0%	35,9%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €
40,0%	78,4%	31,4%		0,00 €	0,00 €	60,0%	0,0%	0,0%	0,00 €
50,0%	60,4%	30,2%		0,00 €	0,00 €	0,0%	50,6%	0,0%	0,00 €
30,0%	100,0%	30,0%		0,00 €	0,00 €	0,0%	100,0%	0,0%	0,00 €
50,0%	57,5%	28,7%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €
50,0%	38,5%	19,3%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €
30,0%	59,6%	17,9%		0,00 €	0,00 €	30,0%	0,0%	0,0%	0,00 €
55,0%	30,0%	16,5%		0,00 €	0,00 €	5,0%	0,0%	0,0%	0,00 €
70,0%	22,2%	15,6%		0,00 €	500,00 €	70,0%	0,0%	0,0%	0,00 €
50,0%	24,5%	12,3%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €
26,9%	40,1%	10,8%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €
37,0%	26,7%	9,9%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €
50,0%	0,0%	0,0%		0,00 €	0,00 €	0,0%	0,0%	0,0%	0,00 €

Figure 106: Risk management plan part 1.

These risks can concern any task, as it can be observed in the figure. For example the risk 6 “Bad Teamwork” affects all task while the risk 16 “Double information” just affect task number 12. Also it can be appreciated probability, impact and total score of a risk, in this project, the most important risk is “Lack of project management knowledge” which has a likelihood of 50 %, an impact of 86.6 % with a total score of 43.3 %. As consequence it should do a planning in order to avoid its appearance during the project implementation.

These values can be defined by expert judgment, documentation reviews, checklist analysis, and so on. In this case, these values has been calculated by team members using experience and logical after a brainstorming session. The impact of a risk can lead to problems like extra charges, delay, quality problems, or even project cancellation. It adds simply the likelihood of occurrence of a risk; as well as the strength of its impact.

8.8.1 Mitigation plan

Once the risks are defined, the next step would be to define the mitigation plan where there will be a series of responses and mitigations in order to avoid appearance or impact of the risks. The same as with risk identification, this mitigation plan can be defined by expert judgment; as well as being able to contain strategies for opportunities or threats.

The mitigation plan on this project is composed of a series of actions which are contained in the following figure 107:

	Risk Mitigation or Response Plan	Plan Type	Used in risks:
1	Do small project management course	Mitigation	Risk: Lack of project management knowledge
2	Search information about Project Man	Mitigation	Risk: Lack of project management knowledge
3	Communication management plan	Mitigation	Used in 2 risks. Click here to view the list.
4	Scope report after the meeting with St	Mitigation	Risk: Unclear goals and objectives
5	Pay a translator	Mitigation	Risk: Problem with languages of Nordic Coun
6	Use a automatic translator	Mitigation	Used in 2 risks. Click here to view the list.
7	Having different platforms	Mitigation	Risk: Loss of information
8	Ask information to experts	Mitigation	Used in 4 risks. Click here to view the list.
9	Work with a clear database and struct	Mitigation	Used in 3 risks. Click here to view the list.
10	Weekly meetings	Mitigation	Used in 2 risks. Click here to view the list.
11	Overtime	Mitigation	Risk: Sick leave
12	Project management plan	Mitigation	Used in 2 risks. Click here to view the list.
13	Own choice of team members	Mitigation	Risk: Bad teamwork

Used in risks:	Cost	Prob. R...	Impact ...
Risk: Lack of project management knowledge	450,00 €	50,0 %	50,0 %
Risk: Lack of project management knowledge	0,00 €	15,0 %	15,0 %
Used in 2 risks. Click here to view the list.	0,00 €	40,0 %	40,0 %
Risk: Unclear goals and objectives	0,00 €	60,0 %	60,0 %
Risk: Problem with languages of Nordic Coun	500,00 €	0,0 %	100,0 %
Used in 2 risks. Click here to view the list.	0,00 €	0,0 %	30,0 %
Risk: Loss of information	0,00 €	100,0 %	100,0 %
Used in 4 risks. Click here to view the list.	0,00 €	50,0 %	50,0 %
Used in 3 risks. Click here to view the list.	0,00 €	75,0 %	75,0 %
Used in 2 risks. Click here to view the list.	0,00 €	75,0 %	75,0 %
Risk: Sick leave	0,00 €	0,0 %	80,0 %
Used in 2 risks. Click here to view the list.	0,00 €	65,0 %	65,0 %
Risk: Bad teamwork	0,00 €	75,0 %	75,0 %

Figure 107: Risk management plan part 2.

It can be appreciated the different likelihoods and impact for each one, as well as the cost which would suppose if it was necessary its implication and their assigned risk. The operation is as follows:

Supposing we have the risk “Unclear goals and objectives” (number 9 in the previously figure), which have a likelihood of 50 % and an impact of 38.5 %. If this risk appears during the project implementation, we would have some problems which can cause extra charges or delay the deadline. Nevertheless, according to the mitigation plan, we have a response or mitigation in order to avoid these problems. The assigned mitigation is “Scope report after the meeting with Stakeholders” which has a likelihood of 60 % (here, it acts like a mitigation) of avoiding the risk and a percentage of 60 % of reducing the impact of the risk (here, it acts like a response).

So, an action can act like either mitigation or response (or both), in the previous example, it acts like both. For example, the action 5 “Pay a translator” cannot avoid the risk (0 %) but it can reduce its impact (100%), however it entail a cost which is very expensive.

8.8.2 Risk Matrix

It is about a very useful tool, which can be calculated before or after mitigation plan, in this case, the risk matrix without plan mitigation.

It allows us to take a look quickly in order to know which risks are more dangerous and which have to be solved before. The risks, which are on the red zone, are the most dangerous risks on the project, so these ones should be solved as soon as possible. The arrows show us

the post-mitigation results of each risk, so a risk, which was very dangerous, can be reduced to a low risk.

Therefore, the project would not have any dangerous risk, however it can continue being a bit dangerous because still there are risks on the orange zone or risks with certainty probability and impact (figure 108).

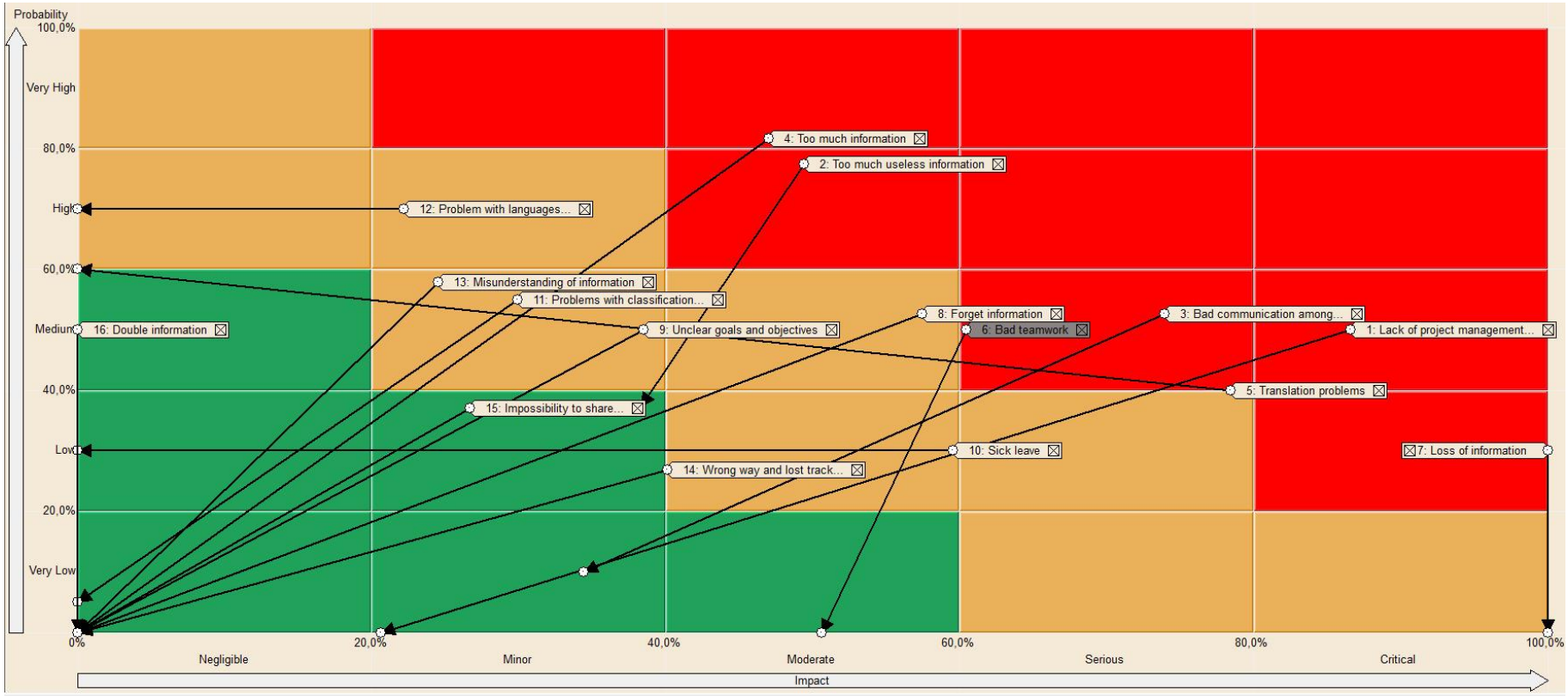


Figure 108: Risk management plan matrix 1.

8.8.3 Cost evolution

The software allows us to know the cost evolution throughout the project implementation, with the plan mitigation or not, as it can be appreciated in the following figure 109.

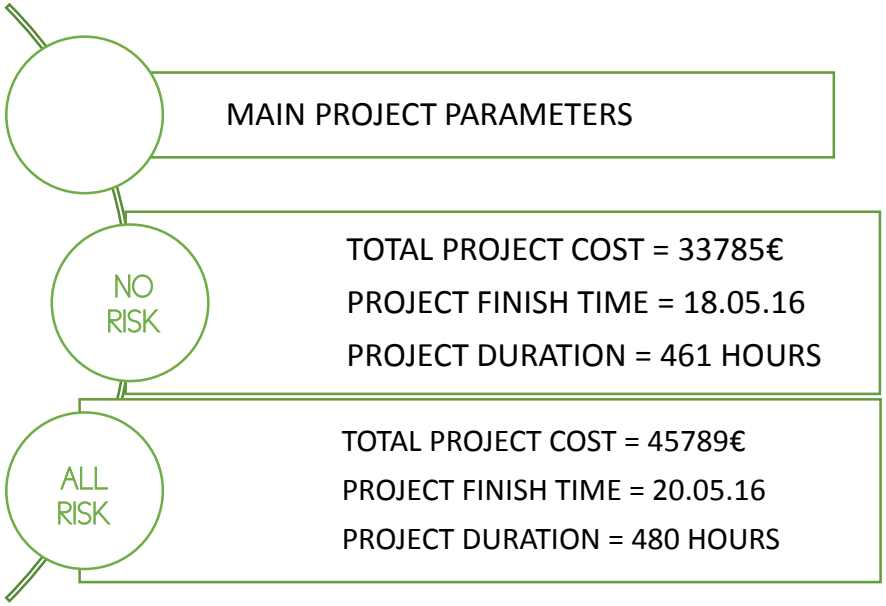
This graphic shows the difference between both evolutions. The red one indicates the budget according to the current schedule without risks (on this project is 33785 €) and the blue one indicate the worst case, counting on risks (on this project would be 45789 €). There would be a green line in the case that the project has already begun.

It is obvious that impact of risks causes an extra charge in the estimated budget, this may be due to increase of working hours, which would cause more budget for the resources situated to each task.

Figure 109: Risk management plan part 3.

8.8.4 General summary

Below, it represents a general summary of the project, where it can be seen the critical risks and tasks. In addition the possible change is reflected in costs and duration of the project, taking into consideration the risk and uncertainties.



Also it could be important to know intermediate cases, because it would be very strange that all risks appear on a project, so it would be more realistic to know it. The software provides us lots information about that, for example the low-medium-high duration of a task or even when this starts though it has delay. In the following table 30, it is possible to know this information for the present project.

	Task Name	Succe...	Low Dur	Mean Dur	High Dur	Finish High	Low W...	Base ...	High W...
1	**Planning**		**33,05 hr**	**34,25 hr**	**37,22 hr**	**02/19/16 15:13**	**106,05 hr**	**129,65 hr**	**156,63 hr**
2	Developing project m	100,0%	25,2 hr	32 hr	37,22 hr	02/19/16 15:13	100,8 hr	123,2 hr	148,8 hr
3	presentation of the p	100,0%	1,05 hr	1,28 hr	1,57 hr	02/19/16 10:34	5,25 hr	6,45 hr	7,83 hr
4	**Research**		**97,5 hr**	**128,75 hr**	**174,35 hr**	**03/28/16 16:21**	**487,5 hr**	**673,69 hr**	**871,74 hr**
5	Gathering informatior	100,0%	34,5 hr	40 hr	59,37 hr	03/08/16 13:22	172,5 hr	227,25 hr	296,78 hr
6	**Gathering informat**		**63 hr**	**88,75 hr**	**114,98 hr**	**03/28/16 16:21**	**315 hr**	**446,44 hr**	**580,9 hr**
7	Information from G	100,0%	63 hr	88,75 hr	114,98 hr	03/28/16 16:21	94,5 hr	133,94 hr	174,28 hr
8	Information from F	100,0%	63 hr	88,75 hr	114,98 hr	03/28/16 16:21	63 hr	89,28 hr	116,18 hr
9	Information from S	100,0%	63 hr	88,75 hr	114,98 hr	03/28/16 16:21	94,5 hr	133,94 hr	174,28 hr
10	Information from A	100,0%	63 hr	88,75 hr	114,98 hr	03/28/16 16:21	63 hr	89,28 hr	116,18 hr
11	Analysis of the informatior	100,0%	40,5 hr	54,77 hr	54,77 hr	04/06/16 16:33	153,58 hr	229,43 hr	300 hr
12	Classifying of the informati	100,0%	40,07 hr	48 hr	54,02 hr	04/21/16 14:34	180 hr	228,13 hr	285,08 hr
13	Comparison of methologie	100,0%	28,05 hr	28,05 hr	35,17 hr	04/27/16 17:44	126 hr	155,59 hr	186,08 hr
14	Desing of platform to share	100,0%	31,5 hr	48 hr	48 hr	05/05/16 10:24	157,5 hr	192,54 hr	232,58 hr
15	**Reporting results**		**94,5 hr**	**120 hr**	**135,92 hr**	**05/30/16 10:19**	**472,5 hr**	**577,57 hr**	**697,67 hr**
16	Developing results re	100,0%	63 hr	80 hr	90,92 hr	05/20/16 14:19	315 hr	385,04 hr	465,08 hr
17	Period corrections	100,0%	31,5 hr	40 hr	45 hr	05/30/16 10:19	157,5 hr	192,54 hr	232,58 hr
18	Sharing report with s	100,0%	0 hr	0 hr	0 hr	05/30/16 10:19	0 hr	0 hr	0 hr
19	**Progress meeting**		**184 hr**	**184 hr**	**184 hr**	**03/23/16 09:00**	**0 hr**	**0 hr**	**0 hr**
20	Meeting presentatior	100,0%	0 hr	0 hr	0 hr	02/15/16 09:00	0 hr	0 hr	0 hr
21	Meeting n°2	100,0%	0 hr	0 hr	0 hr	02/23/16 09:00	0 hr	0 hr	0 hr
22	Meeting n°3	100,0%	0 hr	0 hr	0 hr	03/08/16 09:00	0 hr	0 hr	0 hr
23	Meeting n°4	100,0%	0 hr	0 hr	0 hr	03/15/16 09:00	0 hr	0 hr	0 hr
24	Meeting n°5	100,0%	0 hr	0 hr	0 hr	03/23/16 09:00	0 hr	0 hr	0 hr
25	Midterms presentatic	100,0%	0 hr	0 hr	0 hr	03/30/16 09:00	0 hr	0 hr	0 hr
26	**Others**		**0 hr**	**0 hr**	**0 hr**	**02/23/16 09:00**	**0 hr**	**0 hr**	**0 hr**
27	Project Webinar	100,0%	0 hr	0 hr	0 hr	02/23/16 09:00	0 hr	0 hr	0 hr
28	Meeting with differen	100,0%	0 hr	0 hr	0 hr	03/17/16 09:00	0 hr	0 hr	0 hr
29	**End of the project**		**31,5 hr**	**40 hr**	**46,52 hr**	**05/18/16 16:31**	**157,5 hr**	**192,54 hr**	**232,58 hr**
30	Preparing presentatic	100,0%	31,5 hr	40 hr	46,52 hr	05/18/16 16:31	157,5 hr	192,54 hr	232,58 hr
31	Final Presentation	100,0%	0 hr	0 hr	0 hr	05/18/16 15:00	0 hr	0 hr	0 hr

Table 30: Midterm report tasks duration

In any case, the project would fulfill the schedule of the day 05.18.2016, such as it is fixed on the management plan. In the other hand, the costs are the main problem, as it can be seen in the following table 31:

	Task Name	Res.Cost	Tot.Cost	Cost Low	Cost	Cost Hi...	Income A...
1	**Planning**	**1.825,00 €**	**1.825,00 €**	**1.916,25 €**	**2.342,80 €**	**2.830,37 €**	**0,00 €**
2	Developing project m	1.728,00 €	1.728,00 €	1.814,40 €	2.217,60 €	2.678,40 €	0,00 €
3	presentation of the p	97,00 €	97,00 €	101,85 €	125,20 €	151,97 €	0,00 €
4	**Research**	**8.100,00 €**	**8.100,00 €**	**8.775,00 €**	**12.126 €**	**15.691 €**	**0,00 €**
5	Gathering informatior	2.700,00 €	2.700,00 €	3.105,00 €	4.090,54 €	5.342,06 €	0,00 €
6	**Gathering informat**	**5.400,00 €**	**5.400,00 €**	**5.670,00 €**	**8.035,87 €**	**10.456 €**	**0,00 €**
7	Information from C	1.620,00 €	1.620,00 €	1.701,00 €	2.410,84 €	3.136,95 €	0,00 €
8	Information from F	1.080,00 €	1.080,00 €	1.134,00 €	1.607,09 €	2.091,16 €	0,00 €
9	Information from S	1.620,00 €	1.620,00 €	1.701,00 €	2.410,84 €	3.136,95 €	0,00 €
10	Information from A	1.080,00 €	1.080,00 €	1.134,00 €	1.607,09 €	2.091,16 €	0,00 €
11	Analysis of the informatior	2.700,00 €	2.700,00 €	2.764,50 €	4.129,76 €	5.400,00 €	0,00 €
12	Classifying of the informati	2.700,00 €	2.700,00 €	3.240,00 €	4.106,30 €	5.131,50 €	0,00 €
13	Comparison of methologie	2.160,00 €	2.160,00 €	2.268,00 €	2.800,67 €	3.349,50 €	0,00 €
14	Desing of platform to share	2.700,00 €	2.700,00 €	2.835,00 €	3.465,67 €	4.186,50 €	0,00 €
15	**Reporting results**	**8.200,00 €**	**8.200,00 €**	**8.605,00 €**	**10.502 €**	**12.668 €**	**0,00 €**
16	Developing results re	5.400,00 €	5.400,00 €	5.670,00 €	6.930,67 €	8.371,50 €	0,00 €
17	Period corrections	2.700,00 €	2.700,00 €	2.835,00 €	3.465,67 €	4.186,50 €	0,00 €
18	Sharing report with s	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
19	**Progress meeting**	**1.500,00 €**	**1.500,00 €**	**1.500,00 €**	**1.583,33 €**	**1.800,00 €**	**0,00 €**
20	Meeting presentatior	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
21	Meeting n°2	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
22	Meeting n°3	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
23	Meeting n°4	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
24	Meeting n°5	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
25	Midterms presentatic	1.000,00 €	1.000,00 €	1.000,00 €	1.055,56 €	1.200,00 €	0,00 €
26	**Others**	**200,00 €**	**200,00 €**	**200,00 €**	**211,11 €**	**240,00 €**	**0,00 €**
27	Project Webinar	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
28	Meeting with differen	100,00 €	100,00 €	100,00 €	105,56 €	120,00 €	0,00 €
29	**End of the project**	**3.700,00 €**	**3.700,00 €**	**3.835,00 €**	**4.521,22 €**	**5.286,50 €**	**0,00 €**
30	Preparing presentatic	2.700,00 €	2.700,00 €	2.835,00 €	3.465,67 €	4.186,50 €	0,00 €
31	Final Presentation	1.000,00 €	1.000,00 €	1.000,00 €	1.055,56 €	1.200,00 €	0,00 €

Table 31 Final report tasks duration

That is to say, the project does not have problem with the deadline (even with risk) but it has extra charges in the case some risk appears. It is important to analyse this information, because maybe, it would be better to spend more money with a good mitigation plan in order to avoid a higher extra charges.

8.8.5 Conclusion

The project counts on a series of risks which would put in danger goals cost, time and quality which were estimated at the beginning of it. In this project, it has been reflected a number of risks which could originate an increase in project costs as well as its duration, however, as to the end date, the project fulfils the planning, although it does not happen with the costs,where it has a cost overrun of approximately 35% of planned. Therefore it is important to establish a contingency plan that minimizes both the likelihood and impact of the identified risks on the project. It has been stated in this risk management plan that with an appropriate mitigation plan can be greatly reduced both the likelihood and impact, ensuring the achievement of the objectives of the project in terms duration cost and quality.

8.9 Project workflow

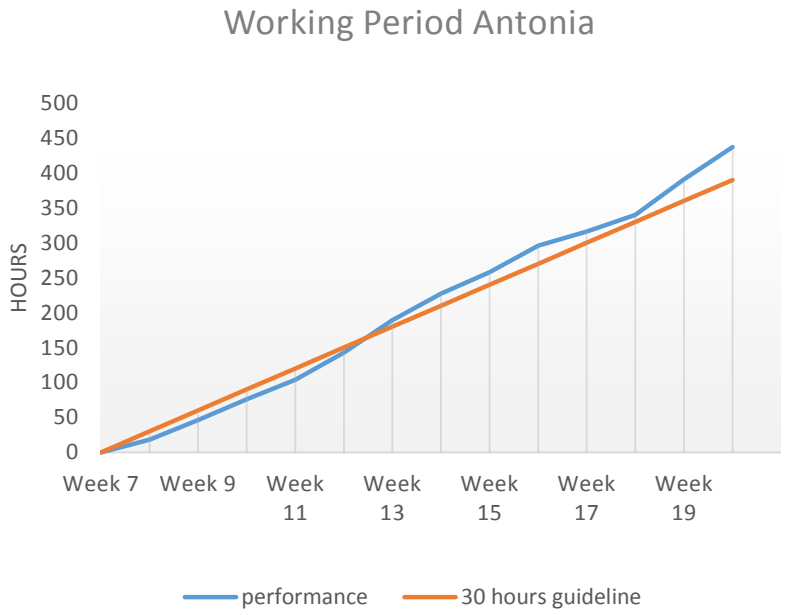
At first, one of the courses we want to present is project management. It has helped to manage the tasks of organization and relies them on the right track, because we have learned how to start with the exercise and what we had to consider in every task. Furthermore, the course taught as team problems analyzer, developing solutions and clear instruments shows. The course was very helpful for the team development, it was offered by Roger Nylund.

Later on, another part of our project workflow was, the Research part which was quite long and difficult. The group members spend a lot of hours searching classificatory information of all European countries. Nevertheless in these period the ESN student organization offered some trips to know more about the Finnish culture and doing sightseeing. The team takes part of some of these trips, just to disconnect and doing some external research and fieldwork. This occasion kept the motivation high and helped us to continue with the same encouragement as the beginning.

Another positive aspect in our project has been the Gantt chart system, in where we have set our goals and deadlines. Because one of the team members had already some experience in this issue, the other members learned a lot about it, and it helps the whole group to apprehend a greater knowledge about the project plan.

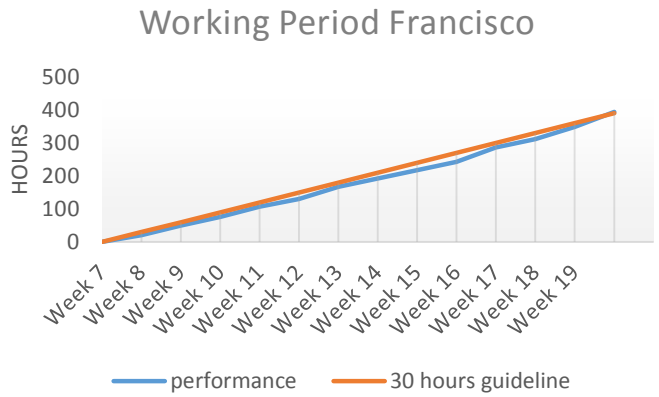
8.10Working period

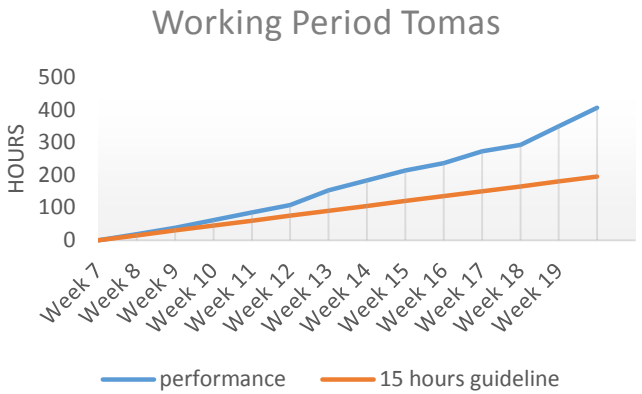
The graphs bellow shows the working period during the EPS semester. In our group were five full time students and one part time student.

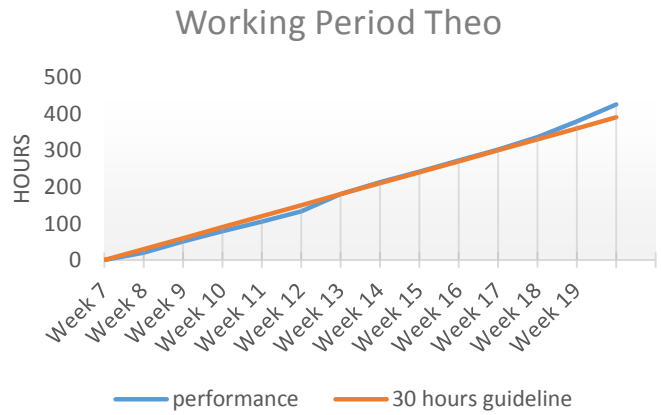


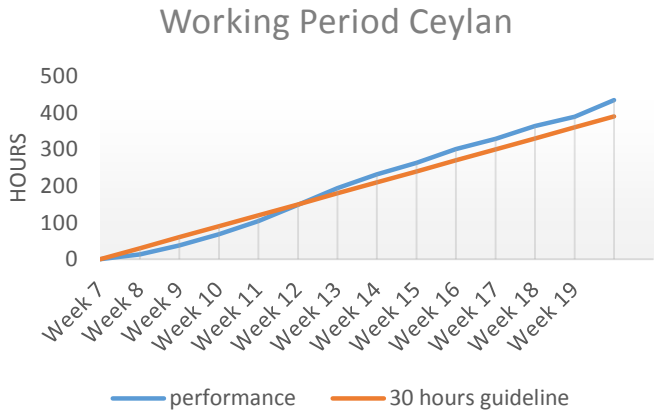
The full time students had to work 30 hours each week and the part time student 15 hours. In the graph there is a red line, this one show where everyone should arrive at the end. The blue line is the personal performance.

On the horizontal axis are the calendar weeks listed and the horizontal axis shows the working hours. In the end everybody reached the goal or worked more and we finished the project on time.



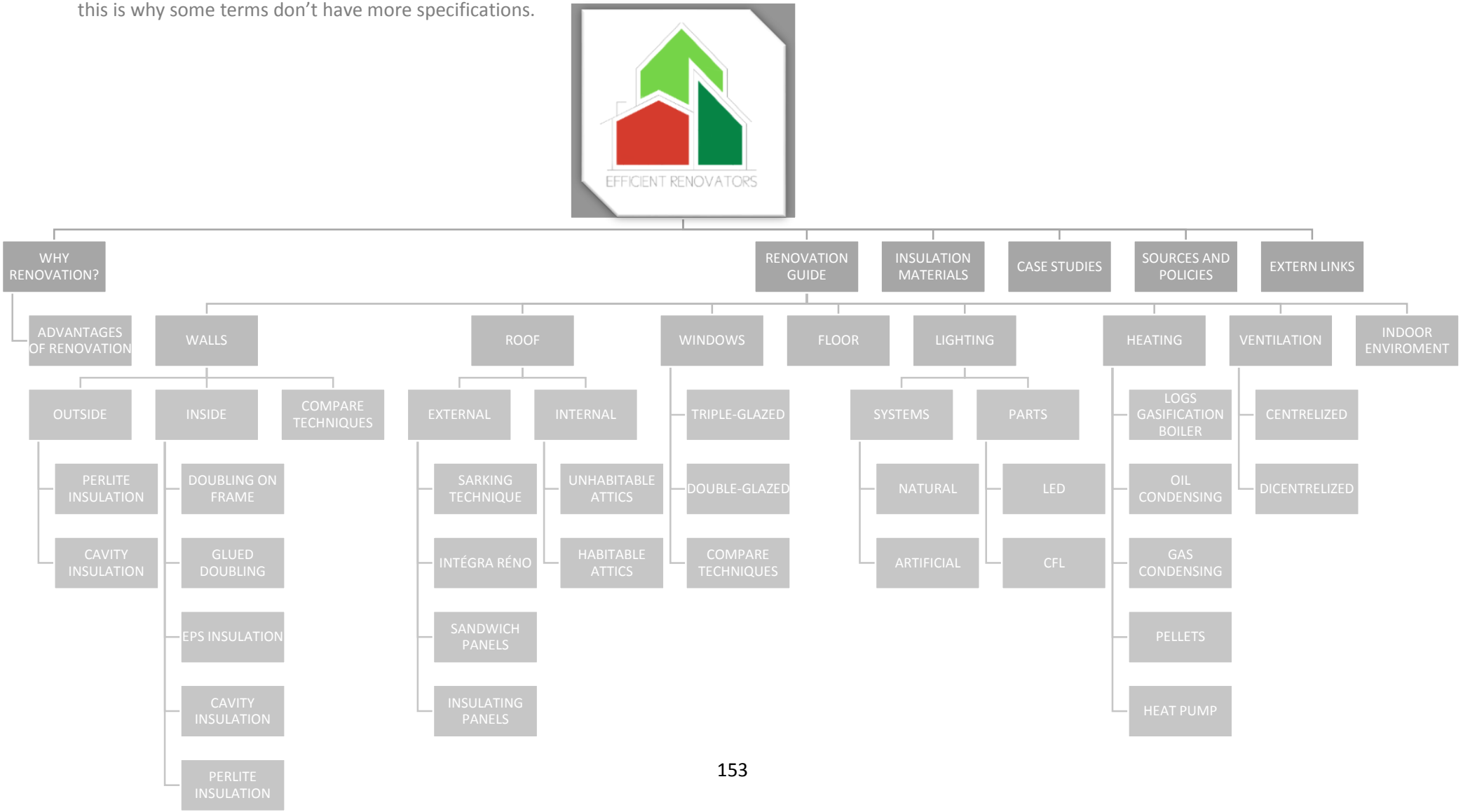






8.11 Website design instructions

In the following scheme it can be seen which could be the different ways that the stakeholder could take on our website. The scheme is not completed jet, this is why some terms don't have more specifications.



INFORMATION ABOUT THE SPECIFICATIONS

HOW DO THE RENOVATION GUIDE WORKS?

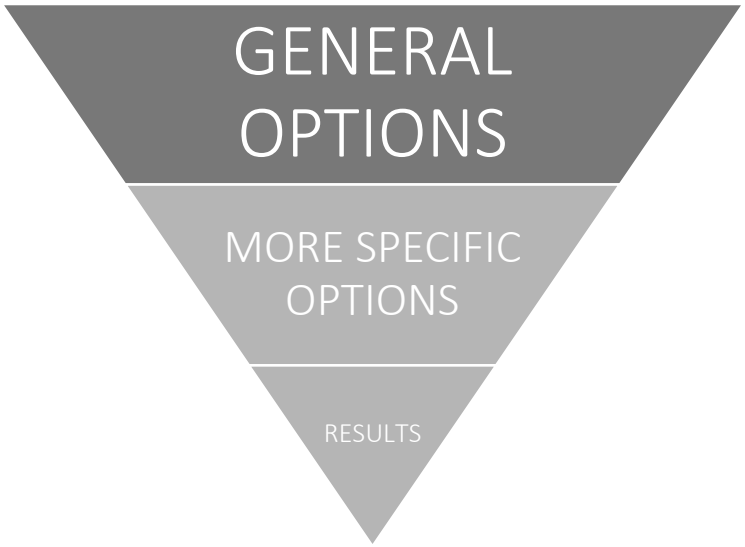
The user will just have to click on the option which fills mostly his/her needs and then automatically more options will appear below.

In this way the costumer will be directed step by step to the useful information. This will simplify the research for the users and reduce the researching time for the correct information.

The meaning of each color at the graphic:

The user didn't choose this option (or also any option).

The user chose this option.



MORE INFORMATION

Every time when the user can choose between different options, a little window appears below the concept (as it can be seen in the figure 1) which will say always "more information".

If the costumer isn't sure what does the concept mean and what specification will appear after, he/she can click on it and a little window will appear with basic information (as it can be seen in figure 2).

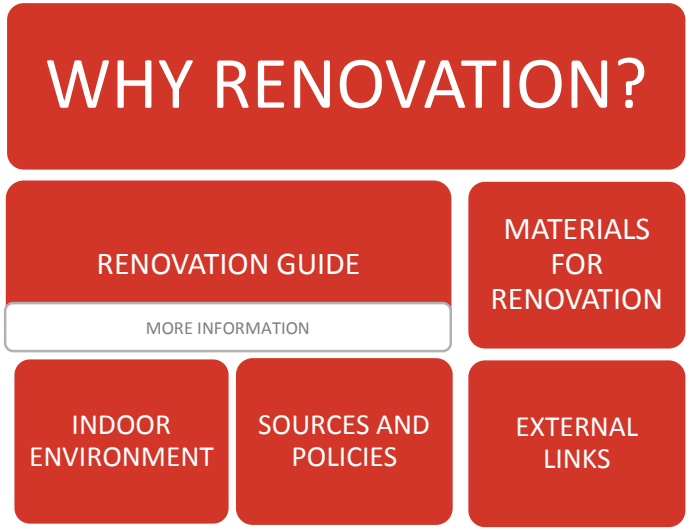


Figure 1

Figure 2

SYSTEMS OR TECHNIQUES

Every time when the user will click on a technique the structure of this will be always the same. In the following figure 3 it can be seen how it will look like:

Figure 3

COMPARE TECHNIQUES

Whenever a user click on the option “compare techniques” a chart will appear where the different techniques will be compared by determinate concepts (figure 4).

This will help the costumer to choose which technique is the best one for his/her renovation project.

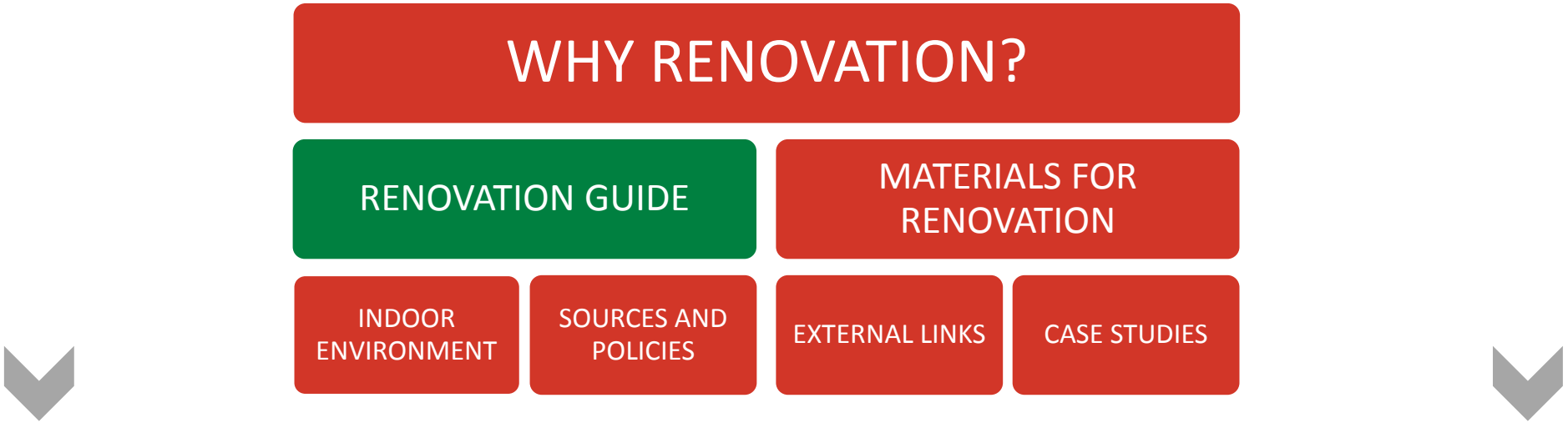
At the option “materials” just clicking on the name of the material the user will be re-directed to the page of “materials of renovation” where all the information can be found.

CONCEPT	TECHNIQUE A	TECHNIQUE B
ADAPTABILITY		
COSTS		
DURATION (TIME)		
MATERIALS		
EVALUATION		

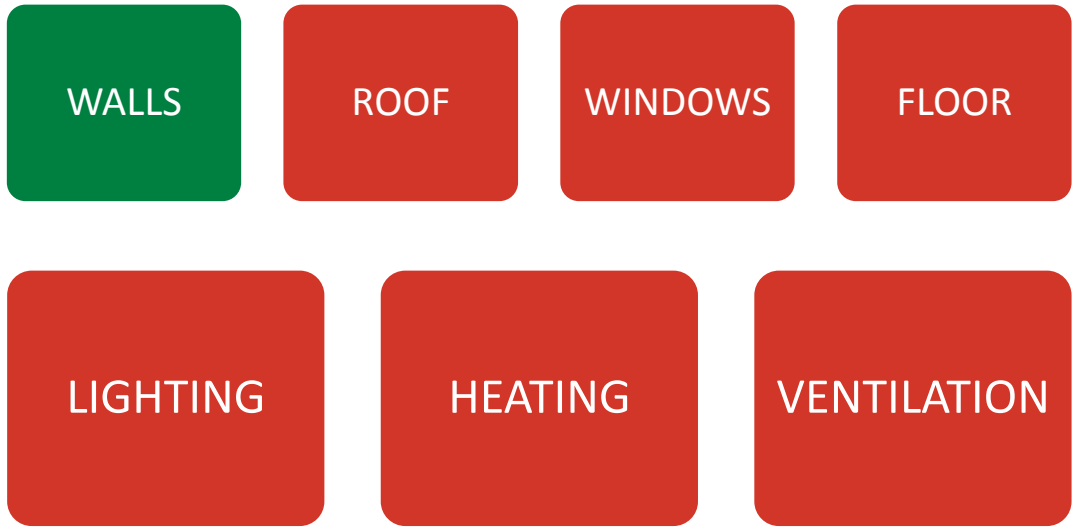
Figure 4

RENOVATION GUIDE EXAMPLE

On the following pages there can be seen how one way could be for a costumer through the RENOVATION GUIDE, who wants information about inside insulation for outer walls.



The next option will just appear when the user has already clicked on the option RENOVATION GUIDE. This happens with every option.



WHICH PART DO YOU WANT TO INSULATE?

COMPARE TECHNIQUES

EXTERNAL

INTERNAL

SOME INSULATE SYSTEMS AND TECHNIQUES ARE…

COMPARE ALL TECHNIQUES

DOUBLING ON FRAME

GLUED BOUBLING