SUSTAINABLE BUILDING REFURBISHMENT

UNDERTAKING THE SUSTAINABLE REFURBISHMENT PLANNING & PRE-DESIGN
PROJECT BRIEF DEVELOPMENT

Master Final Dissertation

Marta Hervías Gallardo
Master in European Construction Engineering

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Final dissertation of the Master program in European Construction Engineering

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ABSTRACT

This report aims to clarify the current situation of refurbishment in comparison with new build, to encourage its implementation. An initial sustainability study is performed to determine the opportunities that refurbishment brings to the building stock market situation. A further research in refurbishment is performed, to determine possible problems and solutions. After that, the refurbishment planning process is studied, and risks and management processes to undertake evaluated; there the need of a project initial information brief in the pre-design phase is stated. Conclusively, a building check list is developed and implemented in a case study, to work as an information brief, and a sustainable solution catalogue of possible options is completed.

KEYWORDS: SUSTAINABILITY, REFURBISHMENT, INTEGRATED DESIGN, PRE-DESIGN PROJECT BRIEF

RESEARCH STATEMENT

The fact of having developed the previous stages of the Master in European Construction Engineering related with sustainability issues, has led me the opportunity to capture some of these ideas into a research project.
Building refurbishment has always been an important topic in my academic career, thus my final dissertation project for the Degree in Architecture was about the refurbishment of a docomomo catalogued building.
Developing a thesis with the incentive of sustainability, has allowed me to a further study of refurbishment possibilities.

The work performed in THM University, with the guidance of professor Dirk Metzger has endorsed the possibility of developing a thesis with a theoretical analysis followed by a real case study provided by him. With this input, the research is fulfilled and has a satisfactory result.

ACKNOWLEDGEMENTS

The development of this master dissertation has been a challenge in which many participants have been involved, directly or indirectly.

Thanks to the THM University staff that helped the master students first in our integration in Gießen and assisted us in any problem, personal or academic.
Special mention to Professor Dirk Metzger, without whom the realization of this dissertation would not have been possible. I thank him for his guidance, and for enabling having a real case study building to implement the dissertation results.

I also want to thank my family, for the energy and support they have offered me, not only during the dissertation itself, but also during all the extension of the master.

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LIST OF ACRONYMS

BPIE: Building Performance Institute Europe
BRE: British Research Establishment
CIB: International council for research and innovation in building construction
GDP: Gross Domestic Product
NASA: National Aeronautics and Space Administration
SME: Small and Medium-sized Enterprises
UNEP: United Nations Environment Program
UNFCCC: United Nations Framework Convention on Climate Change

Building check list
C.E.: Consumption. Electricity
C.H.: Consumption. Heating and cooling
C.W.: Consumption. Water
C.WA.: Consumption. Wastes
P.A.: Potentials of the site. Potentials of the area
P.R.B.: Potentials of the site. Potentials for renewable energies. Biomass
P.R.G.: Potentials of the site. Potentials for renewable energies. General information
P.R.G.: Potentials of the site. Potentials for renewable energies. Geothermal heat
P.R.S.: Potentials of the site. Potentials for renewable energies. Solar radiation
P.R.W.: Potentials of the site. Potentials for renewable energies. Wind speed
P.R.WF.: Potentials of the site. Potentials for renewable energies. Water flows
S.B.: State of the building. Building internal organization
S.F.: State of the building. Façade
S.S.: State of the building. Structure

CHAPTER 1 INTRODUCTION

1.1 Background

The existing global stock market calls for a change in the building construction sector, from new build to refurbishment. The refurbishment though, has to be based in sustainable implementation techniques. With all this in the same project, many problems arise, due to uncertainties, planning failures and lack of information and of knowledge of the participants involved. All these problems have to be faced by an integrative planning and a competent initial evaluation of the building status, which will determine if a building is suitable for the refurbishment option.

1.2 Aims and objectives

The aim of this research is to determine the benefits of refurbishment versus new build.
A comparison between both options will be developed and the advantages of the refurbishment will be highlighted.
In a further analysis in the field of refurbishment, the problems to face when undertaking a refurbishment project will be stated, and the possible solutions will be catalogued.

After that analysis, the planning process of a refurbishment will be studied, focusing in the pre-design phase, and problems generated over the entire project by the lack of information in this phase. As a solution for this problem a building preliminary brief will be developed in the pattern of a check list, that will analyse the current status of a building, and will state whether the building is suitable for refurbishment or not.
As a second part of this brief, a sustainable solution catalogue for refurbishment will be developed, for the building to select the convenient solutions for its specific situation.
As a final part of the report, the building check list developed will be implemented in a case study and the building will be rated.

1.3 Research methodology

As a theoretical research, this dissertation has based almost entirely in literature review. This entails that the results will not go over the theoretical plane, and should be implemented in real construction projects in the future to prove their real results. Mainly the literature review will include the research in Scientific Journals through databases such as: Engineering Village, Scopus-Sciverse and Web of Knowledge.

For the materialization of the building check list and the sustainability solution catalogue some guides will be consulted, obtaining them from sources such as the International Energy Agency or governmental agencies related with energy and design. Books, previous research papers and guides of green buildings will also be a part of the sources for this report.

Also in case needed, specialist in the matter will be contacted for the required information.

1.4 Limitations and scope

The fulfilment of a dissertation based on theoretical research has its limitations by itself as mentioned in the research methodology.
However some specific limitations have to be taken into consideration due the time available for the dissertation work:

- The examples of sustainable building refurbishment have remained as a sample of the possibilities for its implementation, thus they have not been fully analysed.
- The analysis of the planning process in refurbishment has focused only in the pre-design phase.
- The economic analysis in the refurbishment building check list has not been considered.
- The sustainable solution catalogue has remained as a catalogue, and has not been implemented in the case study, due to the multiplicity of options it entailed.

1.5 Dissertation report outline

As an introductory part, sustainability has been analysed, and its relationship with the building construction sector, analysing impacts, costs and solutions for the sector. Then a comparison is made between new build and refurbishment, where the refurbishment option will be highlighted.

As a second part, a thorough analysis of refurbishment will be performed, studying the building stock market current status and its possibilities, economic benefits and drawbacks, and the problems derived from the market itself.
As a summary of this part, the opportunities for refurbishment will be stated and some examples of sustainable refurbishment projects will be presented.

The third part of the report will focus in how to undertake a sustainable refurbishment, risk management and planning process. In this planning process, the research will focus in the pre-design phase of the project, and will present a solution for the lack of information in this stage.

As a final part, a preliminary brief will be developed in the pattern of a building check list with rated questions to be answered by the building, where it could be stated its suitability for refurbishment.
To complete this check list, a sustainable solution catalogue will be elaborated, to allow the building project to have a list of possible implementation options and choose the best for the specific situation of the building.
As an implementation part, the building check list will be applied to an existing building and the results will determine the suitability its suitability for refurbishment.

CHAPTER 2 SUSTAINABILITY

Climate change is one of the biggest problems that our current society is going to face in the present environmental situation, specifically the direct implications it will have in the early future.

Many countries all over the world are arranging agreements to reduce greenhouse emissions as much as possible. International agreements such as the Kyoto Protocol (UNFCCC, 1997) were set to achieve real reductions for these emissions. Currently the second commitment period of the Kyoto Protocol was agreed in the conference of Doha, this continuity of commitments is vital to achieve the reduction targets needed.

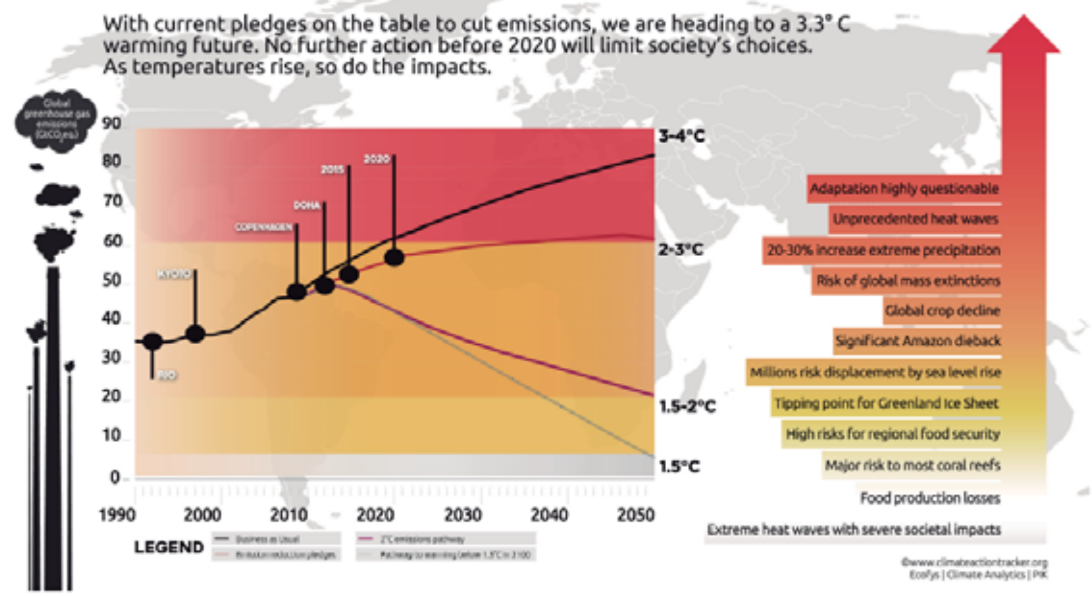


Figure 2.1. World warm temperatures and greenhouse emissions (Höhne et al., 2012)

If the warming global pledges are not accomplished, extreme environmental and social impacts will occur in the short future.

It is the duty of the society then, to engage with solutions to this global problem adopting sustainability as an inherent part of their way of living.

2.1 Sustainability global introduction

Analysing the origins of the word sustainability, it drifts from the Latin word "sustinere", that means to hold up. There are many definitions for the word, however, since the Brundtland Commission on environment and development of the United Nations on 1987, it has adopted a meaning more related with sustainable development for humanity, which final goal will be improve the quality of life, the existing environment and the social and economic status of the current and future generations (United Nations , 1987).

From that point, sustainable development has increased its global importance, finalizing in a report that requested for a common strategy of all the nations to face development and environment as a unique purpose for the progress of the humanity. The main statement of the report defined this concept in this way: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations , 1987).

That aim of global sustainable development is believed to be the greatest challenge of the 21st century (Sachs & Warner, 1995). According to researchers, this sustainable development should be in equilibrium between the technology advances, innovation methods and governmental policies (Vollenbroek, 2002).

The human kind has now the responsibility to undertake this sustainable development, and will need to take the necessary actions to prevent further irreversible consequences yet not quite perceptible.

The first part of this report will focus in the sustainability in building construction, analysing problems and solutions that the construction industry will have to face, such as energy consumption and supply systems or the environmental damage caused by the excessive use of natural resources to cover the existing demand.

Focusing in the construction industry, statistics confirm the real implication of the building sector in the energy consumption. The 15% of the global energy consumption is related with residential buildings (U.S. Energy Information Administration, 2011). And that is just a global number, in the developed world the energy consumption of the buildings amounts up to 20-40% of the global consumption (Pérez Lombard et al., 2007).

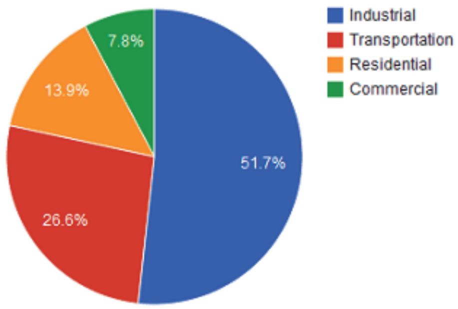


Figure 2.2. World energy consumption by sector 2012 (Bredemberg, 2012)

In the EU the building sector by itself, is the responsible for the 42% of the energy consumption, plus is as well the producer of the 35% of the greenhouse emissions.
In economic terms, the construction industry produces the 10% of the GDP and involves the 7% of the workforce (Prodromou, 2012).

Looking to the environmental side, the building sector is the responsible of the 12-16% of the CO2 global emissions.

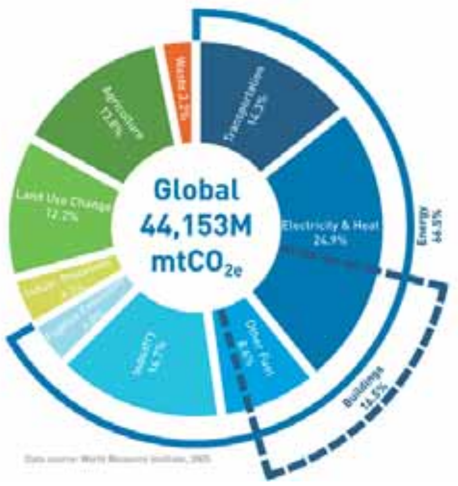


Figure 2.3. Global greenhouse gas emissions per sector (Climate Emergency Institute, 2012)

Furthermore its consumption of natural resources its worrying. The construction market is responsible for the extraction and posterior transformation into construction products of over the 50% of all the materials worldwide (European Commission, 2013). It represents the 25% of virgin wood consumption and the 16% of water withdrawals. All this data are without values for wastes generation, land occupation or further environmental impacts (European Commission, 2012) (International Energy Agency, 2006).

In the current situation, if the construction sector continues at its current rate, over 70% of the Earth's surface will be destroyed by 2032, due to population increase and urbanization. (UNEP, 2002). Nowadays our cities building stock is outsized, only a meagre amount of buildings are being replaced, and the buildings tumble to decay lowering their energetic performance and increasing their consumption and environmental impact. Due to all of these reasons refurbishment represents a wide window of opportunity in the construction sector, being the appropriate tool for buildings to meet sustainability goals (Itard et al., 2008).

2.2 Sustainability in the building construction sector

2.2.1 Current status

It has to be taken into account that sustainability is a bigger concept than construction. It can start with it but certainly will have to continue when the construction is over, during the whole life of the building, including consumption, behaviour and if it is needed a possible change of use, which will imply flexibility thought from the beginning of the construction process.

An analysis of the construction industry will be performed in this report to achieve a deeper knowledge of the implications of sustainability in building construction.

<u>Economic contribution of the construction sector</u>
Construction industry represents the 10% of the global GDP and this industrial sector is the biggest one in Europe, representing the 11 % of its GDP. Also it is the responsible of over 50% of the national investment in many countries (UNEP, 2003).

One important aspect to highlight of this industry is that is composed by many small and medium size companies. In Europe exist 2,5 millions of SME companies, which implies more than the 90% of all construction enterprises (UNEP, 2003).

<u>The construction industry impact</u>
In comparison with other industries, construction represents an unusual product with a larger extent in time. Because of that it is important to achieve higher performance in the products, with a lower impact, in other words, sustainability implementation is needed from the starting point of the project life (UNEP, 2003).

From the International Conference on Sustainable Construction, 1994, Tampa, USA, sustainability was declared as a global problem to face by the construction industry with real technological solutions. Since then many buildings have been created to attest that through sustainability it can be generated a healthier environment for the end user, and moreover the utilities consumption and maintenance has been reduced (Dobson et al., 2013).

The construction industry is based in a very fragmented market. That leads also to a very fragmented demand, in this case for sustainable solutions or products, even when the technical solution needed or the product itself is available. 40% of the construction works are directly related with the public sector, and there is an opportunity to promote innovative products. By not taking this opportunity, the gap of knowledge increase and the possibilities of actual advance in the field, fade away (Dobson et al., 2013).

Currently, the main problems that sustainable solutions have to face are the misunderstanding of the final costs, the belief that the total investment will not be worthwhile of the profits it will generate, and the lack of knowledge in which added value a sustainable building can provide, once it is finished (BRE Centre for Sustainable Construction et al., 2005).

However, in some researches it has been stated that sustainability and business performance are supporting concepts and that their implementation in construction proves a real improvement in the sector competitiveness (Tan et al., 2011). In addition to that, the awareness of life cycle, and the analysis of the benefits it can report may create a new path towards a sustainable construction (Dobson et al., 2013).

Additionally traditional buildings carbon emissions are in high disadvantage compared with the emissions of sustainable buildings, with all that entails, such as running costs and more importantly, although not so valued in terms of economic assets, the constant damage to the environment (Construction, 2012).

For future developments in the sustainability field the regulatory community have to set different policies or measures, and awareness campaigns to promote sustainability within the construction sector. The generation of standards for this industry related with the sustainability issue will improve its general application and the increase of the skilled participants needed for its implementation (European Commission, 2013).

2.2.2 Environmental aspects

Resources consumption

Amongst all the environmental effects that the construction industry is accountable of, the most relevant is the energy and natural resources consumption.

In relation with resources consumption, the construction industry is one of the biggest consumers. Many of the materials consumed are common in the nature, and should be easy to continue their generation as part of a sustainable process, however it is a reality that not the industry, neither the market, gives much attention to environmental impacts and non-controlled consumption of resources (CIB & UNEP-IETC, 2002).

This sector is responsible of half of the global natural resources consumption. The construction is the dominant sector related with material flow in many countries. Mining and quarrying create a huge volume of pollution, plus the wastes generated while using the land. Or even in more extreme points, metals used for construction purposes, like zinc or copper, may become limited in the early future or even disappear.

Over the 90% of the wood used for construction purposes is produced in the north of Europe or the north of America and Canada. The majority of the wood is coming from managed forests, but there are some issues about the sustainability of the methods applied. Apart form that, is the wood coming form tropical areas, in this case sustainability is not an option considered (BRE Timber Division, 1998).

Energy consumption

According to the International Energy Agency, in the developed world, one-third energy determined for end users, is the one used in appliances in general in the non-industrial buildings (International Energy Agency, 2006). And these data are without taking into account the embodied energy of every material or product used in construction. This concept is imperative to the life cycle assessment, which calculates the energy consumption to manufacture a product. In construction, the conversion of raw materials into ready products has large energetic demands.

Of all the resources consumption, the most important one, due to its future supply, is the energy consumption. It has to be taken into account the energy used to produce materials and the one used in transport systems, in some cases the delivered energy consumed from the transport can reach levels as high as the ones consumed by the manufacturing process of the materials. Plus a part of the energy that is related with the materials extraction is in reality part of the transport as well.

It is important to choose materials that can be extracted from a local source to reduce the energy consumed by the material transport. Although in many cases this cannot be achieved due the need for specific materials. This is an issue that have to be treated from the design process, where the suitability of materials has to be analysed and it has to be determined whether a material is worth implementing, taking into account the transportation costs and emissions that it entails.

Emissions

As a result of all this energetic consumption, the construction sector is responsible for the emission of greenhouse gases. Specifically, cement production is one of the biggest sources of greenhouse gasses emissions, and the use of concrete continues growing all over the world, being used twice as much as all other building materials together. In global numbers the construction industry is accountable for the 40% of the global greenhouse emissions (CIB & UNEP-IETC, 2002).

Land use

The construction industry is dependent of some specific materials: aggregates, cement, brick and clay products and wood. These materials as stated before, although highly consumed, are abundant. The problem in this case is related with the land use point, specifically in their extraction and transport (British Geological Survey, 1998).

In Europe as average, from 20% to 40% of the land is used in housing or related facilities (CIB & UNEP-IETC, 2002).
Land use can lead to:

- Deforestation. In developing countries forests are being harvested for the export market.
- Compaction of land. Urbanization involves land compaction due to building or infrastructure construction, which in many cases changes the attributes of the soil in an irreversible way.

About land policies, often in a competitive market, construction involves social problems, e.g. like the ones generated by energy biomass and food crops production.

Transport

The construction transport itself, without taking into account the consumption it entails, also can cause several problems. Noises and vibrations are generated, and the roads can be damaged. Moreover it contributes to the pollution of the city, which is directly connected with the need of air condition in buildings, which at the same time produce more CO_2 and other pollutants.

Transport can be planned to avoid unnecessary travels or optimizing distances. It has been proved that where there is parking space, the cars will be occupied just by one person each. So a careful planning has to be performed in this matter. Moreover with a good public transport service, it can be achieved a reduction of half of the energy consumed by private transport (UNEP, 2003).

To reduce transportation energetic consumption, buildings with high density are preferred, although it can lead to the impoverishment of human conditions. This can be solved through a well thought design. Another solution is renovation. In many cities of Europe refurbishment can be accounted for one third of the current construction works (Howard, 2000).

Water use

Construction water impacts are not easily quantifiable. Mining and raw material consumption cause siltation of rivers due to deforestation. Concrete spillage, and human wastes generation can poison existing water, even the one used for consumption.

Focusing in the source of the water supply, to achieve a sustainable consumption, water extraction cannot outrun the amount achieved by rainfall. Therefore, there is a need of control that these rates are not exceeded, and in the design to think about how the rainfall is going to return to the ground (UNEP, 2003).

Wastes

Concerning waste generation, in developed countries, construction industry held between 30% and 50% of the global waste. Although many countries reach a level of recycling of 80%, many of the material reused is qualified as low value material, so its applications are considerably reduced (UNEP, 2003).

Nowadays the majority of the wastes generated in construction are gathered in landfills. However, with a good waste management during the construction process, is possible to reduce waste production and it can be a profitable option as well. According to estimations (Howard, 2000), the waste in a construction project represent the 25% of the profits, if this percentage can be reduced to a 10% or a 5%, then millions of tonnes of wastes could be eliminated from going to landfill, achieving significant economic savings, avoiding many of the costs related with waste treatment, such as: disposal, transport and labour in the landfill area (Howard, 2000).

Recycling and Disposal

Separating wastes in the construction, for recycling purposes, can lead to the reduction of landfill rates, and can transform wastes into an asset instead of a liability.

As a general fact, the 40% of all construction wastes are produced in the renovation; maintenance and new development of domestic buildings, and the remaining portion belong to the rest of the construction sectors (Howard, 2000).

It is important to highlight that the timber recycling market is growing in horticulture and bioenergy markets, with the only restraint of the quality of the material.
For other materials, there is the need of a more extensive segregation, e.g. for plastic, cardboard or paper. Due to that need, the recycling of these materials is not in a very developed level. Moreover the existing collection systems available are not the desired ones for that kind of recycling treatment.
In the case of metal recycling, the main option is a scrap yard. Due to that, the recycling of metals in construction is less probable to happen than with other materials

Further environmental damages
Corruption in the construction industry also can lead to many environmental damages. Bribed personnel can favour the environment contamination by not paying attention, deliberately to pollution and wastes disposal (UNEP, 2003).

2.2.3 Social aspects

The development of a sustainable project will have a positive impact in the society. The most direct benefit is the creation of jobs related with the construction sector. Taking into account that many of them do not need high technical skills, so it is open to a wide variety of applicants.
Construction industry represents the 7% of the global employment, with a total of 111 million components of its workforce, and the 28% of the industrial employment (UNEP, 2003).

As a negative impact it can be stated that one of the social problems in the construction sector is the existence of corruption. According to Transparency International report in the year 2000, construction was the most inclined industry to take or pay bribes, over all in economic emerging countries, whereas the arm industry was the second (UNEP, 2003).
Quality standards for building construction can be compromised where corruption is involved, what can lead to elevated life dangers if natural disaster or building unexpected problems occur.

2.2.4 Building implementation, benefits and drawbacks

- ✓ Efficiency

Sustainability is a quality that gives the buildings an advantage towards reduction of energy consumption, both embodied and operating one. Therefore one of the main advantages of sustainable construction lays in its efficiency.
Technologically is highly developed if we compare it with the traditional buildings one. Through these advances it is possible a new healthier environment that reduce wastes, implement renewable energies and diminish the conditioning expenses.

From specific construction features, such as high performance windows, passive design solutions or high quality insulation; to the use of renewable energies, solar, wind or hydropower, all of them have been proved as high-energy efficient features to insert in a building project (Examiner, 2009).

- ✓ Maintenance

Sustainable buildings do not need as much maintenance as traditional ones, releasing the environment from the damages that would have occurred in the traditional situation, and saving time and money for the consumer.

- ✓ Higher property value

As stated before, sustainable buildings are highly energy efficient and the resultant costs for water or energy use is considerable reduced. An existing building with these features will achieve an elevated sale value in the stock market.
Moreover if through sustainability, the net zero building is reached, the benefits will change from less consumption to being a profitable asset (depending on the energy policies of the country), from which it will be possible to earn money by producing more energy that the needed one and returning the spare to the grid (Healty Holystic Living, 2011).

- ✓ Tax benefits

Many governments have initiated special tax programs to support the generation of sustainable buildings.
Furthermore, in the existing building stock market, it is being included the energetic certification, also with support of the authorities (Examiner, 2009).

- × Cooling performance

The cooling performance of a building using only natural ventilation techniques can imply some drawbacks, there is not a thermostat that can be set in the desired temperature and when a change is needed it may not come as easy as with a mechanism in an air condition machine, in this sense the level of comfort can be compromised. Moreover in non-residential buildings, this inability of automation can be a greater problem because of the dimensions of the spaces to be conditioned (Healty Holystic Living, 2011).

- × Orientation

The proper orientation for the best energetic optimization of a building is not always the one desired by the adjoining neighbours, or the local regulations.
Moreover to achieve a high performance of a sustainable project, it may be needed the installation of blinds or shades, and this may not be in accordance with the aesthetical image of the building design or the local regulations.

- × Green Roofs

The creation of a green roof may have also some drawbacks. When building the structure, it has to be taken into account that the weight of the roof is going to be higher, thus, it will be needed more material and resources to construct it, besides the one needed to build the green part itself.

- × Regulation

Unfortunately, sustainable buildings are not the common solution when undertaking a project, so regulations in the matter are not quite developed. Because of that, if there is not a legal advisor, the project can undergo through costly liabilities (Examiner, 2009).

2.2.5 Costs

One of the most important disadvantages of Sustainable construction is the one related with the additional costs. However, this consideration is often used both ways. On one hand, energy savings through sustainable techniques are supposed to overcome the additional costs, considering that the return of the investment will be medium or long term. On the other hand, initial costs are considerably high, which implies that investors in the big scale or private owners may not be able, or may not be willing to face this expense (Healty Holystic Living, 2011).

Nevertheless construction market competitiveness is speeding, and in the early future what it is seen now as a big investment, may be reduced considerably reaching even the individual consumer (Dobson et al., 2013).

As stated before, the sustainable construction is a process that needs of a long-term view. The principal benefits to obtain from it will be the reduction in operation and utility costs, the reduction of maintenance costs and the increase of the building energetic efficiency.

In many cases the short-term investment needed is too elevated to be competitive in the construction market. Regardless any advance made until now, the reality is that sustainable practices are not being implemented as much as they should to achieve the necessary competitiveness. This comes in consequence of the short existing demand and the general belief that sustainability comes at a price too high to afford for what it offers (BRE Centre for Sustainable Construction et al., 2005).
The construction industry is to blame in that case; traditionally it has been a secretive enterprise. None of the close participants related with it, clients or stakeholders would give any information about real costs. As a consequence, the actual cost of sustainability remains unknown for many (Halliday, 2008).
Gradually some of these data come to light, and it has been stated the wide amount of economic benefits involved within the sustainable construction, such as: reduction of the energy consumption, decrease of the water used, minimisation of the mechanical equipment needed (Dobson et al., 2013), high productivity, energetic efficiency, better corporate image and a real return on investment and increase of the value (Yates, 2001).

Researches have been done in this specific issue and have concluded that sustainable construction through energy efficient designs can be reached with higher cost reductions than the cost invested in a traditional building.
All around sustainability there is conflicting information about which weight give to what; e.g. if the environmental impact is important enough to increase the budget, etc.; that needs to be changed in feasibility studies. Some studies show that in the current practise, economic accomplishment is the main and only factor in the construction of a project, overlooking social or environmental issues (Shen et al., 2010).

2.2.6 Sustainability solutions for the construction sector

According to this analysis of the construction sector, several solutions can be given to increase its sustainability performance:

- Reduce waste production by increasing the existing fees applicable to landfill disposal.
- Recycling as a real solution. Wastes produced in construction such as building materials should have a closer look to determine where and how they can be used. It is not acceptable the reuse of construction wastes as material of inferior quality, only usable for minor works, but they have to be implemented in building products.
- Improve energy efficiency in the construction sector.
- Avoid water squander in construction sites, and improve its efficiency in its use in buildings.
- Integrated planning for building construction. Which implies a higher knowledge of the whole life of the building, and will allow from the design phase to increase the life service of the building and enlarge the future uses flexibility, in a long-term view.
- Redesign the existing policies influencing the construction sector, committing with them from a financial point of view, and reinforcing the present standards.
- Increasing the social and environmental commitment of the companies. Only by truly

engaging with this global responsibility, will be achieved the sustainable goal.

- Contribute to awake the social awareness, of users and enterprises, about environmental issues in this sector.
- Improve the work force training, and construction site health and safety requirements.
- Technological innovation in the fields of materials or construction management systems can give a push towards the future of the construction industry (UNEP, 2003).
- Increasing data collection systems to develop a more detailed base of knowledge for future projects that will help to increase the performance of the company.
- Currently, sustainability lies to the side of life cycle analysis, taking into account every stage of the project phase, from the design to the end of the building's life, thinking from raw materials to the future recycle or reuse of them (UNEP, 2003).

2.2.7 New build vs. Refurbishment

In the current building stock market, new construction buildings represent the 1% of the construction per year, and the existing buildings represent the remaining 99%.

The current situation in many cities presents some problems with the building stock. Numerous areas are in decay, with deteriorated environments and problems regarding security issues, resulting from the inadequate actions from local authorities and community groups. The actual degeneration of centric areas and this lack of involvement have made the inhabitants of the city move out of these neighbourhoods towards suburbia, promoting land occupation grow every year. To that fact, it is needed to add that all this population migrated from one place to another will own cars, generating another serious sustainable and social problem by increasing the traffic flow.
Sustainability means also taking care of sustainable urban developments. Cities need to keep on living with inhabitants inside and not only holding offices that become empty shells during non-working hours. A moderate population density will create safer areas and promote renovation actions toward building modernisation, avoiding as much as possible building decay (Sustainable Development Comission, 2005).

As stated before new construction buildings represent the 1% of the stock market being built. And even in the worst scenario for refurbishment, still the 70% of the buildings constructed existing today will continue existing in 2050. Thus, is more than reasonable to think in refurbishment as one of the drivers for construction in the early future (Sustainable Development Comission, 2005).
Moreover, improvements in large areas of a city may be accomplished faster and with fewer costs through refurbishment than with a demolition and new build project.
Existing communities regeneration will help to strengthen the cultural and historical heritage of the area. Besides, with refurbishment, problems that derive from new buildings, like the need of constructing new infrastructure for new settlements and the problem of transport impacts will be eluded (Sustainable Development Comission, 2005).

Relating refurbishment and redevelopment to evaluate them, in order to determine which is a better solution, is not easy. Refurbishment entails a whole range of construction works that go from small interventions to a reconstruction project. Regardless, the majority of the buildings to be refurbished will involve fewer investments and less time to finish the works.
Due to these reasons, refurbishment can be selected as a better choice, over all because of the economic savings it can contribute with. However, as a negative factor, the refurbishment can see increased its budget over the one of a new building if the risks it presents are not well managed (GVA Grimley, 2009).

Nowadays it exist a general knowledge about sustainability that hints that new buildings perform better than the existing ones. Standing buildings are seen as obsolete and incapable of being a good investment. And even if that view is not true, the building market keep on having this in mind as a fixed concept when deciding whether to invest in new or in refurbished.

In the recent economic climate, refurbishment is an option to ponder. It represents faster finishing times, and a lower investment to achieve high performance working spaces. With this in mind, owners or investors can reintroduce these buildings again in the market, obtaining a substantial return in the investment made.

Another point to compare between refurbishment and redevelopment is the different considerations that involve sustainability. Beyond energy performance or reduction of the gasses emissions point of view, sustainability ask for other requirements, social factors, for instance the quality of the working space itself for the workers and for the community where the building is located.
The specific location of existing buildings entails benefits by itself that will not be achieved with a new building located in another point of the city. The energy used for the transportation of workers to a distant point will exceed by far the one used to reach the previous one (GVA Grimley, 2009).
Moreover the community value of the building has to be analysed, and it has to be included in the parameters to take into account for the decision making of the project.

Currently the control over the embodied energy of the building is not clear, and in many analyses it is not taken into account. But the requirement levels for energy efficiency are increasing and it will come to the point where the conservation of the embodied energy related with new construction will be regulated.
The embodied energy is the one used in the manufacture and transport of materials used in the construction of a building. It represents in general terms the 10% of carbon emissions over the lifespan of a building. Nevertheless this percentage is taking into account a regular building, if the percentage is applied to a high efficient building, this energy percentage will increase (Sustainable Development Comission, 2005).
When the embodied energy efficiency levels are upgraded, the weight of the embodied energy will become higher, and this will result in a positive decision point towards refurbishment when comparing it with new buildings (GVA Grimley, 2009).

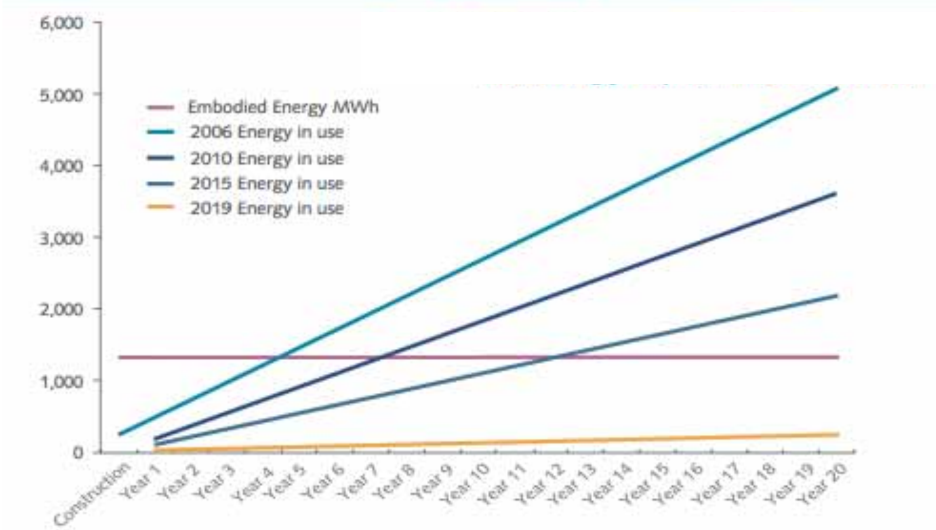


Figure 2.4. Embodied Energy (GVA Grimley, 2009)

CHAPTER 3 BUILDING REFURBISHMENT

3.1 Current status

As a result of the global economic crisis and the lack of invertors in the construction field, the construction industry has seen reduced its number of projects (Construction Industry Council, 2009).
Now the market assumes that the demand is leaning towards sustainable energy efficient buildings, and private and public sectors include that building feature as a basic requirement for a project development. (National Refurbishment Centre, 2010).
Of the two mentioned before, is the public sector the one that is increasing the pressure over sustainability issues, due to binding government targets set for greenhouse or carbon emissions reduction.

Given the existing population and the amount of buildings already built, in 2050, the 70% of them will be the same that are standing now (Sustainable Development Comission, 2005). This is a clear indicator of the role that sustainable refurbishment will play in the future of building construction. It represents not just a governmental target to reduce carbon emissions, but a further view that will increase the performance in existing buildings and a change of concept in the way of social thinking, where new was always better (Langston et al., 2008).

It is now of common knowledge, that refurbishment is a more logical solution that demolition in many cases, and it has been recognised by the researcher community from many years ago (TATA, 2012) (Gorse & Highfield, 2009).
From an environmental point of view, the refurbishment of a building as well as the recycle and reuse of existing products represents a real advantage compared to new construction, which will imply higher natural resources consumption. Moreover the demolition of a building can be the source of huge pollution problems in the nearby area, which in urban settlements will disturb the population and can be consider as a social impact as well as environmental (Langston et al., 2008).

Hence, is has been stated that refurbishment is an increasing value attribute to a building and it will represent a reduction in environmental, social and economic performances (TATA, 2012). The performance of a refurbishment can be as energy efficient and sustainable conscious as a new building (Gorse & Highfield, 2009), plus it add values such as its specific placement or the own building cultural characteristics.
Taking into account all what was stated before, it is clear that the demolition of buildings, in many cases, is a waste of economic resources and can cause more damages than benefits. In addition, the reuse of existing buildings will reduce the construction wastes and the material consumption (Edwards et al., 2001).

Even with all the advantages that refurbishment can offer, there is a general view among investors that new buildings will always be a better choice. Also within the sustainable concept, new buildings are believed to perform better from an energetic point of view, and the solutions implemented would fit better to the specific needs of the users, than refurbished ones (National Refurbishment Centre, 2010).

However, being this view of “new is always better”, general and narrow minded, in some cases the selection of a new building over a refurbished one, can be due to based financial reasons. If the cost of the refurbishment is substantially larger than the new one, and there are not

determining reasons to perform it, it will be unreasonable to choose the refurbishment (Gorse & Highfield, 2009).
Nevertheless, currently both points of view can be debated around this issue, and yet non of them will be totally suitable as a general option. Each project has to be studied individually to determine which problems and advantages can be overcome with a specific solution.

Refurbishment aims to extend the use of a building, offering an efficient alternative to new building construction. This efficiency, over all in the financial aspect, is debatable and in each specific case can be true or not. Each case has to be studied, and it has to be taken into account that many features will be involved in the project and will require collaborative efforts made by the stakeholders involved, to succeed in the decisions made when problems appear (Langston et al., 2008).

3.1.1 Building stock market

After stating the benefits of the refurbishment option over new build, an analysis of the building stock market is needed to determine in which situation are the existing buildings in Europe.
Surveys and databases has been studied from the Building Performance Institute Europe (BPIE) to ascertain the amount, characteristics and energy performance of this stock, to determine its availability for refurbishment. Therefore all the numeric data in this part of the report will be referenced to the BPIE.

Building Typology

The building stock market can be divided in two categories: residential and non-residential buildings. Inside each category there are many different typologies.

The European market possesses 25 billion m^2 of constructed space, and this figure is growing in a proportion of 1% each year. Contrasting data with other countries, Europe's density is the highest followed by China and the USA. It is understandable, taking into account the building development that this continent has had over the centuries and the existing land available; moreover, land occupation also may be related with wealth status and cultural heritage.
All of these indicators illustrate the land availability variation from one area to another. The existing floor space per capita in Europe is around $48m^2$, where in the USA is 81 m^2 and $21m^2$ in China. And certainly, between European countries, it exist asymmetry in these data.

As a general rule, the construction industry has always been inclined to occupy larger floor spaces, particularly if the economic environment was favourable. As the space needs were increasing, the energy demand linked with the buildings was also growing. This trend has led the market to turn toward energy efficient solutions, particularly its integration with the old existing stock.

The Floor space distribution in the European countries can be divided in three groups that answer to climatic, construction types and market similitudes. The North and West regions have the 50% of the floor space and the South and the East, the 36% and 14% respectively.

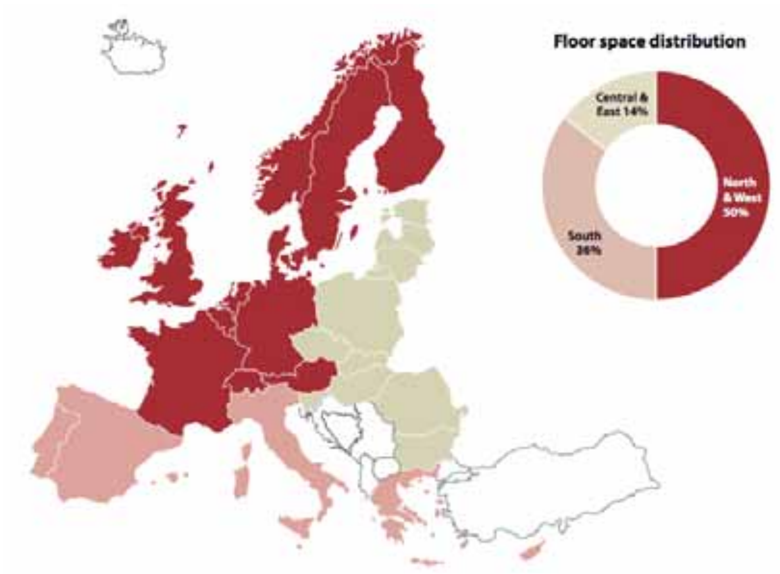


Figure 3.1. Floor space distribution in Europe (BPIE, 2011)

Data collected about the floor space per country, shows that France, Germany, Italy, Spain and the UK, which are the biggest countries, own the 65% of the European floor space. Which is consistent with the fact that the population in those countries accounts the 61% of the total one.
Nevertheless the connection between population and building area is difficult to determine specifically, because it depends on many factors as wealth, climate, existing demand etc.

Focusing in the floor space per country, it can be stated that northern and western regions hold bigger floor area than southern and eastern regions.

- **Residential building stock**

If the building stock is divided between residential and non-residential buildings, the residential ones represent the biggest section, having the 75% of the floor space.
From this residential sector, the 64% of the building floor area is related with single-family buildings and the 36% of this floor is related with apartments use.

As a general analysis overview of these data in relation with its location in Europe, central and eastern countries have both the lowest floor space area in single family and apartments buildings. There is a difference between southern and northern countries, showing that there are more single family in southern countries (possibly due to the holiday houses) and in the northern and western countries, the number of apartments is higher.

The annual growth in the residential construction market sector is about 1%. In the figure 6, a chart is shown where this growth is depicted for a group of countries during a time span from 2005 to 2010.
The majority of the countries present a decrease in new building construction showing the effects of the crisis in the construction sector. From these data it can be stated that this decrease is higher in countries from the central and eastern part of Europe.

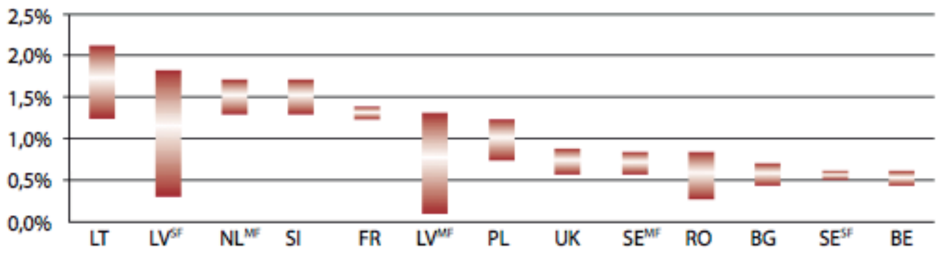


Figure 3.2. Range of new build rates in the residential sector (2005-2010) (BPIE, 2011)

- **Non-residential building stock**

This sector has not many similarities with the residential sector, its diversity is larger and it entails more typology complexity. This market can holds uses from offices, commercial areas, educational centres, hospitals, hotels, sport areas or industrial buildings, and it is usual that those uses can be combined in one building. Furthermore, typology and functionality of the building change when changing of country, so to make a comparison between different countries will not be as exact as with the residential stock market.

In figure 9, it is shown the huge difference that is found between countries. The use of offices and wholesale and retail is the highest in every country, nevertheless, the percentage of "other" typology of buildings in some countries is very high to make this results conclusive, and the typology division should be further developed.

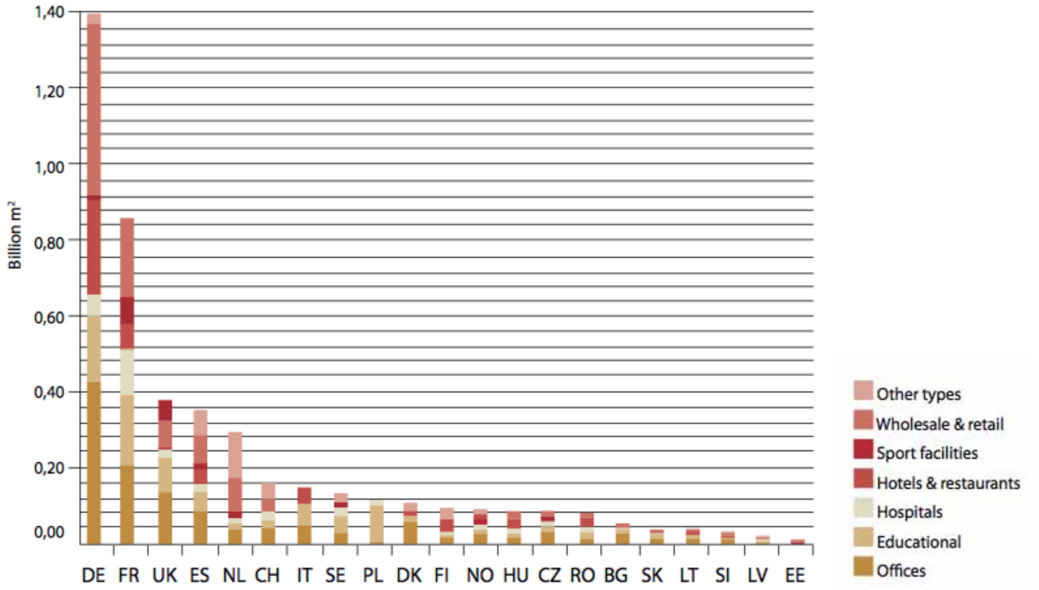


Figure 3.3. Non residential floor space in selected countries (BPIE, 2011)

From this summary it is stated that the residential building data can be catalogued and fully understood, but when referring to the non-residential building data stock, the information is not as clear and there are problems to keep track of the current stock because of its variety of typologies and uses.

<u>**Characteristics of the building stock**</u>

Besides the different typologies, buildings can be sorted by other terms, such as age, dimension and specific location.

- **Age**

All over Europe the building stock market is composed of many different age periods. Historical buildings are a topic aside due to their heritage values and cultural representation in their locations.
For the rest of them, building regulations in every country are changing and demanding a better energy performance depending in the age of the building and the use it is destined for.

Building codes and regulations from the period of the construction of the building have to be consulted, in order to determine its specific construction technique and the subsequent energy behaviour of the building.
Taking the residential market in consideration, the age of a building is directly connected with its energy consumption, due to the fact that many of the buildings have not gone through a refurbishment.

As a summary of the data from the residential market, this chart (figure 8) shows the age of the building stock for each country. To simplify the data only three ranges are depicted: buildings previous to 1960, buildings from 1961-1990, and buildings from 1991-2010.

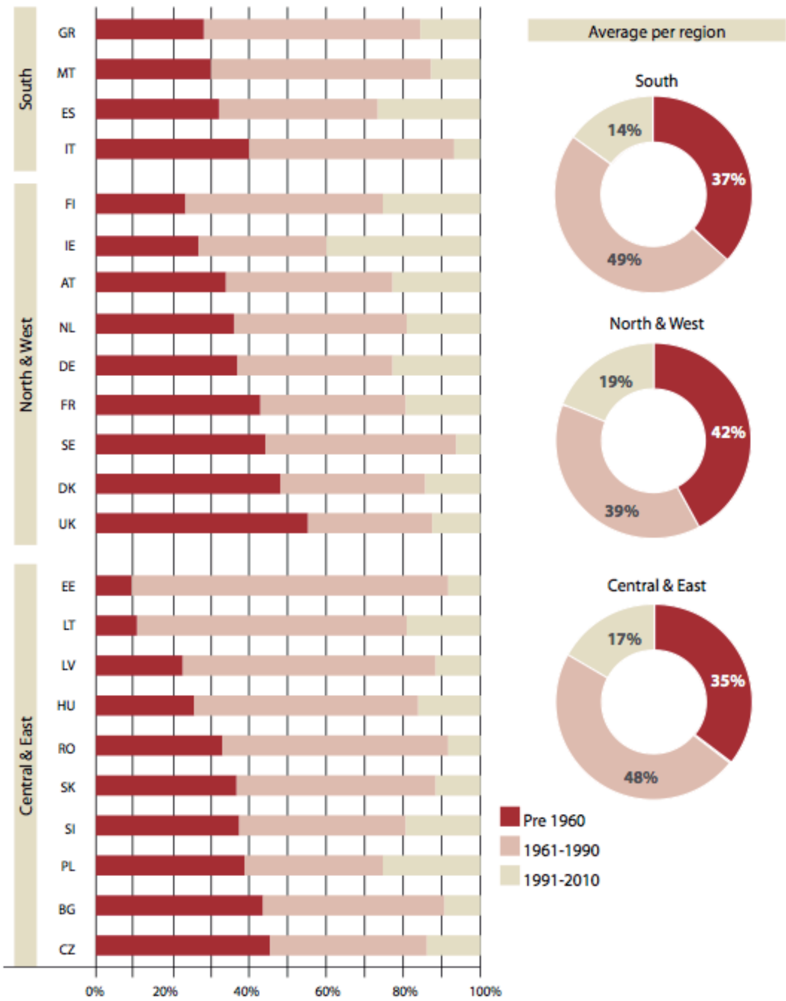


Figure 3.4. Age of the residential floor space (BPIE, 2011)

It has to be taken into consideration that the energy consumption varies from one country to another depending on the specific legislation of each place, plus several factors such economy and social issues.

From this chart can be read that as an overview of the building stock, there is not much difference between countries. In northern and western countries it appear to be a higher amount of old buildings, dated from years previous to 1960. Also it is noticeable the increase in the construction during the middle period from 1961 to 1990 all over Europe, almost doubling the building stock.

- **Dimension**

The dimension of a building more over if it is a non-residential building is useful to catalogue it in different groups of energy consumption.
Buildings with a size larger than 1000 m^2, like hospitals, sports facilities and educational buildings have needs considerably different from buildings about 200 m^2.

- **Location**

Location is also important to determine the characteristics of the building stock. In many European countries, urban areas have the bulk of the building stock with groups of buildings of the same characteristics due to the fact that they were constructed around the same year and possibly with similar structures.
Besides that information, it is usual to find more opportunities to refurbish in urban areas than in rural ones, because the urban environment can engage in renovating streets or communal parts of the city helping the buildings to update their characteristics as well.

Energy performance

As it was stated at the beginning of this report the building sector is the one main responsible for the energy consumption.
This consumption can be divided into different categories depending on which was the fuel consumed. Figure 9 shows a chart where this consumption is depicted, from this chart is possible to determine that the consumption of electricity and gas have grown in a rate of a 50% as the time passed by, and oil and solid fuels have been reduced to the 75% in the second one.

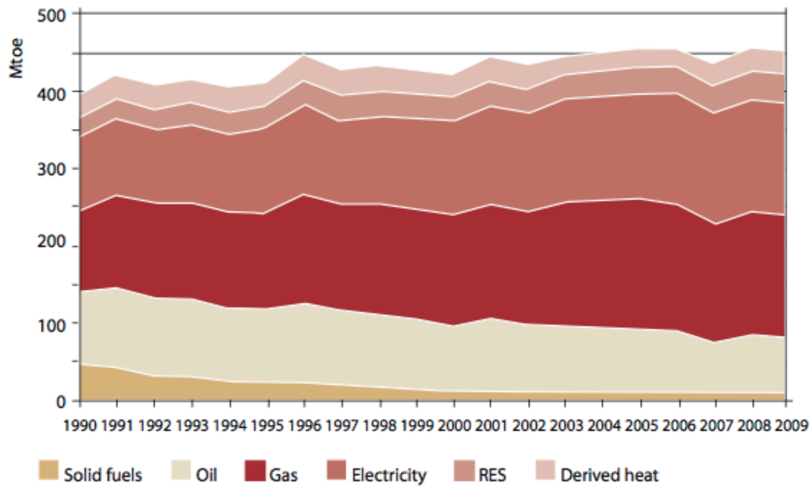


Figure 3.5. European energy consumption in the building sector (BPIE, 2011)

From that trend, a disturbing conclusion can be made: the consumption will continue increasing until dangerous level if no measures are applied to reduce it.

The other side of consumption is the CO2 emissions produced. Buildings in Europe are accountable for emitting the 36% of this gas. In figure 10 are shown the emissions depending on the European country.

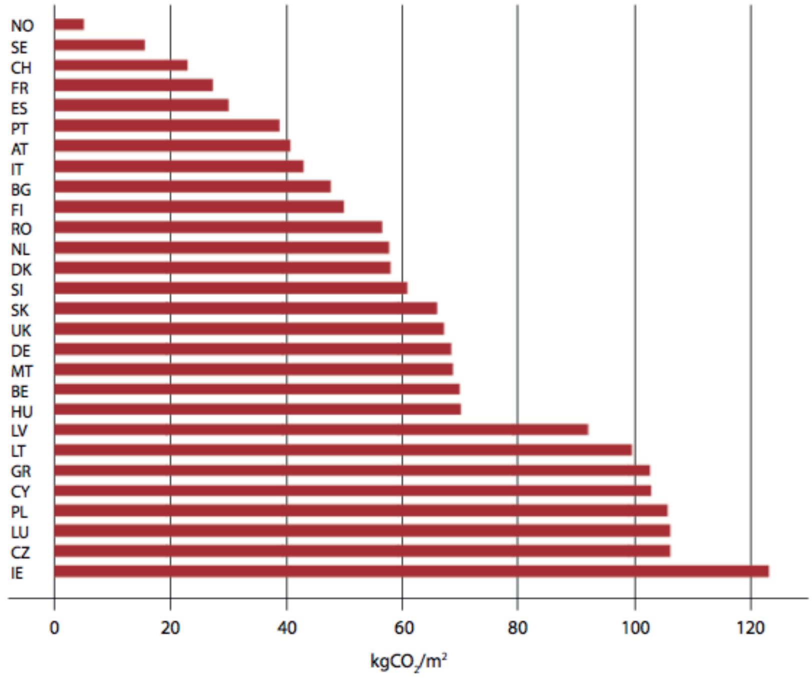


Figure 3.6. CO2 emmissions per country (BPIE, 2011)

To reduce these emissions buildings should improve their performance.
It must be taken into account, while reading this chart that depending on the country the consumption of the energy will be different, depending on the energy itself. Buildings consume an energy mix that can source from different points, from renewable energies, district heating systems or cogeneration plants to the dependency of nuclear energy as in the case of France. Due to that reason this country appears as a low producer of CO2.

- **Residential buildings**

As the residential market is the biggest one, as well is the responsible for the most of the energy consumption. Data from Eurostat shows that in 2009 the European residential market consumed the 68% of the total building energy.
The consumption of every residential building is linked to the use of the building itself with all appliances needed by their inhabitants. However it can be noticed that the biggest consuming activity is the conditioning of the building, heating and cooling, although cooling is not as important.

- **Non-residential buildings**

The energy consumption in the non-residential market is a more difficult problem than in the residential one. Many factors have to taken into account to evaluate the consumption, ventilation, heating and cooling, lighting, etc. Moreover depending on the specific use of the building these values will vary greatly from one building to the following one.
A fact to state is that electricity consumption has intensified in a 74% since 1990 as shown in figure 11, mostly due to the technological changes that society had experienced since this year.

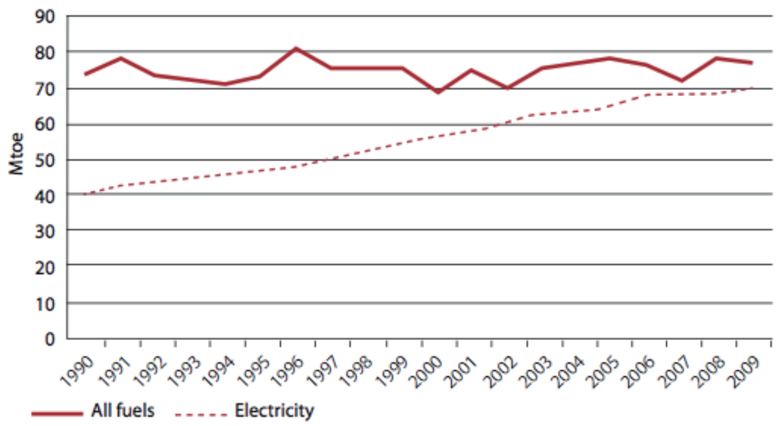


Figure 3.7. Final energy use in the non residential sector (BPIE, 2011)

And this consumption will continue growing as the IT systems advance with the time

In construction terms, residential and non-residential buildings are in many aspects alike. The data collected from the building performance or from its behaviour analysis will be similar to the surrounding ones, if they have been built with the same techniques in the same period.

Whereas the energy performance of the building can entail the same problem patterns, and thus similar refurbishment solutions, in a residential use than in a non-residential, the installation of control systems in non-residential uses represents a more important improvement than in residential buildings. The elevated electricity consumption of their use gives more weight to the savings that can be achieved through building energy consumption control. As an example, the lighting of a non-residential building can be highly improved by control systems that will take care of adapting it to users flows.

3.2 Benefits and Drawbacks

Regardless of the possibilities that the market offers for refurbishment, a series of considerations have to be studied more thoroughly to determine the profits and risks to face when undertaking a refurbishment.

Overall the main problem for refurbishment to be implemented instead of directly decide for a new construction is the investors decision, and all the decisions that come with budget and whether it is going to be worthy to invest with the risks that refurbishment implies (WWF, 2002).
Nevertheless, within this big problem, some specific ones pop up: The misrepresented energy prices, the unqualified personnel in charge of taking decisions and the market problems related with refurbishment construction.
All these problems will be analysed in the following part of the report.

3.2.1 Economic point of view

The economic problem will be always one of the main drivers for any kind of project, and in the specific case of refurbishment, taking into account all the risks this option entails, the costs of the project will have more weight in the decision of whether invest in one or in another.

Investors and the construction sector in general, have the opinion that when comparing new build versus refurbishment, the new build choice will present a better set of qualities than the refurbishment. It is believed that performance and durability will be superior even the costs, due to possible problems usually related with refurbishment, will be lower at the end. All of that including that the end user comfort satisfaction, or the idea of progress and technology advance is always related with new construction instead than with upgraded systems or building characteristics.

The reasons of this economic disbelief are somehow based in previous experiences involving refurbishment projects.

As a general assumption, the cost of a refurbishment will be inferior to the cost of the demolition and erection of a new building (Gorse & Highfield, 2009), and will represent a reduction in the time to perform the project and the cost estimated for it (TATA, 2012).

However, hidden costs or transaction ones can appear in some cases if the needed information has not taken heed of, or the planning has not been made with the attention needed. If the budget was not specific enough or the building starts to show new problems as the renovation goes by, it can result in the cancelation of the project. According to Ecofys, hidden costs can reach up the same level than the budgeted costs of implementation of some solutions (Ecofys, 2009).

Moreover, when comparing the refurbishment project with a new building located in a more convenient position, the cost benefits balance is not that clear.
The sale of a plot well positioned on a city can be considerably profitable, and the construction of a new building from scratch can have a comparable budget than the one of the refurbishment.
It will depend on the investor point of view, and the specific preferences for the functional use of the building, if the investment is comparable, to choose between the refurbishment or the new-built. It has to be noted that this comparison is made without taking into consideration environmental or social benefits from refurbishment that could incline the balance towards refurbishment.

On the other hand, it is stated by researchers that a well-planned refurbishment involves a reduction in the cost of a project. Moreover the cost reduction, there are many benefits to take advantage of a refurbishment when compared with demolition and new buildings.
In many projects, choosing the alternative of refurbishment can stand for a reduction of the time needed to finish the construction works of half or one quarter of the time required for the demolition and new construction (Gorse & Highfield, 2009).

Including the sustainable issue to the refurbishment, it has been analysed that investments in energy efficient buildings can usually present some trust problems. Financial stakeholders still have not the needed experience to state if a sustainable refurbishment can be a profitable solution, so the building renovation market is not as developed as the traditional one (THINK, 2012).
Hence the investment in refurbishment is moderate at the best. Besides the uncertainty of the real savings until the construction is performed, leads banks to be conservative about concluding contracts based on undetermined savings. The absence of financial support for energy efficient buildings represents a real barrier for that kind of projects (EuroACE, 2010).

3.2.3 Market related problems: Inaccurate information

There are two problems with information, the inaccuracy or the lack of it. With incorrect information, all the measures of an existing building will be long, difficult and consequently costly. Moreover it can end up in deficient services (Holt et al., 1995). On the other hand, the lack of information will lead to an inadequate refurbishment with a negative result for the building.
One of the biggest disadvantages that refurbishment involve is this inaccuracy that the projects entail and the risks that are added with it.

The usual uncertainties that can be found in refurbishment projects are: gaps of information, transaction costs and other external problems. In many cases the contractors are not selected well, due to the ignorance of the quality and types of materials or their low knowledge of the actual status of the building, all of that results into in an inadequate performance of the refurbishment market.

3.2.4 Misrepresented energy prices

In addition to the uncertainty, there are other external problems to undertake in a refurbishment and that can make this option less attractive to the building market.

Nowadays, environmental issues are not included in the final energy prices (Gillingham et al., 2009), what does not provide a fair comparison with the buildings that take care of these issues.
Unfortunately current energy prices are yet not related with the emissions that they produce. Despite all the attempts of the EU to integrate the energy market in Europe, there are many countries where the prices for end-users are regulated. Also some EU countries subsidize this consumption by lowering the taxation price on some energetic products (THINK, 2012). With these kind of policies, energy efficient solutions are more expensive and hence, less interesting for the final investors.

Furthermore, nowadays in the construction market when refurbishing a building, energy savings or gasses emission reduction are not one of the principal concern.
Right now exist green building energetic labelling programs that analyse and evaluate the quality of the buildings, but it must be said that in many of them only around the 30% or less of this evaluation is directly related with the energetic savings. Being other points of quality improvement, accessibility, provision of health and well being (THINK, 2012).

On the other hand, as a positive point, the first investors that had experimented reduction of the consumption will create a positive view of the sustainable refurbishment market.

3.2.5 Operational efficiency: personnel qualification

Building refurbishment requires many participants, many of which, have not the experience nor the required qualifications or the information needed to undertake this decisions. Risk evaluation objectivity then is at stake, because in some cases the perception of the economic investment/risk is partially biased.

In construction investments specifically, customers are more likely to be discouraged by higher initial costs, in the majority of the cases investors tend to go close to save money decisions at the beginning and short payback period that to save it in the early-middle future (THINK, 2012).

3.3 Environmental aspects

Every point studied in the building sustainability chapter of this research can be applied to the refurbishment construction, however in this part, the specific environmental aspects related only with refurbishment will be analysed.

From a sustainable point of view, building performance towards energy consumption is one of the key points where changes have to be made to reduce negative implications. One of the less environmental invasive ways to minimise consumption and increase the environmental advantages, is the reuse and recycle of materials, instead of the raw consumption that a new building will entail (Gorse & Highfield, 2009).
By definition, refurbishment implies the reuse of an existing asset, which is a sizable advantage facing new construction. Moreover, when demolishing a building, a huge loss of materials occurs including the following disposal of waste materials will generate carbon emissions (Baker, 2009), and it has to be added the pollution generated by the demolishing action itself.
To that reuse it has to be added, the reduction of land occupation in comparison with new build.

Researchers have stated then, that refurbishment involves considerable opportunities towards energy consumption savings (Zavadskas et al., 1998). Certainly, the reuse of a building, where many of its parts are directly functional by themselves, reduces the environmental impact from production as well as from transportation.
The managing of all the process from a sustainable point of view can result in a benefit. Benefits can be obtained from the use of reclaimed materials and from the recycle of used ones.

Moreover the waste disposal problem, that has been always an important drawback in every construction project can be seen from the point of view of the reuse by segregation of materials on site.
Through careful planning, transport costs can be minimised, and local services can profit from that fact, which will imply a closer involvement with the social aspects around the construction place (WWF, 2002).

The majority of the buildings susceptible to refurbish are located in urban areas. When deciding between refurbishment of new build, it has to be taken into consideration that the refurbished building is likely to have a more privileged place in the city than the new build, which will be relegated to a more distant location. The transport of the users from the building and its environmental impact it is a point to be analysed. Through refurbishment a larger amount of transportation energy will be saved thanks to a better location. Moreover as the building will be better connected with public transport systems, this transportation energy will also be reduced.

3.4 Social aspects

Many social aspects are involved when undertaking a refurbishment, due to the amount of stakeholders that it entails.

By refurbishing, city centres are kept alive, and the cultural heritage of urban areas is preserved. Furthermore, it will give a value to existing building and will contribute with the continuous development of the city through time.

A lower visual impact will be generated than the one created with a new building, just by the fact that the refurbished building held already this place, and the social consciousness of the city had accepted it as part of its image.
Community groups tend to be reluctant to the aesthetical change of the city, and will be more inclined for the refurbishment option.

Additionally, the disturbances created by demolition or and new building are not comparable with the ones created by a refurbishment construction. Moreover the displacement of the activity or the inhabitants of the building to be refurbished is highly respected from a sociological point of view in the refurbishment projects (Gorse & Highfield, 2009). Whereas with a demolish and new build, not only the current users of the building will have to see their activities disrupted, but the nearby area will suffer from the bypass absence of the service they used to have (Babangida et al., 2012).

3.5 Opportunities for building refurbishment

The mere existence of a building implies a notable asset even by its primary concept understood as a shelter, and further development in a producer point of goods and services. It is for that endless use a building will have, that makes it hardly possible for a building to remain in good conditions its whole life. As a result form all the changes it will endure, legislation, technology, comfort standards, etc., the building will eventually be obsolete, and there is where refurbishment has its opportunity to enhance the existing features and update the building to current regulations and standards (Babangida et al., 2012).

The option of demolition and redevelopment is not feasible for all aged buildings, so the majority of them will remain expecting a necessary refurbishment to be competitive in the market again (GVA Grimley, 2010). Refurbishment has many opportunities, and demolition only should be an option where the refurbishment overruns the cost of the redevelopment (Babangida et al., 2012).

Nevertheless, before undertaking any refurbishment plan, the status of the building has to be analysed to determine which will be the best solution if refurbishment or redevelopment (Zavadskas et al., 1998).
It is clear that the most important reason for undertaking a refurbishment project or not, is the financial issue (Gorse & Highfield, 2009), yet there are other problems involved, such as the permission of local authorities to the specific planning designed for a building that can be part of a cultural heritage.

One of the highest concerns of a client when undertaking a refurbishment is the disruption of the work performed in the building, it exists doubts about if the production will be stopped when the construction works start.
In many cases, it does not represent a problem, and the business can be develop with normality while the refurbishment works are developing.
Of course, a specific area of the building will be compromised, so the normal business activities that where supposed to develop there, will be disrupted.
Nevertheless, with a good design planning and the engagement of the participants at the moment, many of the possible problems can be avoided.

From the environmental point of view, as stated in this report, usually refurbishment will represent a better option. However the point of view, refurbishment will imply faster finishing time and lower final costs compared to demolition and new development of a building (GVA Grimley, 2010).
The refurbishment decision will be motivated by several specific situations that the building has to adapt to:

- A change of use, and consequently the space reorganization (Baker, 2009).
- The return to the market competitiveness (TATA, 2012).
- Quality update (Baker, 2009).
- New aesthetical requirements (TATA, 2012).
- Energy efficiency update (Caleb, 2010).
- Replacement of building deteriorated parts (TATA, 2012).

Independently of the reasons for refurbishment, it exist a range of opportunities to take profit of. If all the advantages are taken into consideration, the decision for refurbishment can be based on potentials of the building. In many cases it is a logical decision when evaluating the costs and the environment impact. If a building is reused, that entails significant energy savings just by the fact that there will be no raw material extraction for a new construction.

In addition to that, when refurbishing a building, the cultural identity that was linked to it, is preserved, and this is also a considerable contribution to sustainability.

Eventually, independently of the decision made, the costs and the way the clients are going to recover their investment through this project, will be the major driver for the project.
Prediction shows that with the raise of energy costs, the building market will develop in the direction of high-energy performance development in existing buildings, mostly in the areas of high quality insulation and indoor air control (TATA, 2012).

Seeing the advances of the market in this field, can be also foreseeing that sustainability will be an important goal in the development of the refurbishment construction. This new reality will help to increase the investments in research and innovation solutions for this market (TATA, 2012).

With a new responsible awareness towards sustainability, legislation is beginning to change, and it is plausible thinking that the market can balance between refurbished buildings and new ones.
What refurbishment projects entail, the sustainable care about environmental impacts and the increasing energy prices, will influence investors to decide for this option, and this market trend will increment the performance of future refurbishment projects.

3.6 Sustainable refurbishment examples

In this point of the report, some examples of refurbished buildings that have reached a high sustainable performance will be described, to show that this selection of refurbishment over new build is proved to be cost effective and it exist already in the building stock market; and reductions of time in the construction and energy consumption are reached in a substantial amount.

3.6.1 Savings bank in Rosenheim


Figure 3.8 Savings bank in Rosenheim, 1969 (Green magazine, 2007)


Figure 3.9 Savings bank in Rosenheim, 2006 (Green magazine, 2007)

Year of construction: 1969
Year of refurbishment: 2006

After a thorough study that included, expert analysis, model energy simulations and costs analysis, it was decided that the building was suitable to be refurbished.
The project developed a special glass and wood double façade in combination with an innovative cooling, heating and ventilation system. That transformed the building into a real icon of the city as well as an energy responsible building.
The structure was in good conditions, so it could remain untouched. Two new floors were added to the building, this new loads were counterbalanced with removed ones.
The façades are controlled by a mechanical system that allows the building to adjust itself to specific weather situations. During summer the glass façade opens to provide good ventilation and avoid overheating. During winter, the two façades are closed, so the air heats up and can be used as a heating system.
Including the usage of regenerative energy and the new façade that allows an improved ventilation, heating and cooling system, the total primary energy demand was reduced considerably: from 400 kWh/m^{2}a to 100 kWh/m^{2}a.
The final refurbished image not only achieved a great optical impact, but the individual parts of the façade were produced by local companies. That involves shorter transport distances, and the subsequent reduction of the energy wasted in transportation systems.

3.6.2 Emporio building in Hamburg


Figure 3.10 Emporio building in Hamburg, 2009 (Deal magazine, 2009)

Year of construction: 1964
Year of refurbishment: 2009

The specific situation of this project involved the refurbishment of a protected historic building. The project team had to work closely with the Monument Conservation Agency during all the project development in an integrated process.
The façade was protected and was retained almost completely intact. By avoiding the demolition of the façade, energy, costs and time were saved.
Construction recycled materials and products were used.
All building consumption is being monitored to ensure the long term energy savings and reduce the operating costs.
As a general monitoring of the whole building is being performed, it will be easy to optimise potential savings.
The project was energy and resource conscious, and implemented LCA techniques in construction and planning. One of the principal aims that were reached was to reduce the CO2 emissions from 2750 tones per year to 1700 tons. Moreover, the primary energy consumption was reduced to 158 kWh/m^{2}a.

CHAPTER 4 UNDERTAKING SUSTAINABLE REFURBISHMENT

According to the research conducted in this report, it can be stated that there are many reasons for selecting the refurbishment option over a new building:

- An existing asset is being recycled and reused
- The risk and return balance is more positive
- The finishing times are lower, so the building can be delivered in the market sooner, or it can be refurbished and used at the same time. This time and space advantage is a quality that new buildings do not possess. Depending in the grade of refurbishment, the construction can be from 15% to 70% faster than new build (AECOM, 2012).
- If the building has some special qualities that bond it with the cultural heritage or the image of the society where it is placed, it can be an important asset to take profit from.
- Refurbishment represents a cost saving option. By not constructing structural elements, depending on the grade of refurbishment, the costs can be reduced from 10% to 70% compared with a new build (AECOM, 2012).
- All the embodied energy used to construct the existing building will not have to be spent again, thus great energy savings will be achieved.
- By refurbishing the carbon footprint of a building is substantially lower than the one of a new building. The reuse and recycle of many parts of the building will entail a reduction of the environmental impact created by the construction of a building.

But not every building is suitable for refurbishment, so there is the need to a further analysis that will determine the suitability of a building for refurbishment.

In this part of the report, the planning process of a refurbishment will be analysed, including all the risks and possible problems, focusing later in the initial phase of preparation or feasibility of the project. Through this study it will be determined how to assess the suitability of a building for refurbishment before undertaking any further stage of the project.

4.1 Risks of undertaking refurbishment projects

A construction project by itself holds risks and uncertainties, independently of the type, size or location (Mansfield, 2009). In consequence, risks can be variably predicted, e.g. the refurbishment costs or the forecast of the finishing of the construction works, can be different from the predicted ones. Nevertheless, risks and uncertainties can be minimized through strategies of risk management. Researchers assert the crucial role of these strategies and how their implementation can guide the project towards a satisfactory and a controllable level of risk (Hillson, 2003).

However, refurbishment presents uncertainties, which sometimes obstruct the correct completion of the construction, and risk management strategies will be necessary in order to achieve the desired result. Moreover, within the refurbishment project it can be found besides normal problems of a building construction, occasionally aggravated, other specific problems from the existing building (CIRIA, 1994).
These other problems will include many uncertainties, risks and technical challenges related with the dimension of the work projected, the final cost or completion time and work scheduling (GVA Grimley, 2010).

Mainly due to deterioration of the existing building or doubts about the building itself, the refurbishment project has been analysed in many studies and concluded to have higher risks that the new build (Mansfield, 2009).

As project that involve more knowledge requirements, refurbishments are considered as more demanding, and needed of specialized experience and skills (TATA, 2012), collaboration between the parts involved and well planned coordination (CIRIA, 1994). For all of these reasons researchers state that refurbishment projects can have up to 50% more complication than new building projects. Therefore, information about the specific state of the building, costs, and design has to be handled by a specialist risk manager with expertise in refurbishment works (Abd Karim et al., 2007).

Taking into account the complexity of a refurbishment project, it is likely to end up finding the problems on site while the construction stages are being developed (CIRIA, 1994). Hence, from previous experiences, it can be stated that the uncertainties may appear in the following key points during the refurbishment project:

- Unskilled manpower (CIRIA, 1994).
- Lack of information from the actual status of the building itself (CIRIA, 1994).
- The structural damage of the building (GVA Grimley, 2010).
- Problems related with nearby buildings (CIRIA, 1994).
- Demolition and disposal problems (TATA, 2012).
- Health and safety (TATA, 2012).
- Procurement methodology (GVA Grimley, 2010).
- Bureaucratic work related with specific requirements of the building and the area where it is located (CIRIA, 1994).

All these problems can be minimised with the involvement of a contractor specialized in refurbishment projects, which will be able to anticipate possible problems related with the building itself or the techniques to perform. A specialist contractor can also procure specific information and advice about health and safety in a building refurbishment construction (TATA, 2012).

To all of this information it may be added the additional problem to face when the building to refurbish is a special cultural Heritage building or has any kind of historical value. In this case, the work to be done in the building will be shortened to the legal limit established by the local authorities (Babangida et al., 2012). The requirements asked for this type of refurbishment may demand longer transaction times to perform the construction than the rest of refurbishments, additionally demolition works or remodelling of the building may present the need of techniques and materials that are not the currently used or mastered by a standard workforce (CIRIA, 1994).

4.2 Refurbishment planning

The refurbishment planning is a difficult task due to its complexity and uncertainties. 50% of refurbishment projects began the construction only with a 60% of the design finished (Rahmat et al., 1998). These problems generate a need for a performance improvement that can be achieved by giving flexibility and incorporating all the participants in the planning process.

According to researchers, refurbishment, compared with new build, have the need of a more flexible integrated method (Boyd & Weaver, 1994). Still, the majority of the project managers

for building refurbishment choose the same approach than the one used for a new building, with limited changes.
From all the process to manage in a refurbishment project, the planning is the most challenging part that has to be faced by the manager (Egbu, 1997). It has to be taken into account that many of the decisions made will be done under the shadow of uncertainty, without the necessary information to face the construction. It is this inability to answer to the specifications of the building and the construction, that make architects incapable of giving the contractors a clear scope of the work to be done with enough time (Rahmat & Shah Ali , 2010).

If refurbishment planning is compared with the planning in a new building, in refurbishment a big amount of this work is developed within the project execution. To that, it has to be added that planning for refurbishment needs a higher amount of time, particularly when gathering needed external data, for example material availability, or specific equipment (Rahmat & Shah Ali , 2010).
According to researches, despite the size of the refurbishment project to undertake, tenders can have a higher bid variation than a new build tender (Quah, 1998).
This is due to deficient specific information obtained through surveys and the lack of technical knowledge related with refurbishment project problems.

Is in the design stage, where the planning process can be highly enhanced, the changing costs represent a small percentage of the total project compared with the performance benefits contribution of the design. Furthermore, time can be saved through a good design, avoiding future problems if the design is well developed. On account of this, management in the design process have to be upgraded to achieve a better start point for the start of the works on site (Ali et al., 2009).
But is not only the design itself which can have a significant improvement for the refurbishment, participants with technical skills in refurbishment projects are needed to cope with problems derived from uncertainty in the planning process.

4.2.1 Integrative mechanisms in the refurbishment planning

The problem with uncertainty is that, when tasks have to be accomplished by the specific participants if uncertainty increases, then all the information has to be handled at the same time as the task is being performed (Galbraith, 1977). This uncertainty is subordinate to the number of participants in the project and the relation of the tasks each of them are performing. Subsequently when the quantity of participants increases, the extent of information to be analysed increases too. Furthermore, if the amount of related tasks increases, more information will need to be handled.

Consequently, uncertainty brings complexity as a side problem, and it creates a need to separate the tasks to be accomplished in specific groups and the need to apply integrative mechanisms to connect these tasks.
As more participants are involved in different tasks, it happens that the communication between them is full with gaps and inaccuracies, and as a result project decisions and their posterior implementation are delayed, resulting in a process described as “planning gap” (Rahmat & Shah Ali , 2010). For instance, the relationship between a local authority and a skilled technician, and their specific tasks to be performed, is unsustainable and artificial. Thus it is essential the integration between planning tasks and participants (Laufer et al., 1994).

As a general rule, the main important points concerning project planning were considered the techniques related with time schedule of work and cost estimation (Harrison, 1992).

Nevertheless, as stated before, there are many other points to consider when undertaking the planning process of a project. As an example it can be stated that in the decision making process, when activities and their participants are interrelated, they should be integrated to avoid inaccuracies and time consumption (Laufer et al., 1994).

It exists more problems in refurbishment planning due to uncertainties than in new buildings. Actions and results from the planning process are harder to determine. And new planning models are so focused in new build projects that result inadequate for these kinds of uncertainties (Laufer et al., 1994). Consequently, the work done by the manager in charge of the refurbishment is more difficult, and the goals, organization and integration methods are not easy to be set in motion.

This complexity of participants, technology and specific work to perform, has resulted in the specialisation inside the construction industry (Walker, 1989). To this specialization of course are joined the adjacent specialists of each field, each of them able to contribute in the decisions to be implemented in the building, and thus increasing the differentiation and connexions within the construction process.
This differentiation can be due to several factors:

- The tasks to be performed require a high level of specialization.
- The contract of the project is issued in that way, contracting each problem to a different specialist.
- The inability of the project manager to plan the needed resources of the construction.
- The workforce or the management department has a lack of the knowledge needed to perform this project.

Some researches highlight that in small refurbishment projects, where there is not a need for that amount of specialisation, it exist overlapping between the different participants and the planning and control tasks performed by them (McGowan). This can also worsen by the fact that in these projects, responsibility is not well defined which can lead to conflicts during the project construction. These conflicts are what specialisation wants to address and give a solution to.

Another issue that increase project uncertainty is the maintenance of fixed prices for the project (Hillebrandt , 1974). Traditionally, procurement was developed in early stages of the planning process, mostly during technical or engineering design stages. Therefore, the planning engineers should be in charge of the pre-bid planning.

The project manager has to take control over time scheduling, bid issuing and awarding contracts, because contractors do not have the needed experience. When addressing a new project, is very difficult for a project manager to stop working in an active construction to change to a new one. With this change the project manager must focus immediately in the organization of the new one (Stukhart et al., 1986).

The site manager of a construction project, does not have the time for rearranging the project planning each time a change is made in the construction process (Syal et al., 1992). For this reason, the construction planning evolves changing with time, and as problems arise they are solved in the moment. Thus the planning has to be organized by different participants, combining efforts to achieve the best performance possible. A cost estimator, that will be in charge of the budget meeting the needs of the construction, and a planning engineer or a subsequent consultant, which will be in charge of time scheduling and deadline completion (Laufer et al., 1994). It has to be pointed out that, site managers or construction managers usually do not have time during the project construction neither during the preliminary phase of the project.

The majority of the companies decide to employ planning engineers, or to create a planning department that will be efficient and will be responsible for changes made during the construction phase and the consequent re-planning implementation. Resulting from tasks differentiation, there will be in the construction, a planning engineer, a contract manager and a site manager. From there the tasks of the planning engineers will be the long-term scheduling, and the tasks for the site managers will be a short term planning.

Even when the site manager has time and is willing to get involved in the long term planning, but the personal skills and knowledge is not the required for the situation, could be damaging for the performance of the project (Harrison, 1992). To set all the needed documentation and plans, and the communication of them, it is essential having plenty of time (Laufer et al., 1994). The transformation of a group of decisions into a specific plan is a task that demands special training, technical skills and experience in the field of planning. If site managers do not have the experience or the knowledge of a planning process, it will be hardly possible for them to forecast and answer problems, particularly in the complex refurbishment field.

It has been stated by many researchers that, the main important points for the organization of a project are, the decision-making and the information processing (Galbraith, 1977). And the number of participants involved in this process is due to their limited ability for information processing.

Due to the high amount of participants and the complexity rate that a refurbishment construction entails, the best alternative for managing these projects and the uncertainty they present is the integration of the planning process and the participant decisions. Lawrence and Lorsch (1967) defined integration as “the extent to which the activities of individuals are closely co-ordinated in relation to the project objectives”.

Therefore, the performance of the communications throughout the planning process can be enhanced by the involvement of the specific participants in the decision-making process (Walker, 1989). As an example, in many refurbishment projects, key participants such as estimators, were left aside from the decision-making throughout the construction phase, which is an incorrect strategy since the higher the involvement of estimators in the construction phase, the lower the cost deviations from the initial budget (Rahmat et al., 1998).

4.2.2 Planning process

It has been stated in this report that refurbishment projects differ from new building in diverse ways. The existing constraints of the building structure, and orientation, make the project differ completely from a regular project of a new building.
To undertake the planning of a sustainable refurbishment then, a different path than the normal planning process should be followed for the construction of a new building.

This part of the report will focus in the preparation phase of the refurbishment project, through this study it will be determined how to assess the suitability of a building for refurbishment before undertaking any further stage of the project. However after the preparation or feasibility analysis, design, construction and use phases will need to be developed as a continued process that integrates the whole refurbishment, to achieve a fully sustainable building.

Preparation phase

Achieving a sustainable building is a challenge that has to be organized with a thorough planning strategy. Furthermore in the special case of a refurbishment, where so many participants are involved, and with the amount of information that has to be handled, the planning has to be developed carefully not to overlook the sustainability implementation.

Within the preparation phase of a refurbishment project there are several steps that have to be followed in order to ensure a good sustainable performance:

- Engage the project completely with the sustainability aims

Sustainability has to be the key point for the project to achieve a high performance of the building. If the sustainability of the building represents only a marketing point of view to add to the budget, then it only will be seen as an over cost by planners and estimators, and they will transmit that to the rest of the stakeholders involved. Every participant in the project and building life has to be fully engaged with this aim to achieve the best solutions for the specific situation of the existing building.
Many construction companies have environmental policies, however, when undertaking small refurbishment projects, they skip sustainability opportunities.

- Determine what is sustainability in refurbishment

The objectives for the project should be clarified with a requirement sustainability list. These requirements should define the scope of the sustainable refurbishment for their further compilation in a detailed brief, which will include objectives and targets to be achieved. All the stakeholders involved in the project have to agree with the sustainable vision of the project.

- Determine the energy consumption of the building

It is essential to understand the energy consumption of the building before engaging a refurbishment project. This provides realistic targets to implement and proved increment in the energy performance (Carbon Trust, 2008).
All data collected about lighting, heating, cooling, etc., should be available to the design team. The investor or the final user of the building should be included in that process, considering that information about occupancy and type of use of the building will determine the consumption needs to be achieved.

- Clarify the sustainable targets that have to be undertaken

All the targets included in the detailed brief must be clear and well defined. Benchmarking with other buildings or setting energy performance goals in relation with the current building consumption can be valid approaches to reach these targets.
Modelling the building in an energy simulation software can contribute to determine potential energy savings that can be integrated in the building.

- Stakeholders opinions

An important part of the previous phase to design, is the analysis and establishment of the stakeholders involved in the project. Many stakeholders are involved in refurbishment projects, and the information they can provide can be an important input for the design development. Energy and facility managers have an extensive knowledge of the building and its operation performance.
Integrated planning is the solution to implement, to include all the stakeholders opinions with the targets of the project, and the operation of the refurbished building.

- Take into account the budget of sustainable implementation

If sustainable measures are one of the important parts of the refurbishment project, they will be included in the budget and not valued as a possible plus for the building.
However, the feasibility of the sustainable measures to implement has to be assessed. It is clear that the implementation of these measures will entail an increment in the project budget, in consequence a return on the investment analysis should be performed to determine the suitability each measure.

- Select a suitable design team that fits with the project characteristics

Knowledge and experience in sustainable refurbishment projects is essential to determine the design team. Sustainability entails a series of knowledge and techniques that to an unfamiliar designer will result in a negative decision to pursue them.
A project manager with the required experience will be needed to contribute with solutions beyond the average construction problems and to identify future potential risks. Specialists as well have to be included if the specific characteristics of the project demand it.
The project manager has to be specifically engaged with the sustainable aim of the project to ensure its implementation throughout the refurbishment process.

- A pre-assessment of the building is necessary

An important first step for a refurbishment is a pre-assessment of the building. This will determine whether the refurbishment project is worth to be conducted or not, and what are the possible problems and potentials to be taken into account.
Through this assessment the implementation of sustainable solutions will be analysed from the point of view of their suitability for the specific state, situation and use of the building.
This document has to integrate building current status, orientation and geometry, infrastructure and site potentials. With it, a better knowledge of the building will be achieved in the very first stage of the project and thus risks and building problems can be understood and addressed. Moreover, all building opportunities for sustainability will be identified and assessed.

This report will develop this pre-assessment for a refurbishment project through a check list to be answered by the current situation of the building, and a sustainability catalogue from which select the most suitable solutions to implement in the building.

CHAPTER 5 RESEARCH IMPLEMENTATION

5.1 Refurbishment check list

The scope and the future success of a refurbishment project are determined by the existing building. The existing building will set the constraints and the level of the refurbishment. The building will have its own fixed elements and there lies the challenge of a refurbishment, the specific design solution that will obtain the desired result.

To achieve this solution and a the higher point of the sustainability, many features of the building have to be analysed and many decisions have to be taken to avoid future problems.

In this research, a building check list will be developed, to analyse all the specific characteristics of the building itself, and to assess its suitability for refurbishment.
To complement this analysis, each building feature will be rated, to achieve a final grade, that will give a numeric idea of the suitability of the building for refurbishment.

The rating system will be subjective to the building condition and information available. In this report, a rating from 0-3 is given. The rating from the different areas of the state of the building will be added and the rating from the potentials will represent a 10% to add to the final number.
A final rating number will determine if the building is suitable for refurbishment. If the score obtained is over 55-60%, then the building will be suitable for undertaking a refurbishment project.

After this check list, a catalogue of sustainable solutions will be elaborated.

Remark:
To develop this check list, considerations have been studied from different sustainable certifications (DGNB, 2013), (BREAM, 2013), (LEED, 2013), and private companies catalogues (TATA, 2012), (GVA Grimley, 2009), (THINK, 2012).

BUILDING ANALYSIS		
State of the building		
Structure		
Current status		Questions
		S.S.01. Is the structure solid enough to continue its use during a new period of life of a building? For how long? S.S.02. Are the covering layers of the structure in good condition to face fire exposure? Or should they be replaced?
Rating		Answers
Materials		Questions
		S.S.03. What materials is the structure composed of? S.S.04. Are the materials in good conditions or have them started deteriorating?
Rating		Answers
Insulation		Questions
		S.S.05. Does the structure of the building have any kind of insulation? S.S.06. If it has, should it be removed, or replaced? S.S.07. Due to the specific situation of the building, should it have any kind of insulation?
Rating		Answers
Thermal mass		Questions
		S.S.08. Has the structure, the material or the thickness needed to use it as a thermal storage system?
Rating		Answers
Maintenance		Considerations
		S.S.09. The features of the structure design will imply its posterior maintenance. Evaluate the costs and problems that can be derived from it and bear in mind the requirements and standards to apply.

BUILDING ANALYSIS		
State of the building		
Façade		
Current status		Questions
		S.F.01. Is the façade in good conditions to continue with its use? How long will it be its lifespan? S.F.02. Is the façade fire resistant as it is? Or does it need covering layers to enhance its properties? S.F.03. Has the façade or any of its parts any kind of special value that has to be taken into consideration?
Rating		Answers
Materials		Questions
		S.F.04. What materials is the façade composed of? S.F.05. Are the materials in good conditions or have them started deteriorating?
Rating		Answers
Solar control		Questions
		S.F.06. What type of glazing does the building windows have? U-Values. Does it ensure functioning interior spaces? S.F.07. Do the windows have to be replaced or improved? S.F.08. Does the building have any shading system? Does it need it?
Rating		Answers
Thermal performance		Questions
		S.F.09. Has the energy performance of the façade been analysed? S.F.10. Is the insulation of the façade in good conditions to continue its use? For how long? Should it be replaced? S.F.11. Have the windows thermal transmission problems?
Rating		Answers
Maintenance		Considerations
		S.F.12. The features of the façade design will imply its posterior maintenance. Evaluate the costs and problems that can be derived from it and bear in mind the requirements and standards to apply.

BUILDING ANALYSIS		
State of the building		
Building internal organization		
Current status		Questions
		S.B.01. Is the structure grid able to create economically feasible interior spaces? Or will the spaces be too big or too small? S.B.02. Is the window rhythm as well able to create economically feasible interior spaces? Or will the spaces have too much light or too little? S.B.03. Have the interior walls the quality desired to continue their use?
Rating		Answers
Materials		Questions
		S.B.04. Are the interior wall materials in good conditions to continue their use? For how long?
Rating		Answers
Solar control		Questions
		S.B.05. Has the building any kind of interior system for solar shading?
Rating		Answers
Natural ventilation		Questions
		S.B.06. Does the geometry of the building allow the use of natural ventilation? S.B.07. Would it be feasible for privacy and access control terms, have a functional natural ventilation system, taking into account the new use of the building? Do the volumes and spaces to be ventilated allow having a natural ventilation system? S.B.08. Are there any underground areas in the building?
Rating		Answers
Thermal mass		Questions
		S.B.09. Are there any interior walls that can be used as a thermal storage system for cooling to reduce the air condition requirements? S.B.10. Is the structure, in the interior of the building, exposed in order of being able to function as a thermal mass system for cooling?
Rating		Answers
Maintenance		Considerations
		S.B.11. The features of the interior design will imply its posterior maintenance. Evaluate the costs and problems that can be derived from it and bear in mind the requirements and standards to apply.

BUILDING ANALYSIS		
State of the building		
Consumption		
Electricity		Questions
		C.E.01. Has the needed electricity consumption been analysed for the use of the building? C.E.02. Is it possible to reuse the electricity installation of the building or does it need to be changed? C.E.03. Can the performance of the appliances of the building be optimized in any way to minimise the consumption? C.E.04. Is the performance of the electricity in the building reasonable or not? What are the problems?
Rating		Answers

BUILDING ANALYSIS		
State of the building		
Consumption		
Heating and cooling		Questions
		C.H.01. Is it possible to climate the building only with passive systems, not having to install any mechanical system? C.H.02. Have the comfort levels of the building been analysed? Has it been determined if the climatic conditions are acceptable for the implementation of a passive system? C.H.03. About the existing heating-cooling system: is it possible to maintain its use? ▪ Is it in good conditions? ▪ Size of the systems: does it meet the demand of the use of the building? ▪ Is the area where the systems are situated sufficient for the new requirements? ▪ Are the control systems of the building able to reach the demands of a new building? Can they be used to optimise the systems or change with the changing demand? ▪ Is the control system capable of coping with all modern network communication systems? C.H.04. Has the heating consumption been analysed? Is the performance of the systems reasonable or not? What are the problems?
Rating		Answers

BUILDING ANALYSIS		
State of the building		
Consumption		
Water		
Existing features		Questions
		C.W.01. In the event that the building has a reasonably new plumbing installation. Will it be possible to reuse existing plumbing in the building? Or at least a part of it? Is the existing plumbing suitable for the use of the new building?
Rating		Answers
Water demand		Questions
		C.W.02. Has the water consumption of the building been analysed? C.W.03. Is the quality of the water at the appropriate level? C.W.04. Is it possible/necessary to control the water use in the building?
Rating		Answers
Plumbing		Questions
		C.W.05. In the event of reusing existing plumbing, does it ensure health level in the water?
Rating		Answers
Water resources		Questions
		C.W.06. Where will the water consumed in the building come from? C.W.07. Does the building have any kind of water reuse system?
Rating		Answers

BUILDING ANALYSIS		
State of the building		
Consumption		
Wastes		Questions
		C.WA.01. What kind of wastes is the building going to produce? C.WA.02. Has the building an acceptable wastes management? Or should it be improved? C.WA.03. Is the location for waste gathering the correct one? Or should it be changed?
Rating		Answers

BUILDING ANALYSIS		
Potentials of the site		
Potentials of the area		
District heating		Questions
		P.A.01. Is there a district heating system that can be used by the building?
Rating		Answers
Urban transport		Questions
		P.A.02. Are there any urban transport accesses in the nearby area of the building? P.A.03. Do they have a good connection with the city?
Rating		Answers
Parking space		Questions
		P.A.04. Does the building have enough parking spaces?
Rating		Answers
Nearby facilities		Questions
		P.A.05. Is there in the nearby area any kind of facilities that will make the working environment more pleasant?
Rating		Answers
Marketing		Questions
		P.A.06. Has the building a recognisable place in the city? P.A.07. Is the site a place where marketing goals can be achieved by the specific situation of the building?
Rating		Answers
Environment		Questions
		P.A.08. Has it been considered the waste of transportation energy that will imply the change of location for the specific use of the building?
Rating		Answers

BUILDING ANALYSIS	
Potentials of the site	
Potentials for renewable energies	
General information	Questions
	P.R.G.01. Is it available information about the use of renewable energies in the specific area of the project? This could give an idea about which energies are the most developed ones in the area, or which of them have a better performance and success. Also this will show local suppliers availability, and technical expertise.
	Answers

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Biomass		
Local information		Questions
		P.R.B.01. Is there in the area any producer of biomass fuel? P.R.B.02. Is the production of the biomass local, or will the transportation entail a greater pollution that the one saved by the use of this renewable energy?
Rating		Answers
Building space for installation		Questions
		P.R.B.03. Has the building space enough to perform this kind of installation? P.R.B.04. Will the installation disturb nearby buildings?
Rating		Answers
Regulations		Questions
		P.R.B.05. Does the local regulations allow the installation of these kind of systems? P.R.B.06. Do the community groups agree with the installation? Or will it entail a risk of official complaints?
Rating		Answers

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Solar radiation		
Local solar information		Questions
		P.R.S.01. How much direct sunlight does exist in this specific location in the range of a year? P.R.S.02. Is it worth the installation of the system with the amount of sunlight achieved during a year?
Rating		Answers
Orientation and shadows of the building		Questions
		P.R.S.03. Has the building the best orientation for the installation of the solar collection? P.R.S.04. If the orientation is not the desired one, is there any possibility to adapt the installation to achieve an adequate performance? P.R.S.05. Will the building have any shadows now or in the future that will obstruct the installation to perform correctly?
Rating		Answers
Building space for installation		Questions
		P.R.S.06. Is there enough space in the roof to install the system? P.R.S.07. Does exist the possibility of the installation of the system in the façade? Will it reach an adequate performance?
Rating		Answers
Regulations		Questions
		P.R.S.08. Does the local regulations allow the installation of this kind of systems? P.R.S.09. Do the community groups agree with the installation? Or will it entail a risk of official complaints?
Rating		Answers

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Geothermal heat		
Local geothermal information		Questions
		P.R.G.01. Have boreholes been performed in the area to determine the kind of soil and its properties? Has the soil the specific properties to achieve an adequate performance with this system? P.R.G.02. If no study has been performed, is it economically feasible to perform one to check if the system is at all possible? P.R.G.03. Is there any building in the surroundings with this kind of system that could change the soil performance?
Rating		Answers

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Wind speed		
Local wind information		Questions
		P.R.W.01. Has the necessary information about wind speed in the area been collected to determine if the installation of this system will be feasible? P.R.W.02. Are there other buildings or topography that could affect to the performance of the wind turbine?
Rating		Answers
Building space for installation		Questions
		P.R.W.03. Has the building space enough in the roof to install the system?
Rating		Answers
Regulations		Questions
		P.R.W.04. Does the local regulations allow the installation of this kind of systems? P.R.W.05. Do the community groups agree with the installation? Or will it entail a risk of official complaints?
Rating		Answers

CURRENT STATE OF THE BUILDING		
Potentials of the site		
Potentials for renewable energies		
Water flows		
Local water flow information		Questions
		P.R.WF.01. Has information about water flows in the nearby areas of the building been collected? P.R.WF.02. Would it be possible to take advantage of the water flow, or will it be impossible to modify it in any way?
Rating		Answers

Area	Rating				
Structure	/12	/54	%	%	FEASIBLE/NOT FEASIBLE
Façade	/12				
Building internal organization	/15				
Consumption	/15				
Potentials					
Potentials of the area	/18	/51	%		
Potentials of the site	/33				

5.2 Catalogue of sustainable solutions

This catalogue has been elaborated to answer the needs of the building and cover them with sustainable solutions, focusing in natural resources implementation that can be found in the specific location of the building.
This catalogue is not a unique solution that has to be implemented; it is a group of options where the best solution for a particular problem can be chosen, or where select the best option depending on a specific feature of the building or the environment it is located.

Remark 1:
Some of the points studied will be stated in this remark and not included in the catalogue inside of each subject.
All the solutions gathered in the catalogue, independently of the area or type of system, have to include the following considerations with regards to costs and maintenance:
Costs:

- Analyse the life expectancy of the system.
- Analyse the maintenance costs.
- The operating costs resulting from the use of the system have to be analysed.

Maintenance:

- High costs solutions.
- Quality standard achievement.

Remark 2:
To develop this catalogue, considerations have been studied from different sustainable certifications (DGNB, 2013), (BREAM, 2013), (LEED, 2013), and private companies catalogues (TATA, 2012), (GVA Grimley, 2009), (THINK, 2012).

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Structure	
Area	Considerations
Improvement	• If the structure is not solid enough or cannot stand the loads of the new use: ▪ In the worst-case scenario, where the structure cannot be repaired, the solution will be the replacement. Different structures have to be analysed to determine what will be the best solution for the use of the building. ▪ In many situations the structure is able to continue its use, if the loads are similar to the ones it was built before. In these cases, damages in the structure have to be located. The different reinforcement procedures have to be analysed to determine which and how to apply them. ▪ If it is possible to start the construction works in the structure of one specific floor while the others continue with their current use, the normal use of the building will continue while the construction works go on. Check this possibility with the investor or the final user of the building. This possibility has to be checked with the investors or the final users of the building.
Materials	• It has to be determined the materials and suppliers availability. • It has to be determined if the materials are in accordance with any aesthetic or cultural requirements of the design. • It has to be determined if the materials are coming from a local source to avoid as much as possible transportation emissions.
Insulation	• If the insulation has to be replaced, different typologies of insulation have to be analysed in order to determine the best choice for the requirements of the new use of the building. • Determine if the insulation needs to be reinforced in any point of the building. Different materials have to be analysed to determine whether if it is better to continue with the same material or with a different one. • In cases where slab exposure is needed, if it exist any insulation it has to be removed.
Thermal mass	• The structure can work as a thermal mass for cooling the building. It has to be determined if the current material of the structure can work as a storage system. Determine if with this material it will be reached the performance required to be an economically feasible system. • In case that is not possible, new thermal masses will have to be created to achieve the needed performance. • The existing thermal masses can be improved with other materials. ▪ Implementation of PCM. ▪ Slab exposure.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Façade	
Area	Considerations
Improvement	• If the façade is not in good conditions it will need to be replaced. If the façade is completely replaced, future problems such as thermal insulation, windows and glazing and natural lightning will not longer be a problem to face with refurbishment considerations. • If the façade need any kind of improvement, analyse the available refurbishment techniques, in order to determine which will be the best solution. • The design aesthetic for the new building has to be taken into consideration when deciding how the façade properties will be enhanced. • The aesthetic image of the façade has to agree with the image of the design project, if it does not agree with it, then it should be changed. • Local requirements have to be analysed in order to determine if the façade design has to follow a specific pattern.
Materials	• It has to be determined the materials and suppliers availability. • It has to be determined if the materials are in accordance with any aesthetic or cultural requirements of the design. • It has to be determined if the materials are coming from a local source to avoid as much as possible transportation emissions.
Solar gains	• Determine if the existing glazing provide the specific need of daylight and thermal transmission to the interior spaces. • Different types of glazing have to be analysed to determine which will be the adequate one for the use of the building. As a general rule, in order to reduce the heating gains through the windows, double or triple grazing has to be implemented depending on performance and economic parameters. Moreover, other technical advances are available for implementation depending on the investment of the refurbishment. • If the building have a shading system. Determine if it is worth to maintain it, or if it will be better to replace it with a new one. • If the building needs a shading system. Different types of external shadings have to be analysed. Determine if this system will be user controlled or mechanical controlled.
Thermal performance	• Take into account the importance of the façade related with heating or cooling systems of the building. The participant in charge of conditioning building systems has to be involved in the design process. • If the insulation has to be replaced. Different typologies and techniques of insulation have to be analysed in order to determine the best choice for the insulation requirements of the new use of the building. • Determine if the insulation needs to be reinforced in any point of the façade. Different materials have to be analysed to determine whether if it is better to continue with the same material or with a different one. • Due to the use of the building. Decide if it is necessary to reduce the glazing area in the façade. This decision has to be taken with the designers of the building. • An economic analysis of the vacuum insulated panels system has to be performed, to decide their use in the building.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Building internal organization	
Area	Considerations
Improvement	• It has to be analysed the adaptability of the existing spaces created by the structural grid to the specific use of the building, and if the spaces obtained will be economically feasible. • It has to be analysed the adaptability of the existing windows situation to the specific use of the building. Determine if more natural light be needed. • Due to local legislation requirements, determine if it will be possible to modify the façade, to achieve the interior lighting needed. • Check if the interior distribution of spaces can be reused, or part of it, for the new use of the building. If not, all the interior walls have to be demolished.
Materials	• It has to be determined the materials and suppliers availability. • It has to be determined if the materials are in accordance with any aesthetic or cultural requirements of the design. • It has to be determined if the materials are coming from a local source to avoid as much as possible transportation emissions.
Solar control	• If the building has interior solar shadings. Determine if it is worth maintaining this system or will be better to install a new one that will be in accordance with the new use. • If the building has a solar control system. Determine if it is worth maintaining this system or will be a better solution to install a new one adapted to the needs of the new building. • The shading system has to be analysed within the design process to adapt it to the desired aesthetic of the building. • Preparations for daylight lightning: ▪ Sunlight: it will be always an important asset for a building, yet it must be correctly planned to avoid unwanted solar gains. ▪ Shades: overheating is a problem in many buildings. Specially displeasing in non-domestic ones. This problem must be considered and shading systems applied to solve it. ▪ Different parts of the building can be upgraded with high quality insulation or changing the windows proportions to enhance solar control.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Building internal organization	
Area	Considerations
Ventilation	• Determine if the spaces of the building can be adapted to achieve a natural ventilation system. It has to be taken into account that the air has to flow from one room to another. Security issues have to be analysed within the design process to determine whether natural ventilation will be in discordance with the building security.
	System design
	• Analyse the possibility of installing natural, mixed or mechanical ventilation. It has to be decided in accordance with the design process. • The need of a back up ventilation system has to be considered. • The use of the building has to be taken into account. Determine the affluence of people that will use the building or if it will vary with the time. Determine if it is necessary a pre-installation for future higher demands. • If the building holds different uses. Determine if it is necessary to divide the ventilation systems to adapt to the different comfort requirements.
	Performance
	• The possibility of the appearance of cold airflows has to be evaluated. With a mixed ventilation system, when the weather is cold the air will not go directly inside of the building without being previously heated. • In the event of a double installation of natural and mechanical ventilation. All control procedures have to be set to optimize the efficiency of the ventilation systems.
Thermal mass	• Analyse if the use of interior walls as thermal storage system is economically feasible. It has to be taken into account that the mass of the walls has to be exposed. • The design of the interior spaces have to be developed thinking also in the thermal mass behaviour of the structure. It has to be taken into account that the slabs have to be exposed (no suspended ceilings). Check the feasibility of this solution. The ideal case will be to have the structure exposed for night cooling, nevertheless if the use of suspended ceilings is necessary, then diffuse ceiling ventilation can be used with acoustic suspended ceilings to distribute the air, and will not reduce the performance of the system. • If there are no interior walls to take advantage of. The design of the new interior distribution has to be thought from the point of view of thermal mass storage system. • Analyse PCMs to determine whether the material or the techniques can be adapted to the use of the building. There are some solutions that can be adapted to the refurbishment of a building: PCM composite wallboards, clay bricks with PCM macrocapsules or PCM microcapsule integrated plaster walls.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Building internal organization	
Area	Considerations
Natural lighting	Type of window

	• Selection of the correct type of glazing
	• Take into account:
	  ▪ Transmission
	  ▪ Heat gains
	  ▪ Thermal resistance
	• U-Values

	Performance
	• Analyse the possibility to install atria or patios in order to enter daylight to the spaces of the building. • Determine all the possibilities of reducing artificial lighting during daylight. Analyse control systems that interact with the shading system of the building. • Determine the need for direct or indirect light and its uniformity. • Analyse if the interior building spaces are set in order to enhance daylight achievement. • Analyse if the windows are placed in the right module or rhythm to allow space flexibility. • Determine if it has been taken into consideration the impact of the interior divisions in the performance of natural lighting.
	Problems and opportunities
	• Take into account the projected partitions of the building and their need of glazing area. • Determine if the furniture is going to be an obstacle for daylight, due to its colour or shape. • Analyse the possibility of installing automatic shadings, or user-controlled shadings. If the shading installed is user controlled, the possibility of misuse and underperformance have to be taken into account. • If automatic shading is installed, analyse the possibility of installing a system where the artificial lights are combined with the shading system to reach a better performance.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Building internal organization	
Area	Considerations
Artificial lighting	Lamps and luminaires
	• The lamps and luminaires selection have to be made from the point of view of energy savings. Analyse from the financial point of view the installation of sustainable lamps and luminaires. • The light delivered has to reach the needed standard for the specific use of the building or the spaces it is composed of. • The final lamps and luminaires have to be evaluated to ensure their performance fits the design requirements. • Maintenance costs have to be taken into account for the selection made. • The lamp or luminaire selection has to be made in isolation or in groups of luminaires where their real performance can be fully analysed.
	Performance
	• The needed light level in each space has to be checked depending on its use. • Unnecessary lighting should be eluded • The required light quality has to be achieved. The efficiency in the lighting system and the quality of the lighting has to be achievable goals at the same time.
	Control
	• Determine which part of the system will be automatic and which user controlled. • The building has to be divided in zones where the use changes and so will change the lighting needs. • Opening and closing times of the building, or of the main use of it, has to be analysed to achieve an efficient lighting system. • Determine if the system will be aware of the sunlight. If it will be able to control itself depending on the outside light and the inside darkness. • Determine if the control of the system will be local in the different zones or general for all the building. Local controls can be a better option to maximize customer satisfaction. • Analyse if it is necessary to install dimmable lighting. Taking into account that where daylight can be used, the option of dimmable lighting can minimise the energy consumption. • Determine if there are spaces that need the installation of presence detection systems.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Building internal organization	
Area	Considerations
Mechanised transportation systems	Type of motor
	• All the different type of motors in the market has to be analysed. High efficiency is a goal to aim for. • The influx of building users has to be analysed during its working time in a day. Determine if the transportation system can be adapted to this influx, for energy saving.
	Control
	• Control systems have to be analysed having in mind energy savings in the building.
	Possibilities
	• The different options for choosing a lift have to be analysed. • It has to be considered the possibility to install electricity regenerative system lifts.
	Design
	• Determine if the current location of the lifts is the right one to increase the efficiency of the transportation system. • Analyse the possibility of using heat recovery adjoining with the lifts use. • Analyse the possibility of adapting the system to day use and night use. Taking into account that the amount of passengers will vary heavily.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Consumption	
Area	Considerations
Electricity	• Determine if the existing electric service utilities can be updated to the current legislation requirements. Or if it will be a better choice to replace it with a new one. • All the appliances installed in the building have to be analysed to ensure optimal energy consumption. • All the possible monitor and control technologies have to be checked to ensure the correct operation of the building. • Different procedures have to be established in the control systems to adapt the consumption from the day use to the night use of the building.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Consumption	
Area	Considerations
Heating and cooling	• Having analysed the possibility of a conditioning system only with passive measures. If a mechanical system is needed determine if it is possible to combine it with passive measures. Night cooling systems are always linked with mixed ventilation system. • The external weather conditions have to be analysed in order to determine if the possibility of a passive system will be at all feasible. • Different systems have to be analysed in order to determine which of them will be the most suitable one taking into account the use of the building. This has to be analysed by the person in charge of appliances in combination with the design team, because beyond the system itself it has to be taken into account the geometry and the height of the building. • Determine if the chosen system is flexible enough to adapt to new uses of the building. Flexibility even when it implies a higher investment will have a positive result in the event of placing the building again in the stock market. • In the building design, it has to be taken into consideration the possibility of creating zones to divide different uses that will have different climatic needs. • Determine if it is better to have one system that cover heating and cooling, or if it is better for the use of the building a separate one. • The design has to take into account the spaces needed to install the equipment of these systems. • Control systems have to be analysed to ensure the better performance of the systems.

CATALOGUE OF SUSTAINABLE SOLUTIONS		
Building solutions		
Consumption		
Area	Considerations	
Heating and cooling	Night cooling	Possibilities
		• Analyse when is the cooling going to be needed. Establish peak demands. If the building is going to have a day use, then the night cooling can be the best choice; otherwise the performance will be not as good. • Determine if it is possible or cost effective to adapt the structure and the interior organization to the night cooling requirements. Ventilation has to be performed during the night and the structure has to be exposed to the air. • Analyse the implications related with the acoustic performance of the building when exposing the structure to the external air. • There are two problems related with acoustics: • Openings that allow the air to circulate will diminish acoustic isolation. That can be avoided by closing them during occupation hours. • When exposing the structure or the slabs as a thermal mass, the interior acoustic will become difficult to control. That can be partially solved by the use of acoustic absorbers, but in that case the costs of the system will be increased. • Temperature changes have to be checked to ensure the good performance of the night cooling. The night temperature has to be lower than the daytime comfort temperature for this system to be effective. An analysis with a dynamic simulation software will be needed to assess the performance of this system. • Night cooling systems will always be connected with ventilation systems. • Analyse if it is possible or necessary to install an automatic system, or if it will be acceptable to install a user-controlled system. • Determine if the installation of that system is going to present problems related with security, and how to avoid them. It has to be taken into consideration that if for the night cooling, windows have to be opened, and then a security problem has to be solved. The building is usually going to be unoccupied during night hours, so ground floor windows should be protected with bars or grills. This solution is not the best, from an aesthetical and social impact point of view; so another solution could be the separation of daylight and ventilation. Having independent air inlets for both uses. However, the creation of these inlets will increase the costs of the system.

CATALOGUE OF SUSTAINABLE SOLUTIONS		
Building solutions		
Consumption		
Area	Considerations	
Heating and cooling	Night cooling	Performance
		• Determine if it is possible to reach a high level of comfort using natural ventilation, or if it will be necessary to use also a mechanical back up system. Preference should be given to natural ventilation in order to achieve an energy efficient building. If during winter, a natural ventilation system by itself will not be able to reach the comfort levels required, a mixed system has to be implemented. • Overcooling has to be considered. Analyse the possibility of its existence in the specific location of the building • Control issues have to be studied. Although user controlled systems may be an option, they have drawbacks that make night cooling less operative. The control of the temperature or the openings during non-working hours can be unachievable.
		Problems and opportunities
		• Determine if it will be necessary to install carpets or suspended ceilings. If they are used, the efficiency of the structure as a thermal mass storing system will be lowered. Perforated ceilings can be a replacement instead the suspended ones. • High performance thermal storage systems have to be considered. For instance decking systems have high thermal storage capacity and if this technology is combined with PCMs, it can achieve a higher performance compared with concrete.

CATALOGUE OF SUSTAINABLE SOLUTIONS			
Building solutions			
Consumption			
Area	Considerations		
Heating and cooling	Chilled beams/ ceilings	Possibilities	
		• The opportunities of a chilled ceiling have to be fully analysed. An analysis with a dynamic simulation software will be needed to assess the performance of this system. • The achievable cooling results are reached with water temperatures around the 15ºC, so in comparison with the fan coils, chilled ceilings reduce the energy needed for cooling.	
		Design	
		• The use of the building and the needs of it have to be analysed in order to determine whether if the cooling is needed during night or during daytime. • The condensation problem has to be taken into consideration. To avoid that problem, cooling parts could need to be oversized to reach higher chilled water temperature, or the fact that during some days will not be exactly the one is set in the control should be accepted by the user of the building.	
		Performance	
		• It has to be taken into account that in summer the water will have a temperature of 16-20 ºC for a regular use, if it gets lower that this, condensation problems will appear in concrete elements.	

<table>
<tr><th colspan="3">CATALOGUE OF SUSTAINABLE SOLUTIONS</th></tr>
<tr><th colspan="3">Building solutions</th></tr>
<tr><th colspan="3">Consumption</th></tr>
<tr><th>Area</th><th colspan="2">Considerations</th></tr>
<tr><td rowspan="10">Heating and cooling</td><td rowspan="6">Evaporative cooling</td><td>Possibilities</td></tr>
<tr><td>• Analyse if it is possible to have a continued use of evaporative cooling during the whole year.
• Analyse the possibility of using an evaporative cooling system in all the building areas.</td></tr>
<tr><td>Design</td></tr>
<tr><td>• Analyse the suitability of direct or indirect system.
• Analyse the need for high air exchange in the building. If there is, direct systems will be the ones to be applied in that case.
• All the developing technologies of this system have to be analysed.</td></tr>
<tr><td>Performance</td></tr>
<tr><td>• Check the availability of the data to fully analyse the suitability of this system.
• Determine if it will be cost effective.
• Analyse if the system has the required energy performance. An analysis with a dynamic simulation software will be needed to assess the performance of this system.
• The maintenance costs have to be analysed.
• Analyse if there is in the building the right place to install the equipment of the system. Determine if it does affect in any way to the building, or to the performance of the system itself.</td></tr>
<tr><td rowspan="4">Waste heat recovery</td><td>Possibilities</td></tr>
<tr><td>• Analyse if there is unused heat that can be recovered and used to heat something else.
• Analyse if there are some electrical devices producing heat excess that can be reused.</td></tr>
<tr><td>Design</td></tr>
<tr><td>• Analyse the system options for a heat recovery solution.
• In this evaluation take into account cost savings, installation problems, future maintenance, flexibility for future needs and effectiveness of the system.
• Pre heating from glazed areas has to be taken into account.</td></tr>
</table>

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Consumption	
Area	Considerations
Water	Improvement
	• Choose the best suitable plumbing system.
	Water demand
	• If the quality of the water is not the required one. Analyse quality improvement systems. • Water consumption has to be optimized. • Water control systems have to be analysed to implement them in the building.
	Water resources
	• When the source of the water has been determined, the quality of the source has to be analysed. • Analyse the alternatives of new technologies or better performance companies. • Analyse techniques of water reuse to implement the better one to the specific use of the building. The implementation of low water use fittings, such as cistern displacement devices, delayed action inlet valves, limiting the flow rate in showers or fitting aerator or spray ends to washbasin taps, can enhance the water savings of the building. • Implement drainage and reuse systems implemented from the design stage. Grey water can be used as toilet water, but the acceptability of the users has to be ensured. • Take into consideration rainwater as an important resource from which take advantage of. Rainwater harvesting will need to include filters to remove unwanted particles. This water can be used for toilets, washing machines or outdoor taps for irrigation.
Materials	• The design process has to be made from a “reducing wastes” point of view. • New materials have to be analysed in order to implement them in the building taking in to consideration the precedence of the existing ones. • Analyse the possibility to include recycled materials instead of other if they perform in the desired way. If a recycled material offers the same quality as a regular one, it should be selected for its implementation. • Analyse if the material is easy to clean or if it will need chemical products that will result in an environment impact. • The use of raw materials has to be minimised. Analyse if the design of the building is aware of the environmental impacts created by the uncontrolled raw material consumption. • The material selection has to be made taking into account the source of the materials. This decision has to favour the use of materials that come form the local area. • Transportation energy consumption of the materials has to be analysed. • The design of the building has to be concerned about ozone contamination.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Building solutions	
Consumption	
Area	Considerations
Wastes	• A waste plan has to be created for the construction of the building • Analyse the possibility of recycling materials from the building construction itself. During the refurbishment there are three phases to reduce waste from. →The design phase: Maximize the use of recycled materials or reuse of the existing ones. Use of modular components to generate flexible spaces. In the design phase, the creation of a waste management plan will be a requirement. →Deconstruction phase: The company in charge will have to be inclined to deconstruction rather than demolishment. The company in charge has to have a waste management plan It will be a positive point if this company is related with a retail outlet of second hand building materials. →Construction phase: The construction company has to be flexible to use reused materials. Reduce and recycle the packaging of materials. • Develop a waste management plan to organize all the wastes produced from the building facilities.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Site potential solutions	
Potentials of the area	
Area	Considerations
District heating	• If there is a district heating system. Determine if the building has the proper installations to take advantage of its whole performance. • If its use is not compulsory. The performance of different heating systems has to be analysed to determine which will be the most suitable one for the specific use of the building. • An analysis has to be made of the final costs over a year that this system will entail. Determine if it will be a better cost effective solution than an individual heating system.
Parking space	• The building parking places have to be designed in order to be enough for the use of the building but not much, to favour the use of public transportation.
Marketing	• The building marketing has to be taken into account from the design phase, to take all the benefits from a good situation of the building in the city.
Environment	• Analyse if it is possible to heighten or maintain the current status of the environment in which the building is located, and how to make it possible. • Analyse if the refurbishment project will help to avoid environmental impacts in the local area, and determine the reach of it. • The design has to be performed from the point of view of where and how the construction of a project can be beneficial for the surrounding environment. • The ecological value of the surrounding area of the building has to be analysed and catalogued for further design considerations. • The final environmental impact of the project has to be measured

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Renewable energy potential solutions	
Solid biomass	
Area	Considerations
Supply	• The type of biomass fuel has to be decided based on availability in the area and performance of the system. • The access to the building has to be enough for the supply trucks. • The storage room has to be located in an accessible area of the building. • The storage space has to be analysed taking into account the energy needs of the building. The fuel volume needed has to be analysed. • The space designed for the boiler has to have a size enough to allow the needed maintenance works. • The quality of the different supplies has to be analysed.
Future of biomass	• The costs of biofuels have to be analysed during a long period of time, to determine whether they are likely to rise in price. • The suppliers have to be able to continue with their service over a long period of time. • The market trends involving biomass have to be analysed to determine how will affect for example a rise in the demand. • The legislation has to be analysed in order to determine if it is likely to change in detriment of biomass fuels. • The quality of the fuel has to be analysed in order to determine if it is likely to change in the future. Analyse if the quality changes the equipment will be able to adapt to it.
Environmental impact	• The CO2 emissions of a biomass system have to be analysed over its lifetime. • Analyse the selected supplier in order to determine whether the precedence of its product has been achieved in sustainable way. • The company of the supplier have to have an environmental and social commitment, show it in its policies and perform it inside the company.
Heating and electricity	• Determine if it will be installed a conventional boiler or a system that includes heat and power. • The heating demand has to be analysed in order to determine whether a biomass system is the best solution. • Analyse the possibility of supplying a part of the electricity with biomass CHP.
Back up system	• A back up system for the building has to be considered. Determine the options. • Analyse the possibility of mixing the biomass and the back up system in order for both to use the same boiler.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Renewable energy potential solutions	
Photovoltaic and solar thermal	
Area	Considerations
Location and shading	• Analyse the annual solar inputs of this specific location. • The building has to be analysed in order to determine which is the preferable orientation for the panels. • Analyse if it possible due the current location of the building to have direct sunlight, or if the existing topography allow solar radiation.
Panel installation	• Determine if the system will be connected to the grid or not, and if the grid connection is made in the proper way. Determine if there will be any kind of problem with this installation. • Determine if the workforce is skilled enough to perform the installation. • The selection of the panels have to be made taking into consideration, the sunlight direction, the final use of this technology and the variation of the weather through a whole year. • Analyse the possibility of installing panels that move along with solar movement.
Building design	• Determine if the building has usable roof space to install the panels, and if this space is oriented to the right direction. • Analyse if the panels have the possibility to reach the correct inclination. • Analyse the possibility of installing a façade system. • Determine if the design of the building will be strong enough reason to select more aesthetic solar cells in detriment of a higher system performance. • Determine if the installation will affect users or environment. • The maintenance of the system has to be considered in relation with the place selected for its installation. • Analyse the specific local requirements set by the government that will restrict the installation.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Renewable energy potential solutions	
Air heat pump	
Area	Considerations
Location	• Analyse if the noise generated and the vibrations will affect people or environment. • If there is any other building in the surroundings that use the same technology will be advisable to check its situation and possible interactions between systems.
Building design	• Determine if there is space in the building to install the heat pump. • The weather conditions of the specific location of the building have to be the correct ones to ensure a good performance of the system. • Determine if there is any legislation against the installation of this kind of systems in the envelope of the building. • Determine if the resultant aesthetic of the building is acceptable after having installed this system. • The regulatory entities of the location have to agree with the fact that the heat pump will throw out cool air in winter and hot air in summer.
Environmental impact	• An assessment of the green house gasses emissions has to be performed. • The environment impact resultant from the use of refrigerants has to be assessed. The refrigerant has to be chosen with regards to its environmental impact. • The flammability characteristic of some of the refrigerants has to be taken into consideration.

CATALOGUE OF SUSTAINABLE SOLUTIONS	
Renewable energy potential solutions	
Wind turbine	
Area	Considerations
Stakeholders	• All the stakeholders involved or affected by the use of a wind turbine have to be listed and contacted. • The possible providers have to be selected.
Location	• The noise impact has to be considered. • The flick shadow (of the turbine) disturbance has to be considered. • Analyse if there are any buildings that will create turbulence and thus will decrease the turbine performance. • Analyse if there is any legislation against the installation of this kind of technology. • The wind speed of the area has to be checked in order to determine if the performance of the turbine can reach high levels. • The turbine has to be selected depending on the wind speed of the area. • Analyse if the turbine will create wind disturbances in nearby buildings. • Analyse if the surroundings of the site of the building are likely to change with constructions that could affect the performance of the turbine. • Analyse if the installation of the turbine is near protected environments of any kind. • Analyse if the turbine is going to be an environment or social impact. • Analyse the possibility of lower the noise made by the turbine. • Check if there is any airport that will be affected by the installation of a turbine.
Building design	• Determine if the building structure is strong enough to withstand the installation and the subsequent vibrations generated by the turbine. • Analyse if there is in the building space to install the turbine and the equipment needed for its fully operation. • Analyse the possibility of installing more than one turbine in order to decrease some of the impacts caused by a bigger turbine.

5.3 Case study

To finish with the report performed, a case study was facilitated by the THM University to perform the needed analysis.
In this part, the building check list developed will be implemented in a real case. This case will be evaluated and rated in order to determine its suitability for refurbishment.

The building to analyse is a building constructed in 1975 and situated in Limburg an der Lahn, Germany.
The plans of the building are the following:

Figure 5.1. Underground floor

Figure 5.2. Ground floor

Figure 5.3. First floor

Figure 5.4. Second floor

Figure 5.5. Third floor

Figure 5.6. Fourth floor

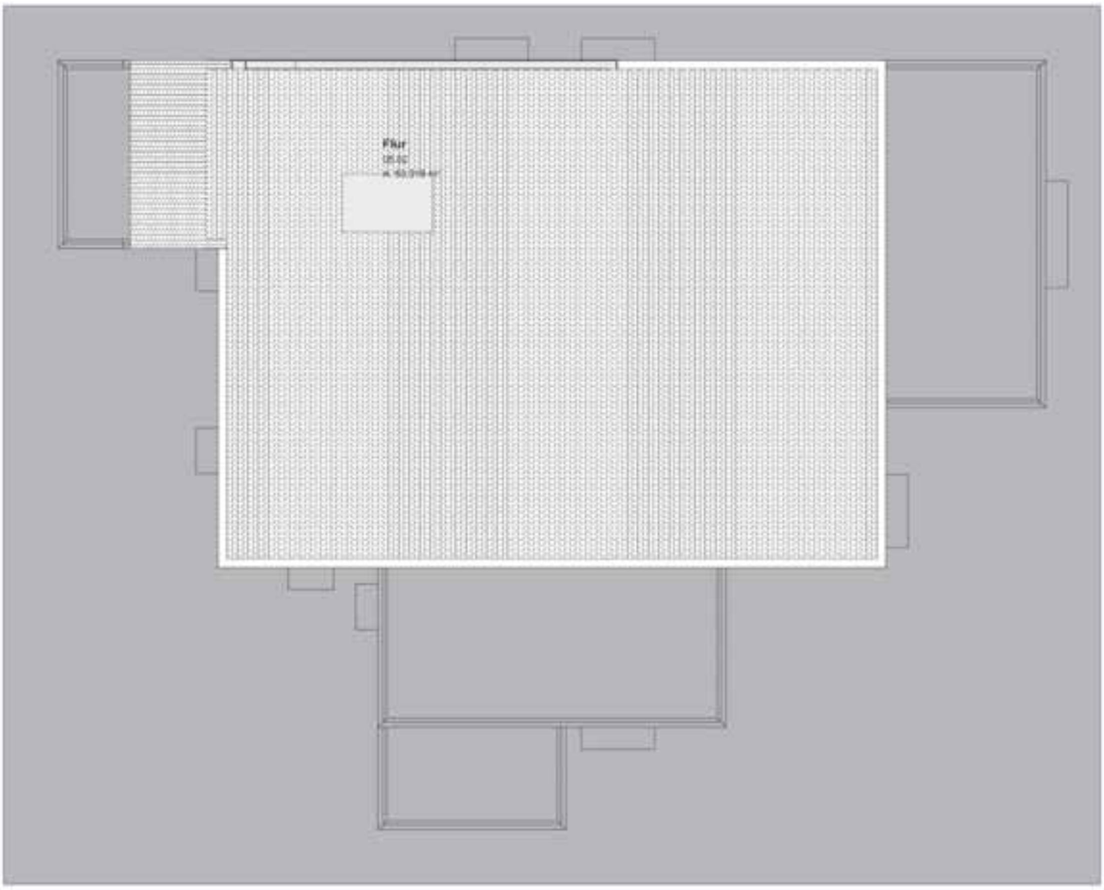


Figure 5.7. Roof

<table>
<tr><td colspan="3">BUILDING ANALYSIS</td></tr>
<tr><td colspan="3">State of the building</td></tr>
<tr><td colspan="3">Structure</td></tr>
<tr><td colspan="2" rowspan="2">Current status</td><td>Questions</td></tr>
<tr><td>S.S.01. Is the structure solid enough to continue its use during a new period of life of a building? For how long?
S.S.02. Are the covering layers of the structure in good condition to face fire exposure? Or should they be replaced?</td></tr>
<tr><td>Rating</td><td>3</td><td>Answers</td></tr>
<tr><td colspan="2"></td><td>S.S.01. The structure is solid enough.

Figure 5.8. Interior of the building

According to life analysis studies (Ebert et al., 2011), a concrete structure has a life expectancy from 50 to 80 years, depending on the specific conditions of the site and the use.
The building was constructed in 1975, and it is in good conditions so, supposing an average life expectancy of 70 years, the structure will be fit for use until the year 2045. Which gives it 32 years more to continue its performance.

S.S.02. In general, the covering layers of the structure are in good conditions. It should not be replaced, but in some points of the roof, the reinforcements of the structure are exposed.</td></tr>
</table>

BUILDING ANALYSIS		
State of the building		
Structure		
Materials		Questions
		S.S.03. What materials is the structure composed of? S.S.04. Are the materials in good conditions or have them started deteriorating?
Rating	2	Answers
		S.S.03. Reinforced concrete structure.  Figure 5.9. Reinforced concrete of the building S.S.04. The majority of the materials are in good conditions. But in some points of the roof, the reinforcements of the structure are exposed.  Figure 5.10. Reinforcement exposure of the building
Insulation		Questions
		S.S.05. Does the structure of the building have any kind of insulation? S.S.06. If it has, should it be removed, or replaced? S.S.07. Due to the specific situation of the building, should it have any kind of insulation?
Rating	2	Answers
		S.S.05. The structure has not insulation by itself; it is located in the façade, with the exception of the roof. S.S.06. It is in good conditions. S.S.07. The insulation of the roof is needed, and depending on the future use, it can be maintained or replaced.

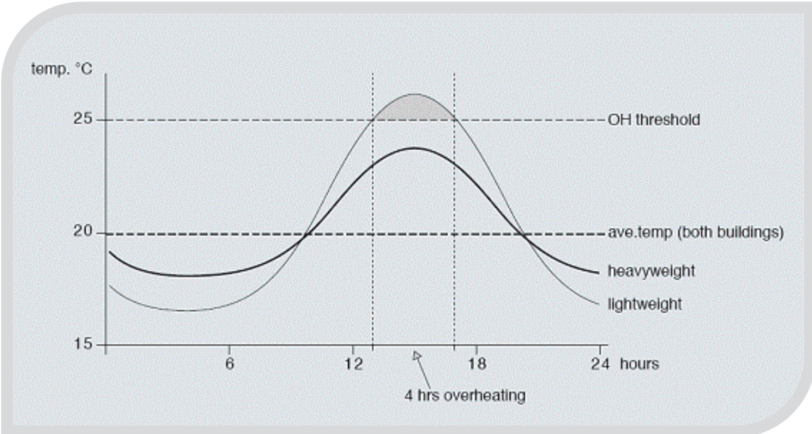
<table>
<tr><td colspan="3">BUILDING ANALYSIS</td></tr>
<tr><td colspan="3">State of the building</td></tr>
<tr><td colspan="3">Structure</td></tr>
<tr><td colspan="2" rowspan="2">Thermal mass</td><td>Questions</td></tr>
<tr><td>S.S.08. Has the structure, the material or the thickness needed to use it as a thermal storage system?</td></tr>
<tr><td>Rating</td><td>3</td><td>Answers</td></tr>
<tr><td colspan="2"></td><td>S.S.08. The building structure can be used as a thermal storage system. The structure is made of reinforced concrete, due to that the building is considered as a high weight building. That makes the structure suitable to work as a thermal storage system.


Figure 5.11. Temperatures achieved by thermal mass storage system (Backer, 2012)</td></tr>
<tr><td colspan="2" rowspan="2">Maintenance</td><td>Considerations</td></tr>
<tr><td>S.S.09. The features of the structure design will imply its posterior maintenance. Evaluate the costs and problems that can be derived from it and bear in mind the requirements and standards to apply.</td></tr>
</table>

<table>
<tr><td colspan="3">BUILDING ANALYSIS</td></tr>
<tr><td colspan="3">State of the building</td></tr>
<tr><td colspan="3">Façade</td></tr>
<tr><td colspan="2">Current status</td><td>Questions</td></tr>
<tr><td colspan="2"></td><td>S.F.01. Is the façade in good conditions to continue with its use? How long will it be its lifespan?
S.F.02. Is the façade fire resistant as it is? Or does it need covering layers to enhance its properties?
S.F.03. Has the façade or any of its parts any kind of special value that has to be taken into consideration?</td></tr>
<tr><td>Rating</td><td>3</td><td>Answers</td></tr>
<tr><td colspan="2"></td><td>S.F.01. The façade is in good conditions.

Figure 5.12. Façade of the building

According to life analysis studies (Ebert et al., 2011), the life expectancy of a concrete wall exposed, will be from 60 to 80 years, and the life expectancy of a brick façade exposed, will be from 80 to 150 years.
The building was constructed in 1975, and it is in good conditions so, supposing an average life expectancy of 70 years, the concrete walls will be in good conditions for 32 years more. And in relation with the brick façade, the life expectancy will be longer, but as the façade is composed by both materials, the life expectancy of the façade remains the same.

S.F.02. The façade is fire resistant. If in some points the reinforcements of the structure are exposed, then they should be covered to achieve fire resistance.

S.F.03. The façade does not have any special value to take into consideration.</td></tr>
</table>

BUILDING ANALYSIS		
State of the building		
Façade		
Materials		Questions
		S.F.04. What materials is the façade composed of? S.F.05. Are the materials in good conditions or have them started deteriorating?
Rating	3	Answers

S.F.04. The façade is composed of brick and concrete.

Figure 5.13. Concrete façade material

Figure 5.14. Brick façade material

S.F.05. The materials are in good conditions.

Solar control		Questions
		S.F.06. What type of glazing do the building windows have? U-Values. Does it ensure functioning interior spaces? S.F.07. Do the windows have to be replaced or improved? S.F.08. Does the building have any shading system? Does it need it?
Rating	1	Answers

S.F.06. The existing windows are composed by two pane wood windows.

Figure 5.15. Existing windows of the building

The U-values have been estimated for a simulation program in: 3.80 W/(Km2) for the window itself, and 4 W/(Km2) for the glazing isolated.

Windows	Area [m²]	U Glass [W/(K m²)]	U Frame [W/(K m²)]	U Total [W/(K m²)]	U*A [W/K]	Shading factor g
NE	84.54	4.00	2.00	3.80	321.24	0.80
SE	150.18	4.00	2.00	3.80	570.67	0.80
SW	91.69	4.00	2.00	3.80	348.41	0.80
NW	64.00	4.00	2.00	3.80	243.22	0.80
Sum[1]/Weighted average[2]	390.41[1]	4.00[2]	2.00[2]	3.80[2]	1483.54[1]	0.80[2]

Table 5.1. U-values of the windows

The windows do not ensure functioning interior spaces. The existing windows lose heat and the energy performance of the building is seriously damaged by that fact.

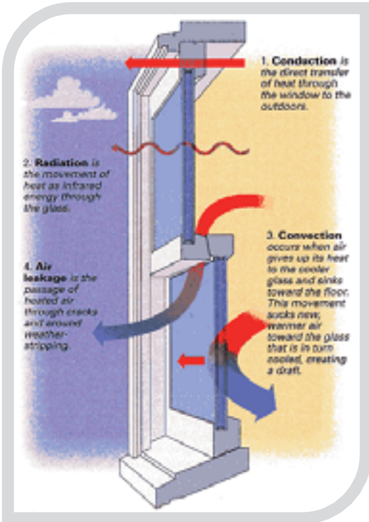


Figure 5.16. Windows heat loss (Fisette, 2012)

S.F.07. The windows have to be replaced.
The estimated U-Values proof that the existing windows have to be replaced, the U-value is too high for a two-pane window. Moreover, several windows have leaks, which is the reason of an U-value that high.

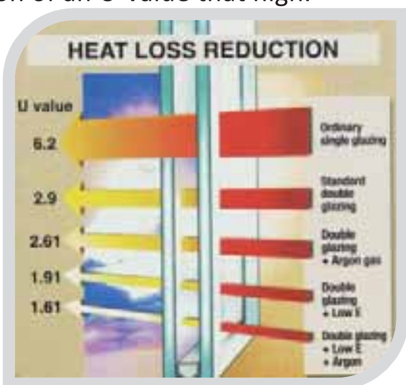


Figure 5.17. Windows heat loss related with U-values (Euro windows UK, 2013)

Nevertheless if replacing the windows is not possible, they can be upgraded. The table below shows the different options to upgrade a window and its effect on the U-values.

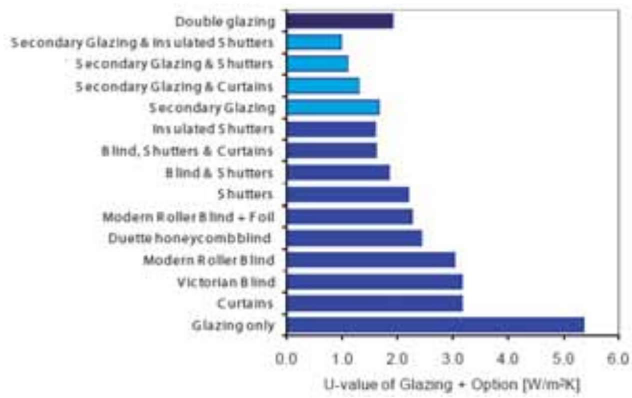


Figure 5.18. Effects of the options on U-Value (Bates, 2011)

S.F.08. Windows southeast orientated have an external shading system with

manual regulation. However, the windows do need a shading system.
It exist several shading systems to implement in a building:
External shadings: In a refurbishment, the implementation of external shading systems entails the change of the aesthetical concept of the façade. This has to be analysed in the design stage to determine its viability.

Figure 5.19. External controlled shades (Levolux limited, 2012)

Figure 5.20. Solar shading device (REVIVAL, 2009)

Internal shadings: They can be more flexible to the specific use of each space, and present a lower visual impact than the external ones. Internal systems separated from the windows will have a shorter lifespan and will imply higher maintenance costs.
Shading systems that are mixed with the window itself offer a better performance. They do not need maintenance and will have longer life expectancy. The selection of these systems will be united with the selection of the windows and will depend on an economic analysis to determine the suitability of the investment due to its higher cost.

Figure 5.21. Aluminium window with integrated blinds (Archiexpo, 2013)

For the specific use of an office building, all the shadings systems have to be mechanically controlled, to reach a better performance.

BUILDING ANALYSIS

State of the building

Façade

Thermal performance

Questions

S.F.09. Has the energy performance of the façade been analysed?
S.F.10. Is the insulation of the façade in good conditions to continue its use? For how long? Should it be replaced?
S.F.11. Have the windows thermal transmission problems?

Rating: 1

Answers

S.F.09. The building energy performance has been analysed and the values estimated for a simulation software are the following:

Building envelope	Area [m²]	U [W/(K m²)]	U*A [W/K]	% of total
External walls	805.58	0.76	610.15	19.54
Roof	349.73	0.59	204.87	6.56
External floor	34.39	0.16	5.65	0.18
Windows	390.41	3.80	1483.54	47.50
External doors	16.76	2.19	36.78	1.18
Thermal bridges			781.94	25.04
Sum[1]/Weighted average[2]	1596.87[1]	1.96[2]	3122.92[1]	100.00

Table 5.2. Building envelope energy performance analysis

Thermal bridges	Area or Length	Avg. Heat conductivity	Sum [W/K]
External wall - Internal slab	629.15 m	0.200 W/(K m)	125.831
External wall - Internal wall	243.70 m	0.148 W/(K m)	36.068
External wall - External wall	98.54 m	0.800 W/(K m)	78.829
Window perimeter	1110.80 m	0.400 W/(K m)	444.319
External door perimeter	28.39 m	0.060 W/(K m)	1.704
Roof - External wall	192.71 m	0.300 W/(K m)	57.812
External slab - External wall	10.13 m	0.300 W/(K m)	3.038
Balcony floor-External walls	0.00 m	0.000 W/(K m)	0.000
External slab - Internal wall	4.02 m	0.015 W/(K m)	0.060
Roof - Internal wall	171.38 m	0.200 W/(K m)	34.276
Exteral walls - Inner corners	20.10 m	0.000 W/(K m)	0.000
Total envelope	1596.89 m²	0.000 W/(K m²)	0.000
Extra losses	-	-	0.001
Sum	-	-	781.937

Table 5.3. Building thermal bridges

S.F.10. The insulation is in good conditions. The facade is partly insulated with 3 – 4 cm of Styrofoam.
As the building site inspection was visual, the specific state of the insulation cannot be determine. To define the life expectancy of the insulation, further analyses have to be done.
For now the insulation seems to be in good condition, but in the future further analyses have to be performed to determine whether to replace or not.

S.F.11. The windows have thermal transmissions problems. The building has two pane wood windows that are in bad conditions and parts of them have leakage. Due to the bad conditions of the windows, a U-Value of 4 has been estimated.

Maintenance

Considerations

S.F.12. The features of the façade design will imply its posterior maintenance. Evaluate the costs and problems that can be derived from it and bear in mind the requirements and standards to apply.

BUILDING ANALYSIS		
State of the building		
Building internal organization		
Current status		Questions
		S.B.01. Is the structure grid able to create economically feasible interior spaces? Or will the spaces be too big or too small? S.B.02. Is the window rhythm as well able to create economically feasible interior spaces? Or will the spaces have too much light or too little? S.B.03. Have the interior walls the quality desired to continue their use?
Rating	3	Answers
		S.B.01. The structure grid (4.4m x 4.4 m) can create economically feasible interior spaces. S.B.02. The windows rhythm can create economically feasible interior spaces. S.B.03. The interior walls have the quality to continue with their use. However, that will depend on the decision of the design team.
Materials		Questions
		S.B.04. Are the interior wall materials in good conditions to continue their use? For how long?
Rating	2	Answers
		S.B.04. The interior drywalls are in good conditions.  Figure 5.22. Building internal space According to the association of the Wall and Ceiling Association (Association of the Wall and Ceiling Industry, 2000), drywalls have a life expectancy of 30-70 years. Supposing an average life expectancy of 60 years, the interior drywalls will be in good conditions for 22 years more.
Solar control		Questions
		S.B.05. Has the building any kind of interior system for solar shading?
Rating	1	Answers
		S.B.05. The building has curtains or fabric shades.

BUILDING ANALYSIS		
State of the building		
Building internal organization		
Natural ventilation		Questions
		S.B.06. Does the geometry of the building allow the use of natural ventilation? S.B.07. Will it be feasible for privacy and access control terms, have a functional natural ventilation system, taking into account the new use of the building? Do the volumes and spaces to be ventilated allow having a natural ventilation system? S.B.08. Are there any underground areas in the building?
Rating	2	Answers
		S.B.06. Due to the size and geometry of the building, natural ventilation could be used, depending on the privacy and control requirements of the users. S.B.07. Due to the specific use of the building and the location of it, a mixed ventilation system should be implemented to avoid the appearance of cold airflows and to maintain the interior comfort levels. As all the building spaces are exterior ones, natural ventilation can be implemented. However, depending in the specific security needs of the building or the users it could be feasible or not. For a building with a normal use, the main problem will be in the ground floor, where the windows have to be opened during non-working hours. Nevertheless, some solutions can be given to this kind of problems such as special protections for theses windows, or separating ventilation inlets from natural light inlets. S.B.08. There is one underground level; the heating system is located in a basement. In that case a mechanical ventilation system will be needed.

<table>
<tr><td colspan="3">BUILDING ANALYSIS</td></tr>
<tr><td colspan="3">State of the building</td></tr>
<tr><td colspan="3">Building internal organization</td></tr>
<tr><td colspan="2">Thermal mass</td><td>Questions</td></tr>
<tr><td colspan="2"></td><td>S.B.09. Are there any interior walls that can be used as a thermal storage system for cooling to reduce the air condition requirements?
S.B.10. Is the structure, in the interior of the building, exposed in order of being able to function as a thermal mass system for cooling?</td></tr>
<tr><td>Rating</td><td>1</td><td>Answers</td></tr>
<tr><td colspan="2"></td><td>S.B.09. There are not interior walls able to work as a thermal storage due to the fact that the majority of internal walls are composed of gypsum.

S.B.10.In many areas of the building suspended ceilings cover the concrete slabs.

Figure 5.23. Building internal space with suspended ceilings

In that case, the suspended ceiling has to be removed and replaced by other system that allows the structure and the slabs to work as a thermal mass for cooling.
The ideal case will be to have the structure exposed for night cooling, nevertheless if the use of suspended ceilings is necessary, then diffuse ceiling ventilation can be used with acoustic suspended ceilings to distribute the air, and will not reduce the performance of the system.</td></tr>
<tr><td colspan="2">Maintenance</td><td>Considerations</td></tr>
<tr><td colspan="2"></td><td>S.B.11. The features of the interior design will imply its posterior maintenance. Evaluate the costs and problems that can be derived from it and bear in mind the requirements and standards to apply.</td></tr>
</table>

BUILDING ANALYSIS		
State of the building		
Consumption		
Electricity		Questions
		C.E.01. Has the needed electricity consumption been analysed for the use of the building? C.E.02. Is it possible to reuse the electricity installation of the building or does it need to be changed? C.E.03. Can the performance of the appliances of the building be optimized in any way to minimise the consumption? C.E.04. Is the performance of the electricity in the building reasonable or not? What are the problems?
Rating	2	Answers

C.E.01. There is no electricity consumption information directly from the building. However, the energy consumption has been analysed by a building behaviour simulation software.

	DELIVERED ENERGY		DEMAND
	kWh	kWh/m2	kW
Artificial lighting	46330	33.3	8.71
Cooling	0	0.0	0.0
Ventilation	0	0.0	0.0
Total facility electric	46330	33.3	
Heating	235929	169.7	98.04
Warm water	0	0.0	0.0
Total facility fuel (heating)	235929	169.7	
Total	282259	203.0	
Artificial lighting	18693	13.5	7.99
Electric devices	6811	4.9	2.91
Total tenant electric	25504	18.4	
Grand total	307763	221.4	

Table 5.4. Building electricity consumption

The resulting monthly delivered energy is represented in the following chart.

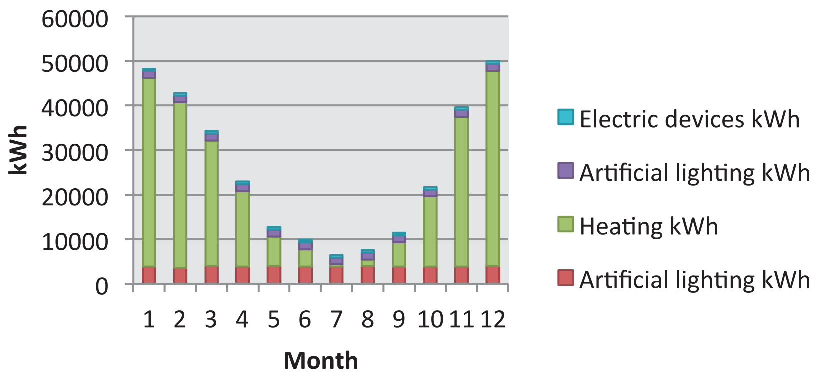


Figure 5.24. Building year delivered energy graph

C.E.02. The status of the electric wiring has not been evaluated, however, as a general rule, for a building of this age, the electric wiring has to be replaced to be adapted to new uses and new demands.

<table>
<tr>
<td></td>
<td>
C.E.03. Yes, by upgrading or replacing appliances the building energy performance can be enhanced.
C.E.04. The electricity consumption of the building is reasonable due to the age and use as an office building, and the regular appliances involved in that use.

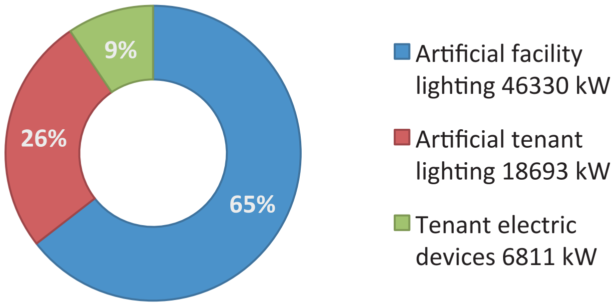


Figure 5.25. Building electricity consumption graph
The main problem is that artificial lighting has an elevated consumption, due to the age of the installation and the control systems of the building.
</td>
</tr>
</table>

BUILDING ANALYSIS

State of the building

Consumption

Heating and cooling

Questions

C.H.01. Is it possible to climate the building only with passive systems, not having to install any mechanical system?

C.H.02. Have the comfort levels of the building been analysed? Has it been determined if the climatic conditions are acceptable for the implementation of a passive system?

C.H.03. About the existing heating-cooling system: is it possible to maintain its use?

- C.H.03.1. Is it in good conditions?
- C.H.03.2. Size of the systems: does it meet the demand of the use of the building?
- C.H.03.3. Is the area where the systems are situated sufficient for the new requirements?
- C.H.03.4. Are the control systems of the building able to reach the demands of a new building? Can they be used to optimise the systems or change with the changing demand?
- C.H.03.5. Is the control system capable of coping with all modern network communication systems?

C.H.04. Has the heating consumption been analysed? Is the performance of the systems reasonable or not? What are the problems?

Rating 2

Answers

C.H.01. It is possible to climate the building only with passive systems, but the appropriate method has to be chosen not to invest in a solution that will underperform due to the specific location or characteristics of the building.

C.H.02. The comfort levels have been analysed by a building behaviour simulation software, and the results are the following:

Percentage of hours when operative temperature is above 27°C in worst zone	15%
Percentage of hours when operative temperature is above 27°C in average zone	7%
Percentage of total occupant hours with thermal dissatisfaction	11%

Table 5.5. Building comfort levels

Many buildings in Germany have reached a high heating and cooling performance with passive systems.
These charts show the monthly averages of Limburg an der Lahn.

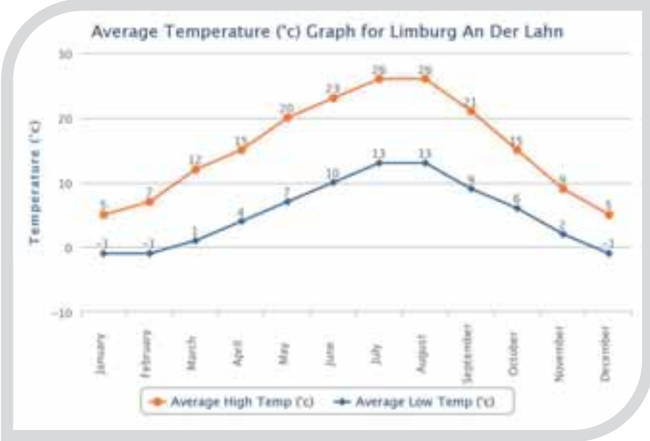


Figure 5.26. Monthly average temperature for Limburg an der Lahn (World weather online, 2013)

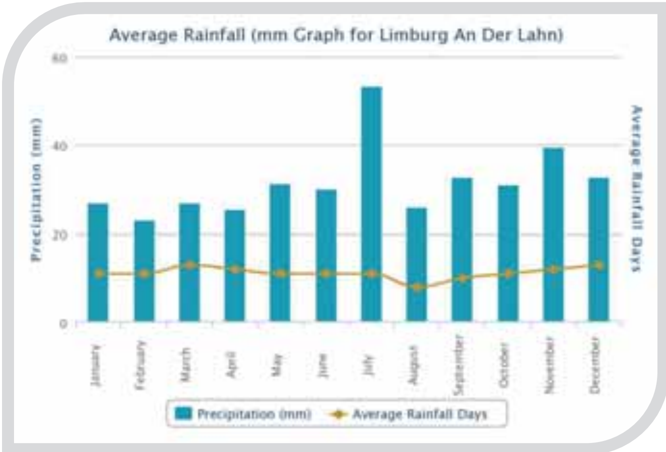


Figure 5.27. Monthly average rainfall for Limburg an der Lahn (World weather online, 2013)

C.H.03. The heating system is a gas heater located in the basement.

Figure 5.28. Building heating system

- C.H.03.1. The heating system is in good conditions to maintain its use. The life expectancy of a gas heater will depend on the type of water heater and the quality of the water, according to use life studies (Old house web, 2010), the life expectancy will be of 30 years. The existing system was implemented in 1998, thus it remains 15 years of life expectancy to perform correctly.

- C.H.03.2. The size of the system installed, meet the demand of the use of the building, due to the fact that the previous use of the building, as an office building, is not changed and the occupancy will remain similar.
- C.H.03.3. The current system is situated in the basement and it has enough space.
- C.H.03.4. The existing control system should be updated or replaced to meet sustainable requirements and achieve the highest performance possible from the system.
- C.H.03.5. The current control system is not able to cope with all modern building requirements.

C.H.04. The heating consumption has been analysed through a building behaviour simulation software. The information obtained is the following:

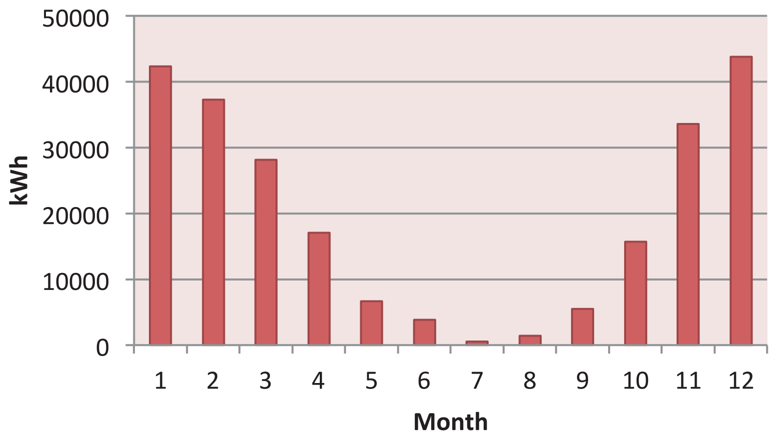


Figure 5.29. Building heating consumption chart

The performance of the system is reasonable taking into account the current status of the windows.

The main problem with the heating system is the amount of consumption, it can be reduced by upgrading or replacing windows and control systems, adapting the building consumption to the users and the specific climatic conditions of each day.

BUILDING ANALYSIS		
State of the building		
Consumption		
Water		
Existing features		Questions
		C.W.01. In the event that the building has a reasonably new plumbing installation. Will it be possible to reuse existing plumbing in the building? Or at least a part of it? Is the existing plumbing suitable for the use of the new building?
Rating	0	Answers
		C.W.01. With the current plumbing system is not possible to reuse any of the installation parts.
Water demand		Questions
		C.W.02. Has the water consumption of the building been analysed? C.W.03. Is the quality of the water at the appropriate level? C.W.04. Is it possible/necessary to control the water use in the building?
Rating	3	Answers
		C.W.02. The water consumption has not been analysed. C.W.03. The quality of the water has the appropriate level, due to its source from the local water network. C.W.04. Yes it is possible to control the water use in the building. However taking into account the size of the building and the water use, the control system for the water can be reduce to specific interventions in toilets and external water intakes.
Plumbing		Questions
		C.W.05. In the event of reusing existing plumbing, does it ensure health level in the water?
Rating		Answers
		C.W.05. In this case the existing plumbing will not be reused.
Water resources		Questions
		C.W.06. Where will the water consumed in the building come from? C.W.07. Does the building have any kind of water reuse system?
Rating	2	Answers
		C.W.06. The water supply comes from the local water grid. C.W.07. The building does not have any water reuse system.

<table>
<tr><td colspan="3">BUILDING ANALYSIS</td></tr>
<tr><td colspan="3">State of the building</td></tr>
<tr><td colspan="3">Consumption</td></tr>
<tr><td colspan="2">Wastes</td><td>Questions</td></tr>
<tr><td colspan="2"></td><td>C.WA.01. What kind of wastes is the building going to produce?
C.WA.02. Has the building an acceptable wastes management? Or should it be improved?
C.WA.03. Is the location for waste gathering the correct one? Or should it be changed?</td></tr>
<tr><td>Rating</td><td>2</td><td>Answers</td></tr>
<tr><td colspan="2"></td><td>C.WA.01. As the use of the building will be as an office building, wastes will be reduced to paper, cardboard and general garbage, as it is shown in the image below.

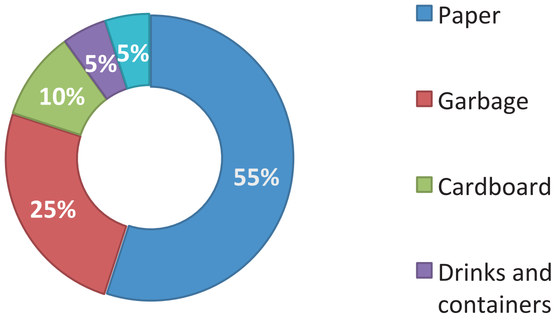
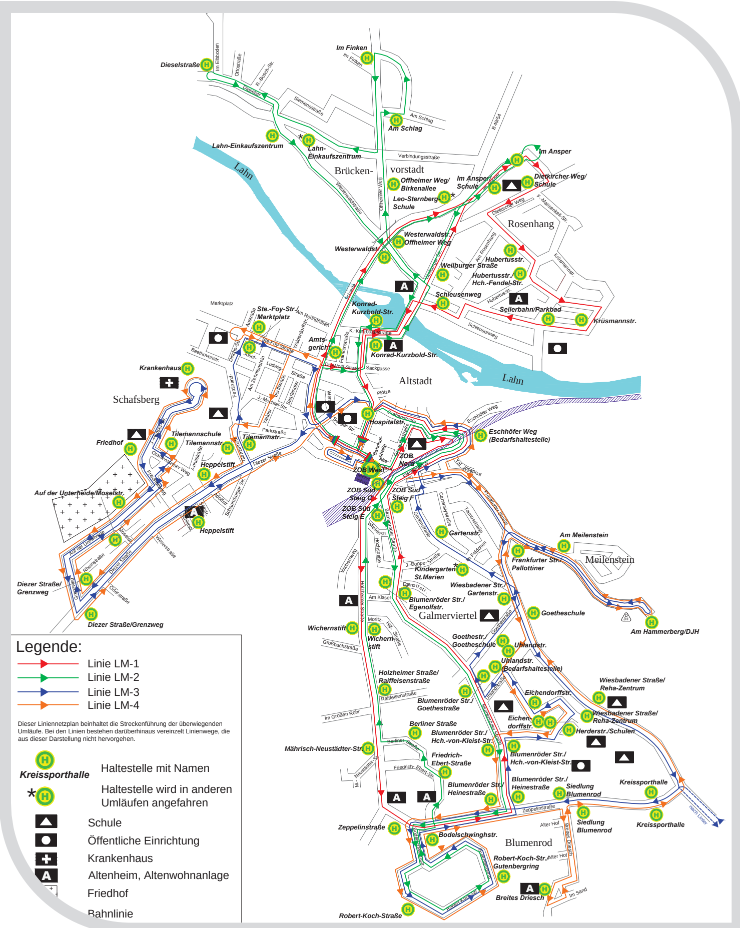


Figure 5.30. Office building wastes

C.WA.02. The existing wastes management should be improved.
The building will have an office use only, so the wastes produced will be paper and cardboard, general garbage, containers and other stationary items.
The goal to aim for is the reduction of the production of these wastes as much as possible. Over all the use of paper, and encourage the reuse of non-damaged items.

C.WA.03. Taking into account the size of the building, the location for waste gathering will not involve many problems, so it can be changed if the design needs it.</td></tr>
</table>

BUILDING ANALYSIS		
Potentials of the site		
Potentials of the area		
District heating		Questions
		P.A.01. Is there a district heating system that can be used by the building?
Rating	0	Answers
		P.A.01. There is not any district heating system in the area.
Urban transport		Questions
		P.A.02. Are there any urban transport accesses in the nearby area of the building? P.A.03. Do they have a good connection with the city?
Rating	3	Answers
		P.A.02. The building is situated near the train station.  Figure 5.31. Limburg an der Lahn bus plan (Limburg, 2013) P.A.03. The building is well communicated with the city and with longer distances by the train station. This is an important asset for the building; its location is excellent to favour urban transport rather than individual one.
Parking space		Questions
		P.A.04. Does the building have enough parking spaces?
Rating	0	Answers
		P.A.04. Due to the specific situation and features of the building, the parking spaces cannot be modified in any case.

Nearby facilities		Questions
		P.A.05. Is there in the nearby area any kind of facilities that will make the working environment more pleasant?
Rating	3	Answers
		P.A.05. The building is located in the centre of the city, and there are plenty of facilities in the nearby area.
Marketing		Questions
		P.A.06. Has the building a recognisable place in the city? P.A.07. Is the site a place where marketing goals can be achieved by the specific situation of the building?
Rating	3	Answers
		P.A.06. The building is located in the centre of the city, near the train station. That will give a recognisable place to it.

Figure 5.32. Limburg an der Lahn map (Google, 2013)

		P.A.07. The fact that it is located near the train station will give the building a wide recognition in the area.
Environment		Questions
		P.A.08. Has it been considered the waste of transportation energy that will imply the change of location for the specific use of the building?
Rating	3	Answers
		P.A.08. By the fact of choosing the refurbishment option, this wast transportation energy will be saved.

BUILDING ANALYSIS

Potentials of the site

Potentials for renewable energies

General information

Questions

P.R.G.01. Is it available information about the use of renewable energies in the specific area of the project? This could give an idea about which energies are the most developed ones in the area, or which of them have a better performance and success. Also this will show local suppliers availability, and technical expertise.

Answers

P.R.G.01. Information about renewable energy use in Limburg an der Lahn:

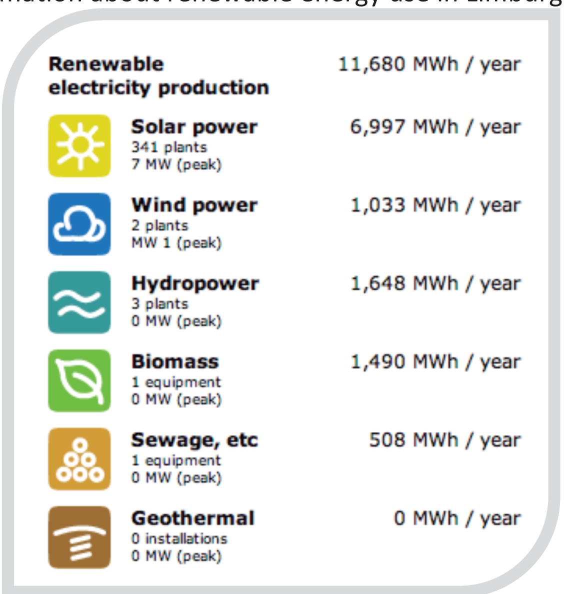


Figure 5.33. Renewable electricity production (Deutsche Gesellschaft für Sonnenenergie, 2013)

In this location it is clear that the solar energy is the preferred one.

Development of the renewable energy since the year 1999:
This analysis shows the amount of energy in kWh, generated by the different systems. This graph does not show the real supply of the energies, but the production potential of it.

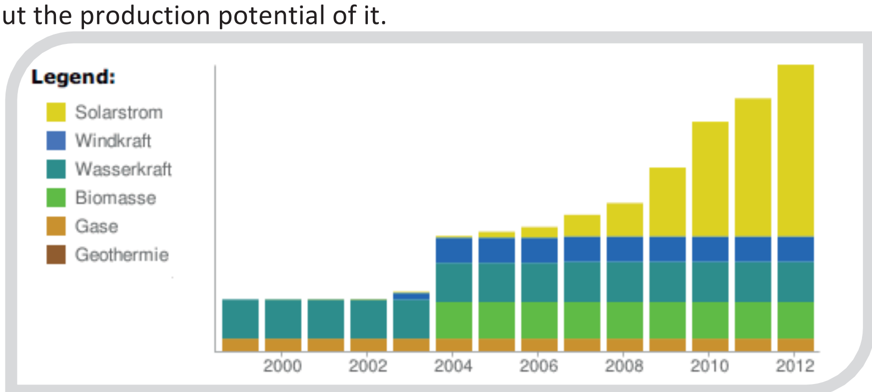
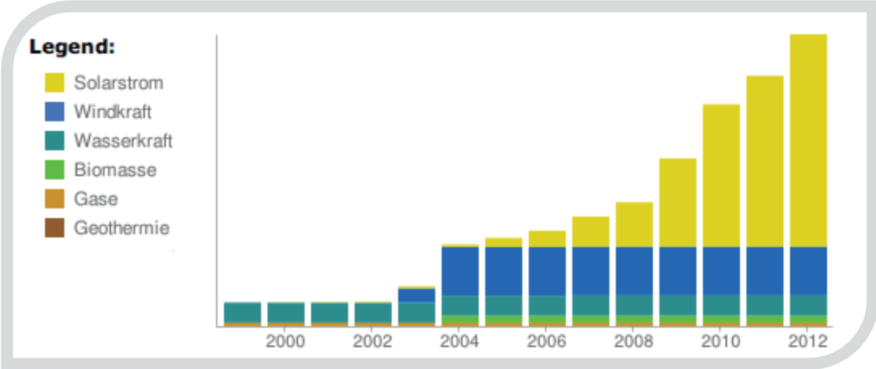
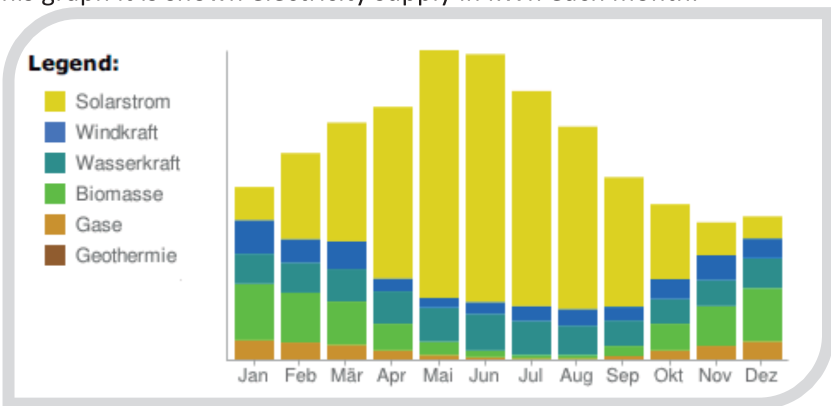


Figure 5.34. Development of renewable energy (Deutsche Gesellschaft für Sonnenenergie, 2013)

	Development of renewable energy (kW peak): This graph represents the sum of the peak power installed measured in kW.  Figure 5.35. Development of renewable energy peak (Deutsche Gesellschaft für Sonnenenergie, 2013) Seasonal energy: In this graph it is shown electricity supply in kWh each month.  Figure 5.36. Seasonal energy (Deutsche Gesellschaft für Sonnenenergie, 2013)

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Biomass		
Local information		Questions
		P.R.B.01. Is there in the area any producer of biomass fuel? P.R.B.02. Is the production of the biomass local, or will the transportation entail a greater pollution that the one saved by the use of this renewable energy?
Rating	2	Answers
		P.R.B.01. In the area there are many companies that can provide biomass. P.R.B.02. The production is local, which will avoid environmental impacts.
Building space for installation		Questions
		P.R.B.03. Has the building space enough to perform this kind of installation? P.R.B.04. Will the installation disturb nearby buildings?
Rating	2	Answers
		P.R.B.03. This will depend on the installation; however, the building has space in the basement. P.R.B.04. If the installation is correctly performed, it should not disturb any nearby buildings.
Regulations		Questions
		P.R.B.05. Does the local regulations allow the installation of these kind of systems? P.R.B.06. Do the community groups agree with the installation? Or will it entail a risk of official complaints?
Rating	2	Answers
		P.R.B.05. Local regulations allow biomass system installations. P.R.B.06. This will involve a community meeting, and selecting the community groups as stakeholders to agree with. However biomass systems are more adapted to standardised social requirements and should not present many problems with social acceptance.

BUILDING ANALYSIS

Potentials of the site

Potentials for renewable energies

Solar radiation

Local solar information

Questions

P.R.S.01. How much direct sunlight does exist in this specific location in the range of a year?

P.R.S.02. Is it worth the installation of the system with the amount of sunlight achieved during a year?

Rating: 3

Answers

P.R.S.01. The annual average normal radiation for this location will be of 2.55 kWh/m2/day.

The table below shows the monthly averaged values for this location.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.26	2.17	2.35	3.06	3.66	3.64	3.94	3.65	2.78	1.94	1.15	0.97

Table 5.6. Annual average normal radiation for Limburg an der Lahn (NASA, 2013)

P.R.S.02. The installation is worth to be installed; what remains to be determined is the payback period of the installation selected.

Orientation and shadows of the building

Questions

P.R.S.03. Has the building the best orientation for the installation of the solar collection?

P.R.S.04. If the orientation is not the desired one, is there any possibility to adapt the installation to achieve an adequate performance?

P.R.S.05. Will the building have any shadows now or in the future that will obstruct the installation to perform correctly?

Rating: 2

Answers

P.R.S.03. The building has a good orientation, in a corner to the southeast direction.

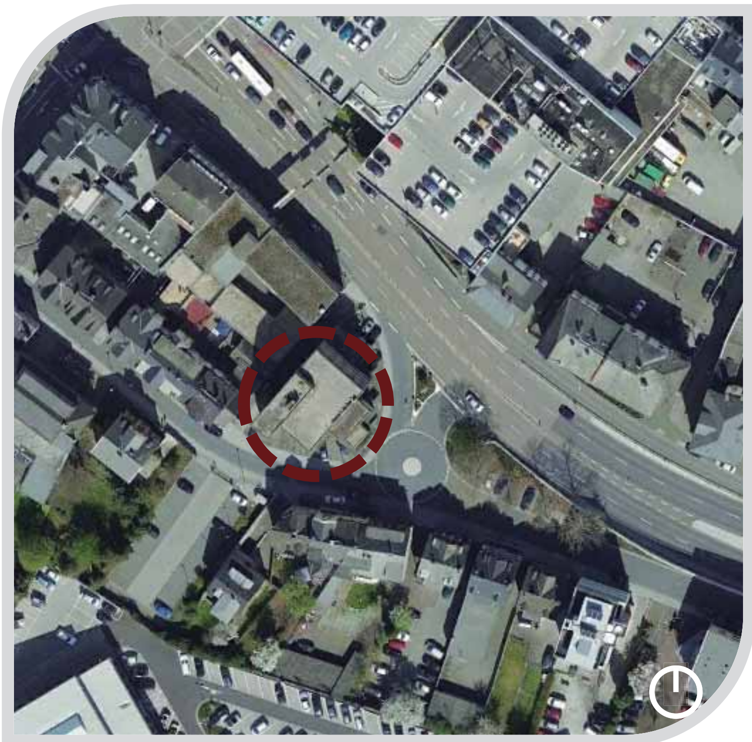


Figure 5.37. Building situation map (Google, 2013)

		P.R.S.04. There is no need to change the orientation. P.R.S.05. Taking into account the current urban situation of the building, it will be highly improbable that any shadows will obstruct the installation.
Building space for installation		Questions
		P.R.S.06. Is there enough space in the roof to install the system? P.R.S.07. Does exist the possibility of the installation of the system in the façade? Will it reach an adequate performance?
Rating	2	Answers

P.R.S.06. The building has enough space in the roof.

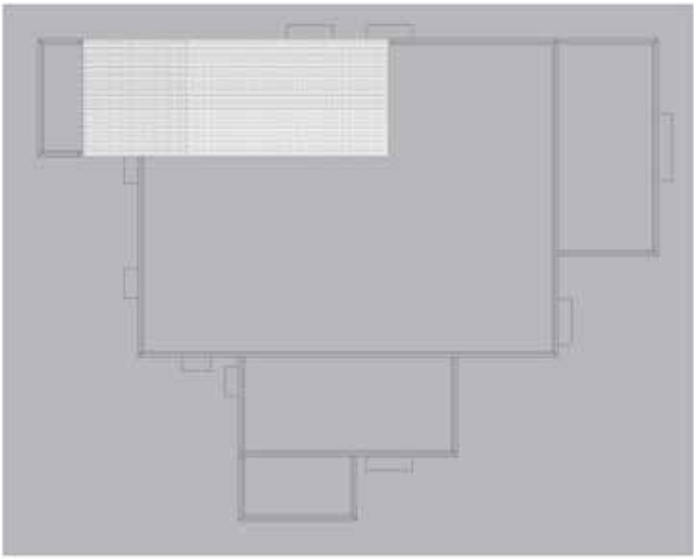


Figure 5.38. Building roof plan

Figure 5.39. Building roof space

P.R.S.07. It will be possible to install a façade system. But for economic, performance and aesthetical reasons, the placement in the roof will be a better option.

	 Figure 5.40. Building façade model  Figure 5.41. Building façade
Regulations	Questions
	P.R.S.08. Does the local regulations allow the installation of these kind of systems? P.R.S.09. Do the community groups agree with the installation? Or will it entail a risk of official complaints?
Rating 2	Answers
	P.R.S.08. Local regulations allow solar installations. P.R.S.09. This will involve a community meeting, and selecting the community groups as stakeholders to agree with.

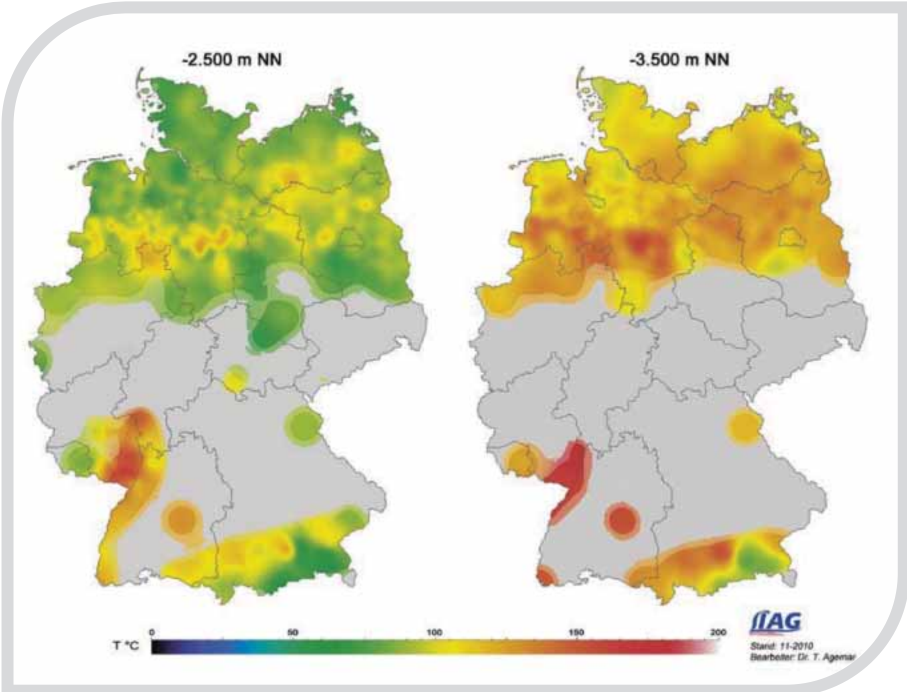
<table>
<tr><td colspan="3">BUILDING ANALYSIS</td></tr>
<tr><td colspan="3">Potentials of the site</td></tr>
<tr><td colspan="3">Potentials for renewable energies</td></tr>
<tr><td colspan="3">Geothermal heat</td></tr>
<tr><td colspan="2" rowspan="2">Local geothermal information</td><td>Questions</td></tr>
<tr><td>P.R.G.01. Have boreholes been performed in the area to determine the kind of soil and its properties? Has the soil the specific properties to achieve an adequate performance with this system?
P.R.G.02. If no study has been performed, is it economically feasible to perform one to check if the system is at all possible?
P.R.G.03. Is there any building in the surroundings with this kind of system that could change the soil performance?</td></tr>
<tr><td>Rating</td><td>0</td><td>Answers</td></tr>
<tr><td colspan="2"></td><td>P.R.G.01. There have not been performed any studies yet in this specific area.


Figure 5.42. Distribution of surface temperature in Germany in 2500 m and 3500m (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2011)

The areas with insufficient data density are shown in grey.

P.R.G.02. Performing a geothermal study is not feasible option, due to the size of the project and the subsequent budget adapted to it.

P.R.G.03. There is not information about the surrounding buildings to determine whether they use this system or not.</td></tr>
</table>

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Wind speed		
Local wind information		Questions
		P.R.W.01. Has the necessary information about wind speed in the area been collected to determine if the installation of this system will be feasible? P.R.W.02. Are there other buildings or topography that could affect to the performance of the wind turbine?
Rating	1	Answers

P.R.W.01. The annual average of wind speed at 50 m will be of 5.85 m/s.
The table below shows the monthly averaged values for this location.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6.96	5.85	6.88	5.96	5.31	5.27	5.54	5.16	5.11	5.35	6.27	6.53

Table 5.7. Annual average wind speed for Limburg an der Lahn (NASA, 2013)

P.R.W.02. There are buildings surrounding the site, with the same high or lower than the building to refurbish.
The main direction of the wind in this area is west.
Studies have found that turbines installed in urban areas, as the location that the building has, are likely to perform at low capacity, intermittent with periods of non-operation. So the payback period in these cases tend to be long.
The best urban locations for this installation will be, open areas on the seashore or situating them in high raise buildings (Susstainability Victoria, 2012).
Due to the specific urban characteristic of the site, the direction of the site and the height of the building, it has to be concluded that the return on the investment for this specific technology will be much higher than other options, and will not be advisable to invest on it to the detriment of other more suitable.

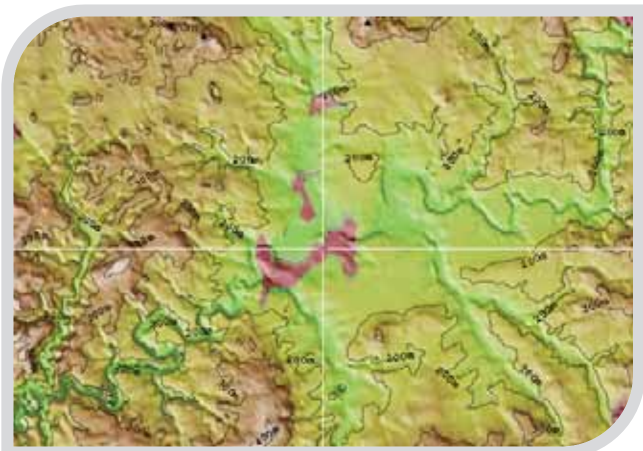


Figure 5.43. Limburg an der Lahn topographic map (Meteo 365, 2013)

The above topographic map of Limburg an der Lahn and the surrounding area has been derived from satellite mapping. The topographic data has been illuminated by a light source corresponding to the position of the sun at mid afternoon in summer. Major roads, railways rivers and other water features are derived from global GIS data.

BUILDING ANALYSIS		
Potentials of the site		
Potentials for renewable energies		
Wind speed		
Building space for installation		Questions
		P.R.W.03. Has the building space enough in the roof to install the system?
Rating	2	Answers
		P.R.W.03. The building has enough space for the system installation. The roof plan information of the building can be consulted in the table of solar radiation.
Regulations		Questions
		P.R.W.04. Does the local regulations allow the installation of these kind of systems? P.R.W.05. Do the community groups agree with the installation? Or will it entail a risk of official complaints?
Rating	2	Answers
		P.R.W.04. Local regulations allow the installation of this system. P.R.W.05. This will involve a community meeting, and selecting the community groups as stakeholders to agree with.

CURRENT STATE OF THE BUILDING		
Potentials of the site		
Potentials for renewable energies		
Water flows		
Local water flow information		Questions
		P.R.WF.01. Has information about water flows in the nearby areas of the building been collected? P.R.WF.02. Would it be possible to take advantage of the water flow, or will it be impossible to modify it in any way?
Rating	0	Answers
		P.R.WF.01. Information about water flows has been collected. It exist one river 500 m away from the site.

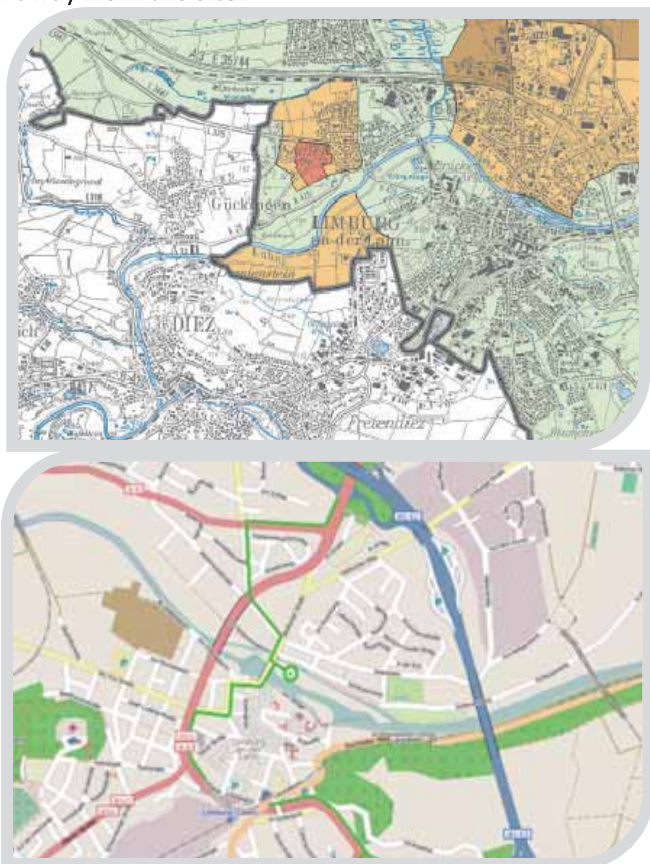


Figure 5.44. Limburg an der Lahn situation maps (SV Lahn Limburg, 2013)

P.R.WF.02. It will not be possible to take advantage from the water flow directly. The distance from the river to the building is long enough to determine this situation as not favourable for its use in this specific building.

Area	Rating				
Structure	10/12	39/54	72%	78%	FEASIBLE FOR BUILDING REFURBISHMENT
Façade	8/12				
Building internal organization	9/15				
Consumption	12/15				
Potentials					
Potentials of the area	12/18	30/51	60%		
Potentials of the site	18/33				

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

After an analysis of the building construction sector it has been stated that the option of refurbishment can contribute with higher sustainable results, due to the existing building stock market.
However, even when refurbishment offers faster, more cost effective and more sustainable solutions with the same performance than new build, the market in general, and the investors in particular, maintain the point of view that new buildings will always be a better choice in terms of energetic performance, levels of comfort achieved and final user satisfaction. This distrust is based in possible problems that the refurbishment entails.

Nowadays many refurbishment projects do not perform in the way they were supposed to, due to the many uncertainties that can be founded over the whole planning and construction process. Many participants are involved, and a high amount of information has to be managed. The existence of a building entails a knowledge need that many planners do not have, therefore when the planning phase start, all the information needed to develop the project correctly is not available. That fact entails risks and technical challenges related with the dimension of the work projected, the final cost or completion time and work scheduling.
It is due to all these risks, why the construction market does not trust refurbishment as a first option.

As stated in this report, many problems found in refurbishment could be solved through a careful planning and integrated design of the project. Nevertheless, if the information needed to perform the project is not available, all integration process may result useless.
The lack of information is one of the main and first problems to face in refurbishment; many of the projects performed have to start the construction works without the adequate data about the existing building, and that results in an under performance of the building.

Not every building is suitable for refurbishment, and there lies the need for a further analysis that will determine the suitability of a building for refurbishment.
It is in the initiation phase of the project, where all the information should be gathered to determine if the building should consider the option of refurbishment or not.

This project has analysed that need of information and has gathered it in a building check list where to determine, with a series of rated questions, if the building is worth the refurbishment.
This check list can be used as a preliminary brief for the project, where all the information can be found, by all the different participants through the project development.
That solution tries to solve the problem of information in refurbishment projects, and will help to reach the desired performance.

After the check list, a sustainable solutions catalogue has been developed, in order to serve as a guideline for the specific situation of the building.
Depending on the features of the building and the environment it is placed, it can be chosen the best solution adapted to the specific situation of the building.
The case study can be seen also as a conclusion of this report. There it can be seen the application of the check list for an existing building.

There is a general practice in construction when implementing sustainable solutions, that the selection of the sustainable measure to implement it is not based in the specific location of the

building itself, or the specific needs of the building, but sometimes is based in some ransom idea of sustainability external appearance of the building. It can be due to the need to fulfil some rating systems at any cost or to satisfy local construction requirements.
With this catalogue, the best sustainable solution for the building will be chosen depending on the specific environment surrounding it, achieving a real essence of sustainability in its primal meaning, taking advantage from natural resources existing in the close area and attaching to building to its location and environment, more that with any attempt of shape, aesthetic or function integration.
Moreover, over costs and problems in the return on investment will be avoided by selecting only the adequate sustainable solutions.

Recommendations

To conclude with this analysis and report, some recommendations have to be made for future studies.

As this project developed a theoretical rating system of the check list, both the rating system and the case study have their limitations with regards to real construction projects. The rating system could be improved, basing in real construction projects, where the importance of the ratings values can be better analysed.

Furthermore, the sustainable solutions catalogue could be further developed as a check list for a building, so specific technical solutions for the building could be analysed from it.

This report is focused in the preliminary phase of the project and solves problems derived from it; a further study is needed in the rest of phases of the refurbishment project, to solve all possible problems in its development.

Moreover, an additional recommendation for future studies will be to analyse specific project participants related with specific problems, to forecast or address this issues faster and save time and money to the project development.

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