UNIVERSIDADE da MADEIRA

HIGH PERFORMANCE GREEN BUILDINGS

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ABSTRACT

This work aims to study and analyze strategies and measures to improve energy performance in residential and service buildings, in order to minimize energy losses and energy consumption.

Due to the high energy dependence of European Union (EU), including Portugal and Slovenia, and high percentage of energy consumption in the building sector, there was a need to adopt strategies at European level with ambitious goals. This came to force EU - Member States to take measures to achieve the proposed targets for energy consumption reduction.

To this end, EU - Member States have adapted the laws to their needs and formed specialized agencies and qualified experts on energy certification, which somehow evaluate buildings according to their performance.

In this study, the external characteristics of the building in order to meet its thermal needs and from there to survey the existing and possible constructive solutions to be used at the envelope will be examined, in order to increase comfort and reduce the need of use technical means of air conditioning.

The possibility of passive heating and ventilation systems also will be discussed. These techniques are developed in parallel with the deployment and design of the building. In this manner, to reduce the energy consumption, various techniques and technologies exploit natural resources.

Thus, appear the more sustainable and efficient buildings, so-called Green Buildings have been appeared.

The study ends with the identification of measures used in several buildings, proving the economic return in the medium to long term, as well as the satisfaction of their users.

RESUMO

Este trabalho tem como objectivo estudar e analisar medidas e estratégias de forma a melhorar a performance energética em edifícios residenciais e de serviços, no sentido de minimizar as perdas energéticas e consumos de energia.

Devido à elevada dependência energética europeia, entre os quais Portugal e Eslovénia, e sendo o sector da edificação responsável por um alta percentagem de consumo de energia, houve a necessidade de adopção de estratégias a nível europeu com objectivos ambiciosos. Isto veio forçar os estados membros a tomar medidas de forma a atingir os objectivos propostos na redução do consumo energético.

Para tal, os estados membros adaptaram as leis às suas necessidades e formaram agências especializadas e peritos em certificação energética, que de certa forma avaliam os edifícios de acordo com a sua performance.

Este estudo analisa características externas ao edifício com o intuito de conhecer as necessidades térmicas do mesmo e daí partir para o levantamento das soluções construtivas existentes e possíveis de ser utilizadas ao nível da envolvente, de forma a aumentar o conforto e reduzir a necessidade de utilização de meios técnicos de ar condicionado.

Foi igualmente abordada a possibilidade de aquecimento e ventilação passiva. Estas técnicas são desenvolvidas em paralelo com a projecção e design do edifício. Desta forma várias técnicas e tecnologias aproveitam os recursos naturais para uma redução do consumo energético.

Assim surgem edifícios mais sustentáveis e eficientes, os chamados Edifícios Verdes.

O estudo finaliza com a identificação de medidas utilizadas em vários edifícios, comprovando o retorno económico a médio/longo do investimento e a satisfação dos seus utilizadores.

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ACRONYMS AND ABBREVIATIONS LIST

ADENE – Energy Agency (Agência para a Energia)

AREAM – Agência Regional da Energia e Ambiente da Região Autónoma da Madeira

CDD – Cooling degree days

CFC – chlorofluorocarbon

CIB – Conseil Internacional du Batiment

EC – European Commission

EU – European Union

EPBD – Energy Performance of Buildings Directive

EPS – expanded polystyrene

GHG – Greenhouse Gas(es)

HCFC – Hydrochlorofluorocarbon

HDD – Heating degree days

HFC – Hydrofluorocarbon

HVAC – Heating, Ventilating and Air Conditioning

LPG – Liquefied petroleum gas

Mtoe – Million Tonnes of Oil Equivalent

PPERAM – Plano de Política Energética da Região Autónoma da Madeira

PVC - Polyvinyl Chloride

RCCTE – Regulamento das Características de Comportamento Térmico de Edifícios (Regulations on Thermal Behaviour of Buildings)

RSECE – Regulamento dos Sistemas Energéticos de Climatização em Edifícios (Regulations on HVAC Systems in Buildings)

SCE – Sistema de Certificação Energética (Energy Certification System)

SIP – Structural Insulated Panel

TREES – Training for Renovated Energy Efficient Social housing

UNPD – United Nations Population Division

UV - Ultraviolet Light

XPS – extruded polystyrene

1 INTRODUCTION

This work goes toward a very basic need of the population, which finds in buildings the protection against adverse weather conditions and comfort for living.

The population growth and development have been accompanied of human activities, the construction is an example of them. However, the world population increased more them two times since 1950 overtaking 6500 millions of habitants in 1997 (UNPD, 1999). This data means important alterations, driving to major needs of the protection of natural resources and to the construction activities with environmental impacts that have to be taken in consideration.

Buildings, infrastructure and environment are inextricably linked. Energy, materials, water and land are all consumed in the construction and operation of buildings and infrastructure. These built structures in turn become part of our living environment, affecting our living conditions, social well-being and health. It is therefore important to explore environmentally and economically sound design and development techniques in order to plan, design and build buildings and infrastructure that are sustainable, healthy and affordable (United Nations, 2010).

In this sense, although still considered a fringe movement, in the early twenty-first century the green building concept has won acceptance, and it continues to impact building design, construction, operation, states development, and sales markets of building industry.

Today the buildings should be planned, constructed and run according to the legal framework principles of energy efficiency adopted by Member States of EU. It is also necessary to initiate a new energy-performance, with the strategic objective of encouraging the use of renewable energy sources (sun, wind, water, etc.) in a way to be pursued diligently, that requiring a string focus on research, which should be supported by adequate investment and energy policies.

Thus, this work fits in the application of constructive measures and design strategies for energy savings but also in several methods and models of how to take advantage from the natural resources.

2 SUSTAINABLE CONSTRUCTION

2.1 Sustainable Development

The theme of sustainable development began to emerge in the second half of the twentieth century, when Man began to be aware of the gradual degradation inflected by their development policies to the environment. It was realized that as a result of its cruel destructive activities, the Earth's biodiversity is declining at rate of about 50000 species per year and that the level of inorganic resources were not infinitely inexhaustible, so that could not continue to base the energy systems in non-renewable recourses (Brown, 2001).

As a concept sustainable development promises many things to many people. Aspects of government policy, business strategy and even lifestyle decisions have been shaped around this concept.

The term 'sustainable development' has been continually redefined to cover ever-growing parts of life on the planet. There are many accepted or acceptable definitions of sustainable development and therein lies the first set of problems; is it possible to have one defining explanation, or does it depend on the personal viewpoint? (Mawhinney, 2002) The most noted definition, which came from the Brundtland Report (World Commission on Environment and Development, 1987) was:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Although this definition has been vague, it brings a very positive and simple message, proposing to seek a balance between levels of development and existing quantity of natural resources so that the development occurred at a level that can be maintained without harming the natural environment or future generations. This report supported the idea needed for a common and global effort towards the correction of the economic development.

Other definitions have emerged as the one from World Wildlife Fund (International Union for Conservation of Nature, 1991) that says:

"Sustainable development means improving the quality of life while living within the carrying capacity of supporting systems."

Sustainable development is actually a much broader concept than environment protection. It implies a concern for future generations and maintaining or improving the health and integrity of the environment in the long term. It also includes concerns about the quality of life, the equity between the generations and different social issues, heath and ethical aspects of human welfare. Sustainable development is proposed to nothing less than the rescue of a complete rationalization seeking to balance the differences in social – through social justice –, economic – through economic efficiency –, and ecological – through ecological prudence (Brüsecke, 1996).

Sustainable development has thus three dimensions: economic, social and environment.

Figure 2.1: Pillars of Sustainable Development
Source: old.manifesto2009.pes.org, 03/08/2010

2.2 Sustainable Construction

Sustainable construction was defined as “...the creation and responsible maintenance of a healthy built environment based on ecological principles, and by means of an efficient use of resources...” during the First International Conference on Sustainable Construction of Conseil International du Batiment (CIB) in 1994. The CIB articulated seven Principles of Sustainable Construction, which would ideally inform decision making during the design and construction process, continuing throughout the building’s entire life cycle, as:

1. Reduce resource consumption
2. Reuse resources
3. Use recyclable resources
4. Protect nature
5. Eliminate toxics
6. Apply life-cycle costing
7. Focus on quality

These factors have also to be applied for the evaluation of the components and other resources needed for construction. The principles of sustainable construction have to be applied during the entire life cycle of construction, from planning to disposal, “deconstruction rather than demolition”. Furthermore, the principles applied to the resources needed to create and operate the built environment during its entire life cycle are: land, materials, water, energy, and ecosystems (Kibert, 2008).

The concept of sustainability in construction has evolved over many years. The initial focus was on how to deal with the issue of limited resources, especially energy, and on how to reduce impacts on the natural environment. Emphasis was placed on technical issues such as materials, building components, construction technologies and energy related design concepts. Sustainable construction techniques provide an ethical and practical response to those issues. Sustainability assumptions encompass the entire life cycle of the building and its constituent components, from resource extraction through disposal at the end of the materials’ useful life. More recently, an appreciation of the significance of non-technical issues has grown. It is now recognised that economic and social sustainability are important, as are the cultural heritage aspects of the built environment (Huovilla, 2004).

Still, sustainable construction adopts different approaches and is accorded different priorities in different countries. It is not surprising that there are widely divergent views and interpretations between countries with developed market economies and those with developing economies. Countries with mature economies are in the position of being able to devote greater attention to creating more sustainable buildings by upgrading the existing building stock through the application of new developments or the invention and use of innovative technologies for energy and material savings, while developing countries are more likely to focus on social equality and economic sustainability (United Nations, 2010).

To conclude, sustainable construction is a way for the building industry to move towards achieving sustainable development, taking into account environmental, socio-economic and cultural issues. Specifically, it involves issues such as design and management of buildings, materials and building performance, energy and resource consumption - within the larger orbit of urban development and management.

2.2.1 Green Building

2.2.1.1 Definition

Green Building may have different definitions due the context of each project and the perspectives of each individual. The site, country, community, climate, etc. can vary. After reading several definitions one of them which seem most appropriate was chosen. The California Integrated Waste Management Board[1] defines a *Green Building* as, "...a green building, also known as a sustainable building that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objective such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment"(Kibert, 2008). For Peter Yost "...the heart of green building is resource efficiency in the design, construction and operation. The soul of green building is systems integration is design and construction. Green building addresses four major areas: energy, materials, indoor environmental quality and site development."(Yost, 2002).

Picture 2.1: Green Tower, Miami
Source: www.inhabitat.com, 15/04/2010

The definition of green building has moved from simple energy conservation, as in the 1980's, to a broader one; adding to it sustainable sites, water and energy efficiency, environmentally preferable construction products, finishes and furnishings, waste

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[1] Leading authority on recycling and waste reduction, created by legislation and adopted by the California Legislature.

stream management, indoor environmental quality, and integrated, whole-building design and construction practices (Herz, 2006).

Figure 2.2: Green Building description
Source: U. S. Green Building, 17/04/2010

The definitions of green building will sometimes include a description of high performance buildings. These buildings while similar to a green buildings specifically aims to be energy efficient and it’s what this dissertation focus about.

Energy consumption remains the single most important green building issue, not only because of its environmental impacts but also because of the significantly energy costs. A green building would ideally use very little energy, and renewable energy would be the source of most of the energy needed to heat, cool, and ventilate it (Kibert, 2008).

2.2.1.2 Benefits

The phenomena of green building is not a simple development trend; it is an approach to building suited to the demands of its time, whose relevance and importance will only continue to increase. The benefits to green building are manifold, and may be categorized along three fronts: environmental, economic, and social (Bloomington, 2010).

Environmental benefits

- Enhancement and protection of ecosystems and biodiversity
- Emissions reduction
- Improvement of air and water quality
- Reduction of solid waste by using recycled building materials
- Conservation of natural resources.

Economic Benefits

A common impression about green building is that it is too expensive to be considered economically feasible. However, studies have shown that the costs of green buildings are not substantially higher than regular development projects. Additionally, green buildings provide an assortment of economic advantages (Bloomington, 2010).

- Reduction of operating and energy costs
- Enhancement of asset value and profits
- Improvement of employee productivity and satisfaction
- Optimization of life-cycle economic performance.

Social Benefits

- Improvement of indoor air, thermal, and acoustic environments
- Enhancement of comfort and health for employees, tenants, students and customers
- Minimization strain on local infrastructure by using less energy, water and reducing solid waste
- Improvement of overall quality of life for employees, tenants, students and customers.

2.2.1.3 Costs

Comparing various building types many inefficiencies can be minimized, overall comfort can be enhanced, many environmental and economic cost can be reduced, and property value can be increased (Cohen-Rosenthanl, 2000).

In quantifying costs of green building there are two factors that need to be considered; the initial capital outlay of the building and the payback period, the time that it takes to pay back the additional sustainability features of the building (Langston, 2001).

Not all projects necessarily have, or require additional sustainability features to be considered green. In many projects, the design and material features that enhance green building criteria are more carefully selected at the early design stages (Beyer, 2002).

Operation costs are significant cost saving. Operation costs relate to energy, as well as to water consumed by active systems within buildings. By implementing technologies that save energy and water, developers, homeowners, and businesses, in addition to the environmental protection, the operation costs save money in every kilowatt of power that is not consumed.

Typically, in residential building, space heating and cooling and hot water heating consume the most operation energy, whilst in commercial buildings, heating, HVAC is the greatest consumer (SEDO, 2002).

Life-cycle costing of energy efficient and green buildings shows significantly reduced operating costs in terms of savings on energy and water.

2.2.1.4 General Techniques

Whole-building design views buildings as integrated systems of interacting components. This analytic approach offers opportunities for developers, builders, consumers, governments, and the general public to analyze and evaluate the relative effectiveness of various building materials, construction techniques, operating procedures and fates of the materials when the building is ultimately retired.

The layout and design of a building has an impact on energy consumption. A well-planned site will preserve much of the natural vegetation and increase the energy efficiency of the building. In addition the amount of excavation required can be reduced, thus reducing construction costs and environmental impacts of the construction process (National Association of Home Builders, 2002).

Greater resource efficiency, in the form of energy conservation, results in cost savings, more so when several technologies are used in conjunction with each other (Anderson, 1993). The savings result from using energy efficient technology rather than nonenergy efficient/conventional, new technology.

Homeowners, home buyers, and home builders can save energy by investing in appliances that are energy efficient.

In residential buildings, homeowners can, for example, install insulation in roofs and walls that eliminate thermal bridging, install high performance windows and seal it well. If there is enough sun available solar panels for water heating can be also installed.

In the case of service buildings, the same basic challenges as residential buildings are taking part. These buildings are usually larger so the opportunities to use high technologies and take advantage of design are bigger.

Heating and cooling systems are usually the largest energy consumers but nowadays specializes companies develop high technology with the highest efficiency intending to reduce that consumption. If they are used at big scales, the savings will be bigger, as well.

The design associated to the orientation of the building can provide natural light and passive heating and cooling. Using several techniques, incorporated in the structural design may significantly reduce the amount of energy needed. Generally, passive methods do not require any mechanical or electronic devices.

3 STATE OF THE ART

3.1 Building energy consumption

3.1.1 The European Union (EU) - Level

The EU - Member States are working intensively to improve energy efficiency in all end-use sectors and to increase the exploitation of renewable energy sources in order to tackle environmental concerns deriving from energy consumption of fossil fuels, and to support self-sufficiency and energy security (EC, 2010).

From the final energy consumption in 2003 there were 1131.6 Mtoe. The share was as follows: 44% is oil, 23.9% gas, 20.2% electricity, 4.8% solid fuels, 4.2% renewables and 2.8% derived heat. This is a grim situation given that the EU-25 import dependency is 48% for all fuels, and 76.8% for oil, 51.3% for gas and 33.2% for solid fuels (Eurostat, 2004).

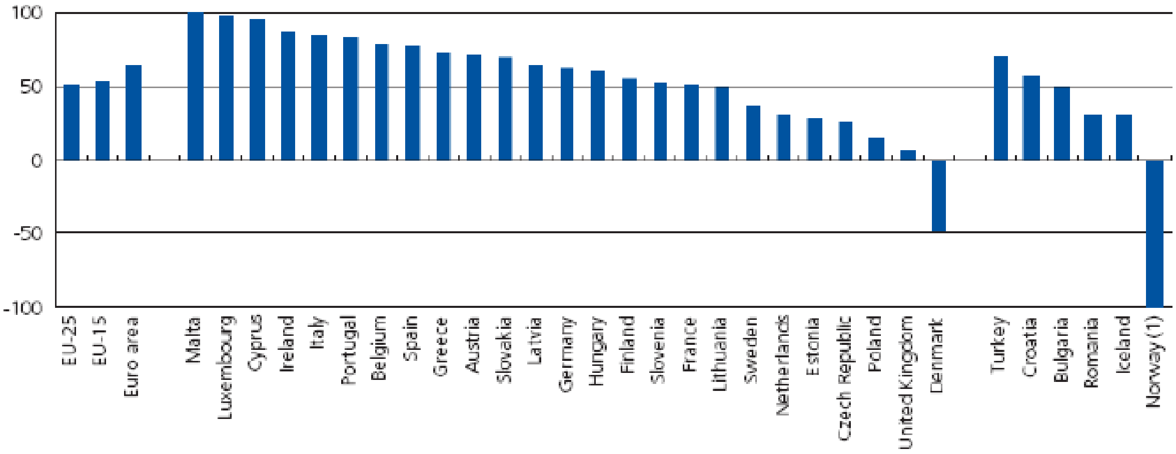

Figure 3.1:Energy dependence rate in Europe
Source: Eurostat, 2004

Energy consumption increased by 12.6 % between 1990 and 2004, thus to an extent counteracting reductions in the environmental impact of energy production, and achieved as a result of fuel mix changes and technological improvements. Between 2003 and 2004, final energy consumption grew by 1.1 %. The fastest growing sector was transport, followed by households and services. Final energy consumption in industry fell during this period but picked up in 2004. The structure of final energy consumption has also undergone significant changes in recent years. The new EU - Member States have seen falling final energy consumption, however, with the recovery in these countries' economies, final energy consumption has grown slightly since 2000.

These structural changes and improvements in energy efficiency meant that between 1990 and 2004 the average annual EU-25 growth rate of final energy consumption of 0.8 % that was well below the one of the EU-25 gross domestic product growth of 2.1 %. Household final energy consumption increased by 17.5 % as rising personal incomes have permitted higher standards of living, with increases in comfort levels and the ownership of domestic appliances. Space heating and cooling is the most significant component of household energy demand; it can vary substantially from year to year depending on climatic variations and from country to country depending on the location. However, it means the demand for electricity from appliances that has increased most rapidly in percentage terms in recent years.

It is projected that after the year 2010, final consumption will decrease. This is in large part due to technological progress in transport efficiency, improved insulation standards in homes and other buildings and further development of industrial energy efficiency (Eurostat, 2002).

There are significant opportunities to reduce final energy consumption in all sectors beyond a baseline development, but particularly in the household and service sectors via the reduction in energy consumption for heating, electrical appliances and lighting. In these sectors, the use of minimum standards for new buildings and appliances, more wide-spread uptake of existing cost-effective measures and the provision of energy services as well as demand side management should be important to ensure that this potential reduction will be realised.

Buildings are responsible for 40% of energy consumption, of which residential use represents 63% of total energy consumption. Various factors influence energy consumption in buildings. Among them, envelope construction, age distribution of the existing building stock, outdoor weather conditions, number and size of buildings, type, age and efficiency of equipment, fuel split for heating and sanitary hot water production. Improving the energy performance of buildings is a cost-effective way of fighting against climate change, improving energy security and an important instrument in the efforts to alleviate the EU energy import dependency (currently at about 48%) as well as to comply with the Kyoto Protocol to reduce carbon dioxide emissions while also creating job opportunities, particularly in the building sector. Buildings are also a major pollution source. The most important greenhouse gas (GHG) by far is carbon dioxide (CO_2), accounting for 82% of total EU emissions in 2002. About 39% of total EU emissions of CO_2 originate from electricity and heat production. In addition, CO_2 emissions from residential buildings are the fourth largest key source of GHG emissions in the EU and account for 10% of total GHG emissions in 2002, while emissions from commercial buildings are ranked fifth and account for 3.7% of the total. However, considering the aggregate electrical and thermal energy consumption, buildings account for about a third of the total energy related CO_2 emissions and almost all atmospheric pollutants, and even higher in some countries depending on the use of electrical energy and fuel used for power production. Reductions in energy use in buildings will lead to a reduction in the use of fossil fuels by reducing emissions of GHG and reducing local-to-regional air pollution problems (Constantinos, 2005).

Given the low turn-over rate of buildings estimating the lifetime of 50 to more than 100 years and the high number of existing buildings, it is clear that the largest potential for improving energy performance in the short and medium term is definitely in the existing stock of buildings. Building refurbishment should also be viewed as an opportunity to exploit renewable energy sources and related technologies, with an emphasis on passive and active solar energy solutions, daylighting, natural cooling, cogeneration of heat and power, connection to district heating/cooling and renewable energy sources.

3.1.2 National Level

Portugal has a territory of 92000 km^2, where most of it is part of the Iberian Peninsula, and the rest corresponds to Madeira and Azores Islands. Portugal has a Mediterranean climate according to Köppen[1] climate classification and is one of the warmest European countries. The annual average temperature in mainland is from 13°C in the mountains to over 18°C in the south (Portuguese Meteorological institute, 2010).

The total final energy consumption in 2005 was 19,48 Mtoe, with a growth rate of 61,1% over 1990 consumption. The final energy consumption is dominated by transport and industry. However, a substantial increase in final energy consumption caused a high dependence of importation due the only energy national source is renewable energy. Portugal imports 87% of the energy that is consumed. Self-supply in 2002 accounted for 13,2% of the total production, from which 10,4% came from wastes and biofuels, and hydropower and other renewable energies (DGGE, 2005).

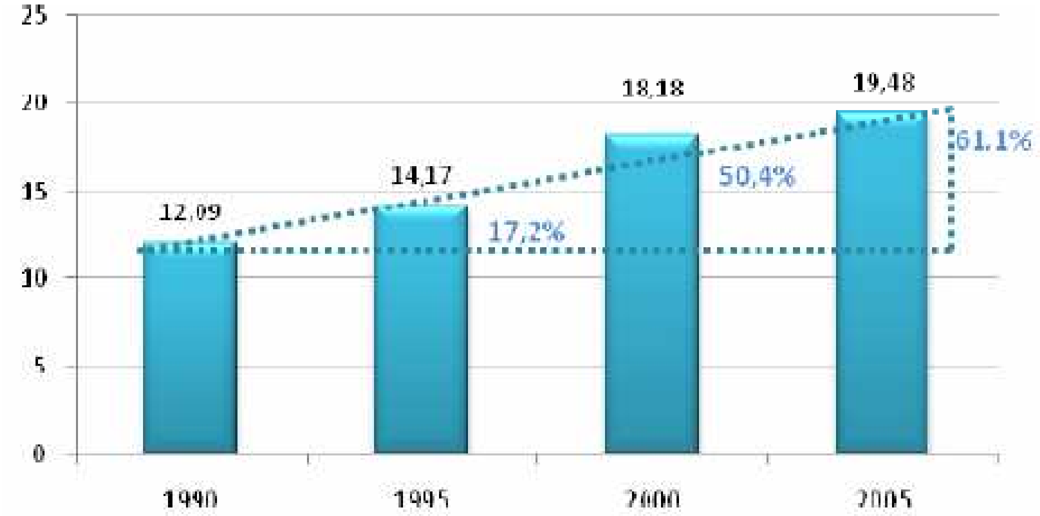

Figure 3.2: Final Energy Consumption
Source: DGGE – Energy Balance (1990-2005)

The oil is the main source of energy supply. Natural gas was introduced first in 1997 and it is important in the energy supply and electricity production. The electricity production highly depends from hydropower, which presents a significant annual variation, and the coal is also important. In combination with the slowing of economic growth the implementation of some important policies and measures were introduced

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[1] 100 years old climate classification system formulated by Wladimir Köppen. It has been made several modifications over the years.

which enabled the diversification of the energy supply structure and a reduction in external dependence on oil (EUSUSTEL, 2006).

There has been a significant boost of investment in renewable energy. The annual rate of installation of renewable energy technologies for electricity generation increased largely since 2004, demonstrating Portugal's determination in diversifying its energy sources and decreasing its carbon impact. This is particularly the case for the wind energy sector, reference targets for which have been raised from 3750 MW to 5100 MW by the Government (Institute for the Environment, 2006).

Residential sector

The buildings are responsible for 30% consumption of the final energy. The corresponding energy sources are very diverse, but there is a preponderance of consumption of electricity in buildings that represents 62% of national consumption.

In the residential sector, with over 3.3 million buildings, the growth of comfort and the rate of ownership of energy-using equipment placed the average annual growth of energy consumption in residential buildings by 3.7% between 2002 and 2007. The 17% of final energy sector, although representing 29% of the electricity consumed in Portugal, is indicating the importance of this source of energy for households.

To conclude, the overall analysis of the distribution of final energy consumption of households reveals the following:

a) 50% are consumed in the production of food and heating of sanitary water.
b) 25% in lighting and appliances.
c) 25% heating and cooling.

These numbers show the need to act on both fronts with measures of rational use of energy. Solar thermal energy could have a big impact, with the promotion of Solar Hot Water Program for Portugal[2]. The area of conditioning is only 25%, but with a high growth rate due to higher demand for thermal comfort. The heating and cooling account for a third part of intervention.

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[2] Council of Ministers Resolution 63/2003, of 28 April.

3.1.3 Regional Level[3]

Madeira Autonomous Region is one of the Portuguese archipelagos located in the Atlantic Ocean with a total area of 801 km^2. The nearest shore (African cost) is the about 670 km away while the distance from the European Continent is about 978 km.

Madeira Island's geographical position and mountainous landscape result in a very pleasant climate which varies between the north side and south side. It's a Subtropical-Mediterranean Climate according to Köppen climate classification. It has a narrower temperature range with annual temperatures exceeding 20°C in the south cost (Portuguese Meteorological institute, 2010).

The demand of final energy in Madeira increased about 76,3% between the years of 1991 and 2000, with a growth rate of 6,4% per year. However, this increment behaved differently for each activity sectors, being accentuated in the services sector, that had a growth of 114,2% in the same time period. The sector of transports doubled the consumption and represented 57% of final energy consumption. This is major evidence that created the need to rethink the energy policy and relate it with land use planning and transportation policy in the Island.

In the year 2000 the residential sector represented 17,4% of final energy consumption. The improvement of living conditions, expressed by comfort levels, resulted in a 13,7% increase of energy use, since 1991.

The liquefied petroleum gas (LPG) was the sort of final energy most utilized in this sector replacing biomass (firewood) and increasing the energy efficiency for food preparation and water heating. The electricity was the second sort of final energy most used and that represented the highest growth since 1991 (68%). The biggest amount of electricity consumed is associated to lighting and cold appliances.

The production of domestic hot water represents the larger parcel of consumption contributing with 35% for the final energy consumption. Right after it is the preparation food with 33% followed by home appliances and lighting with 29%. The HVAC systems have insignificant importance with a residual value of 3% (PPERAM, 2002).

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[3] Plano de Política Energética da Região Autónoma da Madeira, Vice-Presidência do Governo Regional. 2002

3.2 Legal Framework

3.2.1 EU-Level

The EU is facing unprecedented energy challenges resulting from increased import dependency, concerns over supplies of fossil fuels worldwide and the climate change. Europe continues to waste at least 20% of its energy due to inefficiency.

3.2.1.1 Action Plan[1]

The 2006 Spring European Council called for the adoption as a matter of urgency of an ambitious and realistic Action Plan for Energy Efficiency. The policies and measures in this Plan are based on consultations on the Green Paper on Energy Efficiency[2]. Energy efficiency in the building sector was identified as a top priority.

The Action Plan aimed at achieving a 20% reduction in energy consumption by 2020 reducing energy demand and taking targeted action on consumption and supply. This objective corresponds to achieving approximately a 1.5% saving per year. The Action Plan includes measures to improve the energy performance of products, buildings and services, to improve the yield of energy production and distribution, to reduce the impact of transport on energy consumption, to facilitate financing and investments in the sector, to encourage and consolidate rational energy consumption behaviour and to step up international action on energy efficiency. The largest cost-effective savings potential lies in the residential and commercial buildings sector, where the full potential is estimated as around 27% and 30% of energy use, respectively. Achieving the 20% reduction objective will help reduce the EU's impact on climate change and dependence on fossil fuel imports. The purpose of this Action Plan is to mobilise the general public, policy-makers and market actors, and to transform the internal energy market in a way that provides EU citizens with the most energy-efficient infrastructure (including buildings), products, and energy systems in the world. The Action Plan runs for a six-year period from January 1, 2007 to December 31, 2012 (European Commission, 2010).

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[1] Commission of the European Communities, 2006. Action Plan for Energy Efficiency: Realising the Potential, Brussels.

[2] Green Paper on Energy Efficiency, “Doing More with Less”, COM (2005) 265 final of 22/06/2005. A total of 241 responses calling for action in all energy sectors were received during the public consultation process on the Green Paper.

Energy performance of buildings is the issue to achieve the EU economy recovery and competitiveness, energy security and for meeting the commitments on climate change made under the Kyoto protocol[3] whilst at the same time contribute to an improved level of comfort, as well as lower energy bills for citizens. It may, however create new job opportunities, particularly in the building sector.

Measures

Targeted sectoral and horizontal measures are included in the Action Plan. First, the setting of dynamic energy performance requirements for a wide range of products, buildings and services were necessary. Targeted instruments were also needed for the energy transformation sector to improve the efficiency of both new and existing generating capacity and to reduce transmission and distribution losses.

Secondly, appropriate and cost-reflective price signals are essential for improving energy efficiency and for overall economic efficiency. Improved financing tools and economic incentives targeting all sectors were also required. Energy efficiency issues need urgently to be addressed on a global level, using international partnerships. Innovation and technology also play a crucial role.

The saving potentials and the likely impacts of some measures are larger or more evident than others.

Dynamic energy performance requirements for energy-using

A comprehensive framework of directives and regulations to improve energy efficiency in energy-using products, buildings and services is in force in Community law. These include the Eco-Design Directive[4], the Energy Star Regulation[5], the Labelling Directive[6], the Directive on Energy End-Use Efficiency and Energy Services[7] and the Energy Performance of Buildings Directive[8].

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[3] International agreement linked to the United Nations Framework Convention on Climate Change. Bind targets for 37 countries and the European community for reducing GHG emissions. Adapted in Japan on December 11, 1997 and entered into force on February 16, 2005.

[4] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009.

[5] European Council nº 2422/2001.

[6] Directive 2000/13/EC.

[7] Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006.

[8] Directive 2002/91/EC on the energy performance of buildings.

The issue that is of special interests is the Energy Performance of Buildings Directive (EPBD) from 2002. Due to significant potential for reducing consumption energy in building, the EU looks for buildings as an important sector to achieve the energy savings targets and to combat climate change whilst contributing to energy security. An enormous unrealized savings potential lies dormant in buildings.

3.2.1.2 Energy Performance of Buildings Directive (EPBD)[9]

The EPBD[10] was approved on December 16, 2002 and brought into force on January 4, 2003. It was designed to slash emissions and help the bloc meet its targets under the Kyoto Protocol. Minimising energy waste in a sector that covers over a third of the Union’s energy demand was crucial element in reducing Europe’s dependence on foreign fossil fuel imports. On May 19, 2010, a recast of the EPBD was adopted by the European Parliament and the Council of the EU in order to strengthen the energy performance requirements and to clarify and streamline some of the provisions from the 2002 Directive it replaces.

It provided a common methodology for calculating the energy performance of buildings and obliged EU - Member States to draw up minimum standards. These should be applied to all new buildings and to existing buildings.

Consequently, the legislation stopped short of imposing EU-wide minimum efficiency standards in favour of a flexible approach, requiring EU - Member States to lay down concrete requirements, while accounting for local climate conditions and building traditions (EurActiv.com, 2010).

This Directive has as principal objective the improvement of the energy performance of buildings within the EU through cost-effective measures. It lays down requirements as regards:

- the establishment of the calculation methodology where the EU - Member States have to implement a methodology, which may be differentiated at regional level, for the calculation of the energy performance of buildings, taking account of all factors that influence energy use;
- the application of minimum energy performance requirements. There have to be regulations that set minimum energy performance requirements for new buildings and for large existing buildings when they are refurbished;
- the energy performance certificate made available whenever buildings are constructed, sold or rented out;

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[9] Directive 2002/91/EC on the energy performance of buildings.
[10] Directive 2002/91/EC on the energy performance of buildings.

- the regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation when the boilers are more than 15 years old.

Adaptation of a calculation methodology

The specification of the calculation methodology is central to the EPBD as it impinges on the requirements both for building regulations and for energy performance certificates. The Directive does not specify a detailed calculation methodology, leaving it up to EU - Member States, but it does clarify that the methodology is one that embraces the overall energy performance of the building, inclusive of its services. Specifically it says that the methodology shall include at least the following aspects:

(a) thermal characteristics of the building (shell and internal partitions, etc.) which may also include air-tightness;
(b) heating installation and hot water supply, including their insulation characteristics;
(c) air-conditioning installation;
(d) ventilation;
(e) built-in lighting installation;
(f) position and orientation of buildings, including outdoor climate;
(g) passive solar systems and solar protection;
(h) natural ventilation;
(i) indoor climatic conditions, including the designed indoor climate.

In addition, the methodology needs to take account of active solar systems and other heating and electricity systems based on renewable energy sources, electricity produced by CHP, district or block heating and cooling systems, and natural lighting.

This methodology shall be set at national or regional level.

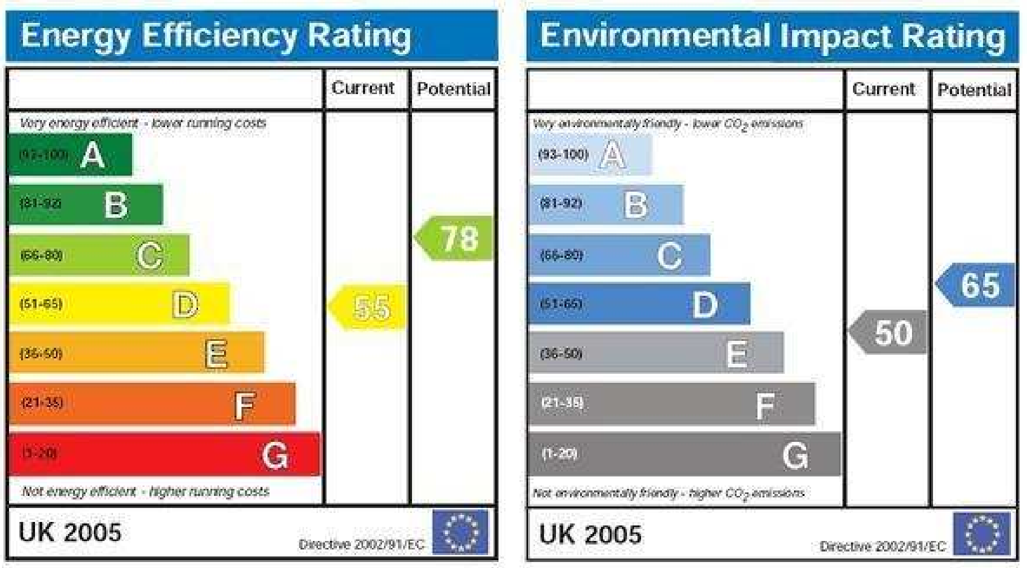
The energy performance of a building shall be expressed in a transparent manner and may include a CO_2 emission indicator, as well.

Energy performance requirements

After the EU - Member States take the necessary measures to ensure minimum energy performance requirements in buildings, they may differentiate between new and existing buildings and different categories of buildings. The Directive says that the requirements for minimum energy performance shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions and the designated function and the age of the building. These requirements shall be reviewed at regular intervals which should not be longer than five years. They shall be applied in the new and in the existing buildings. The exceptions are buildings and monuments officially protected as a national heritage, buildings used as places of worship and for religious activities, temporary buildings, industrial sites, workshops, agricultural buildings, residential buildings which are intended to be used less than four months per year and buildings standing alone with a total useful floor area of less than 50 m^2.

Energy performance certificate

When buildings are constructed, refurbished, sold or rented out, an energy performance certificate makes it available to the owner or by the owner to prospective buyer or tenant. The validity of the certificate shall not exceed 10 years. These certificates shall include reference values such as current legal standards and benchmarks in order to be possible to compare and assess the energy performance of the building. It has to be accompanied by recommendations for the cost-effective improvement of the energy performance. For buildings with a total useful floor area over 1000 m^2 occupied by public authorities and by institutions providing public services to a large number of persons, the EU - Member States shall take measures to ensure an energy certificate placed in a spot clearly visible to the public.



The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills will be.

The environmental impact rating is a measure of this home's impact on the environment. The higher the rating the less impact it has on the environment.

Figure 3.3: Sample of an Energy Performance Certificate
Source: Communities and Local Government of United Kingdom, www.communities.gov.uk (07/04/2010)

Inspection of boilers and air-conditioning systems

Aimed to reduce energy consumption and limit carbon dioxide emissions: the EU - Member States will introduce the necessary measures to establish a regular inspection of boilers fired by non-renewable liquid or solid fuel. These inspections may also be made to boilers using other fuels. The period of each inspection vary according to the rated output of the boilers from 4 to 15 years. EU - Member States shall also lay down the necessary measures to establish a one-off inspection of the whole heating installation, which shall include an assessment of the boiler efficiency and the boiler sizing compared to the heating requirements of the building or take steps to convince and attract the users to replace the boilers, to do modifications on the heating system and look for others alternative solutions which may include inspections to assess the efficiency and appropriate size of the boiler.

Regarding the air-conditioning systems and with the same goal as the boilers, EU - Member States shall adopt measures to insure regular inspection of air-conditioning systems. These inspections shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. Appropriate advices should be provided to the users on possible improvement or replacement of the systems and on alternative solutions.

3.2.2 National Level

Many EU - Member States have already adopted National Energy Efficiency Action Plans, with a dedicated national authority or agency. Under the Directive on energy efficiency all EU - Member States were required to do that. Effective coordination between these National Action Plans and action at Community level will be important. It should be noted that the potential for further energy savings varies from one EU - Member State to another (Energy Policy for Europe, CEU).

Portugal has adopted appropriate measures to implement the EPBD on 4 April 2006. The Government adopted three Decrees that together constitute the transposition of the EPBD into national law. Certification of new buildings started in July 2007.

The three Decrees published by Official Journal regarding the transposition of the EPBD into national law were:

1) Decree 78/2006 creates and defines the operational rules for the System for Energy and Indoor Air Quality Certification of Buildings (SCE)[11]
2) Decree 79/2006 establishes the new revision of the Regulations for HVAC systems, including requirements for regular inspection of boilers and air-conditioners (RSECE)[12]
3) Decree 80/2006 establishes the new revision of the Thermal Regulations for Buildings (RCCTE)[13]

In Portugal, the implementation of the EPBD is the overall responsibility of the Ministry of the Economy together with the Ministry of Environment. The direct responsibility for the three regulations belongs to the Ministry of Public Works.

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[11] Ministério da Economia e da Inovação, 2006. Decreto-lei nº 78/2006, Sistema Nacional de Certificação Energética e da Qualidade do Ar Interior nos Edifícios, In: Diário da República – I Série A.

[12] Ministério das Obras Públicas, Transportes e Comunicações, 2006. Decreto-lei nº 79/2006, Regulamento dos Sistemas Energéticos de Climatização em Edifícios, In: Diário da República – I Série A.

[13] Ministério das Obras Públicas, Transportes e Comunicações, 2006. Decreto-lei nº 80/2006, Regulamento das Características de Comportamento Térmico dos Edifícios, In: Diário da República – I Série A.

3.2.2.1 System for Energy and Indoor Air Quality Certification of Buildings (SCE)

The SCE aims to achieve two primary goals: to save energy, while ensuring conditions and acceptable indoor air quality.

There were different phases until the final implementation of the SCE in January 2009, when all the required buildings were included in the certification system: new buildings, major renovations, public buildings and all buildings when sold or rented. Firstly the certification was only required for all new residential and non-residential buildings with a floor area larger than 1000 m^2 and requesting a construction permit after July 1, 2007. The second phase included all new buildings, regardless of their floor area, requesting a construction permit after July 1, 2008 (Country reports, 2008).

Building Regulations

The system operates in conjunction with two sets of building regulations applied to construction, the Regulations on Thermal Behaviour of Buildings (RCCTE) and the Regulations on HVAC Systems in Buildings (RSECE).

The implementation of these regulations is checked by qualified experts at several stages throughout a building’s lifetime.

The Energy Certificate

The Energy Certificate is the most visible aspect of the SCE. This document assigns an energy performance label to residential buildings and it may list measures for improving their energy performance.

The energy label classifies all the existing buildings on an efficiency scale ranging from A^+ (high energy efficiency) to G (poor efficiency), but for new buildings the efficiency scale only ranges from A^+ to B^-.

Figure 3.4: Efficiency scale
Source: ADENE, Agência para a energia.

The energy certification allows future users to get information about the energy consumption potential for new buildings or deeply refurbished buildings, their actual consumption or measured for typical usage patterns from the criterion of energy costs during normal operation of the building integrating all the other important aspects to the characterization of the building. It also allows verifying the correct application of thermal regulation of the building and theirs energetic systems. In existing buildings, energy certification intended to provide information about the measures to improve performance with economical viability, which the owner can implement to reduce their energy costs and simultaneously improving the energy efficiency of the building.

In January 2009 almost half of the new buildings had energetic class A. In the other hand, a third of existing buildings had energetic class C.

New Buildings	
Class A+	14%
Class A	45%
Class B	28%
Class B-	12%

Existing Buildings	
Class A+	0%
Class A	6%
Class B	29%
Class B-	11%
Class C	32%
Class D	13%
Class E	5%
Class F	1%
Class G	2%

Table 1: Buildings energetic classes in Portugal
Source: ADENE, SCE (05/02/2009)

Qualified Experts

Qualified experts are the only persons permitted to issue Certificates and carry out inspections. They have to be recognised architects or engineers with at least five years' experience, on the basis of peer-analysis of their CVs carried out by elected boards by their professional associations. In addition, qualified experts have to attend recognized courses and pass a demanding examination that evaluates their knowledge about the certification system itself.

Energy Agency[14] (ADENE) co-ordinates the training of qualified experts and is responsible for the Energy Certification module in all courses. A professional license, valid for 5 years, is issued to Qualified Experts, and it is subject to renewal pending proof of continued training and lack of malpractice. (Energy Policy for Europe, CEU)

3.2.2.2 Regulations on HVAC Systems in Buildings (RSECE)

RSECE demands to introduce measure of rationalization, limiting the maximum potency of HVAC systems to install in buildings, to mainly avoid its oversize as markets practice shows to be common, contributing thereby for its energy efficiency.

The current regulation establishes;

1) The conditions to follow in the design of new HVAC, such as:
    - Requirements for thermal comfort and air quality inside buildings, and the minimum requirements for renovation and treatment of the air should be insured with energy efficiency;
    - The conception, installation and the conditions of maintenance of the HVAC should obey the requirements to guarantee quality and safety meanwhile his normal operation;
    - Rational use of energy and application of appropriated technology for all energetic systems in the building, following an environmental sustainability;

2) The maximum limits of energy consumption in the existing non-residential buildings;
3) The maximum limits of energy consumption for all the building and, in particular, for HVAC and power limitation in HVAC;

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[14] Portuguese Energy Agency, Agência para a vida. www.adene.pt

4) The maintenance conditions for HVAC, including requirements to assume the responsibility for it;
5) The monitoring and auditing conditions of building operation, related to energy consumption and air quality;
6) The training of qualified experts for installation and maintenance of HVAC.

Requirements for existing non-residential buildings larger than 1000 m^2

If the primary energy consumption of an existing building, based on fuel bills and covering all types of energy usage exceeds a certain level fixed by the HVAC regulations, an energy efficiency plan have to be prepared and all measures with payback shorter than 8 years have to be implemented over a three year period. This threshold level that triggers an energy efficiency plan should be regularly reduced over the years, to include an increasing number of buildings.

This requirement does not apply to smaller non-residential buildings or to any residential building.

3.2.2.3 Regulations on Thermal Behaviour of Buildings (RCCTE)

The current regulations lay down rules to be followed in the design of all residential and non-residential buildings without centralized HVAC systems, where the requirements for thermal comfort, whether heating or cooling, and ventilation to ensure air quality inside buildings, as well as the needs for hot water, could be reached without excessive use of energy. Also, minimize pathologic situations with potential negative impacts of the durability in the elements of construction and in the air quality.

Requirements for new buildings and major renovations

The type and level of requirements depend on the type of building (dwellings, office buildings, school, etc.) and cover:

1) Maximum Heating and Cooling needs per m^2 of floor area (residential and small non-residential buildings only);
2) Maximum U-value (overall heat transfer coefficient)

3) Minimum shading requirements for all windows;
4) Minimum requirements for thermal bridges;
5) Maximum consumption for production of domestic hot water, including mandatory installation of collectors for solar hot water (all residential buildings as well as large non-residential buildings with significant hot water use);
6) Maximum primary energy consumption per m^2 of floor area;
7) Minimum efficiency and quality requirements for heating and cooling systems components (non-residential buildings).

Periodic Certification

The periodic certificates are based on calculated energy ratings, and have to be periodically renewed once every 6 years. Indoor Air quality certificates have to be renewed every two or three years, depending on building typology.

The periodic certificates have to include a list of recommended energy improvement measures based on actual consumption (“energy bills”). A detailed energy and indoor air quality audit is thus required periodically. When the actual energy consumption is above a certain threshold, an energy plan is required.

3.2.3 Regional Level

If in a continental region the energy is an important strategic factor for its development, in an island as Madeira, the dependency of the system and the weak economic base aggravate the situation making energy a key element of sustainability at all levels. Actually, the alternative energies to oil like nuclear energy, coal and natural gas are not equated in an island with such small dimension. Thus, the fact of big quantities of alternative energies and big energy networks are not accessible to isolated islands, it becomes even more vulnerable to oil price fluctuation, beyond the addition costs of maritime transportation and to the reduced scale of market.

The isolated islands, usually, constitute an exceptional case regarding the sustainable development, with very special energy characteristics. Mostly of isolated islands have a common profile with their own characteristics, advantageous or penalizing, which have to be taken very carefully decisions about energy issues.

Due to these constrains, in the year of 1986 the Energetic Plan of Madeira Autonomous Region (PERAM) was created and approved by the Council of Regional Government in 1990. This plan underwent several changes until 2002 (PPERAM, 2002).

In April 4, 2006 according to the EU that all members have to implement their own system of energy certification, Madeira adopted the SCE, RSECE and RCCTE as used in Portugal continental.

4 METHODOLOGY

4.1 High Performance Building

The built environment is one clear example of the impact of human activity on natural environmental and on the quality of life.

Building impact on the environment can be significantly reduced. The industry's growing sustainability ethic is based on the principles of resources efficiency, health, and productivity (Vilnius Technical University, 2010).

This chapter discusses the characteristics of a high performance building by taking a review at those elements that make a building efficient.

4.1.1 External characteristics

4.1.1.1 Climate and Location

High Performance Building starts with a thorough examination of the Climate and the Location. Climates vary with the earth's position in relation to the sun and with the latitude and the longitude. The characteristics of a climate include the amount of sunlight, humidity and precipitation, and air temperature. Local temperatures vary with the time of day and season of the year (Binggeli, 2010).

The geographic location of the buildings has to be noted, together with the meteorological data for that location (Doty, 2009). Meteorological data can be obtained for any location in the world from Meteonorm[1] dataset. The primary data are monthly means of irradiance (direct and diffuse solar, longwave), temperature, relative humidity, precipitation, luminance, wind speed and direction, and sunshine duration. This data will be very useful in analyzing the need for energy for heating or cooling the buildings.

A convenient indicator of the heating requirement in a given climate is the number of *heating degree days* (HDD), which is defined as the daily average air temperature departure below some reference temperature for each day when the average temperature below the reference temperature, and summed over all such days. As an

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[1] Global Meteorological Database for Engineers, Planner and Education. www.meteonorm.com

average, the reference temperature is 18°C, for conventional houses no heating is required above this temperature. In principle, with lower reference temperature better-insulated buildings should be used. The HDD is a useful indicator of climatically-related differences in the potential heating requirements.

Similarly, the potential cooling requirements in local climate condition is given by the number of *cooling degree days* (CDD), defined as the daily average air temperature departure above some reference temperature for each day when the average temperature is above the reference temperature, and summed over all such days. The reference temperature for CDD should be the outdoor temperature at which internal heat gains maintain the indoor temperature at the desired temperature for comfort. This depends on the magnitude of the internal heat gains, the desired comfort temperature, and whether or not ventilation with outdoor air is permitted. The CDD reference temperature is 18°C (Harvey, 2006).

Afterwards, the envelope characteristics of the buildings are established based on the information collected before (Morrison, 2001).

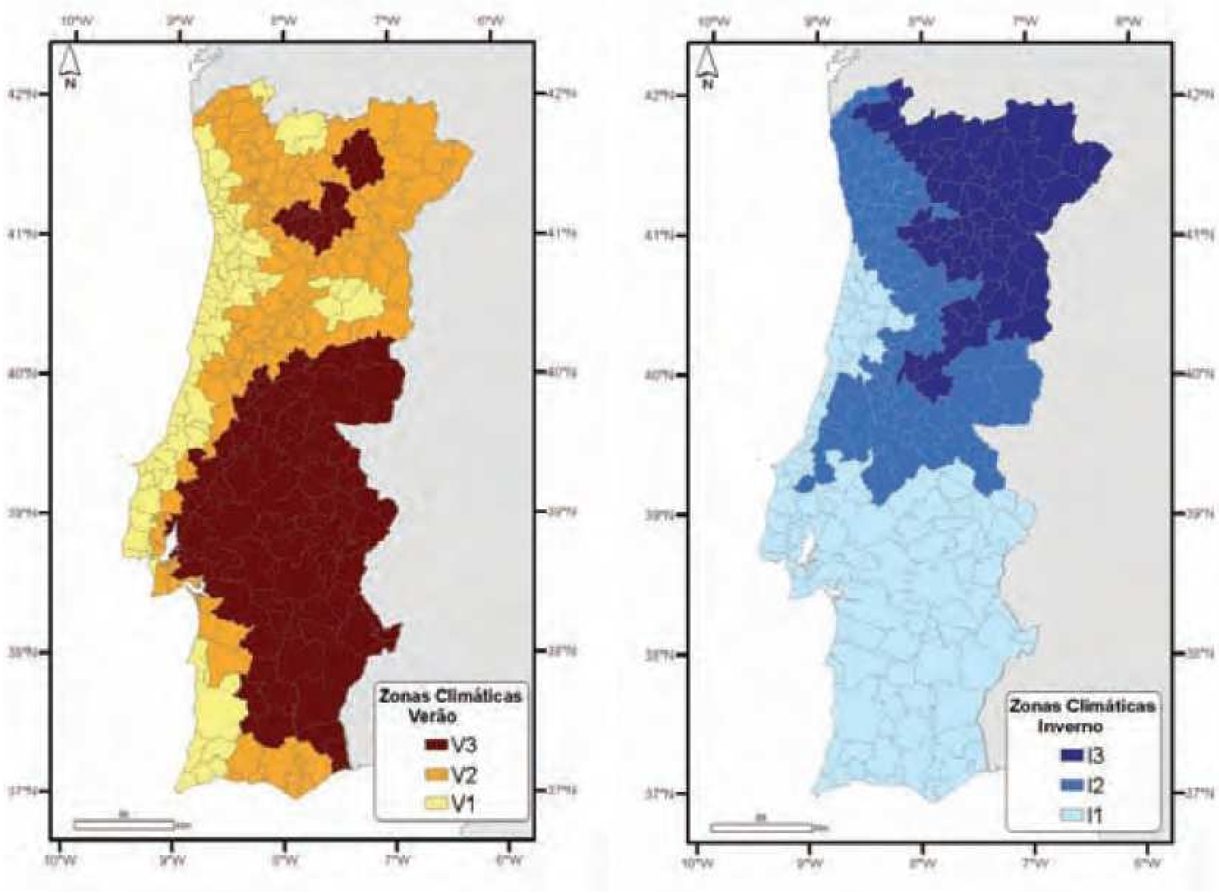

Figure 4.1: Summer and winter climate zones in Portugal
Source: EnerBuilding.eu (16/04/2010)

The areas classified as I1 correspond to locations with less need for heating in winter, whereas I3 zones have higher needs. Likewise, in summer, the areas V3 have greater cooling needs of the regions V1.

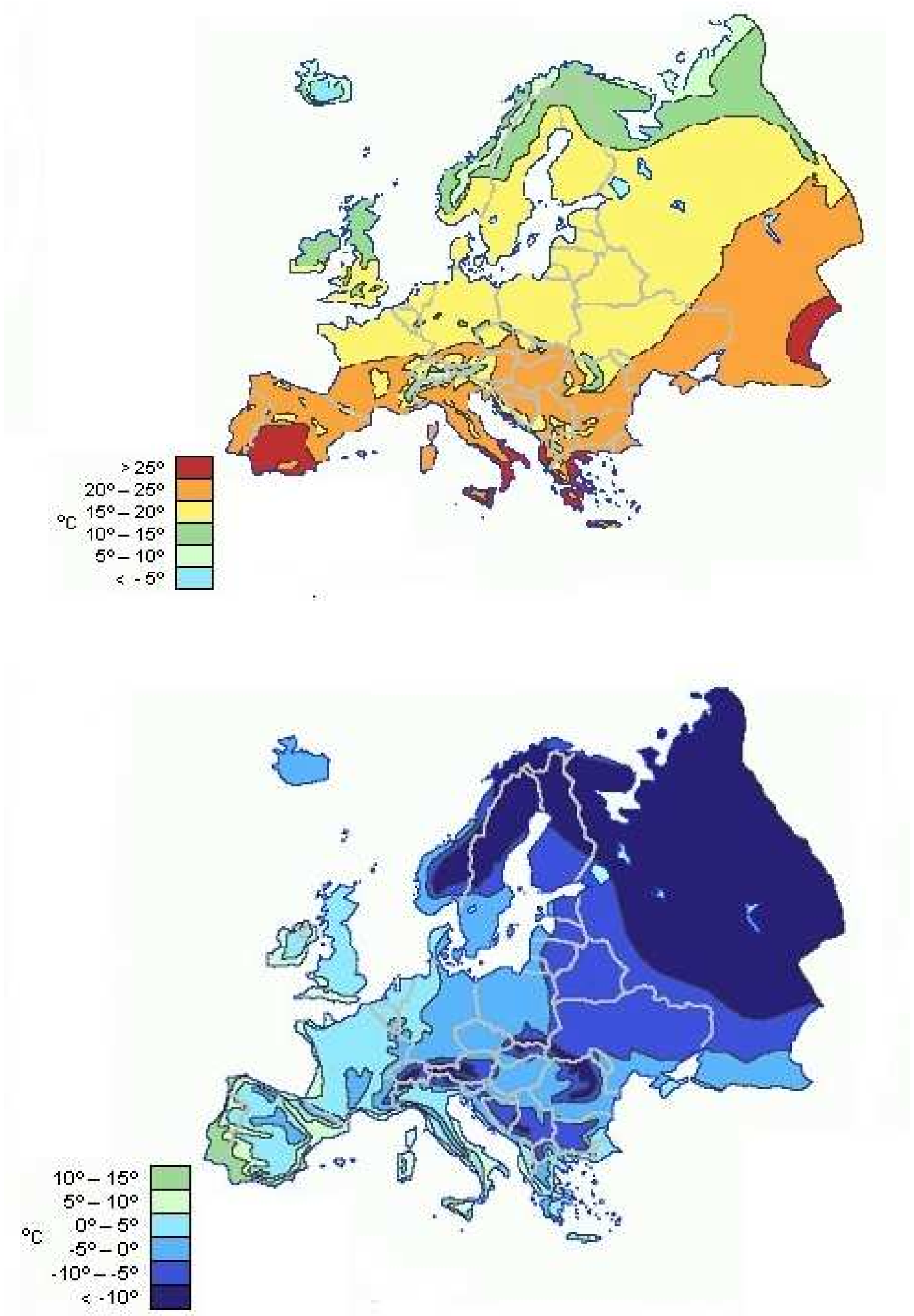

Figure 4.2: Summer and winter climate zones in Europe
Source: Grolier online passport

Experienced energy analysts recognize that the monthly energy consumption is inversely proportional to the average monthly temperature (Doty, 2009).

4.1.1.2 Building shape, form and orientation

Building shape, form and orientation are early design decisions that can have impacts on the energy efficiency and quality of the space. These decisions relate closely to heating and cooling loads, daylighting and the opportunities for passive ventilation, passive solar heating and cooling, and for active solar energy systems. Building shape refers mainly to the relative length of the overall dimensions (height, width, depth), building form refers to small-scale variations in the shape of a building, and building orientation refers to the direction that the longest horizontal dimension faces. Building shape, form and orientation will be more important the smaller the building and for the buildings with a lower-performance envelope. In large buildings, internal heat sources (people, lighting, equipment) will dominate envelope heat gains, while in highly insulated buildings with high-performance windows, shape and orientation will have only a minor impact on net winter heating requirements, particularly compared with the impact of high levels of insulation or of high-performance windows themselves. Nevertheless, the choice of building shape, form and orientation is one more strategy in the quest to minimize building energy requirements (Harvey, 2006).

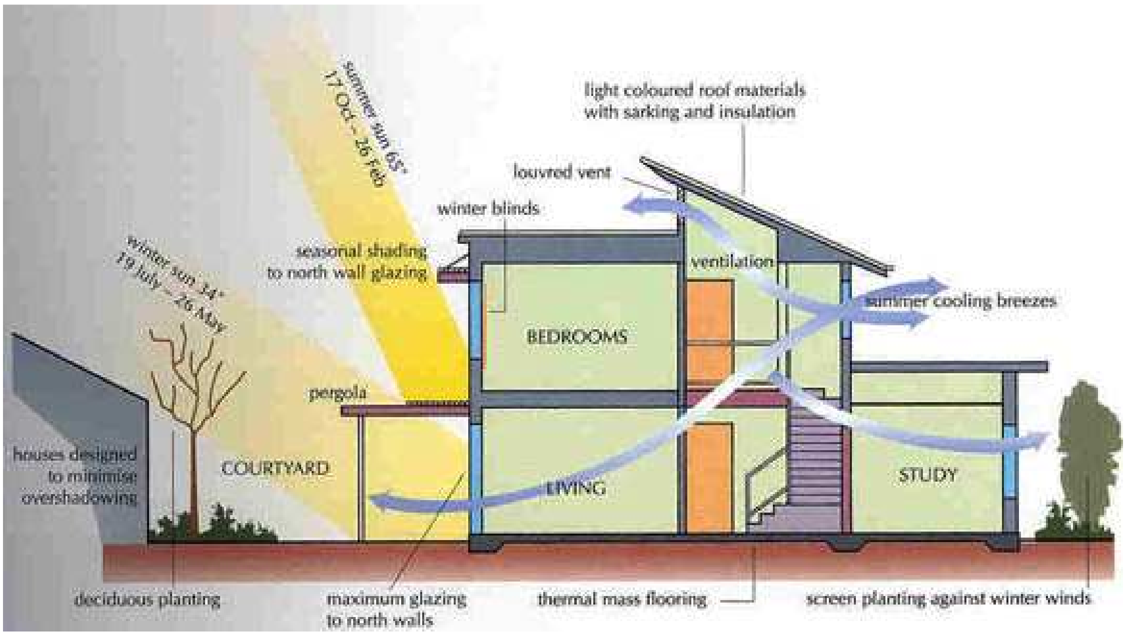

Figure 4.3: Illustration of strategic passive designed building
Source: inhabitat.com (04/08/2010)

Minimizing the surface area to volume ratio of a building will reduce the heating load for a given insulation system because the heat generated inside the building is continuously transmitted to the exterior of the house through walls, windows, roofs, floors, etc..

- **Daylighting**

The orientation of the building can take advantage from the natural light or daylight for illumination. Beyond of free light, natural lighting has been shown to provide great physical and psychological benefits to the building occupants. Developing an effective daylighting strategy can be a complex undertaking due to the trade-offs that occur between admitting light and cooling/heating the building. The cost of windows, lights and other features that function to transmit light, versus conventional construction where daylighting is not much of an issue, have to also be factored in. (Kibert, 2008) Advanced window technology make it possible to increase window area and hence daylighting opportunities without increasing heat loads in winter for most window orientation and with minimal impact on cooling loads in summer. However large or small the benefits of daylighting may be, there seems to be no disagreement that daylighting is strongly desired by people (Harvey, 2006).

Picture 4.1: Daylighting the New York Times Headquarters Building
Source: http://windows.lbl.gov/ (17/04/2010)

As an efficiency measure, daylighting is most effective during bright sunny afternoons when it can supplant the need for electric lighting entirely. Because an electric utility must provide enough generation capacity to serve the highest demand predicted for its service territory, daylighting has the potential not only to reduce the building's overall energy consumption but also to lower the peak demand.

Lighting also has an indirect impact on the total energy use because the heat generated by electricity fixtures alters the loads imposed on the mechanical cooling equipment. As a rule of thumb, each unit of lighting contributes to an additional one-half unit of electricity for space conditioning because of the contributions from the heat generated by electric lighting (Ander, 2003).

- **Active solar energy**

Estimations suggest that if the sunlight that reaches the earth's surface in one day were converted into useful energy forms, it would satisfy the energy needs of the world for more than 50 years. The amount of sunlight falling on a building typically has enough energy to keep it comfortable throughout the year. Solar energy offers an alternative with fewer air-polluting emissions and no danger of harmful radioactivity. Despite the availability of free from the sun, the cost of solar-energy systems has not been competitive with cheaper conventional-fuel systems (Bingelli, 2010).

Active solar energy technologies reduce a building's fossil fuel energy requirements and associated fuel costs. Energy from active solar sources has two major applications or uses for homes and buildings. One is as a source of electricity, and two is as a source of heat for household hot water and space heating.

Solar energy is available in photovoltaic (PV) cells which convert sunlight directly into electrical energy and thermal energy which is used for space heating, domestic hot water, power generation, and the heating of industrial processes. Simple collectors, usually place on the roof of a house or building, absorb the sun's energy and then transfer the heat to a media that moves it to points of usage. In many climates, a solar heating system can provide a high percentage of domestic hot water energy (Reyes, 2007).

Picture 4.2: Photovoltaic cell
Source: gmaganize.com.au (05/08/2010)

A solar hot water system connects the home's exiting gas or electricity water heating system, providing a supplemental source of heat for all hot water needs including showers, dishwashing, clothes washing, and cooking. A solar hot water system can provide 40 to 70% of a household's annual hot water needs. (Wisconsin Energy Bureau) Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater. In one-tank systems, the back-up heater is combined with the solar storage in one tank.

Picture 4.3: Solar panel
Source: a24.pt (04/08/2010)

4.1.2 Construction characteristics

4.1.2.1 Building Envelope

The building envelope is the shell of the building performing the barrier to the loss of interior heat or to the penetration of unwanted outside heat into the building.

The earliest shelters provided only a protection from rain and were warmed by a fire and enclosed by one or more walls. Today, people expect a lot from the buildings, beginning with the necessities for supporting human life. As buildings become more complex, people expect less protection from clothing and more from shelters. It’s also expected the control of surfaces and objects temperature for the thermal comfort (Binggeli, 2010).

It refers to the walls, windows, doors, roofs and floors of the building. The building envelope is more than a thermal barrier, however, as it contributes to the structural integrity of the building and serves as a barrier to moisture, the infiltration or exfiltration of air and noise. These functions are tightly coupled, such as those measures that lead to a higher quality thermal barrier will lead to improvements in the envelope as a barrier for sun, rain, wind and harsh temperatures, thereby reducing maintenance costs and increasing the lifespan of building envelope. Thermally tight buildings will have smaller spatial variations in temperature and lower noise from outside, contributing to a higher-quality and more comfortable indoor environment (Harvey, 2006).

The effectiveness of the thermal envelope depends on:

- Insulation levels in the walls, ceiling, and basement;
- Resistance to moisture migration;
- The thermal and optical properties of windows and doors;
- The rate of exchange of inside air with outside air through infiltration and exfiltration;
- The presence of shared walls with other buildings.

A better thermal envelope reduces the amount of heat that needs to be supplied by the heating system in winter, or the amount of cooling that is needed in summer.

The larger the building or the more compact the building, the less important the thermal envelope for heat gain and loss, but also the smaller the opportunity for cooling through natural ventilation.

4.1.2.2 Process of heat transfer[2]

The process of heat transfer is important to understand the importance of the building envelope. Heat can be transferred across the building through molecular conduction, convective mixing, passage of air through leaks in the envelope and through radiative exchange.

Conduction involves transferring molecular kinetic energy (heat) to nearby molecules through collisions, while convection involves the movement of air parcels from one place to the next either as turbulent eddies, airflow or a combination of the two. Convection can occur in the air on either side of wall or window, in cavities inside hollow-core walls or concrete blocks, and in air gap inside glazed windows. The exchange of air occurs through unintentional infiltration of outside air and exfiltration of inside air, as well as through deliberate air exchange through the ventilation system in order to provide fresh air.

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[2] Harvey, D. 2006. A Handbook on Low-Energy Buildings and District-Energy Systems, Fundamentals, Techniques and Examples, Earthscan, London.

Radiative transfer is the phenomenon of energy transfer in the form of electromagnetic radiation. All the objects above -273,15°C emit electromagnetic radiation. The warmer the object, the shorter wavelengths of the radiation that it emits. The radiation emitted by the sun (solar radiation) is divided into ultraviolet, visible and near infrared radiation. When an object absorbs radiation, it gains energy and warms up. Conversely, when an object emits infrared radiation in loses energy, so it cools.

The heat transfer properties of windows, doors and insulation are rated using three different parameters:

- **U-value** ($W/m^2/K$) is the thermal conductivity (W/m/K) divided by the thickness of the material, and is equal to the rate of heat flow (joules per second, or watts) per unit area and per degree of inside-to-outside temperature difference. It is referred to as a heat transfer coefficient. Overall heat transfer coefficient, describes how well a building element conducts heat. It measures the rate of the heat transfer through a building element over a given area, under standardized conditions. A small U-value implies less heat flow for a given temperature difference. U is the inverse o R (thermal resistance).
- **RSI-Value** $(W/m^2/K)^{-1}$ is the resistance to heat flow, numerical equal to 1/U when U is expressed in metric units. A larger RSI-values implies less heat flow for a given temperature difference. As RSI is in metric units by definition, RSI-values will be stated without units.
- **R-Value** $(Btu/ft^2/hr/F°)^{-1}$ is the resistance to heat flow, numerically equal to 1/U when U is expressed in British units. As the R-value is in British units by definition, R-values will be stated without units. To convert from RSI-values to R-values, multiply by 5,678.

4.1.2.3 Insulation

The primary purpose of thermal insulation is to reduce conductive heat flow through the building envelope, thereby lowering heating and cooling costs while minimizing the potential of condensation on or within building components (O’Brien, 2009).

The complexity of the modern building envelope requires that consideration is given to achieving insulation early in design. Design and construction practice has concentrated recently on heat losses that occur at the junctions between construction elements and around openings, or on the heat losses that occur because of uncontrolled air leakage. As standards of insulation have improved, the proportion of the total heat loss that may be attributed to these causes has increased.

Insulation should be viewed as an assembly rather than a material, since it is constructed in many different forms for various applications.

- **Thermal Bridging**

Thermal bridging is the transfer of heat across building elements, which have less thermal resistance than the added insulation. That represents the thermal bridges where occurs heat losses of 10-15%. Thermal bridges are envelope building zones where, due to geometry or the existence of constructive materials with high U-values, the heat of the indoor environment finds an easy path to get through to the outside environment. The most current situations are the junctions between different constructive elements, e.g. at wall/roof and wall/floor, and around openings, e.g. at windows jambs, where the continuity of the insulations is interrupted.

Another consequence of thermal bridges is the cooling of the inner surfaces on those zones, resulting in higher condensations and the growth moulds, creating poor air quality conditions (Lopes, 2006).

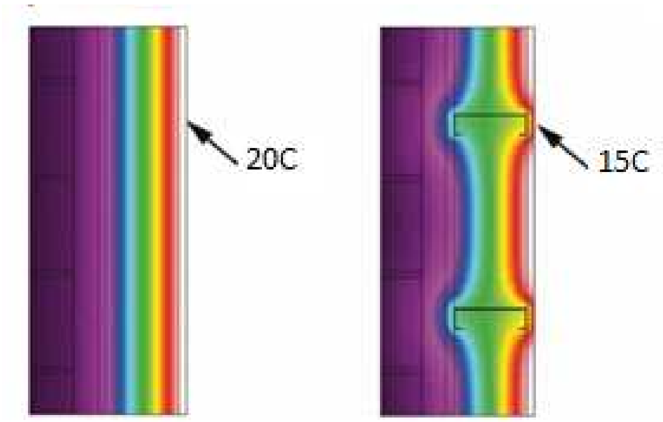

Figure 4.4: Thermal Bridging through steel studs
Source: The American Institute of Architects

- **Types of insulation**[3]

As noted above, heat can be transferred by conduction, convection, exchange of air and exchange of radiation. Conduction, involving molecular-scale motion and collisions, requires a substance through which it can take place. Solid materials are relatively good conductors compared to air, so insulation is made with minimal material so as to minimize conduction. This can be done by making the insulation from

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[3] Harvey, D. 2006. A Handbook on Low-Energy Buildings and District-Energy Systems, Fundamentals, Techniques and Examples, Earthscan, London.

loose fibres or from porous foam. Convective heat transfer, involving small-scale air motion, can be minimized or eliminated if the air pockets are very small. Insulation can take one of the following forms:

A. Conventional insulation:

- Blanket (batts and rolls)
- Cellulose
- Sprayed-on fibre
- Solid foam insulation
- Sprayed-on foam insulation

These listed materials above are the most common and widely available type of insulation. It consists of flexible fibres, most commonly fibreglass and mineral matter. The insulation fibres are oriented perpendicularly to the direction of heat flow and with minimal contact with each other, so as to minimize conduction across the insulation. Mineral fibre is made of dirty raw materials, such as boiler slag or blast furnace slag. Both can be purchased as insulation 'batts and rolls' with a heavy paper backing, or as insulation boards. Fibreglass and mineral-fibre insulation have comparable thermal conductivities and hence comparable resistance values for a given thickness.

Materials		Thermal resistance	
		RSI-value per 25 mm	R-value per inch
Blown-in cellulose		0,63-0,65	3,6-3,7
Fibreglass batts and rolls		0,60-0,62	3,4-3,5
Rockwool batts and rolls		0,67-0,69	3,8-3,9
EPS (pentane expanding agent)	at 23,8°C	0,73	4,1
	at -31,7°C	0,91	5,2
XPS (HCFC expanding agent)	at 23,8°C	0,87	5
	at 4°C	0,95	5,4
	at -4°C	0,99	5,6

Sprayed-on polyurethane	HCFC-blown	1,06-1,14	6,0-6,5
	HFC-blown	slightly less than above	
	water-blown	0,63-0,67	3,6-3,8
Sprayed-on cellulose		0,61	3,5
Polyisocyanurate		1,00-1,25	5,7-7,1

Table 2: Comparison of the thermal resistance for a given thickness of different insulation materials

B. Structural insulated panels

Structural insulated panels (SIPs) are panels with an arbitrarily thick foam core (typically 10-20 cm) with a structural facing on either side. The most common types of facing are drywall and/or structural sheathing such as plywood or oriented strand board (OSB).

Three plastics used for the foam core are:

- Expanded or extruded polystyrene, having insulation values of RSI 0,71 and 0,87 per 25 mm , respectively;
- Polyurethane;
- Polyisocyanurate.

For the latter two cases, the foam injected between two wood skins under considerable pressure, and forms a strong bond with the skins when it hardens. In all cases, an HCFC is used as a blowing agent, and gives an initial RSI-value per 25 mm. Over the time RSI-value decreases to a stable value of 1,05-1,25 per 25 mm, as some of the HCFC escapes. Because of concerns over depletion of stratospheric ozone, HCFCs are only temporary substitutes for CFCs. They are also green houses gases.

SIPs provide more uniform insulation compared with most other methods. Provide a more air-tight building if properly installed, can be installed quickly, and are almost three times stronger than a 2x4 stud wall. An obvious disadvantage is that electrical wiring, cables and hot-water radiator pipes cannot be placed inside the SIP wall.

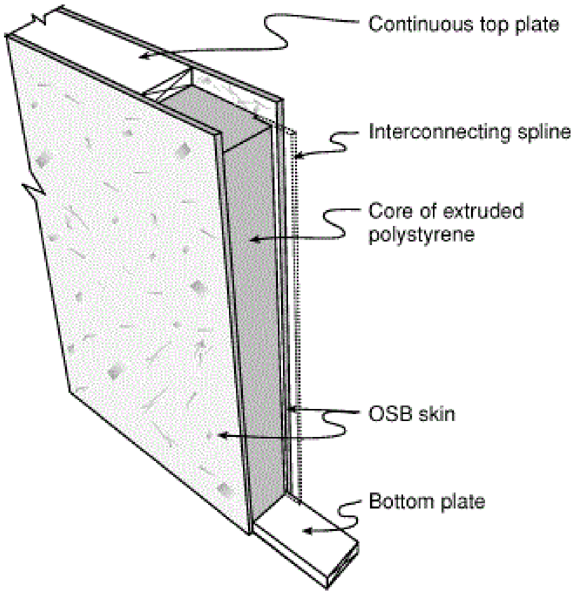


Figure 4.5: Typical structural insulated panel
Source: National research council Canada, www.nrc-cnrc.gc.ca (22/04/2010)

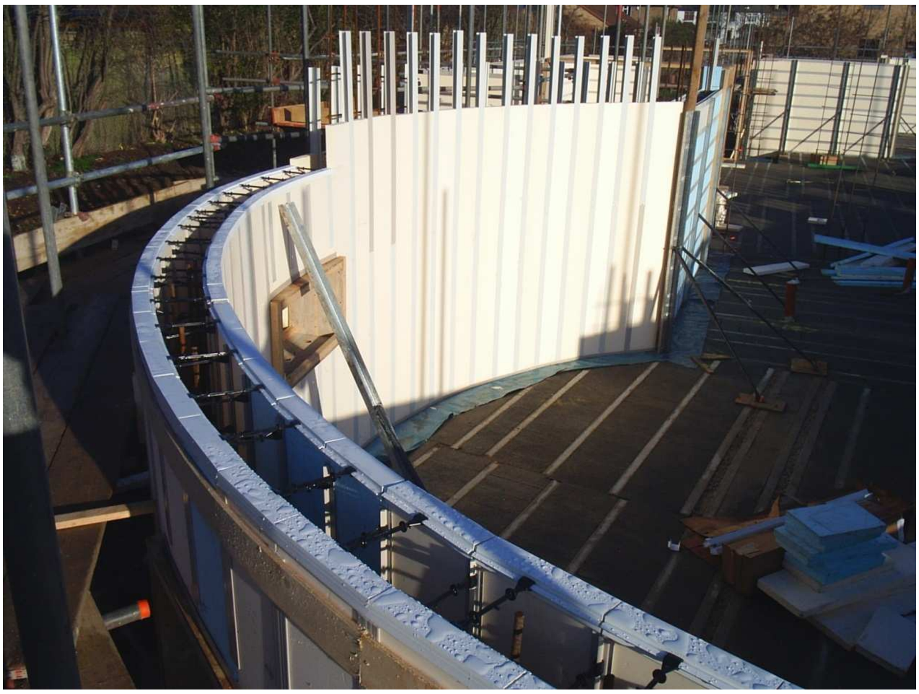
C. Insulation of concrete and masonry

Rigid foam insulation is typically applied to the exterior of concrete slab or concrete block walls in commercial buildings, with an exterior finish separated from the insulation by an air gap. Semi-rigid mineral fibre insulation is equally popular and provides better sound and fire proofing. A 5 cm thick layer of polystyrene provides an RSI-values of 1,76. Noninsulated concrete walls themselves provide another RSI 0,35-0,53 of resistance to heat flow. Concrete masonry blocks provide RSI 0,18-0,44, the lower value pertaining to the coldest conditions, when the larger temperature difference across the blocks provokes convective heat exchange within the hollow core.

There are many ways in which the insulations value of concrete slab and concrete masonry units can be increased. Alternative shapes can be used with or without insulation inserts. If built of normal density concrete (thermal conductivity of 1W/m/K), RSI-values of 0,53-1,94 can be achieved. For light-weight concrete the combination with insulation inserts, RSI-values as high 3,52 can be achieved. However, due to thermal bridges between the insulation inserts, the effectiveness of the insulation is less than if the same amount of insulation were applied as an external sheathing. If one is restricted to concrete blocks without inserts, an RSI-value as high as 1,41 can be achieved. Pre-cast concrete panels consisting of a layer of insulation sandwiched between two concrete layers, which are joined by plastic ties, have an RSI-value of 2,95. Insulating concrete panels and blocks provide one method for achieving relatively high insulation levels, and would be quite adequate in moderate climates where current practice might not entail adding any insulation at all. In cold climates, they could be used to augment currently prescribed insulation levels in new construction.

Picture 4.4: Alternative shaped block with polystyrene insulation
Source: Apex concrete block factory – thermo block

Another option using concrete is insulating concrete forms (ICF). With ICFs, foam insulation serves as the forms into which concrete is poured; the forms stays in place after the concrete has set. Polystyrene, polyurethane and polyisocyanurate foams have been used, either as foam panels held together with pins or as interlocking foam blocks.



Picture 4.5: Insulation concrete forms
Source: Premeré, premereforms.com (05/08/2010)

Typical systems have been built with RSI 3,0-3,5. ICFs are one of the few new products that have been adopted by the mainstream construction in North America.

In the case of hollow-core masonry foundation walls, if the walls are insulated on one side (typically the outside) below grade and on the other side above grade, the insulation will be ineffective no matter how much overlap there is between the inside and outside insulation, unless there is a barrier, vertical air motions provide a thermal bridge between the non insulated side of the wall. A single layer of solid concrete blocks in the region of overlap serves as an air barrier.

4.1.2.4 Windows

Windows are the most prominent architectural aspect of buildings. They serve a variety of purposes. They make the residence look nice, they provide a view of surroundings, they let in daylight for natural lighting, they provide for natural ventilation, and they can be used as emergency exits. It is often forgotten that windows have one of the greatest energy impacts of any building element. They can be major sources of heat loss if not given proper attention. The heat loss and gains of a building occur by the conduction of heat through the solid elements of the building envelope, as windows (Carrow, 1999).

The flow of heat through a window depends on a number of distinct processes[4]:

- Transmission of solar radiation;
- Emission of infrared (IR) radiation;
- Conduction of heat through the glass, through the air between the panes, and through the frame and spacers between the panes;
- Convection between the panes of glass;
- Infiltration of outside air.

The thermal performance of glass is negligible. In a single-glazed window, the resistance to heat flow arises from the thin motionless layer of air on either side of the glass, as motionless air is a relatively good insulator. On a windy day, the thermal resistance on the outside of the glass will be very small, so most of the resistance to heat loss arises from the layer of motionless air attached to the inside surface of the glass.

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[4] Harvey, D. 2006. A Handbook on Low-Energy Buildings and District-Energy Systems, Fundamentals, Techniques and Examples, Earthscan, London.

Overall window thermal performance is a function of the glass, frame and perimeter details. Typically, the overall goal is to achieve the best possible daylight transmission at cost of the least heat transmission (WBDG, 2010).

Layers of glass (glazing)

Glazing selection plays a key role in determining the overall building's thermal performance. Fenestration thermal performance requirements have to be integrated with the design of the building's heating and cooling systems. Single glazing has poor thermal performance and is suitable only for applications where thermal performance is irrelevant, such as interior applications or installations where interior and exterior temperatures do not vary substantially. The thermal performance of insulating glazing depends mainly on the solar energy transmittance through the glazing, the reflectance of the glazing, the width of the air space, and the material and configuration of the spacer around the perimeter of the unit (WBDG, 2010).

Double-glazes windows increase the thermal resistance creating a layer of motionless between the two panes of glass. As the thickness of the gap between two panes of glass increases, the thermal resistance to molecular heat conduction increases, but if the thickness is large enough for convective motion to begin, the thermal resistance will abruptly drop. Averaged over heating season, the heat loss through a double-glazed window increases if the spacing between windows panes increases beyond some optimum value that depends on climate. The optimal gap size decreases from 26 mm at a temperature difference ΔT of 5°C to 14 mm at ΔT = 33°C.

Windows are commercially available with the third and even the fourth pane between the inner and outer panes (a triple or quadruple-glazed window), which inhibit the development of convective cells in the air space, thereby further increasing the thermal resistance.

Picture 4.6: Double and Triple glazing window
Source: Axis Window Company & Greener Space

The thermal resistance of the windows depends not only on the number and space between the panes of glass. The resistance can vary according to the gases between them or even the lack of it (vacuum). Heavy molecular weight gases, such as argon, krypton, and xenon have very low thermal conductivity, some of which one-fifth lower than air, that contributes to decrease the heat loss. The vacuum between the panes of glass also subscribes eliminating completely the conductivity and any convective heat transfer.

4.1.2.5 Doors

A door is actually a door system. The door is a type of mechanical system that has a major effect on a building's heat loss. The door assembly, especially an exterior door, is made up of hinges, a lockset, sometimes a closure, a threshold, a full frame, insulation, some weather-stripping, and the door itself. From an energy standpoint, it represents a large hole in the wall with the capability of introducing a lot of cold winter wind and convenient path for heat to escape. Granted, doors are necessary for egress and ingress of the human occupants, and they should have a good appearance. (Energy Systems, 1999) However, they have various cracks around their opening and they have to be addressed in a special way whenever a heat loss calculation is done for the building, though the heat loss through doors ranges from 4 to 10 times that of a modestly insulated wall. As wall insulation increases, the relative importance of doors to total heat loss will also increase (Harvey, 2006).

One common type of exterior door has a steel skin with a polyurethane foam insulation core. It usually includes a magnetic strip (similar to a refrigerator door magnetic seal) as weather-stripping. If installed correctly and if the door is not bent, this type of door needs no further weather-stripping. However, many doors are equipped with glazing, which has to be treated much like a standard glaze window in terms of heat loss. Most modern glass doors with metal frames have a *thermal break,* which is a plastic insulator between inner and outer parts of the frame. Models with several layers of glass, low-emissivity coatings, and/or low-conductivity gases between the glass panes are a good investment, especially in extreme climates.

Picture 4.7: Polyurethane insulation blown between the door's steel skins
Source: Raynor doors

4.1.2.6 Roofs

The roof of a building is especially important because it is a major area for heat transmission due to its generally large area and exposure to the sun. Failures of roof systems occur more frequently than failures of any other aspect of building enclosures.

There are two categories of roof insulation, rigid and non-rigid. Rigid boards are typically used in low-slope assemblies. Non-rigid insulations are typically used in attic spaces using all insulation materials mentioned before.

When the sun is shining on a building, the building surface temperature can rise substantially above the air temperature (black roofs can reach 70-80°C). This leads to a conductive heat flow through the walls or roof into the building. White, reflective material will tend to be cooler than black material, as less sunlight is absorbed (Kibert, 2008).

Light-coloured, reflective roofs help reduce the thermal load on the building.

Table 3: Reflectance of Roof materials

Material	Solar Reflectance	Temperature of roof over air temperature (°C)
Bright white coating (ceramic, elastomeric) on smooth surface	80%	8°
White membrane	70-80%	8-14°
White metal	60-70%	14-20°

Bright white coating (ceramic, elastomeric) on rough surface	60%	20°
Bright aluminium coating	55%	28°
Premium white shingle	35%	33°
Generic white shingle	25%	39°
Light brown/gray shingle	20%	42°
Dark red tile	18-33%	34-43°
Dark shingle	8-19%	42-48°
Black shingle or materials	5%	50°

New ideas were implemented not only due to their thermal insulation properties, but also because they are considered as a way to recovering benefits provided by the lost green space of cities, I mean green roofs. Green roofs are rooftop gardens that substantially reduce roof temperatures while provide insulation benefit. The cooling effect arises in part from the direct shading of the roof by the vegetation, in part from evapotranspiration cooling (Harvey, 2006).

Picture 4.8: Green Roof of the Garden Street Lofts in Hoboken, New Jersey
Source: ne-rest.com (06/08/2010)

4.2 Technical characteristics

4.2.1 Heating, Ventilating and Air-Conditioning systems

The objectives of HVAC systems are to provide an acceptable level of occupancy comfort and process function, to maintain good indoor air quality, and keep system costs and energy requirements to a minimum. (Sugarman, 2005)

HVAC systems, even when installed into a single system, provide year-round control of temperature, humidity, circulation, ventilation and purification of the air within a facility.

The HVAC systems in most buildings are normally the largest consumer of energy in the building. The total energy consumed by HVAC systems will depend on several factors like climate, type and efficiency of building envelope, amount of internal heat gain requiring cooling (from computers, servers, lighting, electrical components, etc.), amount of fresh air to be introduced, requirements for humidification, hours of operation of the systems, system thermal losses and equipment condition (Doty, 2009).

The components of a HVAC include:

- A *heating device* that transfers heat to air or water or creates steam. Heating devices include furnaces, boilers, electric resistance coils, heat pumps and solar heaters.
- A *cooling device* that removes heat from air, water or refrigerant gas. Cooling devices include chillers, cooling towers and evaporative coolers.
- A *distribution system*, made up of ducts or pipes, or both, that carries the air, water or steam to the conditioned space.
- Equipment that moves the air, water or steam to the conditioned space.
- *Heat transfer devices* that transfer the heat between the heated medium and the conditioned space.
- *Operational equipment and features* that include valves, dampers, safety devices, automatic controls, sound and vibration attenuators and thermal insulation.
- *Specialty devices* including humidification/dehumidification equipment, air filtration devices and water treatment systems.

Figure 4.6: Example of a HVAC system
Source: blog.theultimatehandyman.com (09/08/2010)

4.2.2 Passive systems

With builders focusing on the structure's orientation and energy efficient construction, a building can sometimes practically heat itself. This leads to frequent reducing of dependence of fossil fuels and heating equipment.

4.2.2.1 Heating Systems

- **Passive solar heating**

Passive solar heating systems provide space heat for a wide range of buildings. Unlike other solar energy systems – for example, those that produce domestic hot water for homes – a passive solar heating system contains only one moving part: the sun. It travels in a daily arc across the sky that changes by season. In the summer, the sun carves a steep path across the sky. In the winter, its arc is low in the sky. In the intervening seasons it travels an intermediate path.

Passive solar home designers take advantage of the sun's variable course, using south-facing glass to permit sunshine to enter and properly designed over-hangs to regulate solar gain, permitting the sun to enter when it is needed and blocking its intrusion during the rest of the year.

Sunlight contains energy of many different forms, but for our purposes, visible light and heat (infrared radiation) are the most important.

- **Solar availability and irradiance for passive solar heating**

To implement passive solar heating for a particular region requires knowledge of outdoor temperature during the heating season to estimate heating requirements. Heating degree days is a measure of how many days each year, on average, the outside temperature falls below 18°C. At this temperature, internal temperature in a house usually hovers around 21°C. The heating degree day measurements indicates general heating requirements – how much solar heat or conventional heat a building will require to produce comfortable indoor temperatures. Obviously, the higher the heating days, the greater the heating challenge. Comparing heating requirements with available solar energy helps a designer determine how much heat can be provided passively from the sun. Degree heating days and solar radiation are taken into account when designing a building and running performance calculation (Chiras, 2002).

Very important also in the early design are the decisions concerning building shape and orientation of the surfaces. The seasonal variation in the daily average intensity of solar radiation on walls or windows depends of them orientation. In a complex urban environment, with reflection from nearby buildings, 3D calculations are required, and some software tools are available. On the calculations presented by Compagnon (2004) shows that:

- At the equator, there is little seasonal variation in the diurnally average solar irradiance on east- or west-facing windows, but large swings in the irradiance on north- and south-facing windows occur;
- At 30°N, the maximum diurnally average irradiance on windows of any orientation is on south-facing windows in winter, while the diurnally averaged irradiance on east- or west-facing windows is over three time stronger than on south-facing windows in summer but only 40 per cent that on south-facing windows in winter;
- At 50°N, the maximum irradiance on windows of any orientation is on south-facing windows in spring and fall, while the diurnally average irradiance on east- or west-facing windows is 30 per cent stronger than on south-facing windows in summer but only 25 per cent that on south-facing windows in winter;

- The diurnally-average irradiance on east-, west- or south-facing windows in summer increases steadily as one goes from the equator to at least 50°N;
- During the summer, the solar irradiance is stronger on east-facing windows during mid-morning, on west-facing windows during mid-afternoon, and on equatorward-facing windows at noon, but the peak hourly irradiance is only half that on east- or west-facing windows at 50°N;
- During winter, the peak hourly solar irradiance is twice as large on south-facing windows as on east- or west-facing windows.

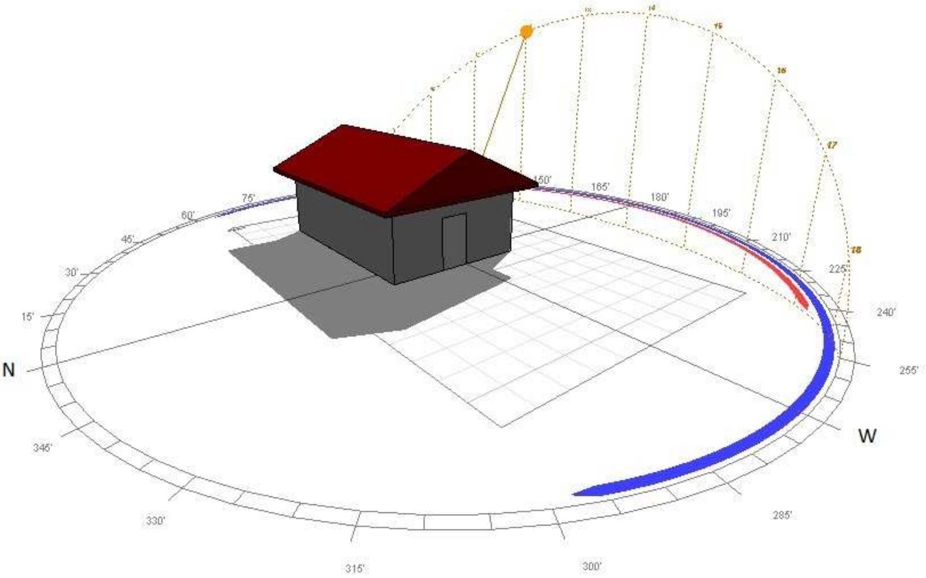

Figure 4.7: Sun's route in Madeira on December, 21

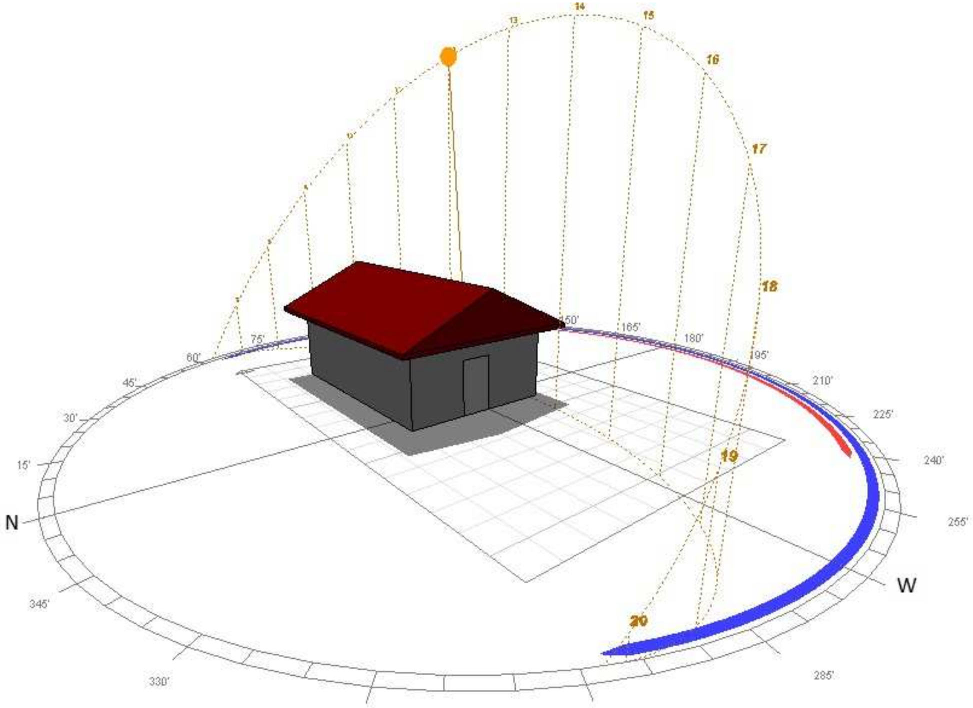

Figure 4.8: Sun's route in Madeira on August, 21
Source: ECOTECT 2010, Autodesk

Thus, equatorward-facing windows maximize the heat gain in winter while minimizing it in summer for mid-latitude sites. During transition seasons, an east-facing window can provide heat gain when it is most needed – to warm up a building after it has cooled during the night. However, a moveable shade will be required to prevent overheating. West-facing windows are more likely to cause to cause overheating. Any heat that is collected will be useful in commercial buildings (arriving as workers begin to leave) but will be more useful in residential buildings. The minimal useful heat gain and maximum summer heat gain through west-facing windows might imply that the window area on western façades should be kept very small, except that substantial energy savings are possible through daylighting. The keys are to choose windows that minimize heat loss and unwanted heat gain and to use adjustable external shading (Harvey, 2006).

- **Direct Gain**

Direct gain is the most widely used passive solar heating strategy. Appropriate for mild to moderate climates, direct gain is a relatively simple and straightforward approach. It involves using the actual living space within a building as the solar collector. To maximize the amount of solar radiation collected during the winter months, rooms should have large windows areas on the sunlit sides of building. Conductive heat loss through the windows needs to be minimized for there to be a net energy gain. Floors and walls should be constructed from materials with high thermal storage capacity. During the daytime, short-wave radiation is absorbed by the exposed high mass interior, while in the evening and at night-time heat is transferred from the warm space surfaces to the occupants (Beggs, 2002).

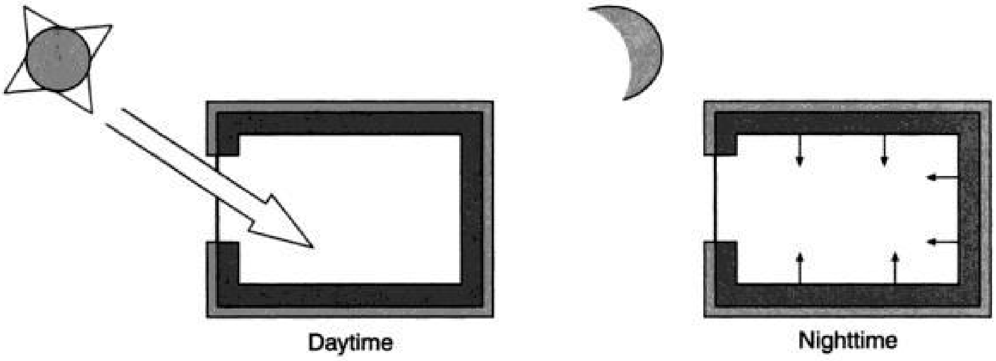

Figure 4.9: Direct gain solar heating
Source: Beggs, 2002

To maximize the utilization of the heat captured, the space should be ventilated with air from elsewhere in the building and exposed thermal mass should be available. This will prevent or minimize overheating and minimize the associated heat loss through emission of infrared radiation, thereby increasing the net heat gain and distributing it to rooms not directly exposed to solar gain. A high-performance envelope (more insulation, better windows) will tend to reduce the fraction of available solar energy that can used, thereby increasing the need for effective thermal mass and ventilation. Solar radiation striking a floor or wall can be stored if they have significant thermal mass, such concrete. The colour significantly influences heat storage in materials with thermal mass, dark colours being better. Carpets reduce the ability of a floor in a direct sunlight to store heat.

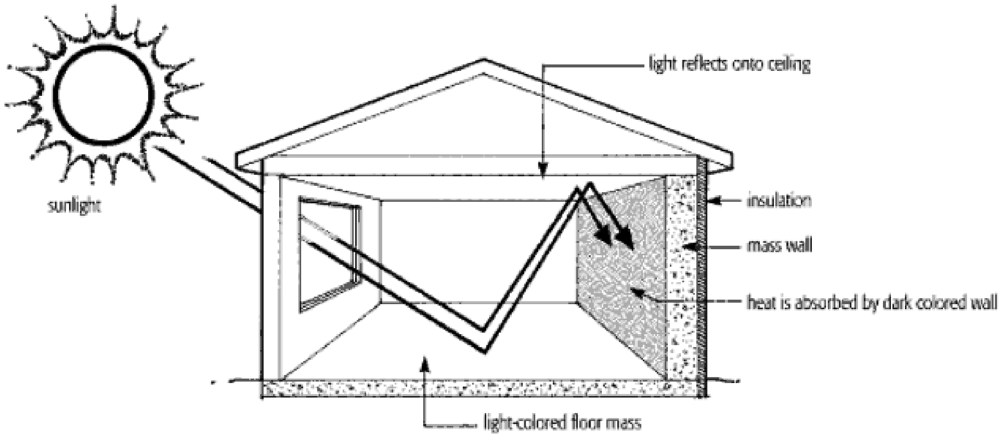

Figure 4.10: Sunlight absorption
Source: Chiras, 2002

Finally, in assessing the optimal window area for solar heat gain, the impact on summer cooling load should be determined. Increasing the window area will increase the cooling load even if the window is shaded, although this penalty can be minimized if insulated external operable shading devices (such as shutters) are used (Harvey, 2006).

4.2.2.2 Passive Cooling

Passive cooling can broadly cover all the measures and processes that contribute to the control and reduction of the cooling needs of buildings. Passive cooling techniques have proven to be extremely effective. Efficient passive systems and techniques have been designed and tested. Passive cooling has also proven to provide excellent thermal comfort and indoor air quality, together with very low energy consumption.

- **Classification of Passive Cooling Techniques**[1]

Solar and Heat Protection Techniques

The first technique include measures to avoid overheating in the interior of buildings and strategies for rejection to the external environment of the internal heat, either generated in the interior or entering through the envelope of the building. These measures may involve: landscaping and the use of outdoor and semi-outdoor spaces, building form, layout and external finishing, solar control and shading of building surfaces, thermal insulation, control of internal gains, etc. It aims to minimize the heat gain and to lower the interior air temperature.

Heat Modulation Techniques

These techniques deal with the thermal capacity of the building structure. High-thermal-mass materials, like bricks and concrete, act as a storage for both cool and heat as they cool down and heat up relatively slowly. This strategy provides attenuation of peaks in cooling load and modulation of internal temperature with heat discharge at a later time. The larger the swings in outdoor temperature, the more important the effect of such storage capacity. The cycle of heat storage and discharge must be combined with means of heat dissipation, like night ventilation, so that the discharge phase does not add to overheating.

Heat dissipation techniques

In many climates, the protection and modulation techniques related to heat gains are not sufficient to keep indoor temperatures at a comfortable level during the day. The design of the building should ensure means to reject the heat build-up in the interior of the building (natural or hybrid cooling). The main techniques of natural cooling, according to the mode of heat transfer and fluid flow, can be classified as:

- Cooling with ventilation
- Radiative cooling
- Evaporative cooling
- Earth cooling

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[1] Santamouris, M., Asimakopoulos, D., 1996. Passive Cooling of Buildings, James & James, William Road, London.

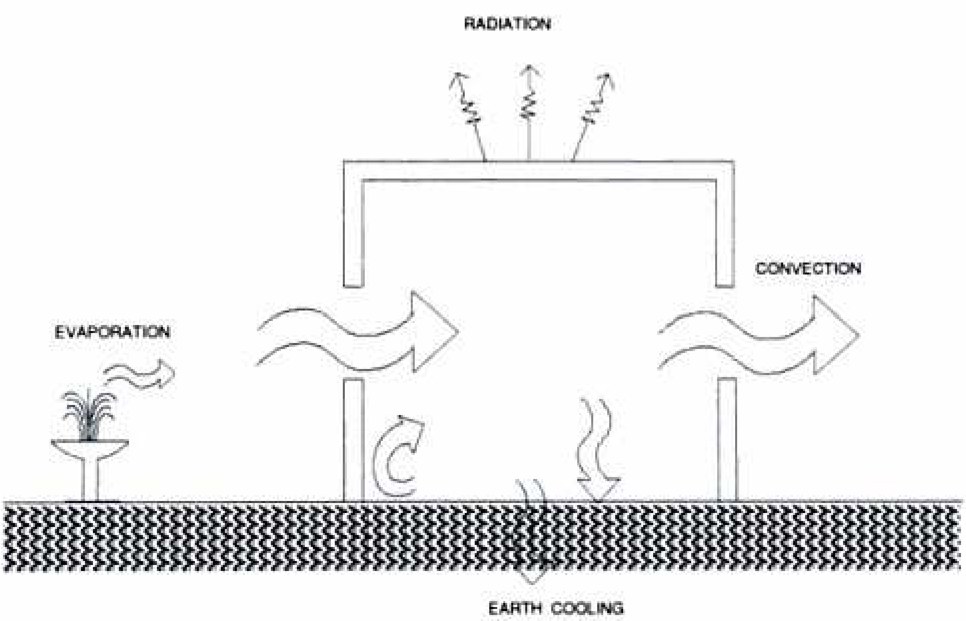


Figure 4.11: Modes of heat transfer
Source: Santamouris, 1996

Some of the techniques provide a direct instantaneous cooling effect. In others, the coolness is collected during night-time and is released the next day, thus smoothing the effect of the accumulated heat inside the building. Materials suitable for storage, which can even store the coolness of the cold winter ambient air, are: building mass, rock beds, earth, water, phase-changing materials.

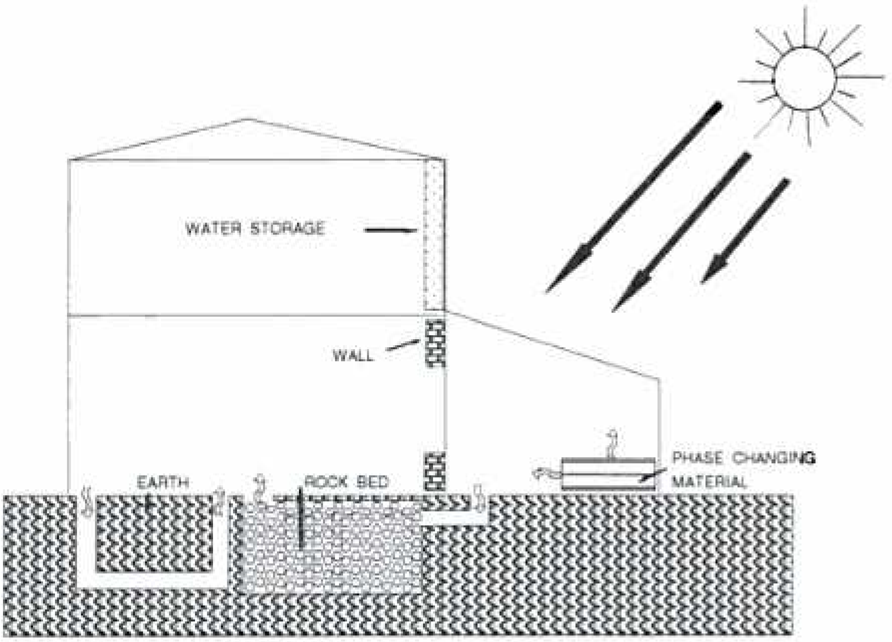


Figure 4.12: Different methods of heat storage
Source: Santamouris, 1996

a. Ventilation

Ventilation is based on the fundamental heat-transfer mode of convection, where the air flowing next to a surface carries away heat, provided it is at a lower temperature than the surface.

Air movements through buildings result from the difference in pressure indoors and outdoors which can be achieved by:

- Natural forces:

  Wind-induced pressure difference.

  Pressure difference induced by temperature gradients between the inside out of the building (sack effect).

- Mechanical forces:

  Pressures difference induced mechanically.

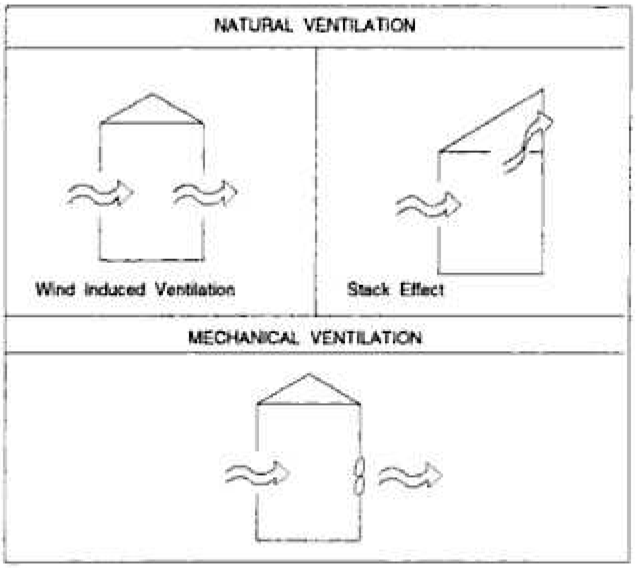


Figure 4.13: Ventilation strategies
Source: Santamouris, 1996

b. Radiative cooling

Radiative cooling is based on the fundamental principle that any warm body emits thermal energy in the form of electromagnetic radiation to the facing colder ones. The sun is radiating heat to the earth during the day and earth is radiant back heat to the cool sky. The radiant heat loss takes place both day and night. During the day, the absorbed solar radiation counteracts the cooling effect of the long-wave emission. The radiative cooling is stronger in clear night skies but it is reduced be the existence of particles, such as water vapour, carbon dioxide and dust in the atmosphere.

Radiative cooling is the sum of three sources of radiation: outgoing radiation from objects versus incoming sky and cloud radiation.

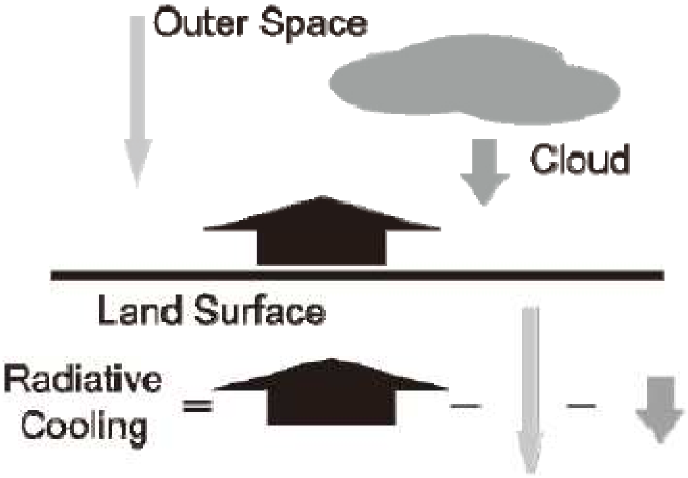


Figure 4.14: Simple radiative cooling illustration
Source: Luciuk, 2009

c. *Evaporative Cooling*

Evaporation is the phase change of water from liquid to vapour. This is accompanied by release of high amounts of heat (sensible heat) from the air that comes in contact with the wet surface or from the surface where evaporation takes place. Depending on fluctuations of the air's moisture content, evaporative cooling is characterized as direct evaporative cooling of the ventilation air – the ventilated air passes over wet surfaces (e.g. a pong or fountain) and is cooled by evaporation; and indirect evaporative cooling – the evaporation takes place on a surface which is cooled during this process.

d. *Earth cooling*

The earth can serve in many climates as a cooling source. Its high thermal capacity keeps the soil temperature, below a certain depth, considerably lower than the ambient air temperature during summer. Seasonal variation of the earth temperature decreases with increase of depth, moisture content and soil conductivity. It is estimated that a few metres below the surface, the earth temperature remains constant throughout the year.

The cooling potential of the earth can be utilized by direct earth contact cooling – the cooling capacity of the earth mass is directly exploited by fully integrating the building within the earth or by partially integrating the building's envelope; and indirect earth cooling – by precooling the air entering in the building through use of underground pipes.

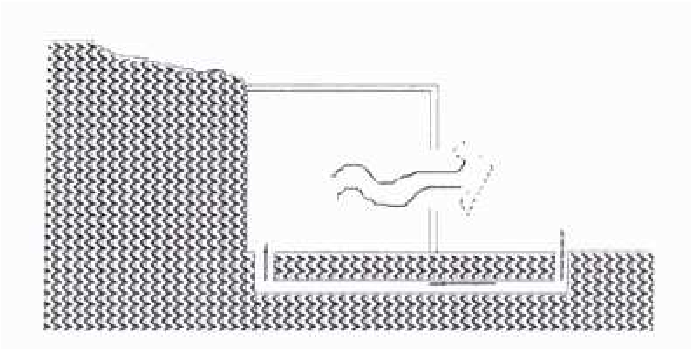


Figure 4.15: Earth cooling
Source: Santamouris, 1996

4.3 Integrated design of Green Buildings

The integrated design is a process in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that permits synergistic benefits to be realized. The goal to achieve high performance and multiple benefits at a lower cost than the total for all the components combined. This process often includes integrating green design strategies into conventional design criteria for building form, function and performance (Kibert, 2008)

After analysing all measures and strategies it's understandable that to achieve successful performance is needed the integration of different specialities as building envelope, architecture, HVAC systems, passive systems, etc. By working together at key points in the design process can be identified solutions that would otherwise not be found.

The level of interaction needed to ensure the success of a green building project is significantly high. Green building is new concept to the industry, and it is generally necessary to orient all members of the projects team to the goals and objectives of the project that are related to issues such as resource efficiency, sustainability, certification, and building health. This orientation can familiarize the project team with the owner's priorities for the high-performance green building aspects of the project and also familiarize the group with the building, the building program, and the building's green building issues (Kibert, 2008)

The integrated project of the Menerga Building will be analysed next, as a green building where several different techniques were combined to achieve the highest energy efficiency possible. Measures at architectural level, building envelope, efficient air-conditioning system, passive system, daylighting and shading control, etc. exemplifies one of the best practices in Slovenia and Europe.

Also some other good practices around the world will be more superficially studied where different techniques and strategies are performed according to their needs and functionality.

5 CASE STUDY

5.1 Menerga Building

As the first case, the Menerga Building, as an example of successful green building projects being in operation since 2004, will be presented.

This project joined the GreenBuilding Programme initiated by the European Commission in 2004, and was the first Green Building partner from Slovenia. This programme aims at improving the energy efficiency and expanding the integration of renewable energies in non-residential buildings.

Menerga d.o.o. is a private company starting in 1980 based on the design of energy efficient ventilation and heat recovery systems. In 2004 they moved in a newly built office building, after a 2 years period of construction.

The design of the new headquarters demonstrates all of the technological concepts the company stands for.

Picture 5.1: Menerga Building, Maribor
Source: eu-green

Although the red colour of the metal cladding characterizes this building as an obviously artificial object that stands in contrast with nature, the construction is actually largely environmentally friendly.

5.1.1 General characteristics

5.1.1.1 Location and Climate

Menerga building is located in Zagrebška cesta 102, 2000 Maribor, Slovenia. The geographic coordinates are 46° 31.363’N 15° 40.233’E, 268 m above sea level (Google earth, 18/08/2010).

Picture 5.2: Detail of building area in Maribor
Source: Google earth

The average summer air temperature in Maribor is about 20° and winter about -1° C. Maribor is one of the most sunny places in Slovenia, for on an average it has 266 sunny days per year (Slovenia.info, 18/08/2010).

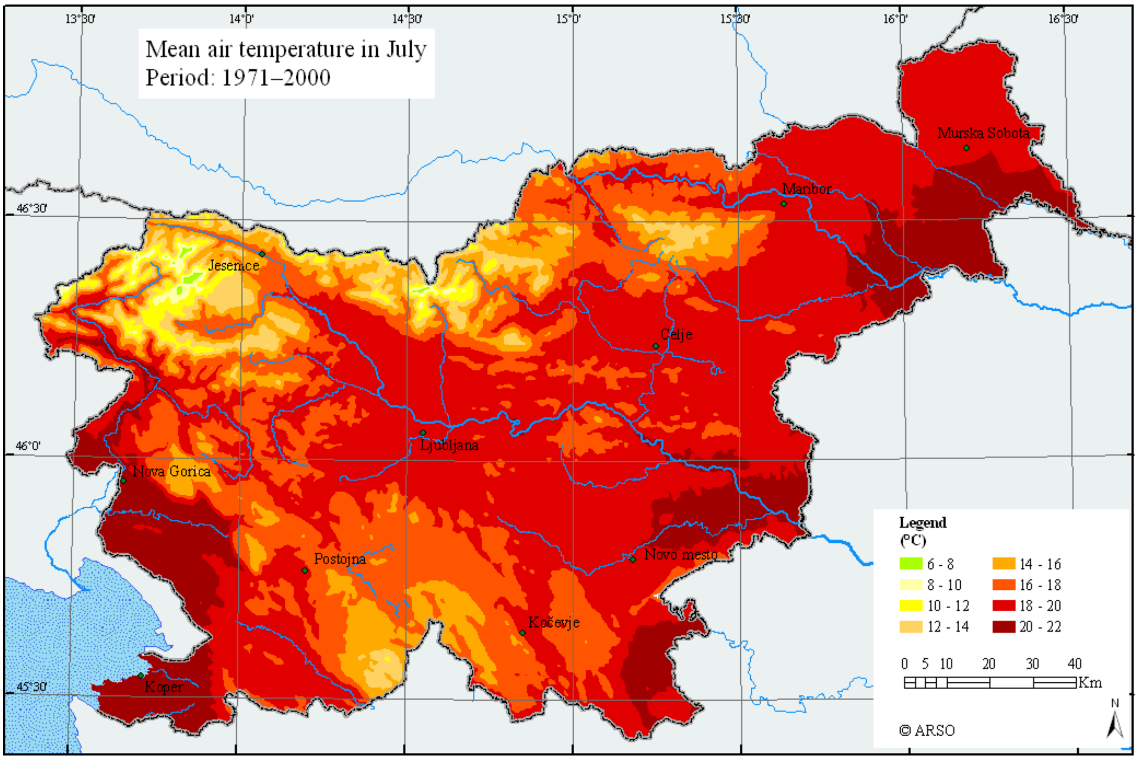


Figure 5.1: Mean Slovenian air temperature in July between the periods of 1971-2000
Source: meteo.si (18/08/2010)

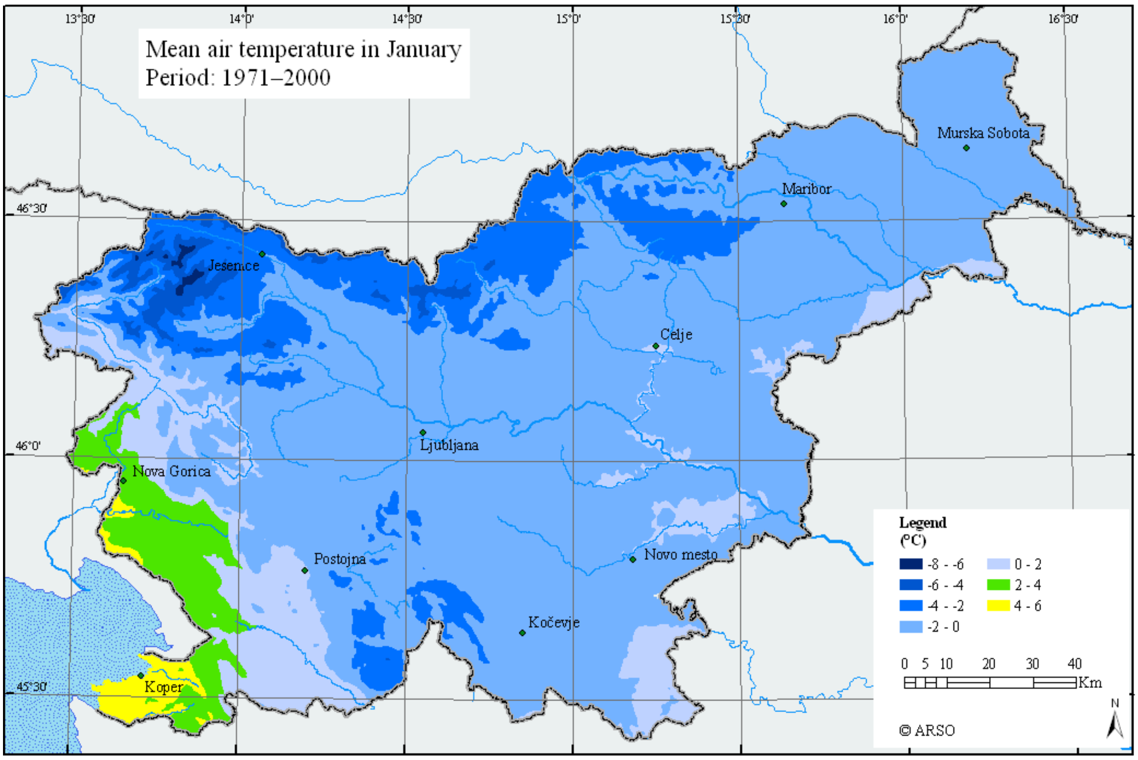


Figure 5.2: Mean Slovenian air temperature in January between the periods of 1971-2000
Source: meteo.si (18/08/2010)

5.1.1.2 Architectural design

The building is a five-storey office building with an effective indoor area of 3117 m^2 and living area of 2720 m^2. The author of the architectural design is the Slovenian architect Nande Korpnik.

The architecture design scheme contributes most to the building's efficiency. In the compact and attractive volume, the service core is placed at the centre, freeing up all possible stretches along the windows for work space and reducing the use of artificial lighting.

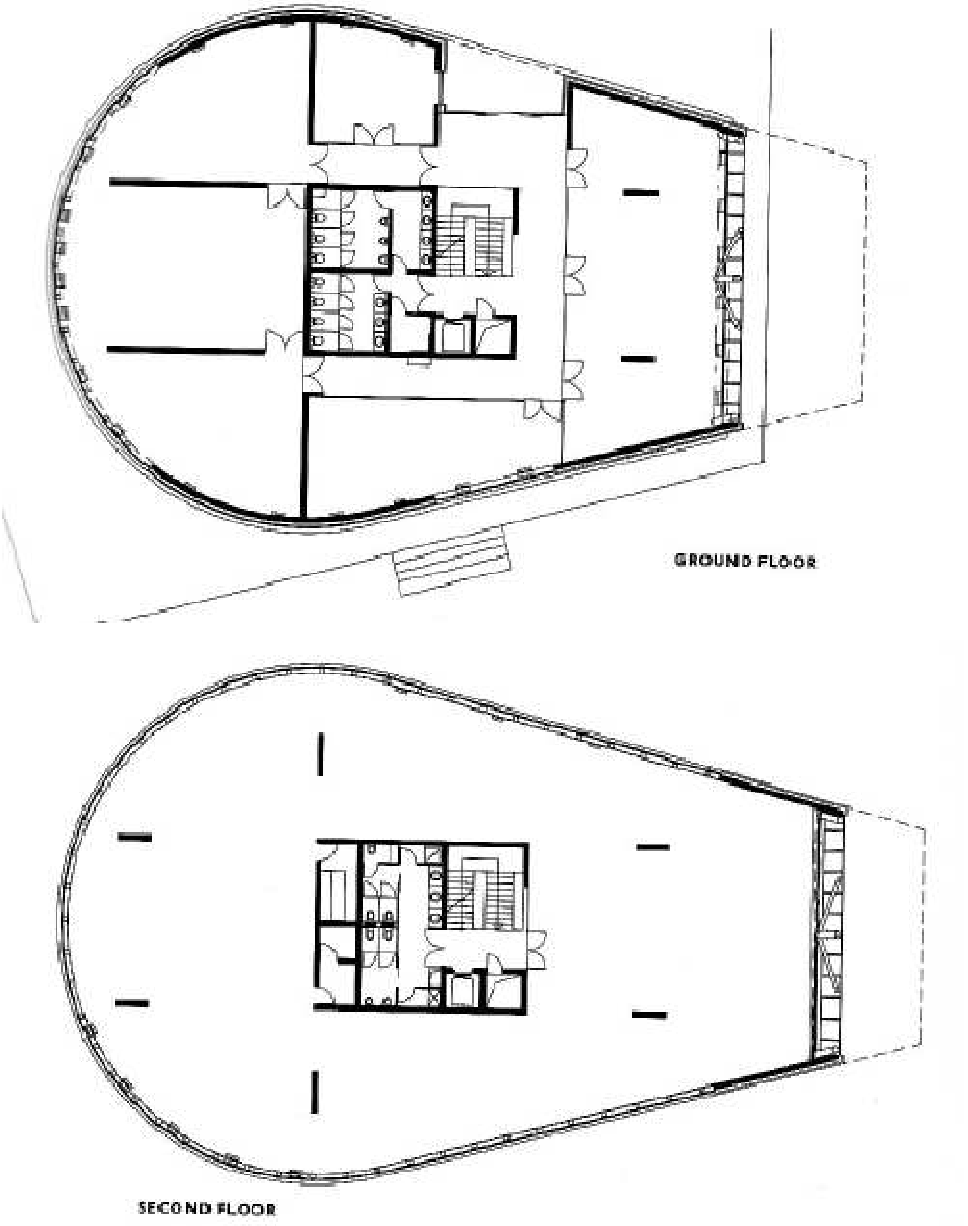


Figure 5.3: Blueprints of ground floor and second floor
Source: Celik, M. (2007)

The round, northern side contains the offices, while the administration is placed to the south. The southern front is glazed to collect the warmth of the sun in winter and the natural light.

But the front is inclined forward, hanging over the entrance and protecting the offices from over-heating that could be affected by the sun’s radiation in the summer.

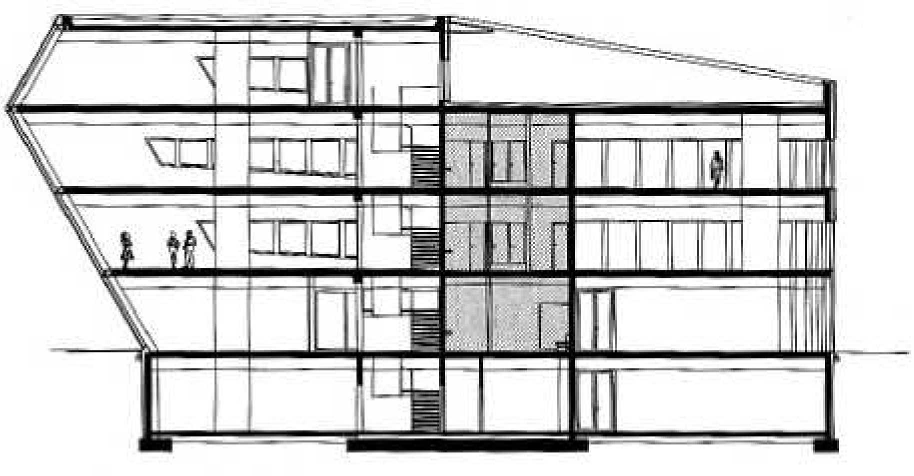


Figure 5.4: Longitudinal section
Source: Celik, M. (2007).

The highly efficient use and control of sun radiation and internal energy sources allows for the possibility of not using heating until late in the autumn, while operation in winter is particularly economical.

Picture 5.3: South façade
Source: Celik, M. (2007)

Picture 5.4: Natural lighting
Source: menerga.si (20/08/2010)

5.1.1.3 Technical systems

An extra investment of 61600 € was made in measures to improve the energy performance designed by the engineers of the firm Menerga specialised in air-conditioning systems. The costs are still in the same range as the investment cost for a traditional building.

The measures performed were:

- Building envelope with improved insulation;
- Heating and cooling system, in connection with thermal activation of a concrete construction;
- Ventilation systems with 90% heat recuperation;
- Ground water heatpump;
- Energy efficient lighting;
- Intelligent central control system.

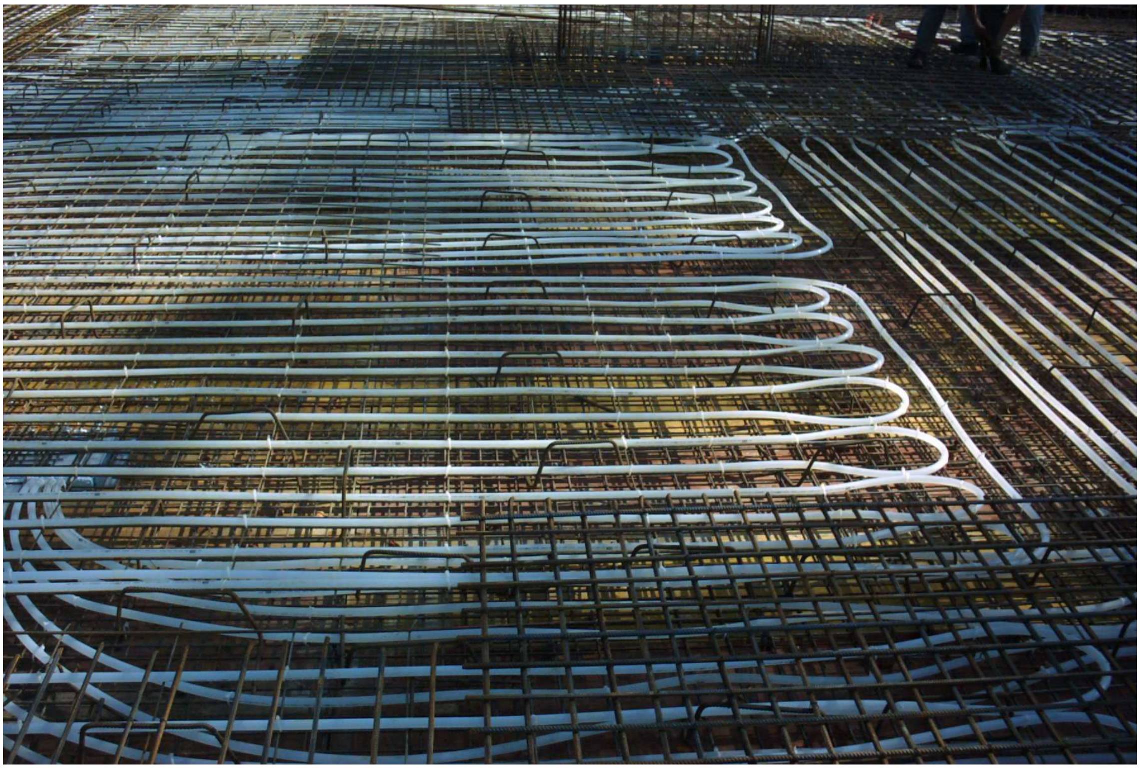
These measures turned this office building an intelligent and low energy consumer.

- **Building envelope**

The basis of an efficient building is firstly very efficient thermal insulation. The building is insulated by 16 cm thick insulation in average, all thermal bridges are eliminated as high as possible and deliberately disconnected. Specific heat losses of the building amount to 26 W/m^2 and specific cooling needs are 27 W/m^2.

- **Thermal activation of the concrete construction**

Basically the temperature of the building in winter and as well in summer is maintained by maintaining a suitable temperature of the buildings concrete construction. In the winter regime, at lowest exterior temperatures , space temperatures around 22°C are achieved by water temperature in the concrete construction thermal activation system around 25-26°C. In the summer regime, by input of water of temperature around 20-22°C in the building construction, in combination with cooled input air (air temperature about 19°C), the temperature in spaces does not increase over 26°C.



Picture 5.5: Thermal activation system
Source: Menerga d.o.o., Maribor, Slovenia

- **Ventilation and air-conditioning**

Comfortable working and living atmosphere is enabled also by constant input of fresh air into working spaces, with three exchanges of air per hour. Fresh air for ventilation is also carrier of heat for local regulation of temperature in winter and annual operation regime. Ventilation with 100% outdoor air would not be energy rational, if it was not carried out by ventilation and air-conditioning that have sensible heat recuperation of 92% and latent heat recuperation of 87% at the lowest outdoor temperatures. Air-conditioning devices in the annual regime dehumidify outdoor – input air if necessary, that ensures comfortable working conditions even at extreme summer condition of the outdoor air. Additional heating after air dehumidification is carried out by heat, taken from the air during dehumidification.

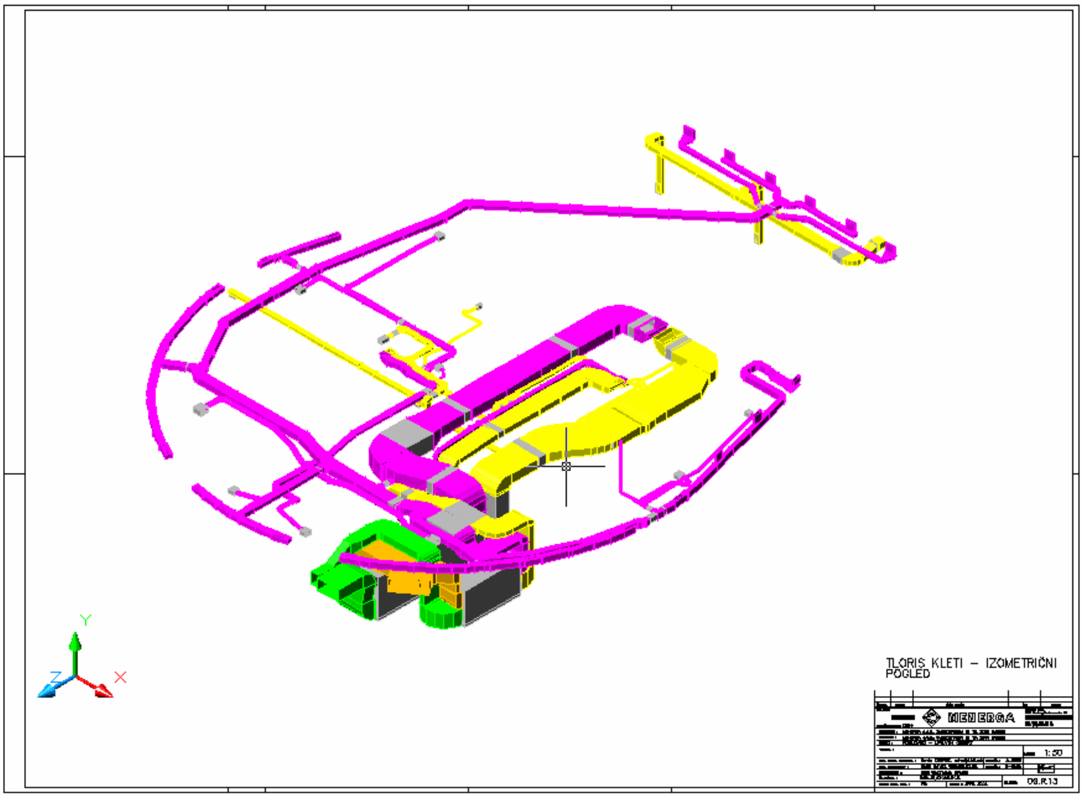


Figure 5.5: 3D ventilation systems in the cellar floorplan of the Menerga building
Source: Menerga d.o.o., Maribor, Slovenia

Picture 5.6: Fresh air underground canal
Source: Menerga d.o.o., Maribor, Slovenia

Picture 5.7: Air-conditioning unit with high efficient regenerative heat recovery
Source: Celik, M. (2007)

- **Preparation of heating energy**

Basic source of heat is represented by the underground water. In winter the underground water has the temperature of 10-13°C that ensures that the heat pump works with a high coefficient of performance. The heat pump exploits the heat of the underground water. The increase of the temperature above the temperature of the underground water is, due to the small temperature difference of the heating medium, minimum for the thermal activation of the concrete core and space temperature.

A low temperature condensing gas boiler was installed, representing alternative heating system or parallel – bivalent operation to the heat pump.

- **Preparation of cooling energy**

The source of cooling energy is the heat pump, which functionally represents combined heating-cooling device and in the annual operation regime functions as a cooling aggregate water-water. In the annual regime, thermically activated construction acts as a cooling body with great surfaces. Latent heat is reduced by fresh – input air for ventilation, which is in the annual regime suitably cooled and dehumidified.

- **Local control of the building automation**

Local control performs individual regulation of temperature, lighting, opening and closing windows, and controlling sunscreens in individual working places.

Picture 5.8: Lighting control with interior blinds.
Source: rtvslo

- **Glassing and shading**

Great glass surfaces of the building are not equipped by reflective glasses that enable exploitation of solar heat as an emergent. On the exterior side of glazed surfaces, shades are set, which are automatically controlled, as regards heat needs of building.

Individual segments of shades are controlled by individual functionally terminated units, as regards their desired temperature. The practice has shown that shades replace very successfully reflection glass and prevent breaking in of the heat due to solar radiation at high outdoor temperatures, at the same time they enable uninterrupted regulation of the energy input sue to solar radiation.

- **Energy efficient lighting**

Individual space units are equipped by technology T5 fluorescent lamps, electronic controlled ballasts with analogue input 0-10V analogue input and illumination sensors. Efficient lighting of working spaces follows the influence of outdoor lighting as well, dependent on deviation of the desired value, dims lamps by intensity and depth of sectors. Individual connection intervals, security disconnection of sectors and entire optimization of consumption are realized. Energy savings of lighting are 40-60% in comparison with regular lighting, without a possibility of lighting dimming.

Picture 5.9: Working spaces lighting
Source: rtvslo

- **Direct digital control**

The building is, in a control regulation sense, carried out as a complete intelligent building. All functions, related to thermal energy, lighting, watering system, defrosting snow and ice on the parking places and accesses in the winter regime, lifting and lowering of window shades are run by a system of a uniform digital regulation and can communicate reciprocally without interfaces. This is most important for the harmonic functioning of all the energetic systems that interact directly. Control units are freely programmable and thus enable complete flexibility and optimization of operation of all processes. A system of metering of electricity consumption on individual system consumers is introduced.

- **Central control system**

Entire system of digital regulation is connected into a central control system. Classical functions of the central control system, management and survey over all regulation parameters are upgraded by a possibility of local individual changing and adjusting of parameters on each working place.

5.1.2 Experience of the design of “intelligent” building

The sustainable planning of the building Menerga began with the deployment and design. Even without the introduction of the technical aspects this building would undoubtedly be more efficient than a regular office building. It is an effort that begins at the location to the smallest detail of windows for example. All these measures required extra investment, as stated above, and after twenty months of operation has been proven beyond doubt that in medium/long term the investment would return. The average monthly costs for heating is 330,00 €. In this amount the heat losses of the building and ventilation losses of air-conditioning units are included. Average cost of electricity for air-conditioning units and pumps is 2080,00 € per year.

The cost for cooling is 1050,00 € per year. The cost for lighting and computer is 2250,00 € per year. It has to be taken in consideration that the ventilation system is working at 50% of its capacity, but the thermal activation of the concrete construction is in operation in the complete building in winter and also in summer.

Beyond economic level, Menerga being a company that creates indoor climates, could prove and demonstrate the efficiency of its technologies, equipments and strategies, to attract possible investors.

Buildings like this one, turn the works living indoors much more comfortable and motivating which increases yield and satisfaction.

Such buildings are increasingly getting more adepts as evidenced with several projects that Menerga executed all over the Europe.

Additionally, there is a list of references designed by Menerga team as low energy intelligent buildings, such:

- University Library Split, Croatia, 2008;
- SPA Laško, Slovenia, 2007;
- Business building Santa Lucía, Madrid, Spain, 2005;
- SPA Hotel Marriot, Palma de Mallorca, Spain, 2001;
- Aqua Park Bohinj, Slovenia, 2003;
- Offices, kindergarden, SPA VIPnet Zagreb, Croatia, 2005.

University Library Split **Santa Lucía** **SPA Laško**

Picture 5.10: Intelligent buildings
Source: Menerga d.o.o.

5.2 Best Practice Cases of Green Buildings – specific features

5.2.1 Science and Technology Park, Gelsenkirchen, Germany

All over the world, many buildings have been built and planned implementing efficient and intelligent methods that offers a wide range of possibilities according to the needs and functionality of the building, its location, climate and to the existing technology.

First the measures performed in the Science and Technology Park that was built in Germany, Gelsenkirchen, will be analysed The conceptual and physical architecture of the park stands for a new era with the intention to erect a structural change in the district.

Picture 5.11: Science and Technology Park, Gelsenkirchen, Germany, Panoramic view of the park
Source: University of Hong Kong, www.hku.hk, (25/08/2010)

- **Architectural design**

A glass arcade have within a public space planed to contain shops and cafes, with a length of 300 meters is connecting in total nine three-storey institute pavilions, together with access to an underground car park. Nearly 9000 m^{2}of valuable office and laboratory space in the science Park are complimented by nearly 1800 m^2 of office and work shop space at especially reasonable conditions in the neighbouring small business incubator.

Picture 5.12: Science and Technology Park, Gelsenkirchen, Germany, Glassing arcade connecting the pavilions
Source: University of Hong Kong , www.hku.hk, (25/08/2010)

The façade is glazed with Thermo plus heat-insulating glass and can be adapted to seasonal changes. In the winter the lower panels are closed, but in summer they slide upwards, like large sash windows, for ventilation and access to the lake. In summer the floor heating system is used to cool the interior, and use is made of the water that is warmed in the process. There is also an external awning to protect the floor of the arcade from overheating in summer.

The façades of the pavilions are constructed of simple wood and aluminium elements with heat insulation glass. They incorporate ventilation panels for night cooling the concrete floor slabs which, accordingly, act as a thermal flywheel. The façades are fitted with automatically controlled external fabric blinds.

- **Technical systems**

The building's performance is controlled by its energy management system. Lighting is automatically adjusted in accordance with external light levels, and heating switches off when the ventilation panels are opened. With a largest rooftop solar power plant with about 1236 m^2 area provides the equivalent of electricity enough to cover energy demand of forty four-person households and saves an estimated 4500 tons of environmentally harmful CO_2 over the course of its service life.

Picture 5.13: Solar power plant
Source: University of Hong Kong , www.hku.hk, (25/08/2010)

5.2.2 Charles Hostler Student Center, Beirut, Lebanon

Next the Charles Hostler Student Center on the campus of the American University of Beirut, Lebanon provides a model for environmentally responsive design that meets the social needs of the campus. It is situated on Beirut's seafront and main public thoroughfare.

Picture 5.14: Background sea and view across green roof spaces.
Source: AIA, The American Institute of Architects

- **Architectural design**

It was designed by Vicent James Associates Architects a multiple building volumes connecting a continuous field of habitable space with gardens and multiple levels.

The total area of the campus is 18952,220 m^2 and the buildings 9690 m^2

This project was chosen as an AIA Committee on the Environment Top Ten Green Project for 2009.

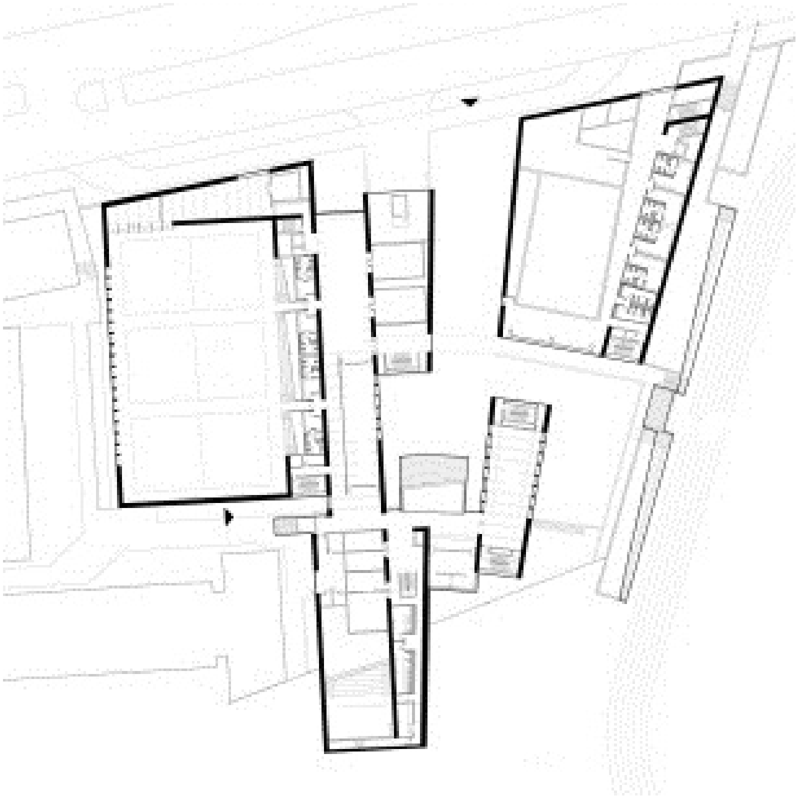


Figure 5.6:Floor plan of the arrangement of the buildings
Source: AIA, The American Institute of Architects

The campus project was organized as a cluster of interior and exterior spaces rather than a single building, allowing the building form themselves to redistribute air, activity and shade. The east-west orientation of the building forms helps to shade exterior courtyards, reducing the amount of southern exposure. The orientation also directs nighttime breezes and daytime sea to cool outdoor spaces.

To emphases air movement, the design incorporates radiant cooling for select areas of the buildings. Evaporative and radiant cooling are also used in the outdoor courtyard water-walls.

- **Technical systems**

Solar panels heat water for pool and for other uses. Floor piping directs the water into the pool are to warm the floor surfaces. During the summer, the excess thermal energy can be used for chilled water production.

It was designed a seawater cooling system from below the site with a low energy absorption chiller. Large concrete slab integrated heat exchangers satisfy a major portion of the cooling load. The additional air system provides dehumidified fresh air. These systems reduce consumption significantly.

A Building Management System operates lighting controls and temperature and humidity.

To achieve the thermal insulation was required in a single wythe a double-shelled stone and concrete cavity wall with 7,6 cm of insulation within. In the roof 20 cm insulation was applied under several green roofs.

A variety of shading systems were deployed in strategic locations throughout the project. Aluminium louver systems shade each building to the south, and precast louvers on the east and west walls provide shading for windows and doors.

Given the University's desire to build efficient spaces that minimized energy usage, the design process and techniques focused on an efficient and innovator project.

Picture 5.15: View of pool building and courtyard
Source: AIA, The American Institute of Architects

5.2.3 Manitoba Hydro Place, Winnipeg, Canada

Moreover, Manitoba Hydro Place introduces the next generation of sustainable, energy-efficient development under a formal Integrated Design Process. The design bonds principles such as massing, orientation, and exposed thermal mass with immediate digital analysis and computerized building management systems to create a climate-responsive design that relies on passive energy.

- **Architectural design**

The single building is located in Winnipeg, in the province of Manitoba, a place that is well known for its extreme climate. It is a 22-storey office building with an area of ca. 65000 m^2.

The design aligns with Manitoba Hydro's policies of energy-use reduction and clean power sources. It successfully establishes an exemplar of climate-responsive, energy-efficient design for large buildings in extreme climates.

Picture 5.16: Manitoba Hydro Place, Winnipeg, Canada, nighttime aerial view from the southeast
Source: AIA, The American Institute of Architects

- **Technical systems**

The original saving goals were 60%, but now is targeting 64,9% energy savings. The integrated design process ensures a rigorous integration of system and operations, including radiant heating and cooling delivered through an exposed concrete thermal mass. The large geothermal field, high efficient condensing boilers, and efficient heating and cooling systems ensure that supply and exchange is utilized. A sophisticated building management system monitors internal and external environments to optimize lighting, solar shading, and heating and cooling loads while taking advantage of passive energy sources. User control of lighting in the offices, managed through computer, is projected to save additional 10-15% in electrical lighting loads.

Site and climate analysis identified unusual abundance of sunshine and dominant south winds as opportunities to harness passive solar and wind energies. Several measures were provided to achieve to optimal performance, highlighting passive solar gain in winter and natural ventilation in the summer seasons.

Figure 5.7: Building's passive mechanical systems
Source: AIA, The American Institute of Architects

Climate-responsive features include a high-performance building envelope and a massive geothermal system. Three south-facing, six-story "winter gardens" act as lungs, with 24 meter tall waterfalls that humidify and dehumidify the air entering the building. The concrete structure carries thermal mass to moderate extreme temperatures swings.

The advanced façade system ensures 100% fresh air and maximum daylight. Automated louvers and windows open and close in reaction to light and temperature changes. A radiant slab between the double façades maintains minimum temperatures in winter and heat exchange with the geothermal field in summer.

In winter, the solar chimney draws exhaust air down to heat the car parking and pre-heat incoming cold air via the south atria. During warmer seasons, the solar chimney acts to exhaust unclean air from the building.

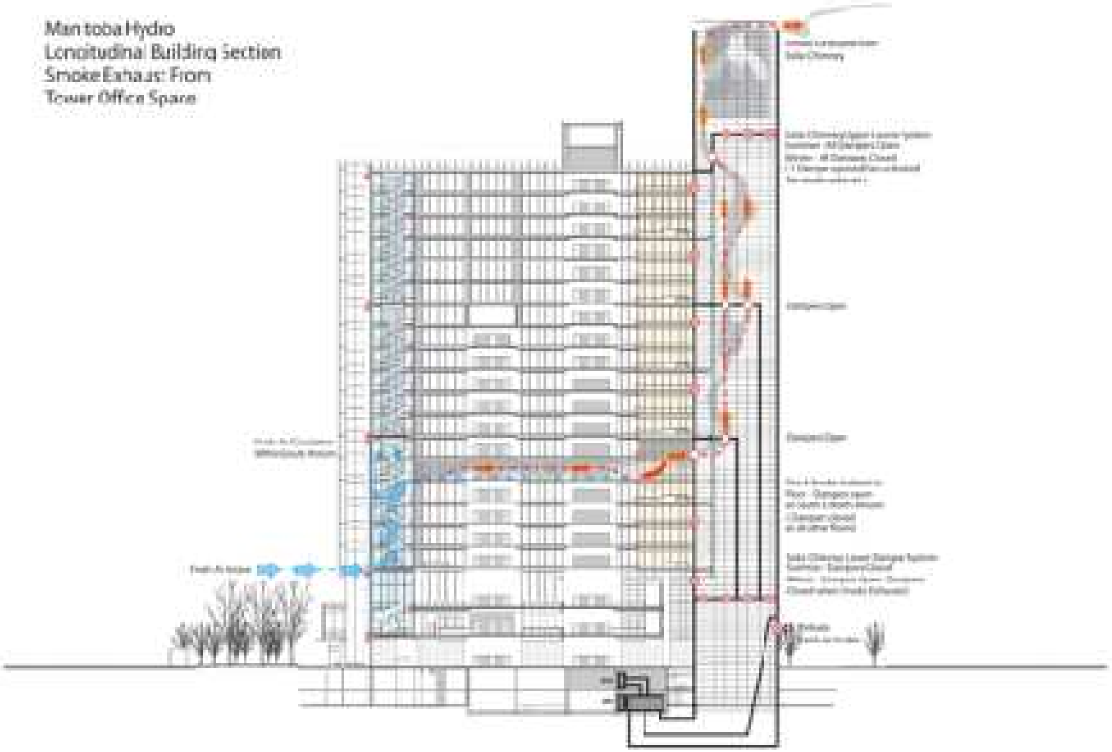


Figure 5.8: Building smoke exhaust system
Source: AIA, The American Institute of Architects

6 Conclusions

With this work, while focusing on the energy performance of buildings, the general conclusion could be that the crucial social and economic benefits come from environmental protection.

Generally, a green building is an environmental sustainable building, which is designed, constructed, renovated and operated to minimise total environmental impacts. Several strategies can be followed to achieve sustainability, such as water conservation and recycling waste, but reducing energy consumption will turn our ecological footprint significantly smaller. To reach reasonable energy consumption levels some measures have to be studied, never forgetting the occupant's comfort.

All these measures will be underpinned if the people would be more conscious about the environmental issues. The results would be in reducing costs and higher comfort, in general.

The challenge of the construction of new built buildings is the advantage the contemporary design that can be modelled in order to adapt to climate and sun path. With simple and affordable measures the quality in the performance of buildings can be increased heavily. However, for the existing buildings mainly technical and structural measures can be performed. On the other hand, the building companies, by using all technologies available, can reduce the maintenance costs and increase workers productivity.

Thanks to the building certification, today the families when buying a residence can make a choice on the basis of the information on the level of the energy efficiency of the dwelling.

It is obvious, that green buildings will continue to develop technologies and strategies to be more efficient in the next future. In contrast to many other areas of environmentalism that are stagnating, green building sector has proven to yield substantial benefits. Despite the progress, however, significant obstacles remain, erected by the inertia of the building professions and the construction industry.

Lack of collective vision for future green buildings, including design, components, systems, and materials, may affect the rapid progress in this area.

6.1 How to achieve sustainable performance of Green Buildings in Madeira

The aim of the dissertation was also to investigate the simplest appropriate methods to introduce the benefits of the green buildings technologies related to the Madeira environment.

According to the very mild climate, with a relatively high outside temperature in winter, which rarely drops below 8°C, and in summer rarely rises above 26°C, the energy needs for heating and cooling of the building are fairly lower in comparison to the buildings in continental region of Central Europe.

The Menerga engineers and experts, have long run experiences in projects and construction of low energy intelligent buildings around the Europe concerning to that, we used the opportunity to interview them about their ideas bases on the long term experience in designing the technical equipment for different climates and projects.

6.1.1 Recommendations introduced by Menerga team

Prepared by Director Danijel Muršič and the Design Engineer Aleš Gašparič a concept solution for Madeira or similar climate region will be presented. It can be assumed in following recommendations in order to achieve energy efficiency by passive and active measures which might be performed as:

- **Efficient thermal insulation of building envelope**: Thickness of insulation layer minimum 6-8 cm, glass envelope elements with U-factor of around 1,1 W/m^{2}K;

- **Glass envelope elements on sun side (south):** To reach the maximum passive insulation of the object in wintertime;

- **Efficient sun shading on glass envelope elements:** Shading the outside of building envelope in order to prevent the passive insulation during summertime;

- **Usage of renewable energy sources:**
    - seawater for indirect heating with heat pump, direct cooling possible – thermal activation of building construction (for cases near the shore);
    - photovoltaic generator;
    - wind power for electric production;
    - other renewable energy resources as absorption cooling with solar heat or fuel cells may be implemented, but they are really economical

justifiable in only rare cases in such an object in relevant climate region. Precise economical analysis is required.

- **Heating energy preparation:** Basic heat source could be seawater. Its fairly constant temperature during whole year enables high energy efficient heating with combined heat pump/chiller and cooling directly (thermal activation of concrete structure) or with heat pump/chiller;

- **Cooling energy preparation:** Basic cooling source is seawater, which can be used for cooling the concrete structure through a system of heat exchangers. When the dehumidification is needed, heat pump/chiller will be used for preparing of chilled water of ca. 7°C, which is leaded to water coolers in ventilation units. Condensation heat of the cooling process will be transported on seawater;

- **Thermal activation of concrete structure elements:** For energy efficient performance of heat pump in wintertime, the medium temperatures achieved by water in the concrete construction are about 25-27°C. High coefficient of performance values can be reached (ca. 4,5 – 5,5). Energy efficient cooling - cooling with seawater is possible, without function of heat-pump, which can be used also for cooling (as chiller);

- **Heating of domestic hot water:** In office building can be performed with small electrical boilers, because of low demands, energy consumption is very low;

- **Energy efficient controlled ventilation:** With air handling units with efficient recuperative and regenerative energy recovery (regenerative with energy efficiency ratio over 92% and recuperative over 80%). This enables energy efficient supply of fresh, conditioned air in each room in winter or summer and sucking out the exhausted air. It is important, that it is always enough, controlled amount of fresh air in building. Natural ventilation in this climate area has very poor effect, because of low temperature differences between inside and outside air that is needed to drive the natural ventilation process. Local temperature adjustment can be enabled with small heating coils in supply air distribution elements, so no further elements such as fan-coils is needed, it is all done with supply air, which is in one way or other needed for ventilation - enabling good quality room-air. Although local temperature adjustment is not necessary needed at climate environment of Madeira. Ventilation air handling units enables heating, cooling and dehumidifying of fresh supply air. They have heating and cooling coils, which are using warm and chilled water, prepared by heat pump/chiller;

- **Energy efficient lighting:** Rooms would be equipped with T5 fluorescent lamps, electronic controlled ballasts with a 0-10V analog input and light sensors. Efficient lighting of the work places follows the influence of the outside light and depending on the difference to the desired illumination continuously controls the intensity of the lamps;

- **Digital control system:** The building is realized as an intelligent building with integral control system. All functions that are linked to the thermal energy system, lighting, watering system, sunscreens are controlled with a unified system of digital controllers that can directly communicate with each other without any interfaces. This is most important for the harmonic functioning of all the energetic systems which interact directly. The controllers are freely programmable that enables a total flexibility of the system and easy optimization of the process operation;

- **Rainwater collecting:** Rainwater collecting from roofs and impermeable surfaces, for exterior irrigation and gardening, car, boat washing, etc.;

- **Seawater desalination system:** Low-energy desalination system on basis of reverse osmosis.

Steps to be taken to plan installations for low energy intelligent (office) building, as follows:

1. **Concept scheme**
    - Energetic analysis, analysis of consummated energy
    - Guidelines for building-physics
    - Analysis of building-physics details
    - Preparing of energy solution on area of building physics
    - Project task
    - Concept of energetic resources
    - Conceptual scheme of HVAC installations
    - Conceptual scheme of DDC (direct digital control) installations
    - Reconciliation of architectural and installation details

2. **Heating and cooling**
    - Calculation of heat gains by VDI 2078 cooling load calculation of air-conditioned rooms (VDI cooling load regulations)
    - Calculation of heat losses by EN 12831 heating systems in buildings, method for calculation of the design heat load
    - Dimensioning of heating and cooling needs
    - Dimensioning of elements for heating and cooling
    - Planning of heating and cooling system

3. **Ventilation and air-conditioning**
   - Calculation of demanded air flow
   - Systems for energy recycling (recuperation, regeneration)
   - Planning of thermodynamical processes
   - Dimensioning of functional groups for air-conditioning and ventilation
   - Planning the air distribution

4. **Planning of producing and distribution of heating and cooling energy**
   - Individual specification of combined heat pump/chiller units for producing the heat and chilled water
   - Planning the concept of using the condensate heat
   - Planning the concept of distribution of heat and chilled water
   - Planning the concept for heat supply
   - Composition of main energetic scheme

5. **Planning of implementation of renewable/alternative energy resources**
   - Usage of geothermal energy - analysis
   - Usage of renewable energy resources - analysis
   - Planning the concept of thermal activation of concrete structure

6. **Integral DDC (digital direct control) system**
   - Control of heating and chilled systems
   - Regulation of separate branches of heat and cooling energy users
   - Regulation for domestic water heating
   - Regulation of air-conditioning and ventilation units
   - Local room control, BMS (building management system)
   - Control of inner and outer lightning
   - Composition of control plans
   - Composition of DDC electrical board

7. **BMS (building management system)**
   - Definition of the extent and functionality of separate components
   - Definition of separate systems, to be implemented in extent of the BMS
   - Structure of links from all the implemented systems with alphanumerical and picture display

8. **Controlling**
   - “Fast online help” on distance
   - Controlling on distance including “history”
   - Informing in real-time (E-mail, SMS, iPad)

- Control function via Smartphone

9. **Execution**
   - Specification of the system
   - Supply of the systems
   - Putting the systems in function
   - Individual adaptation of devices and systems in order to meet the building's requirements
   - Instructions on usage and maintenance of systems
   - Teaching the staff how to manage with systems
   - Dispatch eventual disturbances in warranty time limit
   - Service/support

6.1.2 Recommendations by AREAM

Other recommendations rose from a project for sustainable tourism in Madeira financed by the European Commission providing the opportunity to develop a study. The potential of the site according to the location and climate was studied to find out the most sustainable scenario and to reduce the negative impacts of the tourism and to look upon the integration of new and renewable energy sources for island sustainable development (AERAM).

To analyse appropriated passive measures for green building (Green Hotel) in Madeira leading to a 30% more efficient energy solution, two types of buildings were developed by Planeamento e Arquitectura, Lda. First building was a fourth floor and ventilated attic meant to be a Hotel and the other was treated as a small part of the hotel that could be considered a room.

For the calculations, temperature, humidity and solar radiation data were necessary, obtained from meteorological station installed at the Caniçal and radiation data from satellite measurements (Meteostat).

The building elements simulated were:

- Construction material and glasses;
- Space division, concerning the use;
- Geometrical description of each space, by defining the delimiting surfaces (walls, roofs, interior partitions, underground surfaces), windows, doors, and applying the wall materials and glass types previously specified.

From the different studies performed, for both building types, a set of recommendation by the team leader, coordinated by AREAM were made that allow generalization of the results and applications.

Main issues regarding the climate:

- High availability of solar radiation makes solar control a key issue;
- High relative humidity originates high latent cooling loads;
- Mild temperatures facilitate night cooling of high thermal inertia buildings.

Recommendations for the buildings:

- Exterior double 10 cm concrete hollow block with insulation and air gap;
- Interior walls that are adjacent to technical areas should be insulated;
- In conditioned spaces, reduce the infiltration, especially during the day, in order to reduce the latent cooling loads;
- Small windows are recommended (windows' areas should not exceed 10 to 15% of exterior wall areas);
- Use of double glazing, with high visible transmission and low solar transmission (thermal conductivity is not the key issue for glazing choice);
- Shading by overhands showed to be the best solution for reducing the solar gains;
- User dependent management of solar control (venetian blinds, drapes) have to be used in complement with other solutions that are not user dependent, such as overhangs and tree shading;
- Overhangs are especially effective for south-facing windows;
- For east and west facing windows, the advantage of overhangs over internal shading is less significant;
- East and west windows can be partly shaded by trees, as the Sun is lower at these directions.

The replication of the study is high. Nearly all of the recommendations can be applied for similar sized buildings. These results are valid for significant territories, not only in Madeira Island but also in other islands and coastal regions in temperate climates.

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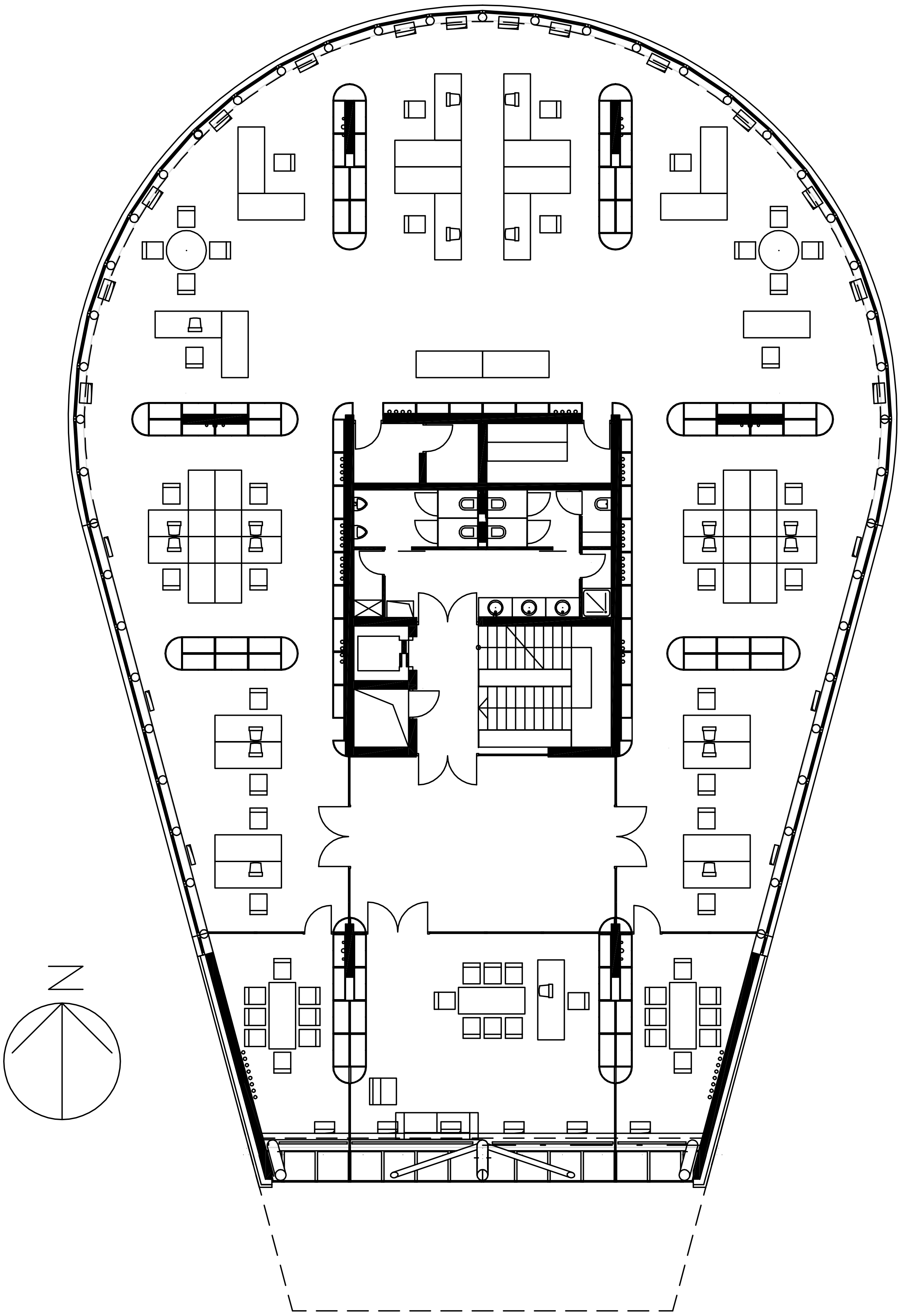
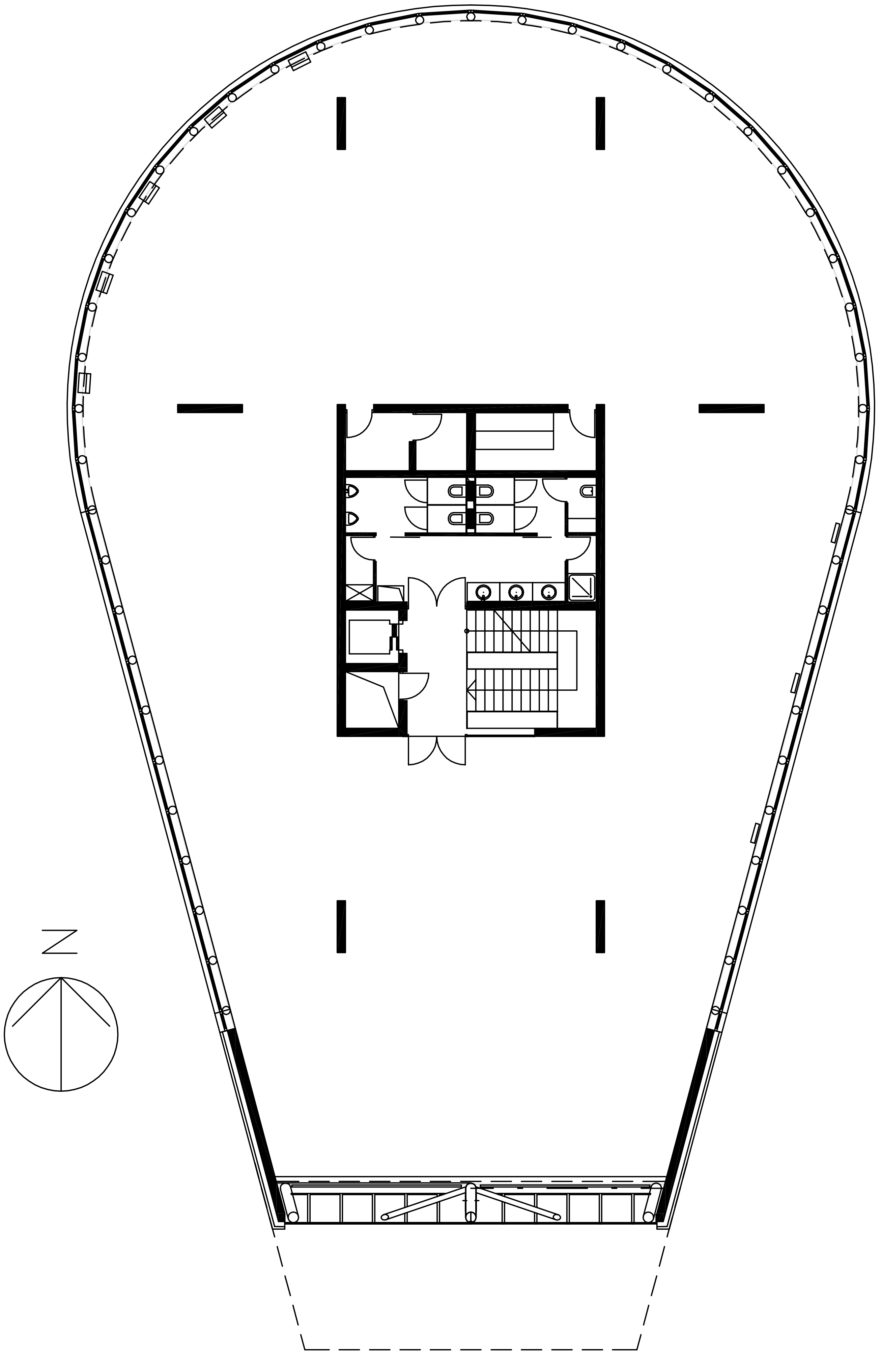
ANNEX



Layout 1st floor



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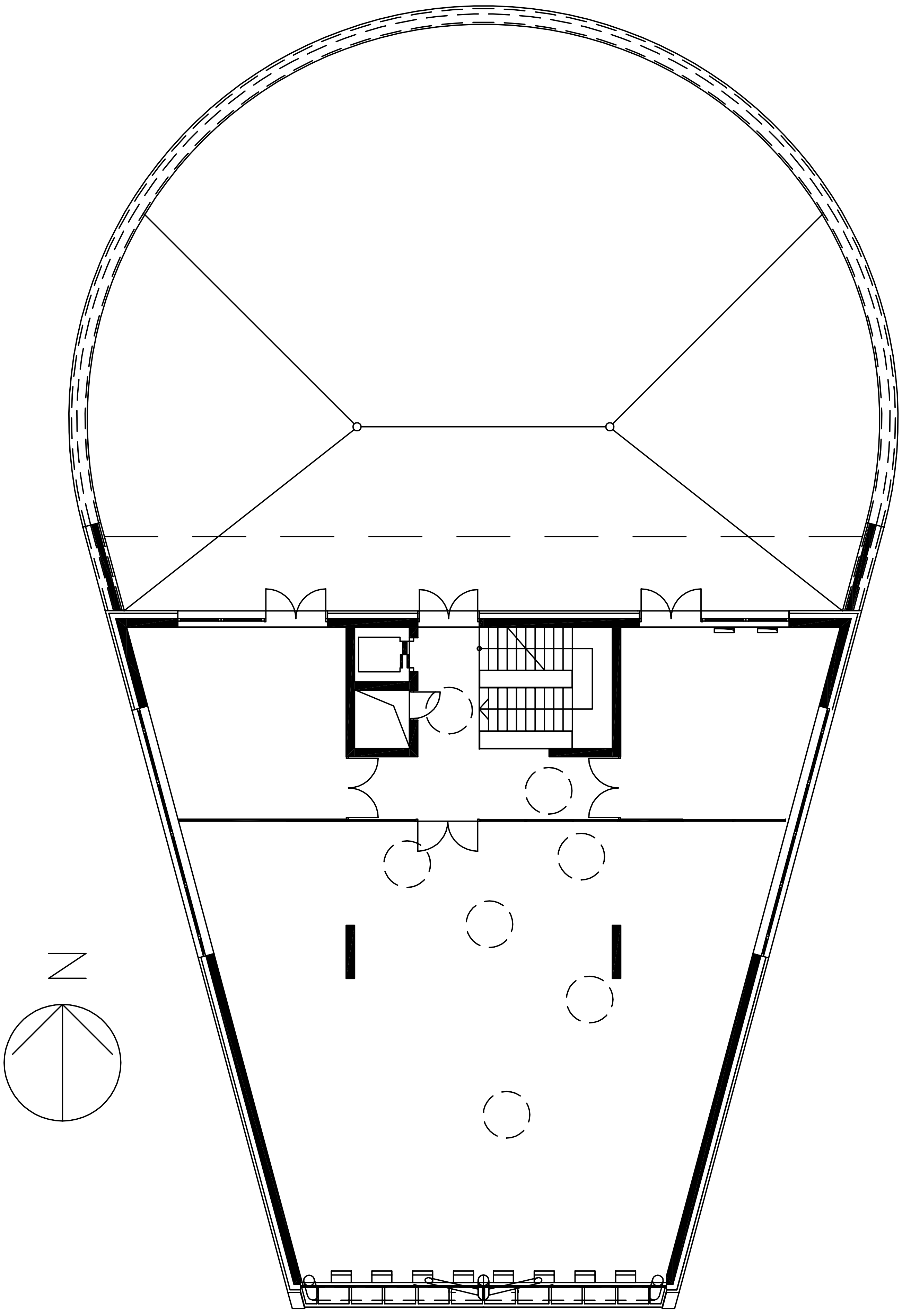

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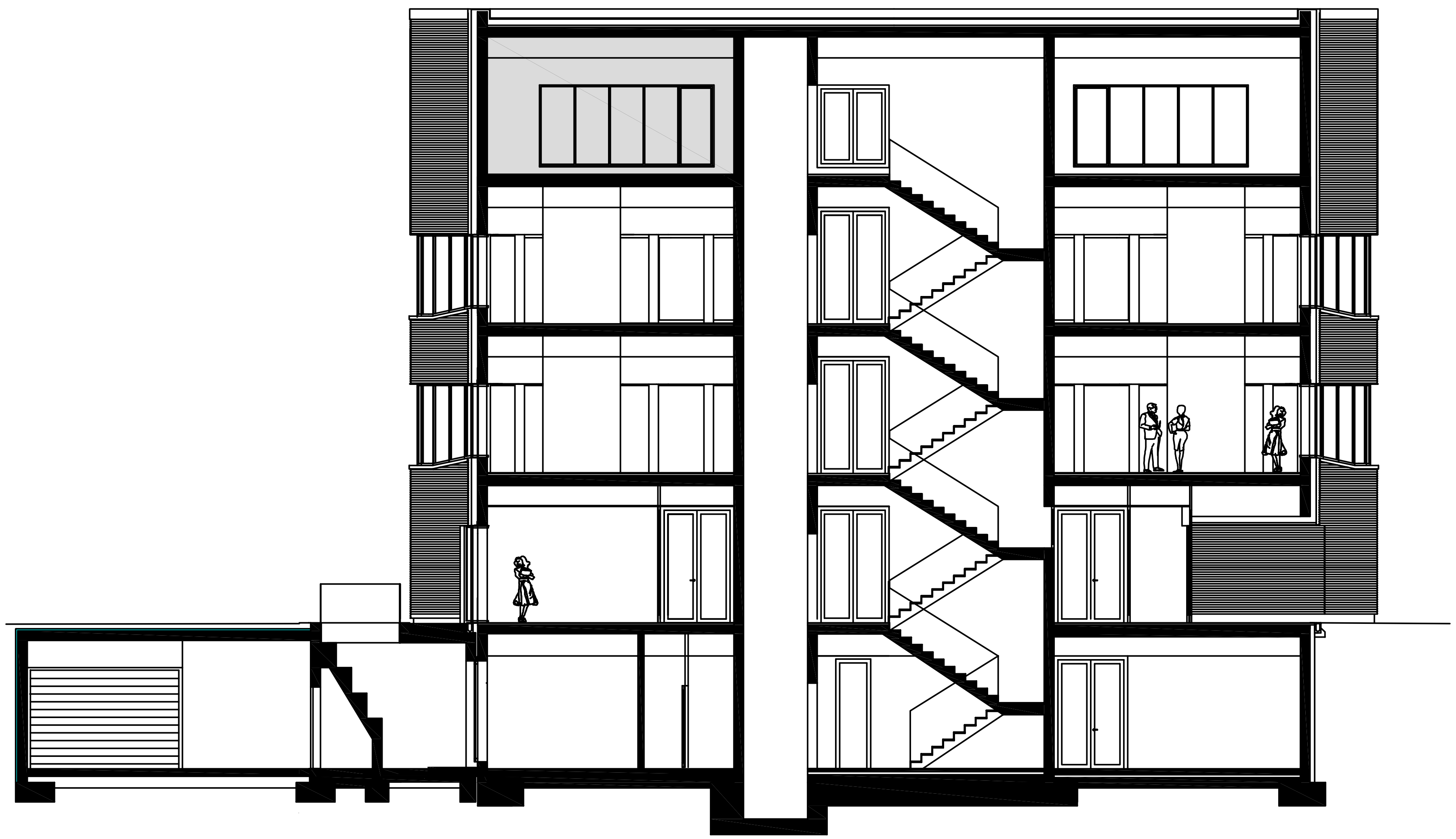
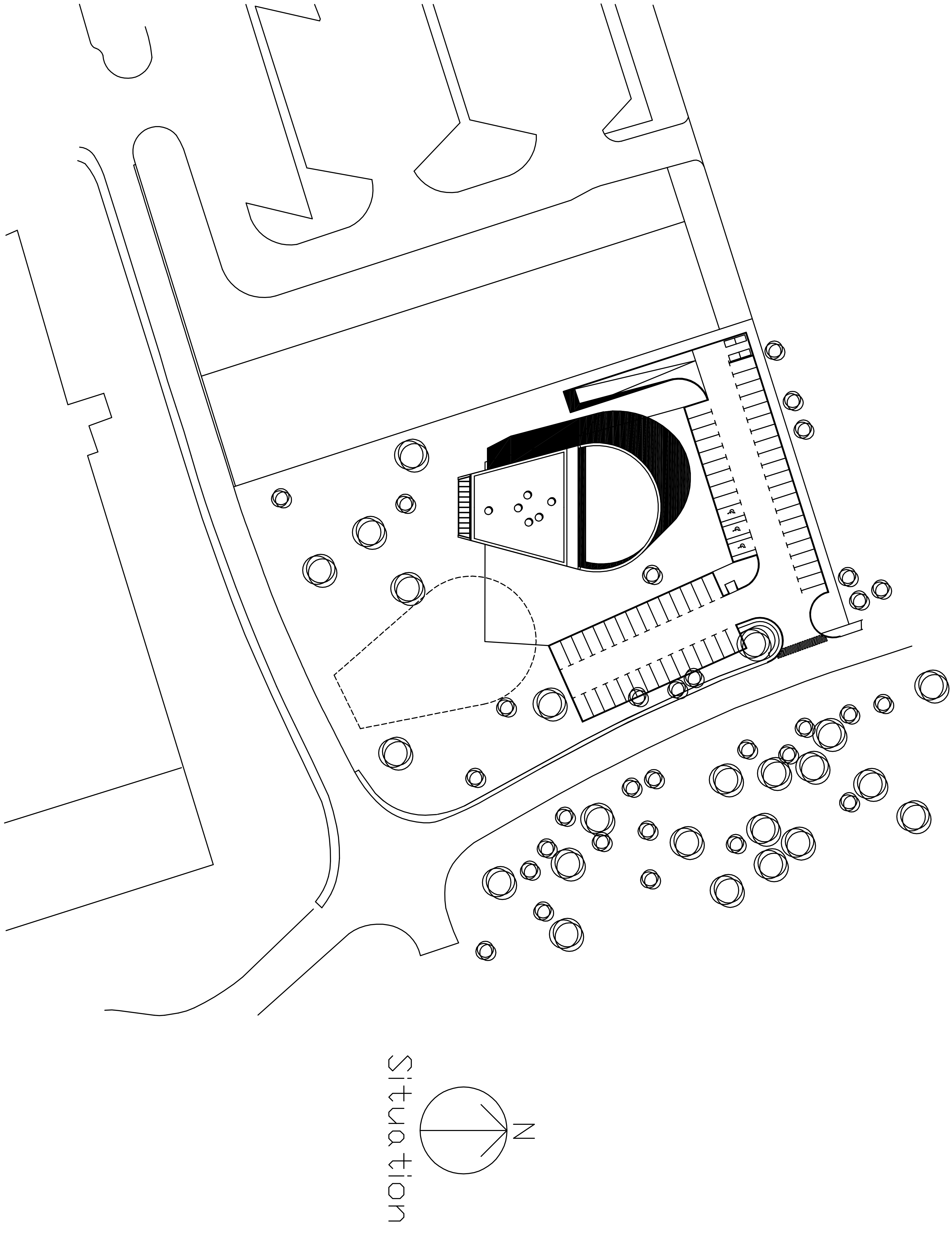


Cross section

Longitudinal section



Situation