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Abbreviations:

GHG : Greenhouse gas emissions.

WEC: World Energy Council

TFC: Total final consumption

PV : Photovoltaic panels

CCS : Carbon cycle system

HCESD: Creation of the High Council for the Environment and Sustainable Development

MTEM : The Ministry of Territorial and Environmental Management

NSE : National Strategy for the Environment

LCEA : Life Cycle Energy Assessment

EE: Energy efficiency

HVAC : Heating, Ventilation and Air Conditioning

EA: Environmental assessment

EU: European Union

MEPS : Minimum energy performance standards

BEECs : Building Energy Efficiency Codes

R-value : Thermal Resistance

λ : Thermal conductivity.

U : Coefficient of heat transmission

α : Coefficient of sound absorption

E : Absorbed sound energy

E_0: Incident sound energy

EPS : Expanded polystyrene

XPS :Extruded polystyrene

MDI : Methylene diphenyl diisocyanate

PUR: Polyurethane

TIMs : Transparent insulation materials

Low-E : Low-emitting

PF: Phenolic Foam

COP : Coefficient of performance

LCA :Life-cycle analysis

LCC : Life cycle costs

INTRODUCTION :

The energy demand in buildings has increased rapidly in recent years and exceeded 40% of global consumption **[1]** . This increase resets fundamentally in question the economic model which is dependent for its development of a colossal amount of energy.

This energy remains in the overwhelming majority, of fossil origin and therefore non-renewable in the short and medium term and which is the main source of greenhouse gas emissions in a world that is already suffering from the effects of human activity on its environment.

In Algeria, most of the buildings constructed are relatively uninsulated, which means that these buildings have high heat loss and therefore consume much more energy, and energy efficiency is still not applied in the production of buildings. In addition, residential buildings consume about 38% of the total **[2]** . Since 97 per cent of fossil fuel-based energy consumption, Algeria is one of Africa's main CO_2 emitters. Therefore integrating renewable energy sources and enhancing energy efficiency are crucial. In this regard, Algeria and many countries are looking for serious solutions to these energy and environmental issues.

A building's energy consumption is heavily dependent upon its envelope characteristics. The thermal performance of external walls is a key factor in improving the building sector's energy efficiency and reducing greenhouse gas emissions. Thermal insulation is undoubtedly one of the best ways to reduce the energy consumption due to both winter heating and summer cooling. Insulation materials have an important role to play in this scenario, since the choice of the correct material, its thickness and its position make it possible to achieve good indoor thermal comfort conditions and adequate energy savings. Thermal properties are extremely important, but they are not the only ones that need to be addressed when constructing a building envelope, sound insulation, fire resistance, water vapor permeability and environmental and human health impacts also need to be carefully examined.

The goal of this work is to do a study of energy efficiency of a building located at Zenata, TLEMCEN. This study allows calculate the energy consumption of this building (isolated and not isolated) , We'll do this analysis using design software to calculate annual and monthly heating , cooling, electricity consumptions . Then we propose solutions for reducing energy consumption and saving the most energy adapted without departing from a regulated cost goal.

To achieve these goals we must first ask ourselves the following questions: energy consumption is increasing day by day, thermal regulations in Algeria are not applicable, greenhouse gas emissions and all of the following are often heard;

What is the influence of the building envelope on losses and its energy demand?

What solutions are available to reduce losses and ensure thermal comfort? and save energy?

Does this insulated building require a source of air conditioning in the summer? And does it require a heat source in the winter? what is the power of these two resources?

CHAPTER 1 : BUILDINGS,ENERGY AND CLIMATE IMPACT

1.1. Introduction :

Energy is the golden thread linking economic development, increased social equity and a prosperous environment for the world. It is a dynamic force powering business, manufacturing, and goods and services transportation to support world economies; it is a key element of sustainable development. In today's world, the energy issue is becoming more and more important due to a potential energy shortage in the future and global warming too. The report by the World Energy Council (WEC) found that world energy demand is expanding by 45 percent between now and 2030 – an average annual rise of 1.6 percent – with coal accounting for more than a third of the overall increase. The construction industry and its global activities account for a surprisingly high 40 percent of global energy consumption and are responsible for more than half of overall greenhouse emissions **[3]** . About 85% of the world's existing energy needs are fulfilled by fossil fuels like coal, oil, and natural gas**[4]** .The continuous and drastic impact of fossil fuels on the balance of nature, ecosystems and the overall environment, water and soil, biodiversity and climate stability.

The concentration of our energy supply on (non-renewable) energy production poses an growing danger to civilization development at a global level. It is therefore important that we move towards energy sustainability. Energy sustainability is about finding the balance between a rising economy, the need to protect the environment and social responsibility to provide an better quality of life for current and future generations. In short, it is addressing current needs without compromising future needs **[5]**.

After the first energy crisis in the 1970s and until to the last ones in the 2011 Arab Spring and Fukushima till now; it is the key reason for developed and developing countries to reduce energy consumption. They started in two ways: reducing the use of energy (demand side) and trying to find another source of renewable energy (supply side). Energy consumption can be reduced for buildings by improving their efficiency. Many previous technical studies demonstrated the built environment's potential for energy saving. It is also increasingly understood that the complex interplay between various design strategies that can be applied to buildings and the potential to increase their energy efficiency is that.

1.2. Energy in buildings :

In terms of thermal comfort (heating or cooling), and air quality (ventilation), much of the energy used in buildings is used to maintain a healthy indoor climate. Many applications of energy include electric light, hot water and household appliances or other electrical devices (refrigerators, computers, televisions etc.) **[6]**.

1.2.1. Energy Use in Buildings (Past, Present, and Futur) :

In the last 20 years, energy consumption in buildings has grown. Sheer statistical increases underlie most of this growth — more people, more households and more oftices. Growing demand for service——more air conditioning, more computers, bigger houses —- has also contributed. However this increase has been moderated by the use of new technologies. Energy-efficient materials, appliances, and building designs have lowered residential energy intensity (energy consumption per household per year) and maintained commercial energy intensity (energy consumption per square foot per annum).

In the future, building energy use will be driven by technological change but will also be affected by other factors, including population and economic development, changes in household six, changes in lifestyle, and patterns of migration. The complexity and interactions of these factors make it difficult to predict exactly future levels of building energy use, however OTA estimates that building energy use will continue to grow at a moderate pace in a "business-as-usual" scenario (that is, assuming no policy change). While estimates of the forecasted savings are highly unpredictable, there is general consensus that there is significant technological and economic potential for savings**[7]**.

1.2.2. Primary,secondary and final energy :

a) Primary energy :

Primary energy includes all unprocessed, directly exploited, or imported energy products. It involves primarily crude oil, oil shale, natural gas, solid mineral fuels, biomass, solar radiation, hydraulic energy, wind energy, geothermal energy, and uranium fission energy **[8]**.

b) Secondary energy :

Secondary energy sources are derived from the transformation of primary energy sources, also called energy carriers. They are called energy carriers, since they transfer energy from one position to another in a useable way **[9]**. Registered carriers of energy are:

- Electricity
- Petrol
- Hydrogen

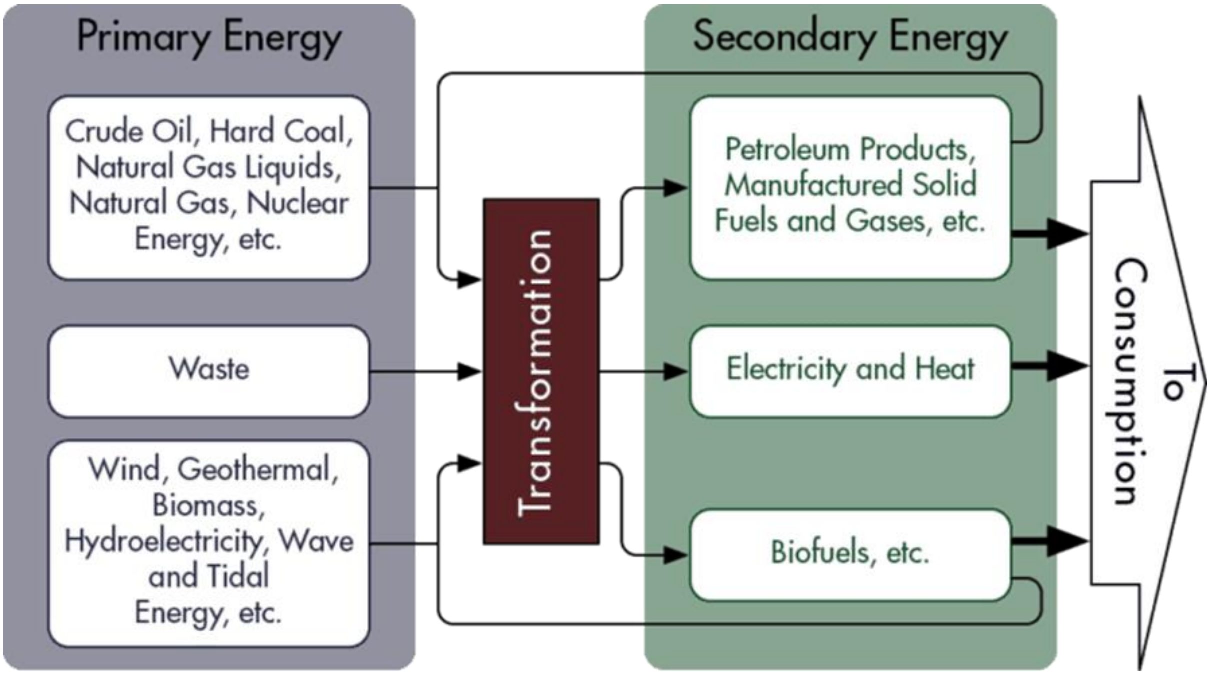


Figure 1 : primary and secondary energy [10]

c) Final energy :

Total energy consumption is the total energy consumed by end consumers, such as households, industry and agriculture. It is the energy that reaches the door of the final user, and excludes what the energy industry itself uses **[11]**.

1.2.3. Final energy consumption by type of energy in algeria :

In 2015 energy consumption has primary energies (gas and oil) as its sole source. Algeria remains overwhelmingly dependent on petroleum products, accounting for nearly half of the energy base overall.The reverse is the case, as the production of electricity is focused almost entirely on gas-fired plant output, in which case the latter is the dominant source. GPL which represents 5% is a gas by-product. So we come to 40% of energy from gas**[12]**.

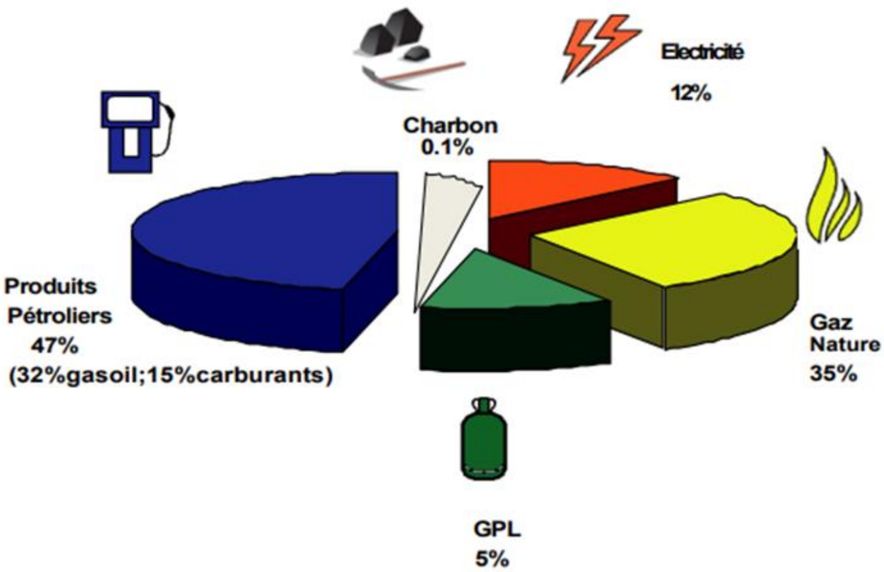


Figure 2 : final energy consumption by type of energy in algeria [12]

1.2.4. Sectors of final energy consumption in algeria :

Total final consumption in Algeria (TFC) has risen steadily in recent years. Although energy consumption in 2010 amounted to about 31,500 ktoe, it increased in 2013 to 38,543 ktoe, which means that the country has seen an rise of 22 per cent in just three years. **[13]**

In 2015 ,the transport sector is the one which consume the most energy (41%), followed by the residential sector (36%) , the industry sector (15%) and agricultural sector 3% **[12]**.

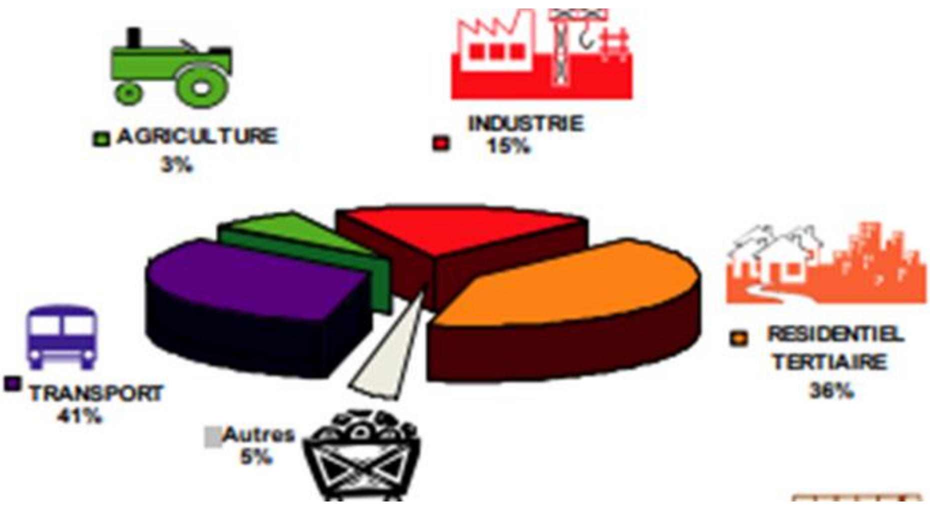


Figure 3 : sectors of final energy consumption in algeria [12]

1.2.5. Distribution of consumption residential sector by types of energy :

In Algeria, the building sector (residential and commercial) consumes more than 30% of the total national energy production ,final consumption in this sector reached 10.5 million toe .

Electricity consumption in the residential sector reached 1690 KTep. It represents 40% of the total electricity consumption. It reached 8,756 KTep in gaseous products, i.e. 60% of total consumption of gaseous products, It therefore represents the first large sector energy consumer at the national level **[12]**.

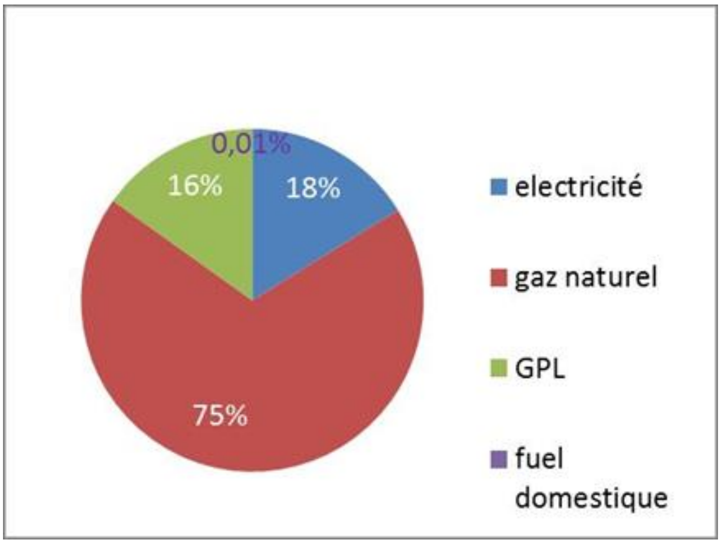


Figure 4 : Distribution of consumption residential sector by types of energy in algeria [12]

1.2.6. Renewable energy and energy efficiency :

a) Renewable energy :

Uses energy sources that are continually replenished by nature, such as light, wind, water, earth heat, and plants.Sustainable energy technologies turn these fuels into usable energy forms, which do not affect the environment.

- **Types of renewable energy in buildings :**

i. Solar energy :

Solar energy is the use of the sun's energy either directly as heat or by using solar photovoltaic cells and transparent photovoltaic glass to produce electricity.

1: solar photovoltaic

2 :solar heating and cooling

Figure 5 : Integration of solar energy in a house cnerib/Algiers

- **Solar Photovoltaic (PV):**

Energy directly transforms light from the sun into energy by solar PV panels. Today, this device is used in a number of applications. Smaller-scale photovoltaic systems are typically seen on the rooftops or homes, whereas larger-scale solar photovoltaic or solar parks are related **[14]**.

Figure 6 : solar photovoltaic panels [15]

- **Solar heating and cooling:**

Produce thermal energy from the sun to provide hot water, heating and cooling, and heating for the pool. Though similar in nature to PV systems, solar water heat collectors generate heat while solar PV systems generate electricity **[14]**.

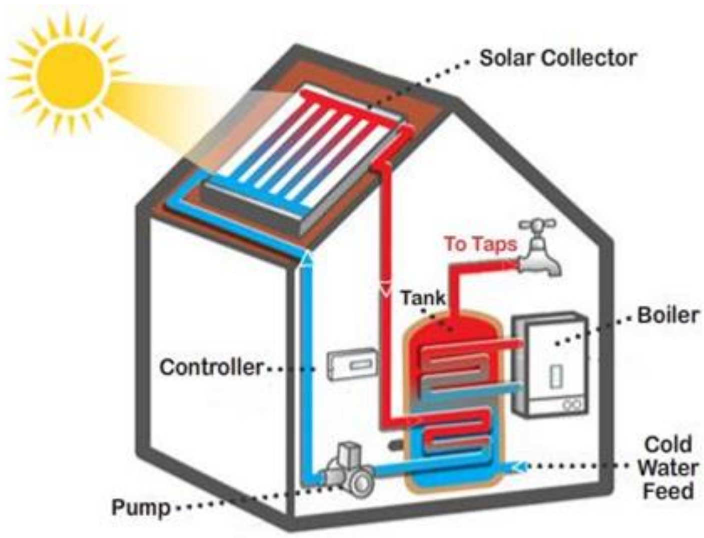


Figure 7 : solar heating and cooling [16]

ii. Wind energy :

Wind energy or wind power describes the process by which mechanical power or electricity is produced by the wind. Wind turbines transform mechanical power to the kinetic energy in the wind. Such mechanical power can be used for different tasks (such as grinding grain or pumping water), or a generator can turn it to electricity **[17]**.

Figure 8 : wind energy [18]

iii. Geothermal energy :

Geothermal energy is heat coming from inside the Earth's sub-surface. Water and/or steam convey geothermal energy to the surface of the Earth. Geothermal energy can be used for heating and cooling purposes, or harnessed to generate clean electricity, depending on its characteristics. However, high- or medium-temperature resources are required for electricity generation, which are typically located near tectonically active regions.

Worldwide, people are using geothermal energy to generate electricity, heat buildings and greenhouses, and for other purposes **[19]**.

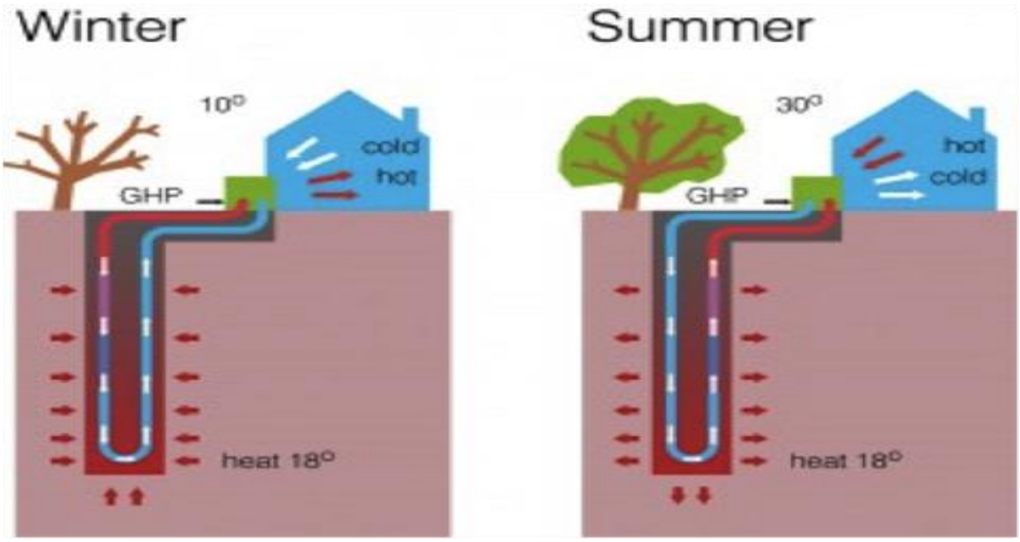


Figure 9 :geothermal energy [20]

b) Energy efficiency:

Energy efficiency means actually using less energy to achieve the same function – that is, reducing energy waste. Energy efficiency offers a number of benefits: reduction of greenhouse gas emissions, reduction of demand for energy imports and reduction of our household and economical costs. Although renewable energy solutions often help achieve these goals, the easiest – and also the most effective – way of reducing fossil fuel usage is to boost energy efficiency. In every area of the economy, whether it be housing, transport, manufacturing or energy generation, there are significant opportunities for efficiency improvements **[21]**.

c) Energy efficiency in buildings :

Energy-efficient buildings (new buildings or renovated existing buildings) can be characterized as buildings built to substantially reduce the energy demand for heating and cooling, independently of the energy and equipment used for heating or cooling the structure **[22]**.

Buildings that are energy-efficient in seating and architecture ensure cultural, social and environmental benefits. For through new development, an obvious energy preparation should be in place to identify how to achieve these benefits. The amount of energy use in a building is a direct consequence of the environment, building use and its architecture. It is no exaggeration to suggest that improved design of new buildings would result in a 50–75 per cent reduction in their energy use, and that appropriate intervention in current stocks would result in a 30 per cent reduction **[23]**.

Additionally, this can effectively lead to a reduction of the nation's energy bill, it plays an effective role in reducing environmental impacts and reducing the stressful indoor circumstances experienced by many citizens . Ensuring energy efficiency in buildings in order to mitigate environmental impact needs consideration of passive and active strategies described as follows:

1) Energy generation :

Buildings use sustainable energy. Renewable energy concerns energy resources which occur naturally and repeatedly in the environment and which can be utilized for the benefit of humans. This form of energy originates from the natural movement of sunlight, wind, or water from the Earth. Through the use of special collectors we can capture some of the energy and use it in our homes and businesses. As long as sunlight,water and wind continue to flow and trees and other plants continue to grow we have access to ready energy supply. **[23]**

2) Solar Passive Concept:

The principal concept of passive solar buildings is that the building elements, i.e. windows, walls and floors, are made capable of capturing and storing solar energy. This energy is then used for heating in the winter, and used in the summer seasons to avoid heat. Unlike some other mechanical device the buildings transform the solar energy into usable energy. **[24]**

The passive solar buildings work based on the following principles:

-The first concept is based at different seasons on the sun's path. In winter the sun will fly on a lower route than in summer.

-In winter, glass faced to the south will help to retain and store energy in the house.

- The location of the thermal mass in a position allowing easy absorption of solar energy at a later date would help to release the same during the evening.

- The direct sun can withstand overhanging elements as shown in the figure below. These are also known as control elements.

- Good insulation allows warm weather in winter and cool weather in summer.

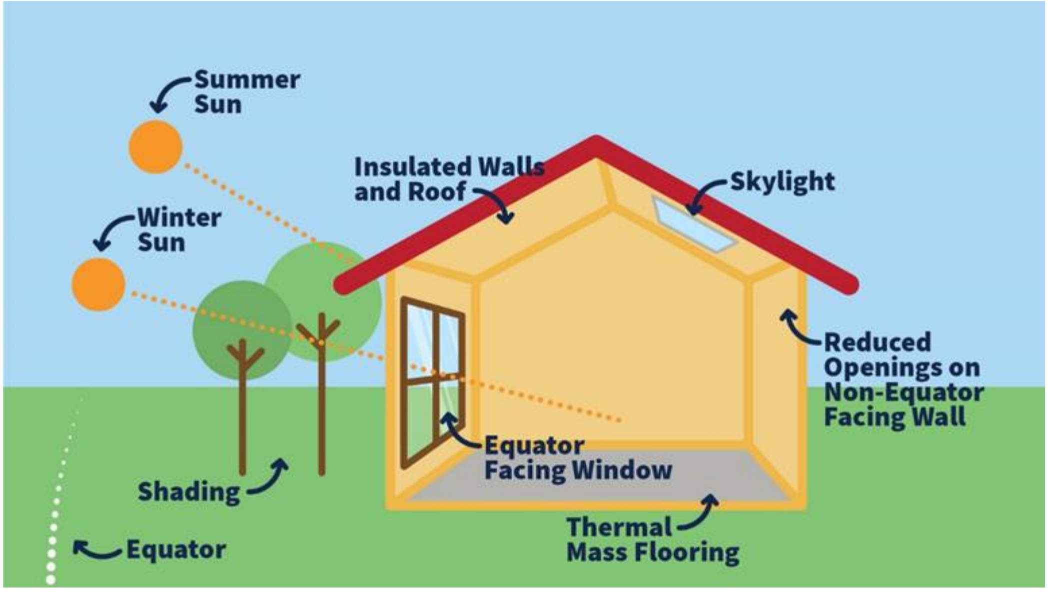


Figure 10 : passive solar design [25]

❖ **Passive solar heating :**

Passive solar heating uses the rays of the sun to heat a living space by opening the area to sunlight. Passive solar buildings take advantage of how the sun moves into warm living spaces during the day (with exposure to seasonal shifts in sunlight), without needing any mechanical equipment or fuel to do so.

Passive solar designs usually require five major factors: sunlight aperture to pass through, heat absorbers and thermal mass to absorb and maintain heat, heat transfer distribution, and a fixed control to provide shade throughout the summer.**[26]**

❖ **Passive cooling :**

Passive solar cooling systems work by reducing the excessive heat gain during the day, generating non-mechanical ventilation, exchanging warm indoor air for cooler outdoor air where possible, and storing night coolness at moderate warm daytime temperatures. Passive solar cooling systems at their simplest include overhangs or shades on windows facing south, shaded trees, thermal mass and cross ventilation. **[27]**

❖ **Building orientation :**

Form and orientation are two of the most important passive design techniques to minimize energy consumption and enhance the thermal comfort for a building's occupants. It affects the amount of sun going down on the ground, daylighting and wind direction. Forms and orientation have a significant impact on the energy efficiency of buildings towards net zero energy targets by harnessing sun and prevailing winds to our advantage.

Combined with other energy efficiency features, good orientation can reduce or even eliminate the need for auxiliary heating and cooling, resulting in lower energy bills, reduced greenhouse gas emissions and increased comfort.

If appropriate, a North / South orientation (that is, giving a wider façade to the south) is preferred for a building. Since the sun rises in the east and sets in the west, to take full advantage of the available energy of the sun, the side of the building used for solar gain must be facing the south. If the axis of the building is in the east-west direction, with its longest dimension facing the south, more of the building is positioned to capture the heat energy of the sun. If the building in the middle were longer, extending into the two houses on either side of it, it would better place more of its mass to absorb and radiate heat in the winter. **[28]**

Passive solar buildings are typically rectangular with the building facing south from the long side. The distance from the incoming heat source (south) to where it is absorbed (usually a northern wall) should be minimised. **[29]**

Table 1 : Indicator System of Passive design Model : [30]

Indicator Categories	Indicator Sets	Individual Indicators
Passive heating	Solar geometry	heating and cooling
		building Orientation
		seasonal changes in the building and its surroundings
		shading devices
Passive cooling	Wind and shading	
Day-lighting	Indirect lighting and materials issues	
Insulation		
thermal mass		

3) Active Strategy :

Active strategy is the technique of using the electro-mechanical fitted conditioning room to achieve the necessary level of comfort. The active strategy, such as air conditioning systems, transport systems, fire safety systems, plumbing systems, audio systems, bangunan cleaning systems, can be used by almost all utility systems in building. According to Wonoraharjo (2012), the active device is used particularly for thermal environment for:

1. Artificial air circulation
2. Ventilator
3. Humidity regulator
4. Air cooler

Active strategy is used on air conditioning systems for lighting, cooling, or space heating, and ventilation systems. Active systems are used on the lighting systems to illuminate the room, especially at night. Apart from illuminating the room, it also uses lighting for aesthetic interest.

The main considerations for optimal performance are the choice of type of lighting, location and period of usage. Active strategy is used on cooling or heating systems to cool the room with cold air and run it into the room at the desired temperature. For optimum performance a selective effort was needed to select the type of electromechanical equipment compared to the building characteristics and the requirement for comfort.

Because active strategy uses a variety of electro-mechanical equipment for building conditioning system so the deficiency is the large amount of energy and emissions required as well. High energy consumption also means higher funding costs. Although the benefits of using active strategy are the simplicity of having as planned comfort conditions. Ease of use is what makes it tempting to select an active strategy even though the cost is high. **[31]**

1.3. Energy and environnement :

There is general consensus among climate scientists around the world that the latest strong proof of climate change is 90 percent likely to be due primarily to human activity by fossil-based energy burning. This should be sufficient enough to persuade us that human intervention will eventually put a brake on the advance of global warming and its climatic implications. Buildings are particularly involved in this process, currently responsible for around 47% of carbon dioxide emissions in all 25 countries of the European Union. That being the case, it is appropriate that the design and construction of buildings should be the primary driver of climate change mitigation efforts. The security of the planet rests on our ability and willingness to use this free energy without creating unsavory side effects. **[32]**

1.3.1. Enviornnement impact :

Carbon is the main ingredient of earthly life.The carbon cycle system works on the premise that the carbon that is trappedin plants and animals is released slowly into the atmosphere after they die and decompose. This carbon in the atmosphere is then taken up by plants that transform carbon dioxide (CO_2) into roots, trunks, leaves etc.By photosynthesis**[32]** .While the atmosphere was tropical on the majority of the world and the amount of CO_2 was very high, the well-known emission amount of 386 g of CO_2/kWh was imposed by gas plants. While the relationship between CO_2 concentration, temperature change and adverse climate changes is very complex and therefore very difficult to forecast accurately, it is generally agreed that this concentration does not occur**.[33]**

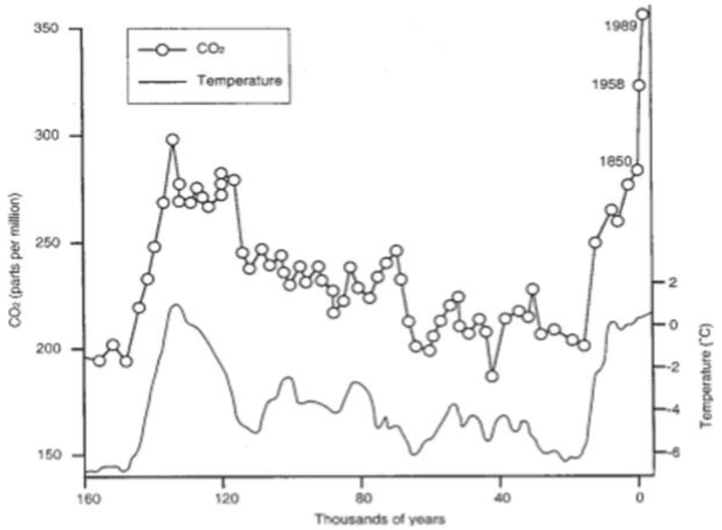
1.3.2. The green house effect :

The greenhouse effect is caused by long-wave radiation, which is reflected back into the atmosphere by the Crust and then reflected back by trace gasses in the colder upper atmosphere, resulting in further warming of the Earth's surface (Figure 1.1). Without the greenhouse effect, the surface temperature of our world would have been-18 ° C The presence of this phenomenon means that the average temperature of the planet is 15 ° C. Our world uses an average of 240 W / m2 to warm up to 13. **[33]**

1.3.3. Climate change – the paleoclimate record :

In June 1990, scientists were sharply drawn by a graph published in the journal Nature (Figure 1.2). Data from ice core samples shows a surprisingly strong connection between temperature and atmospheric CO_2 concentrations from 160 000 years ago to 1989. This has also been shown that the present concentrations of CO_2 are higher than at any time during that period. At the very least, the rate of growth has been sustained since then. Core ice samples provide information in four ways. First, their melted layers provide an indicator of the time period of the heart. Second, the calculation of the degree to which the ice melted and cooled during the summer provides a impression of the relative warmth of the season. The third measure is the ^{18}O heavy oxygen isotope in the air trapped in the ice. It's more common in warm years. Finally, the air trapped in the snow layers makes it possible to measure CO_2 in the atmosphere in a given year. Certain ice core data indicate that at the end of the last ice age 20 000 years ago, the sea level was around 150 m lower than it is today.**[32]**

Figure 11 : Correspondence between historic temperature and carbon dioxide [32]



1.3.4. The Environmental Policy in algeria :

In Algeria, the awareness of environmental problems has been progressive **[34]** The approach followed was the establishment, by successive strata and by sector, of the institutional framework for environmental management. Most of the institutions that have been set up have an area of action based on narrow, compartmentalized concerns, This limits the effectiveness of the actions. The legislative framework is also inadequate. Algeria has certainly drawn up a framework law for the environment (5 February 1983)**[35] ;**However, its application has been delayed due to excessive procedures and design deficiencies. From 1995 Creation of the Directorate-General for the Environment and Environmental Inspections,at the level of the different departments of the country was intended to strengthen the institutional architecture and improve the surveillance and control capacity of the state of the environment**[36].**Similarly, Creation of the High Council for the Environment and Sustainable Development (HCESD)was intended to lead to a global and integrated approach. In reality, the HCESD has not been operational. Thus, despite the existence of multiple institutions, the capacity of the latter has remained limited to different areas: strategy formulation, coordination, studies and research, control and impact studies . At the decentralized level, municipal environmental management has also proved to be very inadequate The Ministry of Territorial and Environmental Management (MTEM) was created in 2000 opened new perspectives. An extensive institutional and legal strengthening program is underway. A National Report on the State and the Future of the Environment and Sustainable Development (RNE 2000) was adopted by the Council of Ministers. A National Strategy for the Environment (SNE) and a National Action Plan for the Environment and Sustainable Development (PNAE-DD) have been prepared; In a ten-year perspective. A triennial priority action plan has been defined. The Government has made significant environmental investments as part of the Triennial Economic Recovery Plan (2001-2004).

Environmental taxation has been introduced in the 2002 Finance Act. The consultation with the socio-economic actors and citizens is taking place: a wide-ranging national debate has been launched at the level of all the municipalities of the country. However, it is clear that, to date, no strategy for the management of toxic and hazardous waste has been put in place by the institutions concerned, despite the many meetings, seminars and seminars on the subject of waste management and the environment. Announcing the danger, predicting the risk, projecting into the future, short, medium and long term forecasting does not take the place of an operational decision .**[37]**

1.3.5. Algeria climate :

In Algeria, Africa's largest region, there are three types of climate: the Mediterranean climate along the coast (zone 1 on the map), the climate of transition of the hill and mountain ranges of the north, slightly more continental and moderately rainy (zone 2), and finally the desert climate of the large area occupied by the Sahara (zone 3). **[38]**

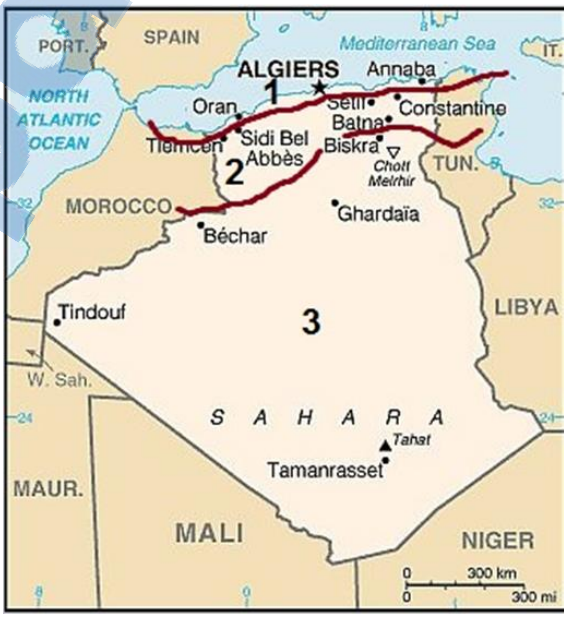


Figure 12 : algerian climat zones [38]

1.3.6. The varriation of temperature in some states of algeria :

- **Algiers-Average temperatures :**

Table 2 : Algiers-Average temperatures **[38]**

Month	Jan	Feb	Mar	Apl	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	6	6	7	9	12	16	19	20	18	14	10	7
Max (°C)	17	17	19	21	24	28	31	32	30	26	21	18

- **Algiers-Average precipitations :**

Table 3 : Algiers-Average precipitations **[38]**

Month	Jan	Feb	Mar	Apl	May	June	Jul	Aug	Sep	Oct	Nov	Déc	An
Préc. (mm)	80	75	55	60	40	9	5	8	30	60	90	90	600
days	11	11	10	9	7	3	2	3	5	9	11	12	92

- **Algiers-The sunshine :**

Table 4 : Algiers-The sunshine **[38]**

Month	Jan	Feb	Mar	Apl	May	June	Jul	Aug	Sep	Oct	Nov	Déc
Sun(hour)	4	6	7	8	10	10	11	10	9	6	5	5

- **Algiers-The temperature of the sea :**

Table 5 : Algiers-The temperature of the sea **[38]**

Month	Jan	Feb	Mar	Apl	May	June	Jul	Aug	Sep	Oct	Nov	Déc
Temp. (°C)	15	15	15	16	18	21	24	25	24	22	19	17

1.3.7. The Mountain Zones :

- **Sétif-Mean precipitations :**

Table 6 : Sétif-Mean precipitations **[38]**

Month	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Déc	An
Préc. (mm)	40	35	35	40	45	25	10	15	40	35	35	50	400
days	11	10	9	9	8	6	3	5	8	8	10	12	98

1.3.8. Desrt :

- **Biskra-Average temperatures :**

Table 7 : Biskra-Average temperatures **[38]**

Mois	Jan	Feb	Mar	Apl	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min (°C)	7	9	11	15	19	24	27	27	23	18	12	8
Max (°C)	17	19	23	26	31	37	40	40	34	28	22	18

1.4. buildings and environnement :

1.4.1. Demography and cities planning :

On a global scale, the building sector is responsible for approximately 30-40 of the annual global energy consumption and nearly 30 of all greenhouse gas (GHG) emissions. conscious of protecting the environment and reducing these losses, Algeria, aware of the predominance of conventional energy in interior,, adopted in 1999 (MDE Act). **[39]**

These cities, increasingly searching for energy and continuing to pollute the environment, were confronted in the twentieth century with an increase in urban population multiplied by ten times 16. This galloping approach is nevertheless one of the main causes of the maleness of the planet. Urban congestion, urban sprawl, deterioration of our ecosystems, greenhouse gases, insalubrity, poverty ... In order to understand the emergence of a concern for sustainable development in urban planning, we must first understand the context in which these concerns have emerged. We can say that urban growth has been the most striking phenomenon of the evolution of the territories since the industrial revolution, almost everywhere in the world. This phenomenon is all the more troubling as this urban demography will mainly take place in Africa and Asia, where the urban population will double from 2000 to 203017, hosting over 80 per cent of the world's population**[40].**Poor housing is one of the most visible effects of poverty. Currently, one billion people do not have adequate housing, and it is estimated that more than 100 million people are homeless. In 2025, 14 million people will be living in our big Algerian cities.**[34]**

1.4.2. Impact of urban planning:

Interest in assessing the sustainability of socio-ecological systems of urban areas has increased notably, with additional attention generated due to the fact that half the world's population now lives in cities. Urban areas face both a changing urban population size and increasing sustainability issues in terms of providing good socioeconomic and environmental living conditions. Urban planning has to deal with both challenges. Households play a major role by being affected by urban planning decisions on the one hand and by being responsible – among many other factors – for the environmental performance of a city (e.g. energy use).**[41]**

Indeed, the understanding of energy issues must today take into account a more global approach, aiming at integrating the climate approach into a sustainable urban development. The city, the main part of sustainable development, which includes building and urban transport, accounts for more than half of greenhouse gas emissions and about two thirds of energy consumption. Its development is composed of three dimensions: urbanism, building and transport, have become the number one problem of climate change and energy supply**[42].** Climate conditions are not the only factors in the shape of the habitat in terms of urban planning.

Environmental changes humanity faces are deeply intertwined with complex urbanization processes and happen at a previously unseen rate and magnitude. The net result is a general scientific acceptance that some climate change effects are now inevitable and unavoidable **[43]**. The impact of these will likely be felt to an increasing degree over the coming decades and potentially for long beyond**.[44].**

1.4.3. Impact of building:

Preservation and sustainability of our earth as well as the safety of the next generation is extremely important. In this regard, actors in different sectors are making major decisions with their operations to reduce their environmental footprint. One way to achieve this is through environmentally friendly construction methods**[23].**Environmentally harmful activities differ from one industry to another, but it is well known that the largest contributor to GHG emissions is the built environment, accounting for up to 50% of global carbon dioxide emissions. In addition, the environmental impacts generated by the building during its entire life cycle can be of the same magnitude as those generated during its lifetime. **[45]**

There are many methods available for assessing the environmental impacts of materials and components within the building sector. LCA is a methodology for evaluating the environmental loads of processes and products during their whole life-cycle. **[46]**

Figure 13 : Life Cycle Energy Assessment (LCEA) of Building Construction [33]

1.5 The bioclimatism :

1.5.1. bioclimatic approach :

Bioclimatic design – combining "biology" and "climate" – is an approach to building and landscape design based on local climate. The method was promoted in a variety of technical and popular publications in the 1950s. In using the term "bioclimatic," architectural design is linked to the physiological and psychological need for health and comfort. In adopting bioclimatic approaches, the designer endeavors to create comfort conditions in buildings by understanding the microclimate and resulting design strategies that include natural ventilation, daylighting, and passive heating and cooling. The principle of the bioclimatic architecture is that buildings use natural heating, cooling and daylight in compliance with local climatic conditions.**[47]**

1.5.2. Bio-climatism and sustainable development:

In both aspects, the limited resources and risks associated with unregulated migration, particularly in the poorest countries, the global management of the earth and its ecosystems must be enforced by man. Amid ups and downs in political will and, in particular, significant differences from one country to another, the UN World Commission on Environment and Development could, in its report entitled Our Future for All, say Bruntland report, in 1988, proposing that nations formally adopt the notion of sustainable development is the term consecrated can lead to confusion. Its definition is as follows: "Sustainable development is a social, economic and political development that responds to present needs without compromising the ability of future generations to meet their own development.

This idea illustrates the need, very new in its recognition of international solidarity, solidarity between all the peoples of the world and solidarity between generations. As a result, each player in each sector of economic life is faced with the responsibility for the overall management of resources and the environment. **[33]**

1.5.3. Urban ecology:

The aim of 'Urban Ecology' is to study these effects. According to Sukopp Wittig (1998), the term 'Urban Ecology' (in German Stadtökologie) can be defined in two ways. Within the natural sciences, urban ecology addresses biological patterns and associated environmental processes in urban areas, as a subdiscipline of biology and ecology.

Urban ecology is an interdisciplinary field that supports the efforts of societies to become more sustainable. It has deep roots in a wide range of disciplines, including geography, sociology, urban planning, landscape architecture, engineering, economics, anthropology, climatology, public health and ecology. Because of its interdisciplinary nature and unique focus on humans and natural systems within urbanised areas, 'urban ecology' has been used variously to describe the study of humans in cities, nature in cities, and the coupled relationships of humans and nature (Marzluff et al. in press; Fig. 14).

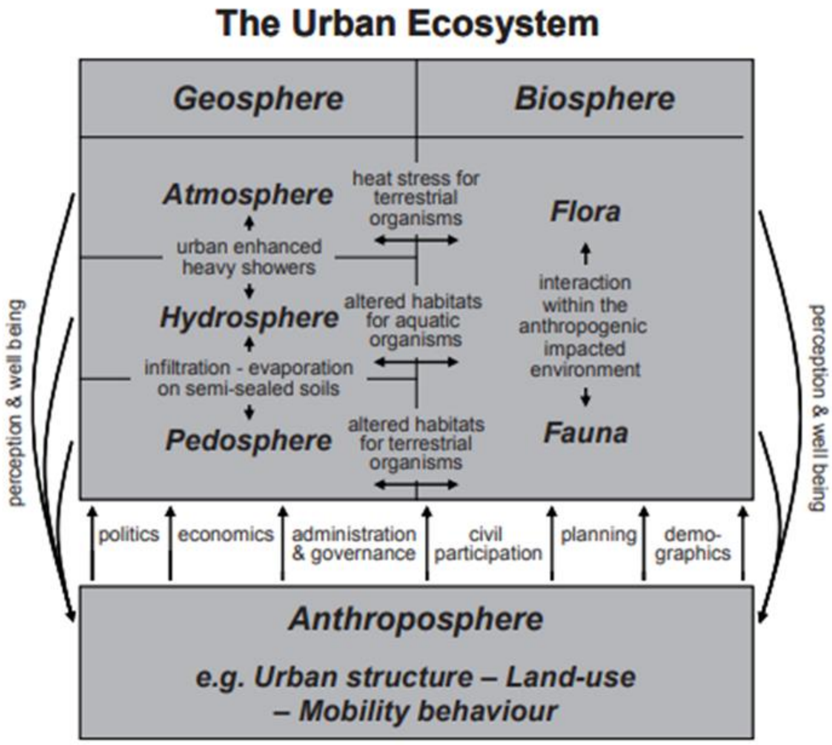


Figure 14 : Basic components of the urban ecosystem;

this concept is focused on the spheres of the Earth system which are important for cities. The processes between different spheres and the impacts of the anthroposphere (six selected examples) are of special interest (MARZLUFF et al. in press; modified)

1.5.4. Challenges for urban ecology and the city :

Cities are typically so large that it is difficult for city dwellers to come into contact with nature, and often it is only poor industrial agriculture or tree monoculture that can be easily accessed outside the city, whereas biodiversity within the city is high and distinguished – but still not noticed. The ecological and economic qualities of 'fourth nature' or 'new urban wilderness' are not yet widely understood. City dwellers spend much of their time indoors — in conditions with artificially heated or cooled ambient air, filtered drinking water from pipes, soil in flowerpots with ornamental plants, and small pets. This ‘home nature’ – a fifth type of nature – goes some way to replacing the outdoor type that city dwellers are disconnected from. However, human well-being, work efficiency and health also depend on intact natural elements close to daily life in cities. The colorful, spotted 'harlequin pattern' (Sukopp) is not only typical of urban biotopes, but can also be found in a variety of local climates and soil sites. Human activity must be seen as an essential part of urban ecology, And the convergence of the geobiosphere-and anthroposphere-approaches is desperately needed. Good examples of these coordinated behavior can be established at ecological hotspots in cities (Fig. 15). **[48]**

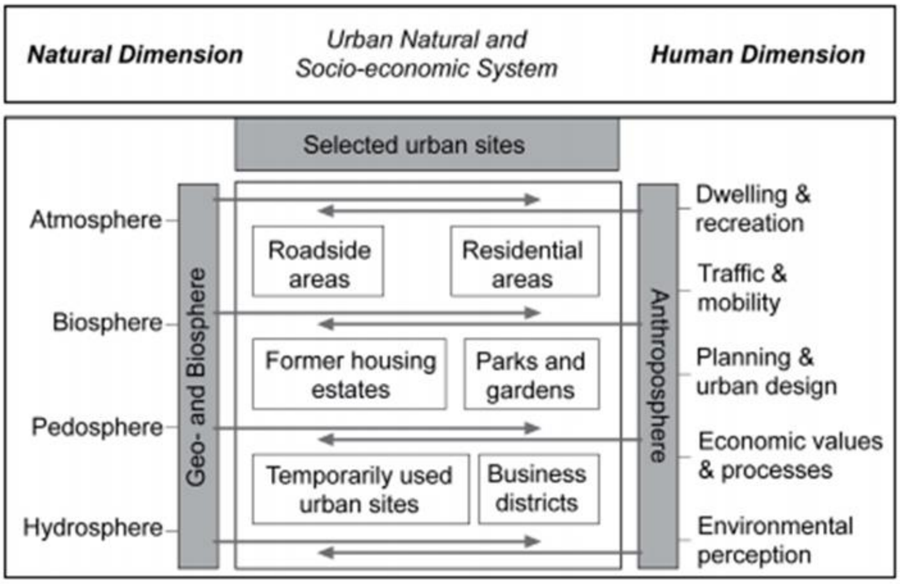


Figure 15 Concept of integrated research in urban ecology*:*

The main focus must be on the human dimension and its interferences with the urban natural system. A robust integration of human activities into urban ecology seems necessary due to the distinct disconnection between nature and daily urban life. To accomplish this, research should be carried out simultaneously from environmental and social sciences at the same urban sites

1.5.5. The German experience :

Germany as the leading country in the use of energy **[33]** . In the world, and probably one of the few countries that produced the idea of passive housing, this idea was born from the experience of the 1970s. Therefore, between 1984 and 1995, the energy consumption in need of heating in this country fell from 220 kWh / m2.year to 100 kWh / m2.year, with the introduction of new levels of defense against loss (insulation). The objective of this policy is to make low energy consumption housing (<70 kWh / m2.year), a construction standard. Passive habitat remains a long-term goal. Currently, 3,000 passive house demonstration projects are being evaluated in Europe. **[49]**

Standards implemented, as well as criteria for failure measures, are checked and corrected on a periodic basis. The results obtained by these countries, in terms of energy efficiency, have had a beneficial effect on both the quality of the built environment and the growth of the construction industry. In photovoltaic, Germany is leading Spain and Japan with an installed capacity of 5400 megawattes. **[50]**

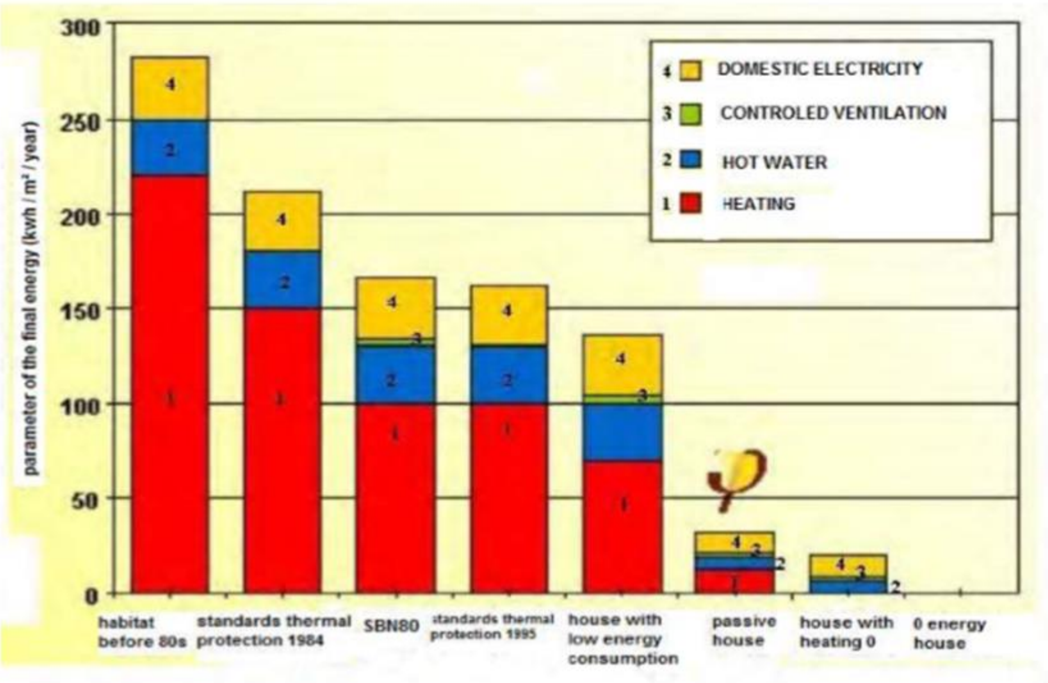


Figure 16 : Reduction of energy consumption in housing in Germany

1.6. Conclusion :

The first observation is The current scientific consensus points to the anthropogenic roots of the current global warming. Different human activities emit significant quantities of greenhouse gasses (GHGs), and these impact global atmospheric processes, especially preventing the re-emission of infrared radiation from the Planet to space. A large portion of greenhouse gas pollution is attributed to energy production and use We are faced with unparalleled phenomena, so as an algerian society we must be the masters of alarm. that’s why we have to contribute in this challege by engaging and respecting a new algerian policy at least applicating the rules of art in buildings. The building industry absorbs up to 40% of all electricity and contributes up to 30% of the annual global greenhouse gas emissions. Despite the rapid growth of new construction in transition economies and the inefficiency of existing real estate in the world, If nothing is done, the greenhouse gas emissions in buildings will more than double in the next 20 years. Energy management is a major economic development concern that goes hand in hand with sustainable growth. For all countries, apart from their differences (climate, environment, politics, need, lifestyle), they all face the question of shortage of energy resources, this shortage is a major challenge, It is above all logically the same resources to know how to manage efficiently in order to react in the most suitable way to the increasing demand for energy of their populations. The residential sector is the most customer, this adds all the more to the Algerian energy model, with a sustained growth due to the increased demand for new homes, built without taking into account the problem of the energy and the rate of household equipment in energy-seeking appliances which continues to grow. Energy efficiency in the construction sector can take on a number of aspects that are materialized through a multitude of techniques and methods, as well as strategies and avenues that remain to be cleared, which will be the subject of our next chapter.

CHAPTER 2 : BUILDINGS INSULATION

2.1. Introduction :

The building sector has become one of the priority areas for meeting the EU 2020 and 2050 targets**[51]**The Energy Performance of Buildings Directive **[52]** promotes almost zero energy buildings as mandatory by 2020. This means that new buildings need less than 30–50 kWh / m2 per year, while existing buildings consume around 250 kWh / m2 per year,**[53]** That's why we need to see the approaches that can be applied to energy efficiency.

In order to improve energy efficiency in the construction and economic promotion sectors, different technologies, policies and funding have been mentioned in the courses and examples for policy makers.

Improving energy efficiency in buildings depends on 3 primary criteria that are:

•Reduce the consumption of heating, air conditioning, ventilation and lighting with architectural and technical reflections for buildings.

•Improve quality of energy-consuming buildings and equipment**[33]**

Two main goals will contribute much of the energy savings of the retrofit: to reduce the need for heating and to improve the performance of the HVAC systems. Improving the performance of systems without affecting thermal comfort is an essential factor in achieving the planned reduction goal. Typical heating-reduction steps include the application of insulation materials on walls and/or replacing windows.

Little attention is paid to how improvements to the building envelope affect the settings and efficiency of the heating system. Essentially, the rise in insulation decreases the need for energy, which in turn will reduce flow levels and/or supply temperatures. Reducing the supply temperature makes the low-temperature heating system important and commercially viable **[54,55]** .

2.2. The current state of construction in Algeria, from passivity to efficiency?

The energy consumption of buildings in Algeria is estimated at 40%, and it is in this sense that the Algerian Government aims to introduce 3000 ecological housing units and the thermal rehabilitation of 4000 other existing housing units, as well as 20 pour le tertiaire (Climate audit) within the framework of the five-year plan 2010/2014.

With its solar capacity measured at more than 3000 hours of sunlight per year, Algeria is one of the countries best suited to promoting solar energy. However, the national policy for the production of renewable energy technology must be based on a financial plan capable of providing sufficient capital for this area of future activity.**[56]**

It should be noted that the implementation of Law 99.09 on the management of energy in the building sector has materialized by the promulgation, on 24 April 2000, of Executive Decree No. 2000-90 on the thermal regulation of new buildings. the introduction of energy efficiency in new buildings for residential and other use and in parts of constructions carried out as an extension of existing buildings.

In order to combine the optimisation of practices, a pilot project has been set up in Souïdania, favoring the use of local materials and alternative energy sources. The Souïdania MED-ENEC pilot project was designed to bring these conditions together, from the stage of construction to the stage of use.

Figure 17 : CNERIB , algies

Figure 18 : Pictures we took as a result of our internship when we visited the site

The results of the project demonstrated that the building's energy consumption was reduced by 56%, while highlighting traditional construction techniques, which are often optimal in terms of energy.

Thus, the use of adobes (dry earth bricks), natural light, the optimum orientation of the building or even natural ventilation during the summer period made it possible to incorporate the cultural aspects of the same project, both ecological and economic. The project time was projected at 86 years due to an increased expense of more than 40 percent (more than 300,000 DA).

2.3. Improving energy efficiency in buildings :

The technological potential for energy savings in buildings is enormous, particularly with"passive" projects that reduce or even remove the need for active energy usage.In cold climate areas , for example, super-isolated and air-tight residential buildings (often referred to as passive houses) use just 10 to 25% of the active heating energy required to heat the average new residential building today. Passive design techniques for buildings in warm climates, such as white roof, sun shading and natural ventilation can also achieve significant cooling load reduction. In addition, market competition and government energy efficiency (EE) policies can lead to new generations of EE equipment that also help bring down the energy use in buildings. Energy usage and performance in buildings is typically characterized by end-use categories such as space heating , cooling and lighting. In these end-use categories, EE is typically defined by the design and construction (including the materials and components used) of the building and by the technological performance and operational management of energy-intensive buildings. Energy consumption is further influenced by variations in building function, climate, energy prices, billing methods, and human behavior.**[57]**

There are three primary ways in which energy efficiency can be improved in residential, public, and commercial buildings:

1 | Through improved design and construction techniques that reduce heating, cooling, ventilating, and lighting loads

2 | Through building upgrades and the replacement of energy-using equipment

3 | By actively managing energy use

The main junctures at which energy efficiency interventions can be launched are as follows:

•**When designing and constructing new buildings :** A building energy efficiency code sets out the minimum energy efficiency requirements of a building. The most effective way to ensure that energy efficiency is included into the design and construction process is by introducing and enforcing Building Energy Efficiency.

•**By retrofitting existing buildings :** Retrofitting existing buildings and replacing energyconsuming equipment are critical for improving energy efficiency in cities. Cities need to be opportunistic in order to capture this potential.

•**By establishing and maintaining energy management systems :** Establishing and maintaining effective energy management systems for monitoring and controlling energy use in large public and commercial buildings is a low-cost means with which to improve energy efficiency and reduce energy demand.

 In following these steps, cities can achieve large energy cost savings, help create new businesses and jobs, increase energy security, and improve the quality of life of their constituents.

2.4. The Opportunities:

Scaling up EE in buildings is a value proposition for both mature and fast-growing cities. Given that most of the buildings in existence today were constructed with little or inadequate attention to EE, the global building sector is a huge untapped source for energy efficiency gains.

City authorities should aim to pursue EE measures that make financial or economic sense. Simple paybacktime is a quick means of evaluating the financial attractiveness of EE measures. **[57]**

Table 8 : Approaches for Improving Energy Efficiency in Buildings [57]

Focal Area	Technical Approach
Reducing heating, cooling, ventilating, and lighting loads for new buildings or when renovating existing buildings.	Apply local climate-sensitive passive design techniques, such as building form, orientation, surface color, sun shading, building envelope insulation, air tightness, ventilation, etc.
Increasing the efficiency of energy-using devices and equipment	Optimize system design and operation to match actual heating, cooling, and lighting loads through commissioning and retro-commissioning Upgrade or replace heating, ventilation, and air conditioning (HVAC) systems, indoor lighting, water heating, home appliances, and other electric and mechanical devices
Manage energy use in public and commercial buildings	Monitor, analyze, and control energy use through energy performance benchmarking Establish new maintenance standards, label building energy performance, and communicate energy performance indicators to building owners/tenants. Organize information and awareness raising campaigns

2.5. Barriers and Challenges :

There are a number of barriers and challenges inherent in improving EE in buildings. Table 9 outlines and provides examples of some of the most common barriers. Addressing systemic problems typically requires policy interventions and support at the national and regional level.

Table 9 : Common Barriers to Improving Energy Efficiency in Buildings [57]

Barrier Categories	Common Barriers
Lack of knowledge and knowhow	Lack of reliable and credible information about energy performance and the costs and benefits of efficiency improvements Lack of implementation capacity: shortage of relevant technical skills in local markets to ensure compliance of building EE codes Risk aversion to unfamiliar materials, methods and equipment, or uncertain outcomes

Institutional and regulatory deficiencies	Lack of national and/or local commitment to EE in general, and to EE in buildings in particular Government internal procedures and lines of responsibility that discourage EE in public buildings (e.g., budgetary and procurement policies not conducive to contracting EE services) Poorly designed social protection policies that undermine price signals for efficient use of energy (e.g., generally subsidized energy prices)
Financing challenges	Local government budget constraints Lack of long-term financing at a moderate cost Hightransaction costs due to small individual investments Unattractive financial returns Unreliable repayments
Market failures and inefficiencies	Split incentives: EE investment decisions are made by actors that do not receive direct financial benefit Suboptimal decisions or choices due to insufficient information Fragmented building trades: multiple professions involved in different stages or decision processes

2.6. Solutions :

Before committing significant private and public financial resources, it is important for city leaders to develop a clear view of the main opportunities, issues, and options available in improving the EE of new and existing buildings. A crucial first move is to carry out a sector EE evaluation that can cover either the entire construction sector or a particular part of it. The basic approach for conducting EA assessments for buildings is defined in a separate guidance note for city EA assessments. City governments should also lead by example by implementing cost-effective programs to improve EA in public buildings and/or by evaluating new EA policy initiatives.. It is critical for city governments to work with national and state/provincial governments, as well as other stakeholders—such as energy utilities, banks, building owners, and energy service trades—to address the major barriers to scaling up EE in buildings .The most common policy and regulatory tools and resources for that EA in buildings are described below. Such interventions need to be followed by tailored support services, since the portfolio of actions is typically more successful than a single, stand-alone EE intervention..**[57]**

1) **Energy regulatory policies** : Usually formulated at the national or regional level, energy regulatory policies address general inefficiencies in energy markets.
2) **Mandatory standards and codes :** Mandatory standards and codes address key market failures or inefficiencies. The case of split incentives (see Table 9) is the main reason for introducing mandatory building energy efficiency codes. Minimum energy performance standards (MEPS) for major energy-consuming equipment are targeted at manufacturers.
3) **Labels and certificates :** These are means of recognizing and encouraging EE efforts that go above and beyond the mandatory requirements outlined above. Examples include the voluntary Energy Star program for buildings, components, and equipment in the United States and the Green Mark scheme for buildings in Singapore.
4) **Financial facilitation schemes :** These include fiscal and monetary incentives to encourage investments in energy efficiency. Examples include tax credits, cash rebates, and capital subsidies, as well as special funding vehicles and risk-sharing schemes to increase funding and lending for investments in EE. This topic is discussed in a separate guidance note on mobilizing municipal EE financing
5) **Requirements for energy management :** Several cities in the US and the European Union have introduced mandatory energy performance benchmarking and disclosure programs. Energy management requirements can also help municipal governments target support for building retrofits.
6) **Public sector financial management and procurement policies** : These can have a significant impact on municipal efforts to retrofit public buildings and upgrade inefficient energy-consuming equipment. This topic is discussed in a separate guidance note on integrating energy efficiency requirements into public procurement procedures.
7) **Awareness-raising and capacity-building initiatives :**Public information initiatives can help increase the knowledge and know-how of stakeholders. These may involve general awareness campaigns.

A city's ability to develop and deploy these tools and instruments varies, depending on the particulars of the local governance structure. Table 10 provides a general map of the key policy tools, the barriers they intend to address, and the potential role of municipal authorities.

Table 10 : Key Policy Interventions and Support: Matching Barriers with Policy Tools [57]

Policy Tools	Issues Addressed	Examples of Intervention	What City Government Can Do
Energy Regulatory Policies	Weak financial incentive to invest in EE by consumers Disincentive for energy utilities to invest in DSM activities due to lost sales	Remove general price subsidies for public, residential, and commercial users Decouple energy utility revenue from sales*	Support and participate in national or regional policy reform programs
Mandatory Standards and Codes	Split incentives, fragmented building trades, fragmented building ownerships, etc. Underinvestment in EE by equipment makers	Building energy efficiency codes Minimum energy performance standards for equipment	Set and/or enforce standards Encourage or mandate (public sector) purchase of EE equipment
Labels and Certificates	Lack of credible and consistent energy performance information and/or recognition of excellence	Energy Star label for equipment or buildings Green building rating systems	Promote the adoption of nationally/internationally recognized labels and certificates
Financing Facilitation	Insufficient financial incentive Lack of commercial lending to EE Risk concerns of commercial lenders	Subsidies for EE investments Dedicated EE fund and credit line Partial risk/credit guarantee	Use public funds to leverage private and commercial investments
Energy Management	Lack of transparent and consistent monitoring and control of energy use	Energy performance benchmarking and disclosure	Require energy performance benchmarking and disclosure for large public and commercial buildings
Public Sector Financial Management and Procurement policies	Disincentive for EE efforts in budgetsupported public entities Difficulty for public entities to contract	Revise budgetary rules to allow retention of energy cost savings for other justified public spending	Make adjustments based on a city's own policy-making authority

	energy service providers, or make EE equipment preferred purchase choices	Revise public procurement rules to allow for contracting of energy service providers and adopt EE purchase requirements	
Capacity Building and Awareness Raising	Inadequate knowledge and skills for BEEC compliance Lack of general awareness and sensitivity to energy waste Lack of specific knowledge and skills to perform energy management duties	Train building trades on BEEC requirements and proper approaches Public campaign to promote efficient use of energy Train building managers of large public and commercial buildings	Organize trainings and sponsor awareness campaigns

2.7. Energy efficiency in new buildings :

Newly constructed buildings represent the best opportunity and greatest potential for reducing heating, cooling, and lighting loads and introducing EE technologies that can pay for themselves over the course of their life cycle.

These gains can be most effectively achieved by introducing and implementing the Building Energy Efficiency Codes (BEECs). The creation and implementation of BEECs is a complex process , requiring a wide range of data and analyses. It also needs thorough consultation and active involvement of a wide variety of stakeholders. An effective enforcement system is crucial to ensure that buildings are designed and built in accordance with the BEEC requirements. Based on the specific material of the finished house, the EE specifications for installed equipment and devices are either specifically regulated by BEECs or set out in different EE guidelines, such as minimum energy efficiency criteria for appliances.

If a well-designed and constructed new building achieves the anticipated energy savings it would primarily rely on user actions and organizational management. If both are present, there are two primary ways of obtaining EE opportunities while constructing new buildings:

a. **Mandatory enforcement of BEECs :** The mandatory enforcement of BEECs is generally stipulated by national and/or state/ provincial governments. Initial compliance is often voluntary so that a government can develop the necessary capacity to enforce BEEC standards.

b. **incentivizing investors and developers to exceed BEEC standards :** The main drawback of mandatory BEECs is that they are minimum requirements that are usually based on the average or even below-average performance of the construction market. This vulnerability can be solved by periodically reviewing BEECs — at three-to five-year intervals , for example — so that EA specifications can be improved as technologies advance. In general, there are no intrinsic rewards in the BEECs for those who are willing to evolve and/or surpass the BEEC thresholds.This is where an EE rating system for buildings—and, increasingly, green building rating systems—can be an important means of recognizing market leaders.

2.8. Regulation of energy efficiency in new buildings :

Since many barriers hamper energy efficiency in new buildings, there is a strong request for policies which address energy efficiency in new buildings. Energy efficiency requirements for new buildings effectively reduce energy consumption in buildings. Building codes or standards for energy efficiency regulate on the efficiency of the building envelope, including the structures around heated or cooled parts of the building, but often they also regulate the efficiency of different part of the heating, cooling and ventilation system and maybe even other energy using equipment.

The energy efficiency standards of the building shell or envelope have traditionally been the first to be established and are now an integral part of almost all energy efficiency regulations for new buildings.

Other segments of buildings and installations that influence the energy performance of buildings20 can be addressed in the Regulation Energy performance, but these elements are more rarely included in the specifications. **[58]**

a) Building envelope :

Building envelope is term for parts of the building which surround heated and unheated parts. This includes external walls, floors or ground deck, roofs or roofs. If a cellar is heated, the cellar walls and the cellar floor requirements for energy efficiency in external parts of the building, the building envelope, and other areas generally set based on resistance to heat transparency through a unit of R-values. U-values or U-factors will typically be given in w/m² per °C.

- **Windows :** In hot climates, the heat from sunlight needs to be removed by cooling. Glass provides buildings with daylight and heat from sun. In cold climates, heat gains can reduce a building's need for active heating. The heat from the sun can also reduce the need for heating in cold climates. The glass can be used to increase the efficiency of buildings.
- **Shading :**Shading, shutters and reflection can greatly reduce sun penetration of windows and other glass areas. Shading is a rather complicated issue which often requires complicated models which simulate three dimensions.
- **Air Filtration :** Air filtering around windows and glass areas creates an indoors draught. The undesired air filtration is a loss of energy as it requires redundant heating or cooling. Air tightness is often treated separately in building codes and can be assessed in a 'blower door test'.

b) HVAC systems :

HVAC systems maintain a building's comfortable indoor climate through Heating, Ventilation and Air Conditioning (Cooling) These systems profoundly influence energy consumption. Without heating, cooling and ventilation systems there would be no energy consumption in the building, since it would be totally dependent on outdoor conditions.

- **Ventilation :** Well-insulated, airtight buildings often require active ventilation to remove used air and introduce fresh air for occupants. Ventilation can also be included in air-conditioners which combine simultaneous heating and cooling.
- **Heating system :** Many possible systems can heat a building. Collective heating can include a combined system based on a heating supply in the building. Buildings can also draw heat from individual systems such as electric heaters, heat pumps or individual ovens.
- **Cooling :**Cooling systems can be centralised or decentralised into small units installed in every room. Air tightness is especially important for building cooling. Some buildings work with natural cooling or with night cooling, both of which reduce the need for active cooling.

- **Air conditioning :** Air conditioning systems generally combine the capacity to ventilate, cool, and heat. In a basic definition, an air conditioning system will supply the building with heated air if outdoor temperatures are cold, with cooled air during hot days and with plain air if the building requires only ventilation. For air condition systems, it is primary the efficiency of the overall system and / or components which are regulated, including the heating, cooling and ventilation components.
- **Dehumidification :** Dehumidification can be integrated into air conditioning systems. Buildings in humid climates should account for the energy involved in humidity control.
- **Hot sanitary water :** Many buildings' occupants require hot sanitary water for hygiene, food preparation, cleaning and commercial purposes. The central heating system can provide this water, as can a separate system using electricity, oil, gas, solar thermal energy, heat pumps or district heating. Efficiency regulations often address hot sanitary water.
- **Ducts and pipes :** Because ducts and pipes determine much of the energy efficiency of heating and cooling system, ducts and pipes should be carefully dimensioned, assembled, insulated and placed in the most efficient manner inside or outside the building shell.
- **Automatic contrôle :** Good and efficient automatics can ensure the optimal use of the HVAC systems can be addressed. Individual systems as heating, cooling, ventilation or lighting systems can have individual automatics.

c) Renewable energy :

Renewable energy can be either passive or active. In passive systems the renewable energy is used to avoid the need for heating or cooling. With a decreasing energy demand in buildings these sources become an important part of the energy performance.

- **Passive solar** : When buildings are highly insulated and energy efficient, passive solar energy can meet a substantial share of the heating demand. Buildings capturing too much heat may require cooling, offsetting the efficiency gains of passive heating.
- **Passive cooling and ventilation :** In passive cooling systems natural cool resources for instance in water or in the ground can be used to reduce the need to cool the buildings. In larger buildings the use of natural ventilation requires a high emphasis in the design phase. This is typically achieved through an intensive design phase where shape of the building is adjusted.

- **Active renewable energy systems :** Renewable energy systems can often be integrated in buildings or in the building shell. Solar water heaters are one of the most commonly used renewable energy supplies in buildings. Other renewable energy sources in building can be small building integrated windmills or systems that use biomass or waste products.

d) Installed equipment :

Installed systems can influence a building's energy performance in two different ways. Some appliances fall under the auspice of building energy efficiency requirements in building codes. Some equipment and electrical appliances have more loose connection to the building.

- **Lighting :** The need for lighting, especially during daytime, will depend on the size and placement of a building's windows, and the building's situation. Indoor lighting systems produce heat that can reduce energy demand for indoor heating in cold climates or during winter.
- **Appliances :** White goods device or televisions and computers will have an interaction with the building in which they are installed. This will influence the need for heating and cooling. In cooled building waste energy from inefficient appliances can lead to double energy loss.

e) Zoning of buildings :

Zoning of a building means that the building is divided up into separate areas with the potential for uniquely-calculated requirements for energy efficiency and indoor climate.

f) Integrated design :

Integrated design is a process where all the elements described are used to reduce the energy consumption in a building. In this process actions are taken to reduce energy consumption as well through insulation or efficiency. Passive use of renewable energy and other natural sources is an integrated part of the design and development process.

Many building energy efficiency regulations started with requirements for the building shell. As the building's envelope improves, regulations focus on the energy efficiency of HVAC systems. Other appliances and Renewable Energy are more rarely included. Most advanced building codes or standards for energy efficiency in buildings today include all of these aspects **[58]** .

2.9. Main Modes of Heat Transfer:

Heat is a source of energy transferred from hot to cold, or from higher to lower. Maximum heat transfer is equivalent to the amount of heat transmitted through all three heat transfer modes: conduction, convection and radiation.

1. **Conduction :**

When two surfaces are in direct contact at different temperatures, heat will flow naturally from the warmer material to the colder, before a equilibrium is achieved. The rate at which this heat transfer takes place depends on the difference in temperature between the two surfaces and on the thermal material Resistance (R-value).**[59]**

2. **Convection :**

Convection is the process of heat transfer inside fluids such as gases and liquids by the bulk movement of molecules. The initial transfer of heat between the object and the fluid takes place by conduction, whereas the transfer of heat from the bulk occurs due to fluid motion. **[60]**

- Convection is the process of transfer of heat by the actual motion of matter in fluids.
- It occurs in liquids and in gases.
- It can be natural or forced .
- It involves a bulk transfer of fluid portions .

There are two types of convection, and they are:

Natural convection: This is known as natural convection when convection occurs due to buoyant force, as there is a difference in densities caused by temperature differences.

Forced convection: This is called forced convection when external sources such as fans and pumps are used to generate induced convection.

3. **Radiation :**

Radiation is electromagnetic waves transmitting heat into a gas or vacuum. Thus heat transfer by this mode requires a line of sight connection between the involved surfaces. All artifacts above absolute zero radiate heat energy; it is the net transfer of radiative radiation, which is the transfer of interest. For heat transfer between solids and within highly porous solids, radiation is mostly important, but radiation between high-temperature gases is occasionally of practical importance. **[61]**

2.10. Definitions of Relevant Technical Terms of Heat Transfer:

2.10.1. Thermal Conductivity :

Thermal conductivity refers to the ability to conduct / transfer heat of a given substance. It is generally denoted by the symbol 'k,' but it can also be denoted by the symbol λ' and 'κ'.The reciprocal of this quantity is known as thermal resistivity. High thermal conductivity materials are used in heat sinks, whereas low-value λ materials are used as thermal insulators. **[62]**

Fourier 's thermal conduction law (also known as the heat conduction law) states that the rate at which heat is transmitted through a material is proportional to the temperature gradient's negative and is also proportional to the heat flow field.

$$\lambda = \frac{\Delta Q}{\Delta t}\frac{1}{A}\frac{x}{\Delta T} \quad \text{........(1)}$$

Where : $\frac{\Delta Q}{\Delta t}$:the rate of heat flow.

λ :is is the thermal conductivity.

A: is the total cross sectional area of conducting surface.

ΔT: is temperature difference.

x : is the thickness of conducting surface separating the 2 temperatures.

Thermal conductivity is influenced by the constituent material, porosity, surrounding temperature, and direction of heat current.

a) The Material Constitution :

The thermal conductivity may be influenced by chemical composition and molecular structure of the material. Simple chemical composition substance with molecular structure has higher thermal conductivity than complex. **[63]**

b) Porosity:

The thermal conductivity of solid matter exceeds that of air. The higher the porosity, then, the lower the thermal conductivity. In this dimension it matters not only the porosity but also the pores' scale, distribution, shape and connectivity.

c) Humidity:

In humid conditions materials have higher thermal conductivity. This should be remembered is that their thermal conductivity would be higher if water is frozen. This is because water thermal conductivity is 20 times higher than air, while ice thermal conductivity is eighty times higher than air. Special attention should therefore be paid to protecting the heat insulating material against humidity.

d) Temperature :

If the temperature rises, the thermal conductivity rises accordingly. As the temperature rises, the molecular solids' thermal motion becomes more active; the air in the pore's heat conduction is boosted, and the pore wall's radiation effect is strengthened.

e) The Direction of Heat Current:

If the material is anisotropic (like the fibrous material wood), there will be no strong resistance when the heat current flows parallel to the fibers; however, strong resistance will be incurred when the heat current flows against the fibers.

2.10.2. Temperature Stability :

Stability of temperature is the material 's capacity to retain its original property when exposed to heat. The ultimate temperature is usually measured, beyond the point at which the material can lose its heat-insulating ability. **[63]**

2.10.3. Strength :

The heat insulating material is usually measured by its resistance to compression and flexural strength. Its strength is weak, because the material is highly porous. Thus it is better not to allow more weight to carry the heat-insulating material. **[63]**

2.10.4. Coefficient of heat transmission (U):

The U value of a building element is the inverse of that element's total thermal resistance. The U-value is a measure of how much heat is lost over a given material's thickness, so it involves the three primary ways heat loss occurs — conduction, convection , and radiation. **[64]**

2.10.5. Thermal resistance (R-value):

The R-value is a measure of the heat flow resistance by a given material thickness. The higher the R-value , the higher the thermal resistance the material has and the better the insulating properties thereof. The R-value is calculated by using the formula :

$$R = \frac{e}{\lambda} = thermal\,resistance \ldots\ldots(2)$$

Where:

e : is the thickness of the material in metres .

λ : is the thermal conductivity in W/mK..

The R-value is measured in metres squared Kelvin per Watt (m2K/W).

2.10.6.Thermal bridge :

If there is a difference between the materials and the structural surfaces, there is a thermal bridge. At the junctions of facings and floors, facings and cross walls, facings and roofs, facings and low floors are found the main thermal bridges in a building. They also occur every time a hole (doors, windows, loggias ...) is in place. Those are thermal structural bridges. Those thermal bridges vary in importance depending on the wall or roof type (insulated or not).

In a building that is not properly insulated, thermal bridges represent low comparative losses (usually below 20%) as total losses are very high (about > 1W / m2 K) through the walls and roof.

However, when the walls and roof are very well insulated, the percentage of loss due to thermal bridges is high (more than 30 %), but the total losses are very low (less than 0.3 W / m2 K). **[65]**

- **Classification of thermal bridges :**

includes three basic types:

- **Repeating thermal bridges :** usually distributed evenly across the building envelope, and following a regular path. These are most likely to occur in isolated cold pitched roofs at ceiling joists, insulated suspended timber floor joists at ground floor joists, timber frame constructions, steel wall ties in masonry walls or mortar joints in inner wall leaves.
- **Non-repeating (linear) thermal bridges** : are most commonly caused by discontinuities in the building envelope and may appear around openings such as windows and door openings, around loft hatches, rooflights, internal walls and junctions of floors.

- **Geometrical ones** : depends on the form of the structure and can appear as two-dimensional or three-dimensional, typically occurring at outside wall corners, and at junctions including window and wall or door and wall junctions, wall and roof junctions, wall and floor junctions, or adjacent wall junctions. **[66]**

2.10.7. Heat loss :

Heat loss is the decrease of heat present in space , resulting from heat transfer through surfaces of walls , roof, windows and houses. We calculate heat loss by multiplying the area values, the difference in interior and exterior surface temperatures and the material's heat loss value. Convectional heat loss is the interest in ventilating hot processes from the heat loss.

The object's overall heat loss often includes losses that arise by radiation, convection , and conduction. There is no substance that eliminates heat loss entirely, we can only mitigate the heat loss. **[67]**

There are four zones in a house, where the heat is mostly lost, and those are:

- The roof
- Outside walls
- Door and windows
- Ground floors

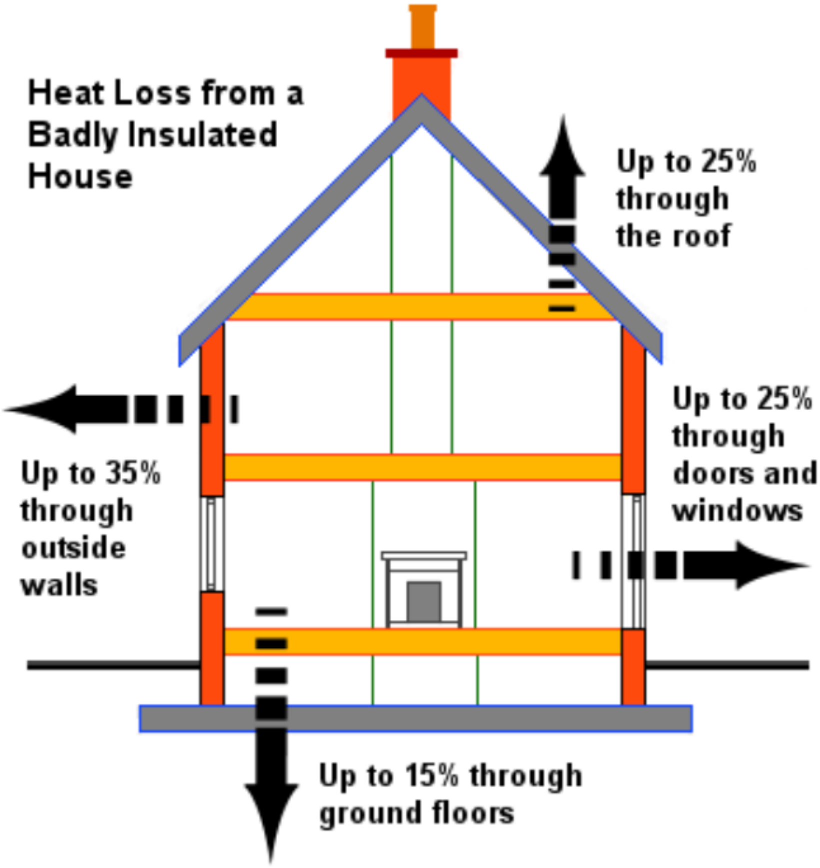


Figure 19 : Heat loss in a house [68]

2.11. Insulation materials :

Insulation is material designed to prevent the transmission of heat or sound from one area to another. This is usually used to retain heat and/or sound inside or outside a house, or to restrict it to certain parts of the body. Insulation can work in a variety of ways, but most commonly it incorporates materials consisting of millions of tiny pockets of air.**[69]**

The main points regarding insulation materials are:

● The option of insulation material shall mainly be regulated by two Factors: Domestic thermal conductivity and location.

● Ecological preference is given to products which are produced from renewable or recycled sources and do not use high energy levels during processing. **[70]**

2.11.1. Thermal insulation to control heat:

Walls and ceilings typically contain thermal insulation, particularly the outside walls of a home where heat is most likely to be gained or lost. The idea behind thermal insulation is very simple; to keep the insulation warmer on one side than on the other. When it is an environment where the weather changes across the seasons, the isolation would need to be combined with the appropriate concepts of passive nature. Whether it is either hot or cold, the insulation with that in mind would be built into the design.

Thermal insulation 's efficacy is calculated by what is known as 'R values.' The higher the R value the better it provides the thermal insulation. R-Values are defined in two ways, one can be considered as the R-Value of the insulation material itself Like the Rm or Entire R value of the building, including all other layers of concrete materials, plasterboard bricks, etc. **[69]**

2.11.2. Acoustic Insulation to control sound:

Sound insulation is the mechanism by which sound / noise propagation is prevented from inside to outside, or vice-versa, or from one room to another.

It has a different function to the absorption of sound. The function of a sound absorption material is to absorb and thereby reduce the sound reflected from a surface, while the function of the construction of sound insulating materials is to reduce the sound through it.

2.11.3. The Sound Absorption :

When the sound waves encounter the surface of the material: part of it reflects; part of it permeates, and the material itself absorbs the remainder. The ratio of absorbed sound energy (E) to incident sound energy (E_0) is called coefficient of sound absorption (α). This ratio is the principal measure used to determine the material's sound-absorbing ability.A formula can be usedto demonstrate this. **[63]**

$$\alpha = \frac{E}{E_0}$$

In this formula:

α is the sound absorption coefficient;

E is the absorbed sound energy (including the permeating part);

E_0 is the incident sound energy.

If 65% of the incident sound is absorbed, and the remaining 35% is reflected, the material's sound absorption coefficient is 0.65. When all sound waves are absorbed, the ratio will be one, and the ratio equals one when the door and window are open. The sound absorption factor of the materials is generally between 0-1. The bigger the numeral, the better the property that absorbs sound. The suspended absorber's sound absorption coefficient may be more than one, as its effective sound-absorbing area is larger than its calculated area. The material 's sound absorption is related not only to its other properties, thickness, and surface conditions (the air layer and thickness), but also to the angle of incident and frequency of the sound waves. The coefficient of sound absorption will change according to the high , medium and low frequencies. Six frequencies (125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz) are set to display changes in the sound absorption coefficient in order to demonstrate the sound-absorbing property of one material in full. If the average ratio of the six frequencies is greater than 0.2, then the material can be marked as sound-absorbing. Such materials can be used for sound insulation of concert hall, theater, auditorium, and broadcast studio walls, floors , and ceilings. The indoor transmittance of sound waves can be improved to generate better sound effects by using the sound absorbing material appropriately.**[63]**

2.11.4. Classification of building insulation materials :

Given the fact that all insulation materials serve the same function to reduce the rate of heat release / gain through the desired enclosed space some different materials serve a specific role, hence they are classified accordingly. These categories classify the isolating materials into: function, form and composition.**[71]**

a) According to heat exchange properties :

insulations can be classified into two main classes: mass insulation and reflective insulation, described by:

- **Mass insulation :**

Objects with high thermal mass absorb and hold heat, increasing the rate at which the sun heats a space and the rate at which space when the sun is gone loses heat. Without thermal mass, heat entering a space would simply re-radiate rapidly back out, rendering the room unnecessarily hot with sunlight and excessively cold without. Mass insulations are those which, by conduction, can delay the heat flow. Insulation may be highly useful in preventing direct heat gain from moving to the ground or outside air, where it is lost. In a hot environment where direct heat gain is not desirable, low thermal mass and low conductivity can also be useful for exterior finishing to improve the effectiveness of insulation. Regarded as the most commonly used type of thermal insulation, mass insulation reduces heat flow rate by conduction in cases where there is virtually no heat transfer convection and radiation. Because of this, the effectiveness of mass insulations depends heavily on the thickness of the insulating material. Increasing the thickness raises the thermal performance of the mass insulation proportionally, and these materials usually have low heat conduction rates. In addition , the thermal performance of thermal insulation material depends also on the condition of material subdivision or density.

Mass isolation usually contains a huge number of tiny air trapped pockets, reducing the conductive transfer of heat. Those tiny pockets of trapped air act as heat flow barriers. Any effort to condense or compress the mass insulation would therefore reduce its efficacy.**[71]**

- **Reflective insulations :**

Reflective insulations are thermal insulation that reflects radiation heat, preventing a reflective (or low emitting) surface from one side to another. Around the same time, this reduces the amount of heat transfer or solar heat gain affecting the building and increases indoor temperatures and air quality. The amount of energy radiated depends on the temperature of the surface and a property called emissivity; the higher the emissivity, the higher the emission in this wavelength, radiation. Reflective insulation uses one or more of these Low-emitance reflective surfaces encompassing air spaces that are commonly used in home attics, roofing and wall systems. The reflective insulation requires, through this case , at least one reflective surface facing an airspace. Several publications studied the reflective insulation impacts on the thermal efficiency in detail.**[71]**

b) According to form :

The four loose-fillers are spray rubber, batts, covers and rigid plate basic Isolation Forms. There are plenty of variables to consider rehabilitation when choosing the material, such as type of construction design and specifications for the application. Many authors have identified material performance characteristics of building insulation by their shape.**[71]**

c) According to composition :

In general, the composition of the insulation material shows the characteristics of the insulation that are directly related to its chemical and physical structure. Papadopoulos has categorized insulation materials based on their structure, which are primarily organic , inorganic, combined, and new technology materials.

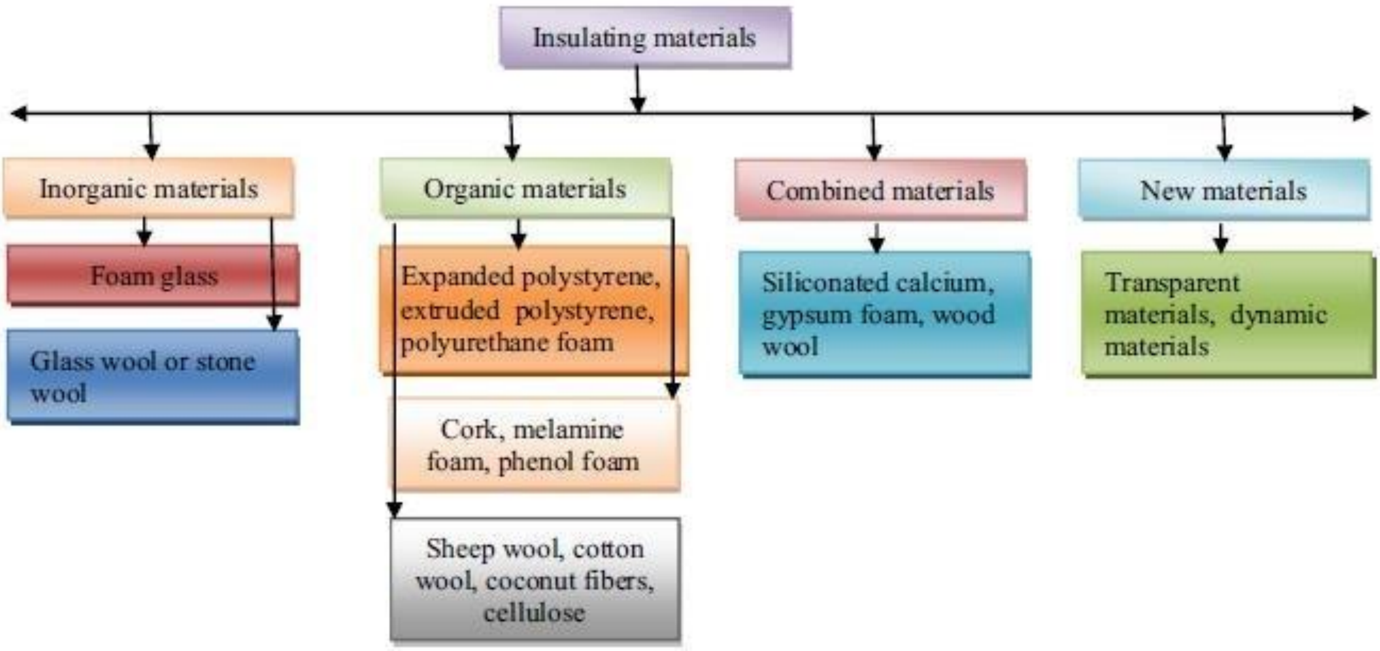


Figure 20 : Classification of the commonly used insulating materials [71]

i. Inorganic and organic materials :

Inorganic insulation materials are made from non-renewable materials but from plentiful available resources. Some example of inorganic insulation materials are mineral wool, perlite, aerated concrete blocks and foamy glass. On the other side, organic insulation materials are derived from natural plants and from renewable resources, such as wood fiber, cellulose, extended rubber, wood fibre, sheep fur, etc. Because of their versatility, there is growing interest in organic insulation materials; they are renewable, recyclable, non-toxic, environmentally sustainable and require very low-resource techniques in production. The energy needed to manufacture organic insulation materials is lower than that required by traditional insulation materials. However, inorganic insulation materials typically provide the same thermal efficiency with higher thermal insulation properties and lower costs. They also show greater tolerance to fire and moisture.[71]

i.i. Examples of organic insulation materials :

a) Expanded polystyrene (EPS) :

Expanded polystyrene (EPS) is a rigid, cellular polystyrene type with excellent thermal insulation and shock absorption properties , high compressive strength, very low weight and moisture resistance. Such EPS properties offer many advantages, in particular to the building and packaging industries.

Building and construction applications are the main outlet for EPS with about two-thirds of demand. Huge amounts are used to render insulation foam for walls, roofs and floor insulation closed to the cavity. EPS foam is also used in road construction, bridge construction, drainage, flotation, and sound insulation.**[72]**

EPS has very low thermal conductivity due to its closed cell structure consisting of 98% air. This air trapped within the cells is a very poor heat conductor and thus offers excellent thermal insulation properties for the foam. At 10 °C, the thermal conductivity of expanded density 20 kg/m3 polystyrene foam is 0.035 – 0.037 W/(m•K). **[73]**

Figure 21:Expanded polystyrene [74]

b) Extruded polystyrene :

Extruded Polystyrene Isolation (XPS) is a high-performance, rigid, closed-cell insulation. XPS products are produced in patented processes that melt plastic resin and additives into a molten material that is extruded into a die through which it expands and cools into a uniform, closed cell rigid board with no vacuum or moisture pathways to join. his makes XPS insulation highly resistant to moisture. The XPS insulation is manufactured in a variety of square and tapered board sizes. Tapered edge units are designed for use in roofing applications, where slope for positive drainage is generated with insulation. It works very well in the ballasted single-ply roof assembly, where a roof membrane is placed above the isolation and ballasted with rock or other material.

XPS has a broad variety of uses-heat insulation of buildings, foundations, socles, facades, walls , floors, used in road and railway construction. This contributes to decreased ground expansion and contraction resulting from change in ground temperature. It is used as thermal insulation on playing fields, cooling, ice arenas. **[75]**

XPS has very low thermal conductivity, poor absorption of water and low specific gravity. The service life of this type of quality manufacturers insulation approaches 40-50 years and is equivalent to that of the entire building. **[76]**

Figure 22 : Extruded polystyrene cnerib /Algiers

c) Polyurethane :

Polyurethane is formed by combining an isocyanate with a polyol mixture, such as methylene diphenyl diisocyanate (MDI). These components are mixed together to form a rigid matrix of cellular foam. The resulting material is an extremely lightweight polymer with outstanding insulating properties.

Polyurethane insulation has the highest thermal resistance (R-values) at a given thickness and lower thermal conductivity compared with other building materials.

Using polyurethane insulation products in residential and commercial buildings helps meet dvanced energy codes, contributes to green building certifications and provides the building occupants with comfort. **[77]**

Figure 23: Polyurethane [78]

d) Cork :

Expanded cork insulation sheets are natural, balanced and unbeatable cork products which do not contain polyurethane or any other fillers or additives with this special type of agglomerated cork. Due to the processing treatment with high temperatures it expands (similar to popcorn) and suberin released during is a natural adhesive that binds the expanding grains.

The low thermal conductivity (λ=0.037 – 0.040 W/m.K) of cork board offers high energy efficiency. Therefore contributing to saving the environment and the economy.**[79]**

Figure 24 : Cork [80]

The use of 100 % natural cork panels on a building ensures optimum thermal and acoustic insulation while protecting the atmosphere as well.

e) Phenolic foam :

Phenolic insulation is manufactured by a process in which a plastic foam forms an isolating center between two layers faced by flexible tissue. It has a high content in closed cells and a fine structure in cells.

Rigid phenolic insulation is created by combining a surface acting agent with high solids and phenolic resin. The heat produced by the reaction in the mixture evaporates a volatile liquid blowing agent that creates a network of small bubbles in the material. The foam can be healed to produce one of two product types. The development of thin sheet material, which is laminated with different facings and cut into boards, can be created by a continuous process.

Owing to the very low thermal conductivity of phenolic foam as opposed to rigid polyurethane or extruded polystyrene, rigid phenolic insulation products give very good thermal insulating properties. The phenolic closed cell insulation material's thermal conductivity is usually between 0.018 W / m. K and 0.023 W / m. K. In reality it can be 50% more efficient than other common insulation materials. Its low thermal conductivity permits the achievement of specified thermal efficiency goals with limited insulation thickness. This is especially significant where saving space is necessary. **[81]**

Figure 25 : Phenolic foam [82]

f) Coconut fibers :

Coconut fiber has a thermal conductivity, k, varying from 0.054 to 0.134 W / mK and an average density of 386 kg / m3. There are two coconut fiber types: brown fiber extracted from mature coconuts and white fiber extracted from immature coconut. Furthermore, coconut fibers are available commercially in three types, such as bristle (long fibers), mattress (relatively short) and decorated (mixed fibers). Insulation made from natural coconut fibers is permeable and is moisturizing. Coconut fibers have a high lignin content and therefore a low cellulose content which makes them robust, sturdy and very durable. The material offers great damping acoustics and has a leveling effect. The regulation of humidity is primarily intended for use in the effect of insulation inside. It is 4-5 mm thick, 8-9 mm,11-12 mm, 15-16mm.**[83]**

Figure 26 : Coconut fibers [84]

i.ii. Examples of inorganic insulation materials :

a) Foam glass :

Foam glass takes as its raw material the cullet and one or two types of adjuvant (foaming agent, calcium carbide, or coke). The raw material is roasted at a temperature of 800 ° C after the grinding, blending, and fitting die until a lot of closed and disconnected pores are created. The porosity of the foam glass reaches ~ 90 per cent high, and the diameter of each pore is 0.1 ~ 5 mm. The foam glass has low thermal conductivity properties , high compression strength , high frost resistance and improved durability. This material can be used for wall building, heat control in refrigeration equipment, or as floating and filtering material. It is an advanced, simple to cut and cement material to insulate liquid.**[63]**

Figure 27 : foam glass [85]

b) Glass wool :

Glass wool is a kind of fibrous material made from the melted glass raw materials or cullet. It consists of two types of wool: loose, and superfine. The loose wool fiber is 50-150 mm in length, and diameter I2~lO-~mm. The superfine wool fiber, by comparison, is much thinner in diameter, usually less than 4~lO-~mm. And superfine glass wool is also named.

The loose wool can be used to render glass blanket and glass wool board bonded with asphalt. The superfine glass wool can be used to make common superfine glass blanket, glass wool board, alkali-free superfine glass blanket, hyperoxic silica superfine glass blanket, and is also used to preserve heat in the exterior and pipeline construction. **[63]**

Figure 28 : Glass wool [86]

c) Stone wool :

Stone wool, also known as rock wool, is based on natural minerals found in the earth in large amounts, e.g., volcanic rock, usually basalt or dolomite. Besides the raw materials, recycled rock wool as well as slag residues from the metal industry may also be applied to the process.

It combines mechanical resistance with good thermal efficiency, fire protection and suitability to high temperatures. Glass and stone wool are produced from mineral fibers and is sometimes referred to as 'mineral wools.' Mineral wool is a general name for fiber materials produced by spinning or drawing minerals of molten content. Stone wool is a molten rock furnace product at a temperature of about 1600 ° C, from which an air or steam stream is blown through. Stone wool uses include pipe insulation, filtration, soundproofing, and hydroponic growth medium for structural insulation. Stone wool is a versatile material which can be used for wall, roof and floor insulation. It should be kept dry at all times during the installation of the stone wool, since an increase in the humidity content causes a significant increase in thermal conductivity. **[87]**

Figure 29 :Stone wool [88]

ii. Combined and new technology materials :

A possible approach to improving thermal performance and energy efficiency at optimized cost is the combination of insulation materials. Besides that, new technical materials for the application of the thermal insulation device were discovered**.** Today, transparent insulation materials are used to replace traditional opaque insulation materials due to their thermal insulation and solar collection advantages. In addition, the implementation of dynamic insulation using the ventilation system was implemented to enhance the efficiency of the insulation. For their insulation properties (bulk density, thermal conductivity, embodied energy and thermal attribute), and their resistivity to biological hazard (insects, rodents, etc.), several researchers have researched various possible insulation materials. The raw resources are based on additional minor classification of insulation materials. The petrochemical substances originate from conventional insulation material. They contain fiberglass, mineral wool, polystyrene, polyurethane foam, and multi-foils. These materials are useful since, with easy installation, the raw substances could be separated into several different variants. However, Unconventional insulation materials pose a threat to the environment that conventional insulation materials may cause. Unconventional insulation materials are renewable; they minimize fossil energy usage and the question of disposal.

In addition, a strong, properly engineered insulation material is necessary for efficient energy conservation in buildings. During the selection of materials there are important factors to consider, such as cost, durability, environment factor, availability, heat transfer mode, ease of installation and orientation of the building. Combined and new technology materials can be one of a good insulating material for thermal buildings as long as it has been properly engineered and all relevant factors are considered. The following materials are the mixed and new technology material type, including mineral fiber, cellulose, expanded polystyrene (EPS), cork, polyurethane (PUR), extruded polystyrene (XPS) and other construction materials such as wood, stainless steel, carbon steel , concrete, stone and glass. **[71]**

ii.i. Examples of combined materials :

a) Gypsum foam :

Gypsum foam is made of natural lime that is foamed with a solvent and converted into foam boards. These gypsum foam boards offer exceptional stability and optimum sound absorption, thanks to the open-cell pore structure.

Gypsum foam has excellent levels of absorption, even at low thickness. The material converts incident sound waves into thermal energy, so they are absorbed before the sound can spread in the room. In addition, during the production of the panels, the absorption coefficient may be adjusted to achieve the ideal room acoustics for individual needs. **[89]**

b) Wood wool :

Wood wool insulation is an environmentally friendly form of insulating. The content originates from sustainably managed forests and is entirely recyclable according to the concept of 'cradle to cradle' Wood wool has a high potential for heat preservation, it is permeable to vapour, and also has excellent sound insulating properties.

The thin wood fibers are blended together with a natural binding agent and other additives (such as a water-repellant). Someone then compresses the wood pulp into a wood wool sheet, which is then dehydrated in an oven. Depending on the type of wood fiber board, the thickness and the necessary demands placed on the material, the manufacturing process varies.**[90]** Wood wool has the benefits of:

- Good capacity to control heat, vapour-permeable.

- Safe material with padding, cradle to cradle .

- Facile to assimilate (can be used by rafters) .

- Good value for insulation (0.038-0.045 W / mK) .

- High ability to store heat (not that warm inside in summer) .

- Sound insulating qualities .

ii.ii. Examples of new technology materials :

a) Transparent materials :

Transparent insulation materials (usually abbreviated to TIMs) are a product class that uses different materials to increase solar heat gain while at the same time reducing conductive and radiation heat loss. The technology has similarities with the passive solar thermal mass wall designs, except for the gap between the glazed outer skin and the surface of the wall facing it, which contains insulation that is transparent rather than just air. The insulation allows the incoming solar radiation to be transmitted but acts as a barrier to the conductive and radiative heat loss, retaining the absorbed heat very effectively. Aerogels are a type of translucent insulating material that is inside a glazing sandwich. **[70]**

❖ **Aerogels :**

Aerogels are mostly air materials – usually around 99% by volume – that can be manufactured from silica, metals even rubber. They are exceedingly light.

Aerogels are excellent insulators, having the thermal conductivity of glass at around one hundredth. Double glazing replacing the gap with an aerogel would improve the insulation value by a factor of three compared to multiple glazing with the best current. A 99 per cent vacuum between the panes could be achieved, as they are backed by a solid. However, the window would still have a slightly frosted appearance even with a thin aerogel sandwich.

The aerogels' thermal properties also make them ideal for solar heat harvests. Flat platform solar panels collect heat and then radiate it back into space. To re-radiate heat from the absorbing surface, an aerogel glass sandwich will have a one way barrier. This will naturally refer to active solar panels and even to solar walls. To improve absorption, the entire surface of the wall will be coated in black. The heat would be held against a glass aerogel shield and radiated into the building's interior. **[70]**

b) Dynamic materials :

Insulation dynamically occurs when ventilation air is inserted through the fabric of a building. It is one of a number of building fabric innovations applied by architects seeking to lower the capital and running costs associated with mechanical systems, without loss of comfort. There is also potential for indoor health benefits by improved moisture control and the prevention of problems due to the lack of sufficient supply side ductwork maintenance. Heat, normally lost in conduction, is recovered through the insulation by air drawn into the house. The insulation serves as an exchanger of heat against wind. There are many examples of its use in high humidity buildings and a constantly high ventilation rate. These were usually farm steadings but the concept was incorporated gradually into homes, classrooms, workplaces, and sport shalls.

Dynamic insulation is based on a controlled constant flow of air through a membrane due to a difference in the pressure across it. The differential pressure, may be induced by natural or mechanical means. Air is typically exhausted through a vertical flue assisted by the fan, although there are examples of the differential pressure being achieved by exploiting and enhancing the stack effect. If air flows in the opposite direction to the conduction, it is referred to as the separation of the contra-flux and pro-flux in the same direction. If the material's pores are fine then the air transfer is directly proportional to the difference in the effective pressure. In the case of the contra-flux heat exchange results between the introduction of cold air into the structure and the loss of heat from the conduction. The existence of a non-linear temperature gradient through the wall was used to provide evidence that bulk air flow exists. **[91]**

2.12. Application of building insulation :

Generally speaking, it is a strategic approach to isolate a building from major components, including walls, doors and windows, where heat transfer is predominant. Thermal insulation helps to preserve energy efficiency, depending on the gradient of air temperature (the difference between inside and outside the building), geographical location, climatic condition and type of heating space.

2.12.1. Insulation on wall

Conservatively woods or bricks build walls, so they have a desirably lower heat conductivity than glass and metal from a thermal perspective. Nevertheless, because walls occupy a building 's largest account, the use of thermal insulation has a direct effect on the total building heat gain / loss. Placing insulation material can affect the performance of insulation materials on the transient heat flow of a building's wall. The insulating material should be installed near the location of the heat inflow or outflow, in order to achieve best performance. For practicality, however, the insulation is usually installed inside or between the cavities of the wall. **[63]**

2.12.2. Insulation on roof and ceiling

Throughout the day, a direct ray of sunlight allows the roof to receive substantial amount of radiative heat from the sun. Roofs can account for up to 32 per cent of the horizontal surface of built-up areas and significantly contribute to heat gain in buildings. Reflective insulation is usually used as a radiant barrier on the roof; this form of insulation will have ample air gaps to minimize heat transfer effectively by conduction and convection. Unlike thermal mass insulation that is shielded by absorption, reflective insulation reflects back to the source of the thermal radiation. They 're much more operative in hot climates than cold climates in this application. Insulation in cold weather is usually limited to the roof. Snow melt patterns on the rooftop are a good energy efficiency measure for buildings. It is a sign that heat is being wasted through the attic. **[63]**

2.12.3. Insulation on windows

The second critical heat sources are in a well-insulated house walls. They are typically transparent due to the design of the windows, which ensures that the light will pass through them and bring the heat within the conditioned space; they are heavily influenced by solar radiation and the airflow around them. Through the windows heat loss / gain can be managed by bulk insulation and glazing minimization. Numbers of relatively new insulation technologies are being developed and implemented on screens, but two of the most common technologies are gas filling and low-emitting (low-E) coating. Low-E coatings are layers of metal or metallic oxide that are nearly transparent and applied on the window glass surface to prevent reflective radiative heat flow. Meanwhile gas filling occupies the spaces between window panels for insulation purposes, with lower thermal conductivity than air. Argon is the most common inert gas used for isolated gas filling glass. **[63]**

2.12.4. Insulation on floor

Floors like those over unheated crawl spaces and concrete slabs are also recommended for adequate insulation. The insulation is applied around the perimeter of the footings slab. Nevertheless, as the heat transfer to the ground at the lower depth of the basement floors is comparatively poor, the insulation for concrete slabs of the basement floors is known to have minimal value. The effect of this low heat transfer is relatively small temperature difference between the ground below the floor and the air above the surface. Building insulation is achieved with the use of a range of building insulation materials followed by their thermal conductivity. **[63]**

2.13. Characterization of insulation materials :

2.13.1. Thermal characterization :

The key parameters describing the thermal efficiency of an insulation material are the thermal conductivity for the stable condition and the thermal diffusivity D for the liquid state. Thermal conductivity is the heat flow that, due to a temperature gradient equal to 1 K, passes through a unit area of a homogenous substance 1 m thick; it is expressed in W / mK. The unpredictable or complex conditions need to be taken into account where the heat flow rate or temperature changes on one or both of the component 's boundaries. Thermal diffusivity is the ratio of thermal conductivity, i.e. the ability to conduct thermal energy, and the density component and real heat power Cp, which reflects the material's ability to store thermal energy: thus thermal diffusivity describes the movement of thermal waves within the media. It is expressed in m2 / s, which is a quantity extracted composed of the material's intrinsic properties. The above quantities may be calculated or analyzed using a variety of methods;Table 11 provides a list of universal measurements that are commonly common.**[92]**

Table 11 : List of methods for the evaluation of thermal conductivity, transmittance and diffusivity [92]

Parameter	**S.I. unit of Measurement**	**Evaluation method**	**Note**
Thermal conductivity □	W/mK	EN 12664	Low thermal resistance
		EN 12667	High thermal resistance
		EN 12939	Thick materials
		ASTM C518	Heat flow meter apparatus
		ASTM C177	Guarded hot plate apparatus
		ISO 8990	Hot box method
Density	kg/m^3	EN 1602	-
		ASTM C303	-
Specific heat capacity	J/kgK	ISO 11357	-
		ASTM E1269	-
Thermal diffusivity	m^2/s	ISO 22007-1	General Principles
		ISO 22007-2	Transient plane heat source (hot disc) method
		ISO 22007-3	Temperature wave analysis method
		ISO 22007-4	Laser flash method

In the case of a multi-layer wall, thermal properties are expressed by thermal transmittance or U-value, which is the heat flow that passes through the unit area of a complex part or inhomogeneous material due to a temperature gradient equal to 1 K; expressed in W / m2 K. The inverse of thermal transmittance is the thermal resistance, or R-value. Thermal transmittance considers also the thickness of an insulator and the heat transfer due to convection and radiation.

Using the procedures described in ISO 13786 , a more detailed thermal characterization of building components for unstable state conditions can be carried out. The standard defines the calculation method for evaluating a component's heat transfer matrix, which describes its thermal behavior when temperature and heat flow density vary with a sine function of the time. The heat transfer matrix correlates the variation of a quantity in one side of the component (m) with the consequent variation in the other side (n) and it depends on thermal conductivity, density, heat specific capacity, thickness and period of the oscillation. **[92]** For a multi-layer wall, the following parameters are used to define thermal insulation in unsteady conditions:

- Periodic thermal transmittance Ymn (W/m2 K): Considering that the component studied distinguishes zones m and n, it is the association between the magnitude of the difference in the intensity of the heat flow rate through the surface of the system adjacent to zone m with the magnitude of temperature variation in zone n; the temperature varies as a sinusoidal function in zone n and is kept constant in zone m**.**

- Decrement factor f (dimensionless): it is the ratio of the intermittent thermal transmittance element to the steady-state thermal transmittance U and describes the reduction of the heat flow through the wall due to thermal inertia with regard to stable state behaviour.

- Time shift Δt (h): the time interval taken by the heat wave to travel through the wall being analyzed is the time difference between the maximum values of the heat flow measured on the m side and the maximum values measured on the n side of the wall being analyzed.

2.13.2. Acoustic characterization:

Built materials can be described from an acoustic standpoint in terms of their ability to complement sound propagation and to withstand impinging sound waves. In the first case sound insulation properties are called airborne and structural (impact). Sound absorption, on the other hand, defines the part of the acoustic energy dissipated inside a material because of friction or thermal loss (porous materials) or of resonance phenomena (perforated and membrane absorbers). Although porous sound absorbers are generally good thermal insulators, the vice versa is not always true: sound absorbers need air moving inside the material, so open porosity is essential; on the contrary, closed porosity is usually advantageous to thermal insulators due to the existence of still air inside the cavities. As far as airborne sound insulation, this characteristic is strongly dependent on the mass of the materials: lightweight materials are commonly poor sound insulators. A large structure's sound insulation primarily relies on the efficiency of the heavy elements, such as masonry or concrete. In the case of a double wall, the inclusion of a sound absorption material in the space causes cavity resonances to be reduced and, thus, the sound isolation of the wall to be improved.Sound absorbers are used to reduce the reverberation time of rooms, with a beneficial effect on acoustic comfort and on speech comprehension. Optimum reverberation time values are determined by the tasks to be done within the room and by the frequency thereof.

When it comes to sound insulation of buildings, it is important to include impact sound insulation, i.e. the ability to distinguish the propagation of impact sounds (footsteps, dropping objects, etc.) across the floor structure. In this case the solutions to achieve good performance are the following: (i) install a false ceiling in the disturbed lower room, (ii) lay a resilient layer on the pavement of the disturbing upper room, such as vinyl or carpet, or (iii) create a floating floor in the upper room, i.e. a floor separated by the structural slab by means of a resilient layer. The latter solution is by far the best one. The most critical parameter to consider when choosing an appropriate resilient layer is dynamic rigidity s, which can range from 4 (best value) to 50 MN / m3Unlike thermal properties expressed as single numbers, in an examined frequency spectrum, acoustic efficiency is generally recorded as spectra, primarily in octave or third octave bands. This is because the sound absorption as well as the sound insulation rely on frequency. Single number indices, such as Rw and STC (Sound Transmission Class) for sound insulation or SAA (Sound absorption average) for sound absorption, can be used to compare various materials, but can be inaccurate as they do not provide any spectral details regarding their actual efficiency.Acoustic insulation can be assessed for airborne and impact sound for real-sized or small samples; in the first case measurements can be performed in laboratory or in situ. With respect to impact sound insulation, the effects of dynamic stiffness tests conducted on small samples (0.04 m 2) can be used to approximate the sound insulation efficiency of a floating surface. 8Sound substance absorption is detectable in a variety of ways; most commonly it is measured in diffuse sound field inside a reverberation room or in an impedance tube in a plane wave field.**[92]**

Table 12 : List of methods for the assessment of sound insulation [92]

Parameter	Unit of Measurement	Evaluation method	Note
Weighted sound reduction index R_w	dB	ISO 717-1	Single number, reverberation room measurements, real sized sample
Apparent Weighted sound reduction index R'_w	dB	ISO 717-1	Single number, in situ measurements, real sized sample
Sound reduction index R	dB	ISO 10140	Reverberation room, real sized sample
		EN 12354-1	Estimation
Apparent sound reduction index R'	dB	ISO 16283-1	In situ measurements, real sized sample
Transmission Loss TL	dB	Not standardized	Impedance tube, small samples
Weighted improvement of impact sound insulation ΔL_W	dB	ISO 717-2	Single number, reverberation room measurements, real sized sample
		EN 12354-2	Estimation
Improvement of impact sound insulation ΔL	dB	ISO 10140	Reverberation room, real sized sample

Weighted normalized impact sound pressure level $L_{n,w}$	dB	ISO 717-2	Single number, reverberation room measurements, real sized sample
Normalized impact sound pressure level L_n	dB	ISO 10140	Reverberation room, real sized sample
		EN 12354-2	Estimation
Weighted apparent normalized impact sound pressure level	dB	ISO 717-2	Single number, in situ measurements, real sized sample
L'n,w			
Apparent normalized impact sound pressure level L'_n	dB	ISO 16283-2	In situ, real sized sample
Dynamic stiffness	MN/m^3	ISO 9052-1	Laboratory, small samples

2.13.3. Environmental characterization: Life Cycle Assessment:

Life Cycle Assessment (LCA) is a well-defined methodology to assess the environmental impact of services or products. The procedures to perform this evaluation are specified in the ISO standards 14040 and 14044 . LCA allows to measure the environmental burden through several indicators; the most used ones are the Cumulative Energy Demand (CED) and the Global Warming Potential (IPPC GWP 2007). CED is Main resources expended during the measured product's life cycle, directly and indirectly. IPPC GWP 2007 is used to measure the effect of a product's life cycle on global warming; it takes into account all the carbon emissions that are measured as equal kilograms of CO2. The predictor will express itself in three horizons in time: 20, 50 and 100 years. Another tool used in LCA studies is the Eco-indicator: it helps to measure the harm to environmental quality , human health and services sustained over a product's life cycle. The LCA of a product / system is normally conducted using one of the following two approaches:

- Cradle to grave: evaluation performed taking into account the entire life cycle of the product/service, from the extraction of the raw materials to the disposal of the product;

- Cradle to gate: the analysis does not consider the life of the product/service after the transportation to consumers, i.e. the use phase and the disposal.

All environmental impacts are normalized to a functional unit, f.u., which is defined in building thermal applications according to the Council of European Producers of Construction Materials as the mass in kg of material required to have a thermal resistance value equal to 1 m2 K/W for a 1 m2 panel. For this cause CED and IPCC GWP 2007 in terms of MJ / f.u are ,eq/f.u., presented .**[92]**

2.13.4. Reaction to fire :

The actions of fire-borne insulation materials can be responsible for significant safety concerns. Several reports have found that poisonous gases are the most significant causes of fire death ; therefore, both the combustion temperature and the smoke output should be addressed while choosing a construction material. The European standard EN 13501-1 defines a rating system based on the parameters listed in Table 13. Table 14 specifies the conditions required for belonging to each class for building materials (floorings, electrical cables and pipe insulations excluded). The additional classification defines smoke development and dropping while burning. The quantity of smoke produced rises from s1 to s3, while the quantity of droplets rises from d1 to d3.**[92]**

Table 13: Parameters involved in reaction to fire classification [92]

Code	**Brief description**
DT	Temperature increase
Dm	Mass loss
Tf	Time of sustained flaming of the Specimen
PCS	Gross calorific potential
FIGRA	Fire grown rate index
THR_{600s}	Total heat release
LFS	Lateral flame spread
SMOGRA	Smoke Growth Rate index
Fs	Flame spread
TSP_{600S}	Total smoke production

Table 14: Reaction to fire classification [92]

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 (1); And	DT ≤ 30 °C; and Dm ≤50 %; and t_f = 0 (i.e. no sustained flaming)	-
	EN ISO 1716	PCS ≤ 2.0 $MJ.kg^{-1}$ (1) and PCS ≤ 2.0 $MJ.kg^{-1}$ (2) (2a) and PCS ≤ 1.4 $MJ.m^{-2}$ (3) and PCS ≤ 2.0 $MJ.kg^{-1}$ (4)	-
A2	EN ISO 1182 (1) Or	DT ≤ 50°C; and Dm ≤ 50%; and t_f ≤ 20s	-
	EN ISO 1716 And	PCS ≤ 3.0 $MJ.kg^{-1}$ (1) and PCS ≤ 4.0 $MJ.m^{-2}$ (2) and PCS ≤ 4,0 $MJ.m^{-2}$ (3) and PCS ≤3.0 $MJ.kg^{-1}$ (4)	-
	EN 13823 (SBI)	FIGRA ≤120 $W.s^{-1}$; and LFS < edge of specimen and THR_{600s} ≤ 7.5 MJ	Smoke production (5), and flaming droplets/ particles (6)
B	EN 13823 (SBI) And	FIGRA ≤ 120 $W.s^{-1}$; and LFS < edge of specimen; and THR_{600s} ≤ 7.5 MJ	Smoke production (5), and flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	Fs ≤ 150 mm within 60s	
C	EN 13823 (SBI) And	FIGRA ≤ 250 $W.s^{-1}$; and LFS < edge of specimen; and THR_{600s} ≤15 MJ	Smoke production (5), and flaming droplets/ particles (6)

D	EN 13823 (SBI) And	FIGRA $\leq$ 750 $W.s^{-1}$	Smoke production (5), and flaming droplets/ particles (6)
	EN ISO 11925-2(8): Exposure = 30s	Fs $\leq$ 150 mm within 60s	
E	EN ISO 11925-2(8): Exposure = 15s	Fs $\leq$ 150 mm within 20s	Flaming droplets/ particles (7)
F	No performance determined		

(1) For homogeneous products and substantial components of non-homogeneous products.

(2) For any external non-substantial component of non-homogeneous products.

(2a) Alternatively, any external non-substantial component having a PCS $\leq$2.0 $MJ.m^{-2}$, provided that the product satisfies the following criteria of EN 13823(SBI): FIGRA $\leq$ 20 $W.s^{-1}$, LFS < edge of specimen, $THR_{600s} \leq 4.0$ MJ, s1 and d0.

(3) For any internal non-substantial component of non-homogeneous products.

(4) For the product as a whole.

(5) s1 = SMOGRA $\leq 30 m^2.s^{-2}$ and $TSP_{600s} \leq 50 m^2$; s2 = SMOGRA $\leq 180 m^2.s^{-2}$ and $TSP_{600s} \leq 200 m^2$; s3 = not s1 or s2.

(6) d0 = No flaming droplets/ particles in EN13823 (SBI) within 600s; d1 = No flaming droplets/ particles persisting longer than 10s in EN13823 (SBI) within 600s; d2 = not d0 or d1; Ignition of the paper in EN ISO 11925-2 results in a d2 classification.

(7) Pass = no ignition of the paper (no classification); Fail = ignition of the paper (d2 classification).

(8) Under conditions of surface flame attack and, if appropriate to end–use application of product, edge

flame attack.

2.13.5. Water vapor resistance factor (µ-value) :

Water vapor resistance metric is a dimensionless parameter used to measure the vapor permeability of building materials when opposed to the unit value applied to air; the higher the µ-value the lower the permeability is. The corresponding air layer thickness sd is also used, in addition to the water vapor resistance: it represents the equivalent thickness of air characterized by the same resistance to water vapor diffusion of the analyzed material. It is calculated by multiplying the µ-value with material thickness reported in meters. A material is considered as a vapor barrier if sd $\geq$ 1000-1500 m and as a vapor retarder if sd $\geq$ 10 m. The µ-value for insulation materials can be determined by means of EN 12086 and EN 12088 , which define the procedures to quantify the amount of water absorbed by diffusion in a long term.**[92]**

2.14. Thermal balance :

The measurement of a thermal balance makes it possible to know accurately the amount of energy it would take to heat and cool a local, the accuracy of this measurement is important not only for the installation cost, but also for its operation.**[93]**

The elements taken into account in this calculation are various, the form, exposure, wall surface, glazed walls , ceilings, soils, these elements must be understood, multiplied by variable coefficients according to altitude, solair radiation , the regional localisation.

Other factors must be taken into account, such as the renewal of natural or mechanical air, the various thermal bridges and the contributions that will weight the measure, such as illumination, human occupation, household appliances, etc.

Here, we will concentrate on two simpler methods of calculation that allow us to analyze our waste.

2.14.1. Method of calculation per coefficient G:

The G is the building's voluminous waste coefficient, it is expressed in Watt per cubic meter and per degree. This coefficient is currently replaced by the Ubat coefficient, but the measurement by the G coefficient still remains practical to use, but relative reliability. **[93]**

Balance Sheet = G x V x Δ T………(3)

- G: global deperdition coefficient (W / m3. ° C)
- 0.65 W/ ° C m3 insulation standard RT 2005

- 0.75 W/ ° C m3 insulation standard RT 2000
- Construction of 0,9 W/ ° C m3 after 1980

- 1.2 W/ ° C m3 constructions reasonably isolated
- 1.8 W/ ° C m3 constructions not isolated
- V: volume of the building(m3)
- T: the temperature difference between the interior (19 or 20 °) and the exterior (base winter temperature of the place of residence).

2.14.2. Method of measurement of the energy balance by the Ubat coefficient:

This more complete method of measurement is promoted by the Climate Engineering Centre for Research and Training. **[93]**

Deperditions = Dp x (19 – T ext base)…………(4)

The value of Dp, which is the building wastage coefficient (W / K), should first be determined.

Dp = Ubat x Sdép + R x Vh + Sdép …………(5)

Ubat: reflects the average total thermal loss of a building(all parois)(W / m2.K) For optimum precision, this coefficient is determined for each wall, wall, house, etc.

2.14.3. The empiric meaning of Ubat:

0.3: house with excellent insulation.

0.4: excellent insulation without thermal bridges.

0.75: for traditional insulation houses 'RT2005' and constructed between 2007 and 2012

0.8: for traditional isolation houses RT2000 and rendered between 2001 and 2006

0.95: for homes constructed between 1990 and 2000

1.15: for homes built between 1983 and 1989.

1.4: for homes constructed between 1974 and 1982.

1.8: house not insulated (walls, attic) and with simple glazing.

- Sdep: sum of the surfaces of the walls [m²]
- Vh: habitable volume of the treated area [m3]

- R: coefficient of feature of type of ventilation
- Self-adjustable VMC: R = 0,2
- Hygro-adjustable VMC: R = 0,14
- 19: The temperature of comfort
- T ext foundation: outer temperature of foundation of the dwelling place

2.13. Conclusion :

One of today's simple and reliable ways of using energy saving equipment is by building insulation. It offers a number of residential, commercial , and industrial applications. The main purpose of installing insulation material inside the building is to minimize energy usage for heating or cooling by increasing the building envelope's thermal resistance. By increasing the thickness of the insulation, the thermal conductivity is reduced, while the cost of the insulation is increased until it exceeds the savings, which this additional thickness will not bring any economic benefit. Therefore the optimum thickness of insulation exists where the savings begin to fall by increasing the thickness of insulation. Most substances may be used as insulating material such as fiberglass, mineral fibers, rubber, and other materials are often used to make the insulations. Built insulation is also an energy-saving tool which decreases the negative environmental effect of the greenhouse gas produced by the buildings.

CHAPTER 3 : Application, results and discussion

3.1. Introduction :

This chapter will define the study objective as well as the building parameters, which are created according to parameters that best reflect the realities of residential construction in Algeria; these parameters include the dimensions, the different areas, the characteristics of the building envelope materials in addition to the geographical coordinates.

The second step will be the opportunity to improve the chosen methodology for the study of energy needs, as well as the relevance of the simulation tool option.

Finally , we will discuss the steps for energy efficiency, which include changes to the building materials.

3.2. Goal of the study:

The purpose of this work is to study a building's energy efficiency. This study makes measurement of this building's energy consumption (isolated and non-isolated).

3.3. Description of the building :

Our project is a residential building, it consists of a ground floor and four other floors. The floor area is 242.59m^2 and the height of the building from the ground floor is 17.5m.

The ground floor contains a store, a garage and a staircase leading to the 1st floor which is made up of two living rooms, three bedrooms, bathroom, W.C, a hall, a courtyard a stairwell leading to the other floors.

This building is located in the wilaya of Tlemcen, Zenata classified as climatic zone A and group of municipalities 3, according to the regulatory technical document (D.T.R.C 3-2-4).

Figure 30 : location plan

3.3.1. Climatic data of Zenata (Tlemcen) :

We will use Zenata climate data provided by energy plus software to do the thermal simulations. Furthermore, we have performed the below climate analysis with the aim of having a clear idea of Zenata climate features.

Table 15 : Climatic data of Zenata

	January 2016	**February 2016**	**March 2016**	**April 2016**	**May 2016**	**June 2016**	**July 2016**	**August 2016**	**September 2016**	**October 2016**	**November 2016**	**December 2016**
Maximum temperature [°C]	20.1	19.2	19.2	22.7	26.2	31.5	33.7	33.4	31.6	28.4	21.3	17.1
Minimum temperature [°C]	7.4	8	6.9	10.1	12.6	16.5	19.6	19.9	17.5	15.1	9.6	8.1
Average relative humidity [%]	68.3	64	64.8	66.7	61.4	50.5	59.2	57.7	57.1	68	64.9	84.6
Average wind speed [km/h]	10	14	10.2	7.4	7.8	9.4	8.8	8.2	6.9	6.8	9.7	5.8

Average annual temperature: 18.5°C

Annual average maximum temperature: 25.4°C

Average annual minimum temperature: 12.6°C

Annual average humidity: 63.9%

Annual average wind speed: 8.7 km/h

3.3.2. Geometric characteristics of this building :

- A total height of 17.5m
- A ground floor height 3.5m
- A length of 14.38 m
- A width of 16.87 m
- The surface area is 242.59m^2

3.3.3. The technical data of this building :

Table 16 : The technical data of this building

Altitude	Latitude	Winter thermal zone	Summer thermal zone
248m	**35.02°**	A	A

3.3.4. Orientation:

the building studied is located in the town of Tlemcen., the front axis is the North.

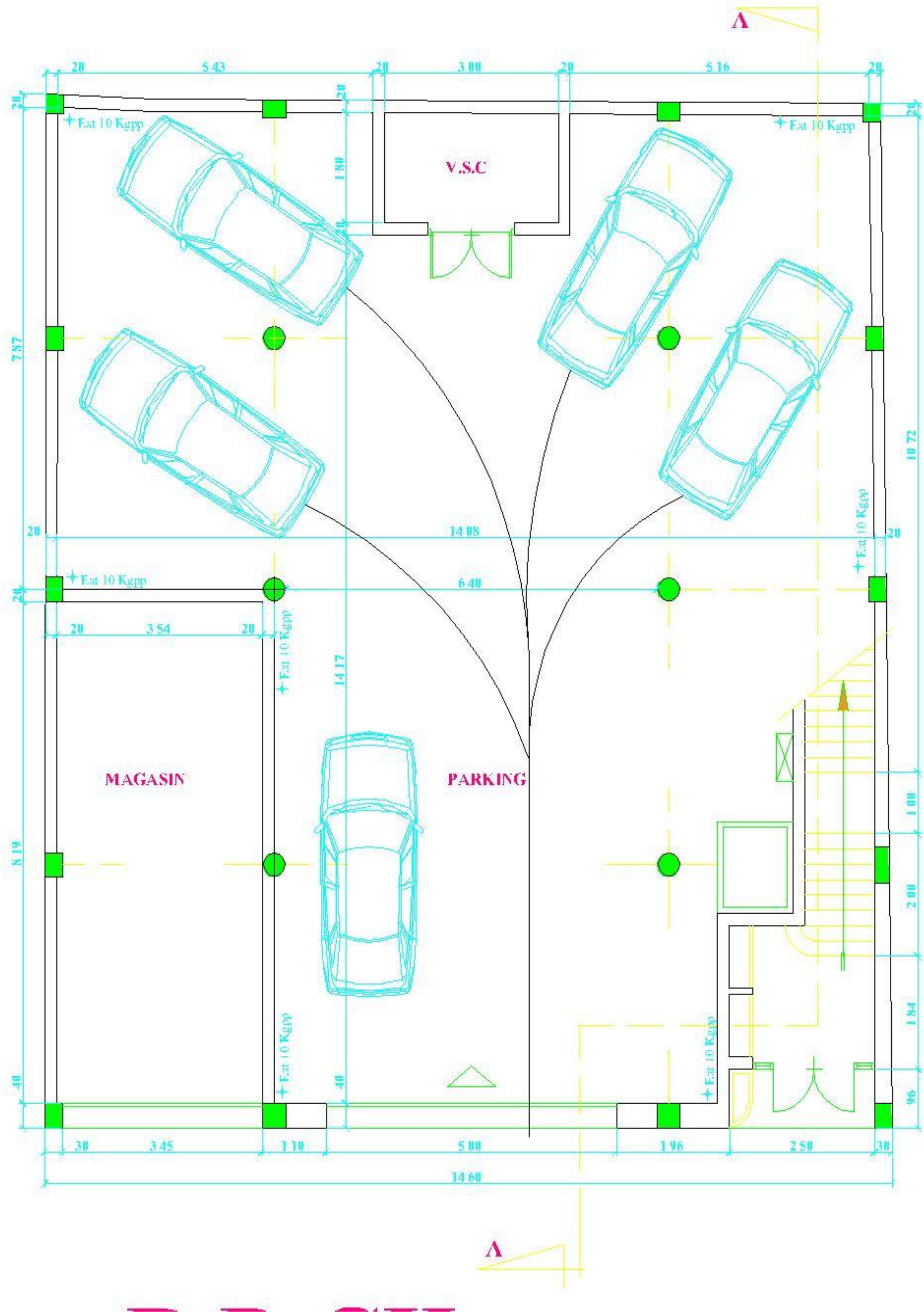


Figure 31 : Ground floor plan

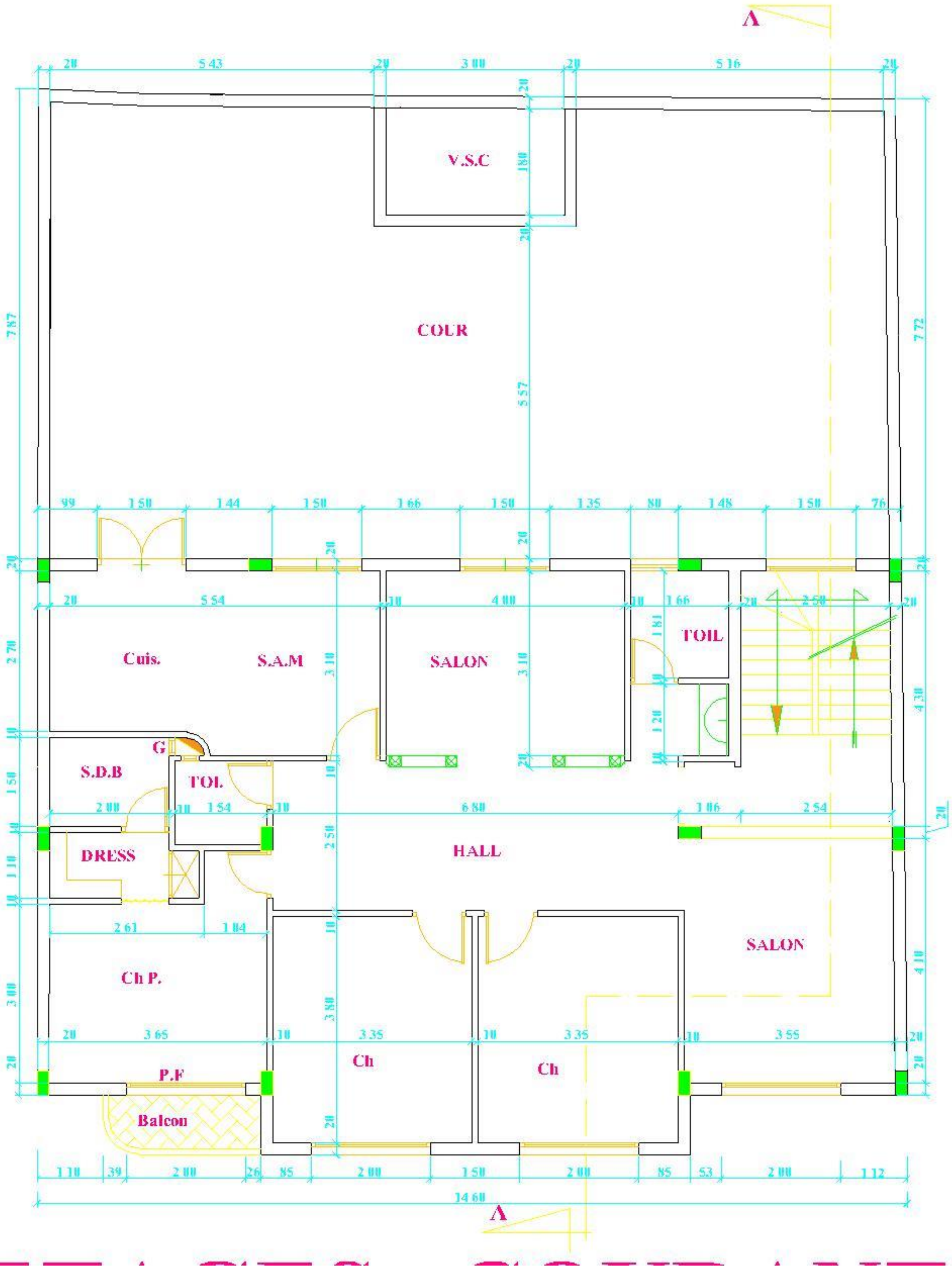


Figure 32 : floors plan

Figure 33 : façade plan

3.3.5. Methodology of the study of energy needs:

The study of the energy needs of the project involves carrying out a series of dynamic thermal simulations:

A simulation of the base case, which is based on a base model and from which we deduce the consumption of the base case.

Optimized case simulations which are based on a project model using energy efficiency measures and from which the consumption of the optimized case is deduced.

We will then distinguish two types of input data:

- Identical data between the basic model and the project models. These are: (surface, volume, surface of facades, etc.) Meteorological data and usage patterns (internal contributions and temperature guidelines, etc.)

  Temperature guidelines: According to the regulatory technical document in application in Algeria (DTR C3.2.4), the comfort temperatures for heating and air conditioning in the bedrooms are respectively (21 ° C, 24 ° C) and the other spaces (kitchen, bathroom and hallway) are (18 ° C, 27 ° C).

- The data which will be authorized to evolve between the basic model and the project models and which will thus translate the energy gain. It is about:

  - The compactness of the building.

  -The distribution of the interior rooms.

  - Kinds of windows.

  -Glass surfaces.

  -Types of building materials.

  - About the impact of insulation.

  - Permanent sun protection

3.4. Simulation tools:

There is a large number of software dedicated to energy simulation. Existing software differs from each other by the algorithms they use, by their user interface and ultimately by their vocations and fields of application.

The software used for this study is **DESIGN BUILDER** version **6.1.6.8**

3.4.1. Presentation of the DESIGN BUILDER software :

DesignBuilder is a user-friendly modeling environment, where you can use virtual building models to work (and play). It offers a variety of data on environmental performance such as: energy usage, carbon emissions, comfort levels, daylight illuminance, average summertime temperatures and sizes of HVAC components.

Some typical uses of DesignBuilder are:

- Calculating the impact of various design options on building energy consumption
- Thermal simulation of naturally ventilated buildings.

- Reporting savings in electric lighting due to use of natural daylight.
- Prediction of natural daylight distribution through Radiance and Daysim simulations.
- Visualisation of site layouts and solar shading.
- Calculating heating and cooling equipment sizes.
- Detailed simulation and design of HVAC and natural ventilation systems including the impact of supply air distribution on temperature and velocity distribution within a room using CFD .
- ASHRAE 90.1 and LEED energy models.
- Economic analysis based on construction costs, utility costs and life cycle costs (LCC)
- UK, Ireland and France Building regulations and certification reports
- Design optimisation with multiple objectives, constraints and design variables.
- Life-cycle analysis (LCA)
- Communication aid at design meetings.
- An educational tool for teaching building simulation to architectural and engineering students.

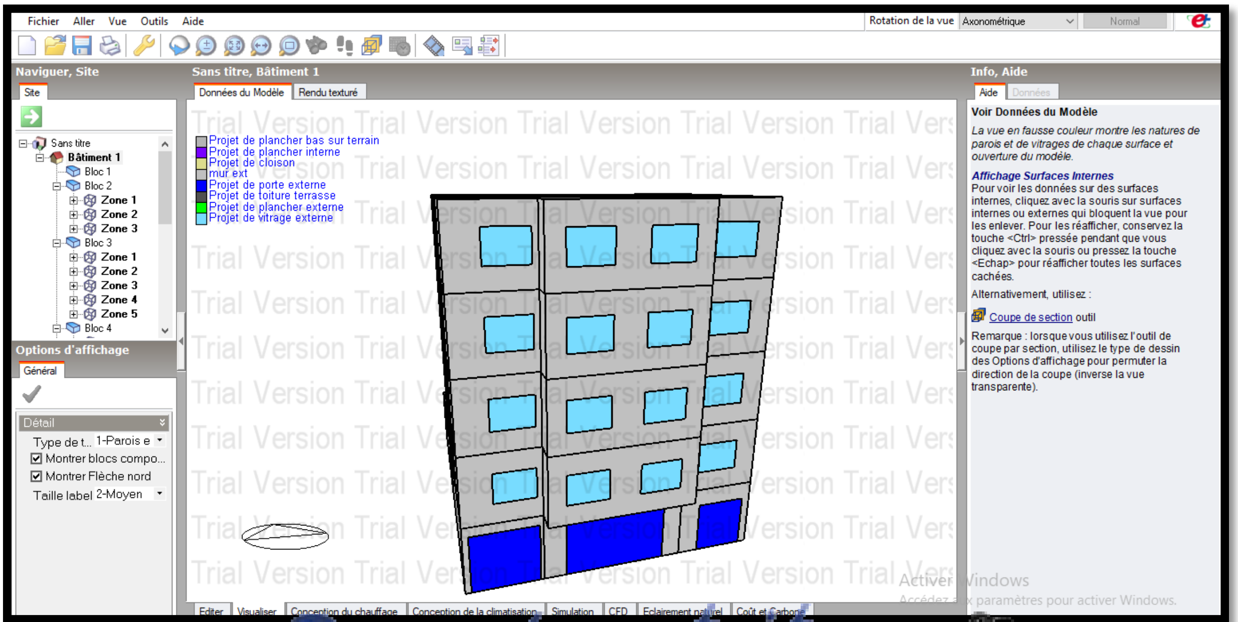


Figure 34 : design builder interface

3.4.2. Energy plus in design builder :

EnergyPlus is a complete simulation program for building energy that engineers architects, and researchers use to model both energy consumption — for heating , cooling , ventilation, lighting, and plug and process loads — and for building water use.

EnergyPlus is a stand-alone simulation software without a graphical interface that is 'user-friendly' - where DesignBuilder joins. EnergyPlus incorporates simulations without any fuss within the DesignBuilder framework – just describe the building model, request data and allow the EnergyPlus simulation engine to take care of the information.

DesignBuilder has been developed specifically around EnergyPlus allowing input of most of the EnergyPlus fabric and glazing data. It offers databases of building materials, constructions, window frames, window gas, glazing units and blinds.

3.4.3. Create Building Geometry :

- **Import Floor Plans :**

We used DXF format in our project, which can be imported as 2-D floor plan layouts. It can be used to trace perimeters of blocks and partitions as a simple way to access the geometry of the layout. A typical process could proceed like this:

1-Create new dsb site file.

2-Select location.

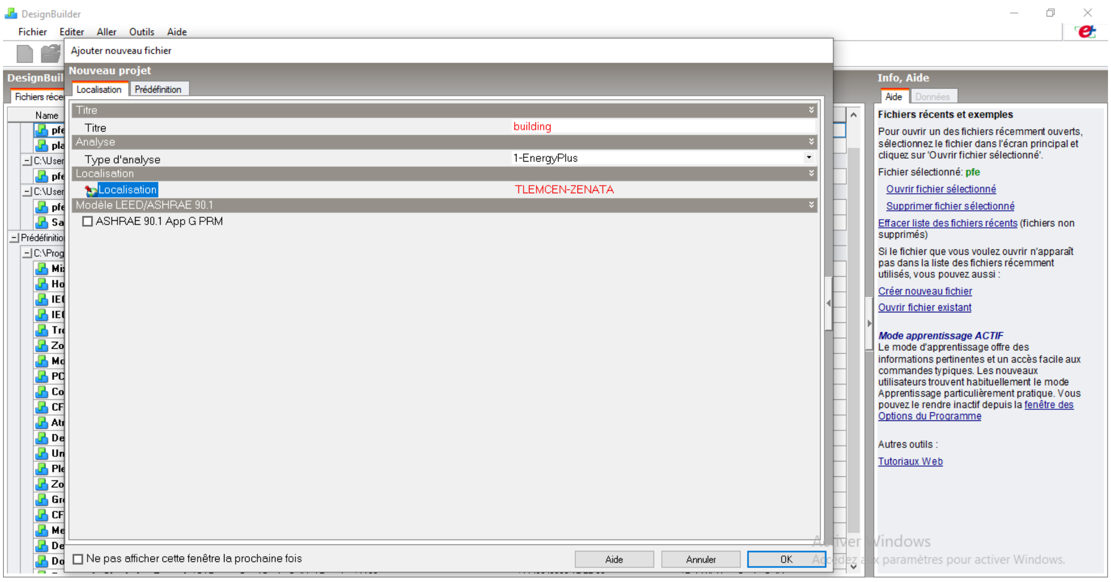


Figure 35 : select location

3-Import floor plan data

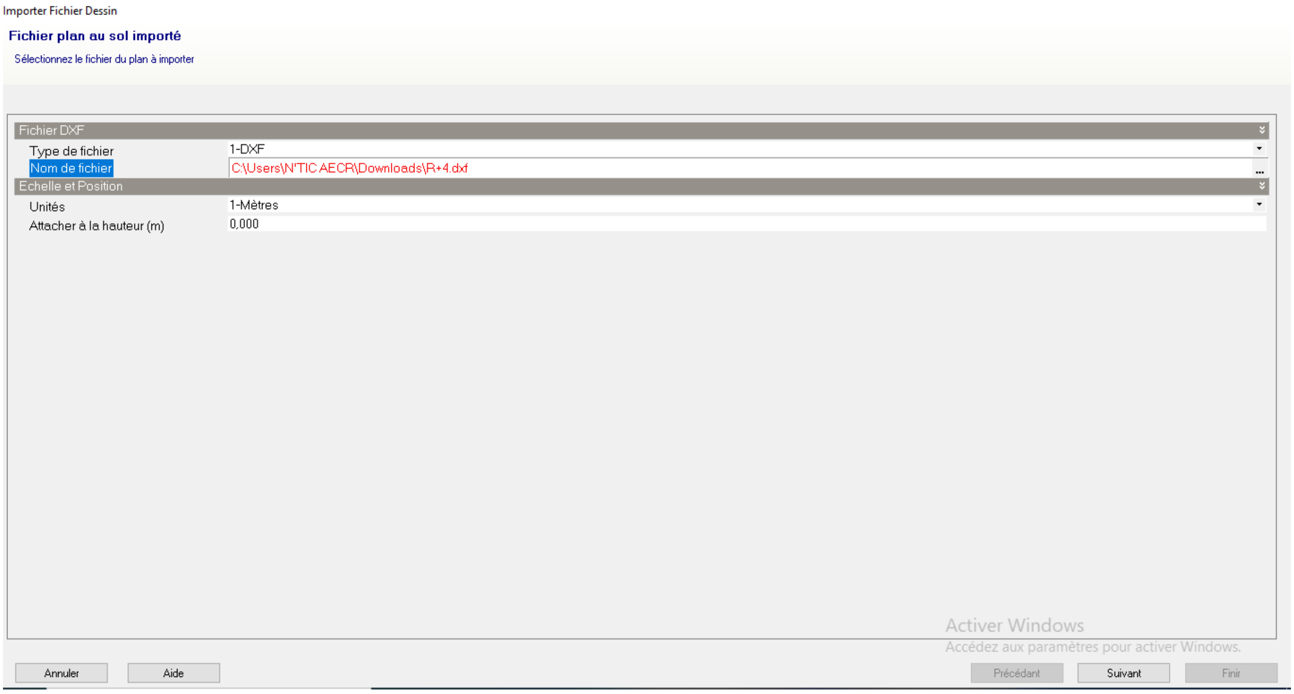


Figure 36 : import floor plan data

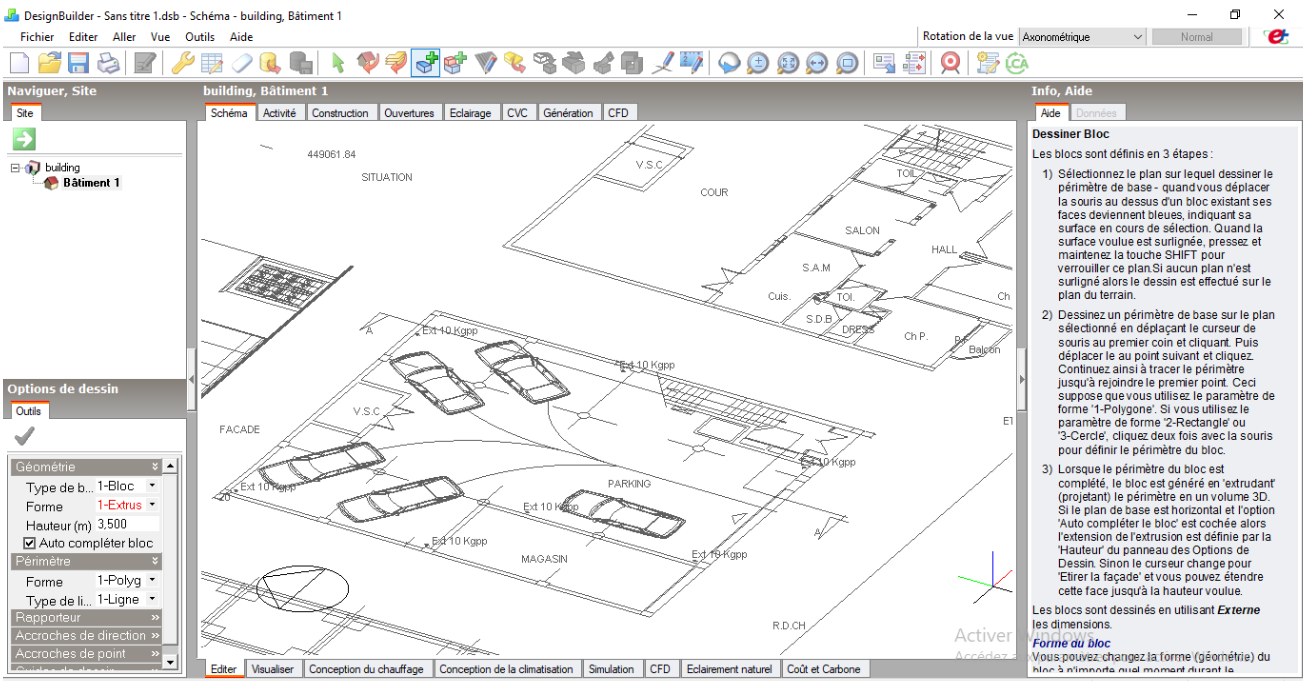


Figure 37 : floor plan

4-Draw blocks by tracing over the external perimeter corners of the floor plan.

Figure 38 : Add new block tool

Click the Add New Block tool to attach or build a new Block. If a new building has just been built, the Add New block tool will automatically be enabled. Most effectively a block is formed by drawing the block's base perimeter using one of the perimeter types such as a polygon.

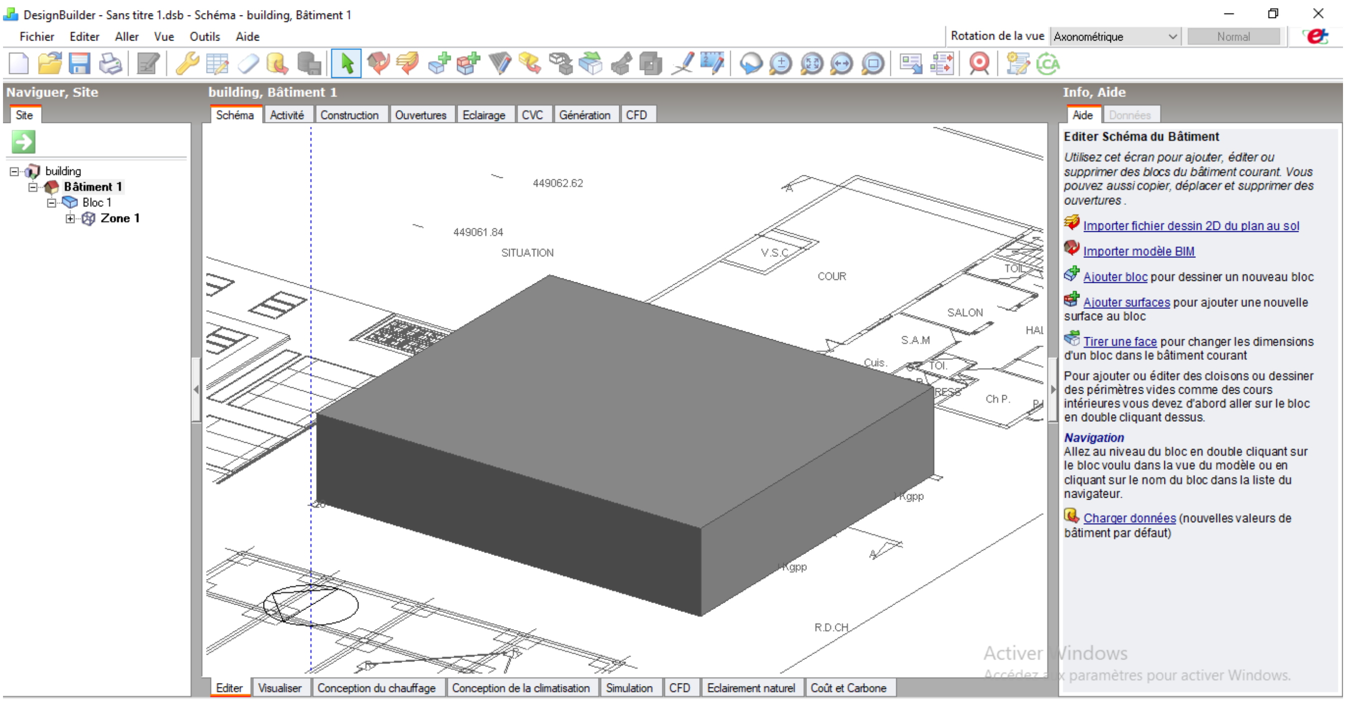


Figure 39 : New block

5-adding windows, doors, four floors and different zones

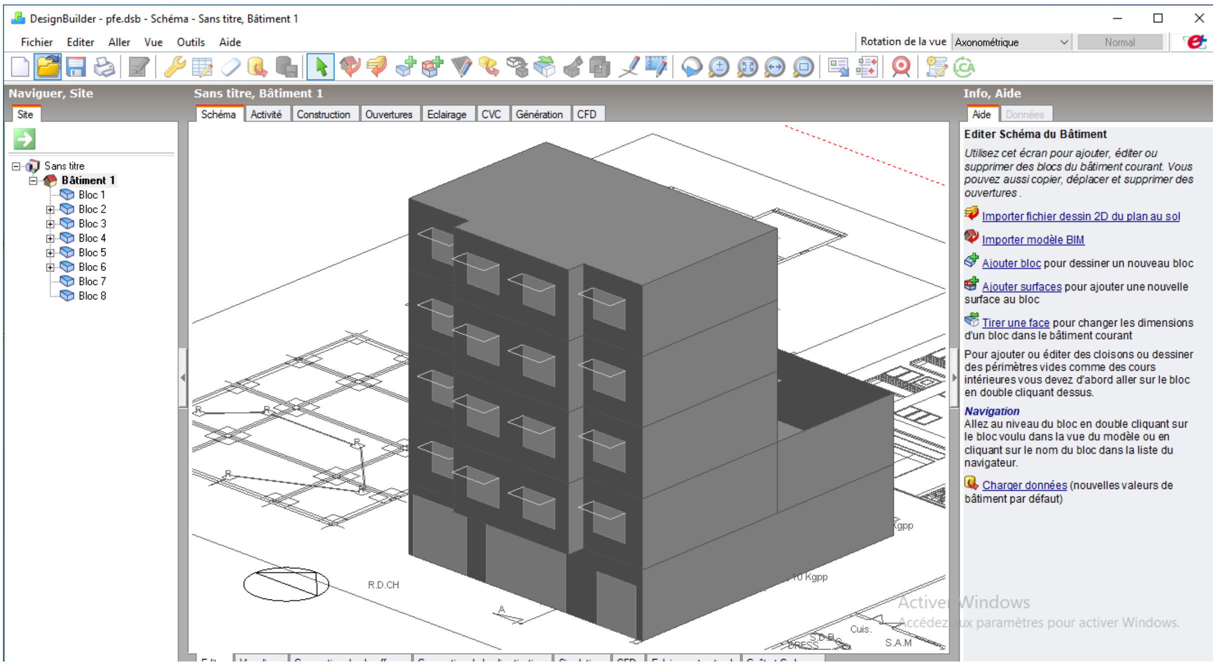


Figure 40 : adding windows, doors, four floors and different zones

3.4.4. Opaque and Glazed constructions:

a) Layers constructions:

DesignBuilder constructions are made up of material layers as required by EnergyPlus.

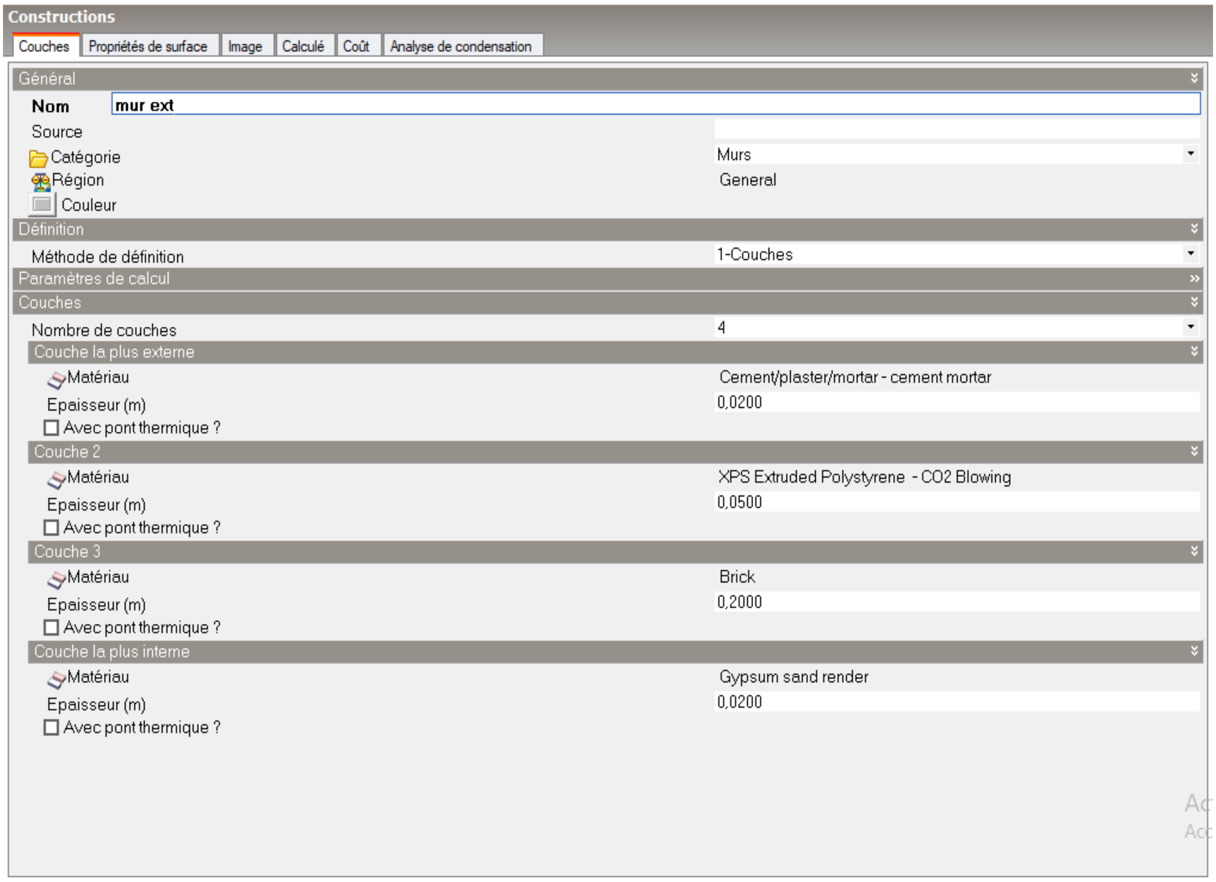


Figure 41 : Opaque construction built up by layers

b) Glazing constructions:

The baseline glazing constructs are also stored in the DesignBuilder glazing database ready to be assigned in the mode.

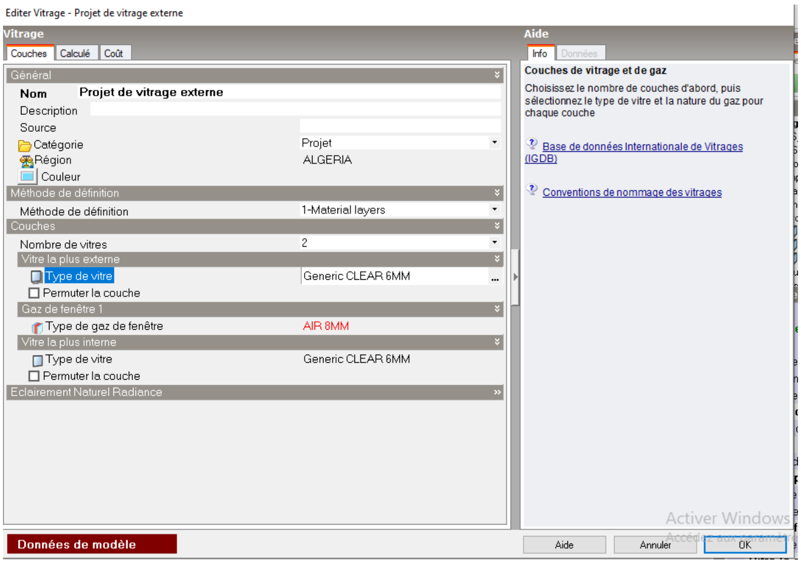


Figure 42 : Glazing construction

3.4.5. Lighting:

DesignBuilder provides a set of predefined lighting models for modeling the proposed building (these are the Those used in the baseline construction when generated) that can be used **directly or copied and edited as needed (figure….).**

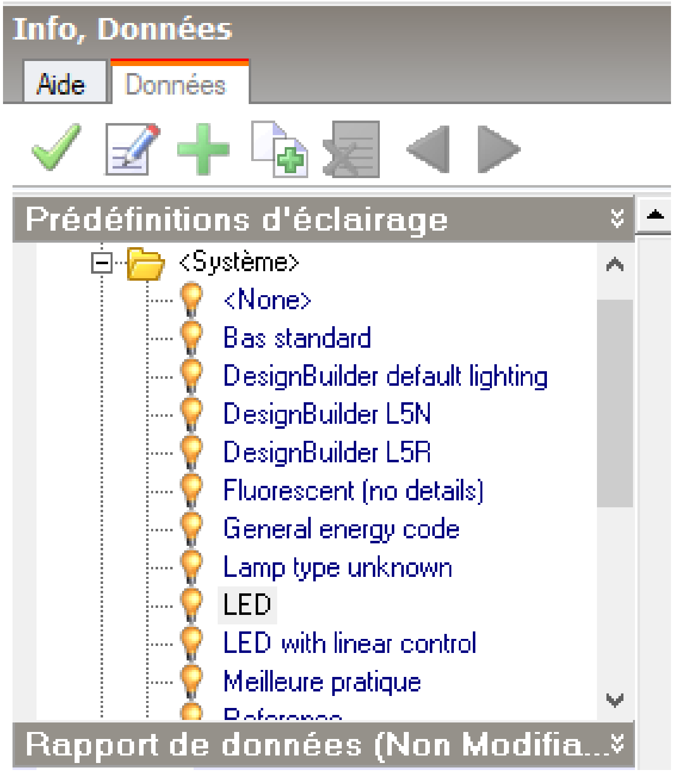


Figure 43 : Predefined lighting templates

3.4.6. HVAC :

The heating / cooling system is modelled using algorithms for calculating the basic loads. The EnergyPlus ZoneHVAC: IdealLoadsAirSystem system is used for measuring heating and cooling charges for convective heating systems and all cooling systems. It offers hot / cold air to satisfy heating and cooling loads.

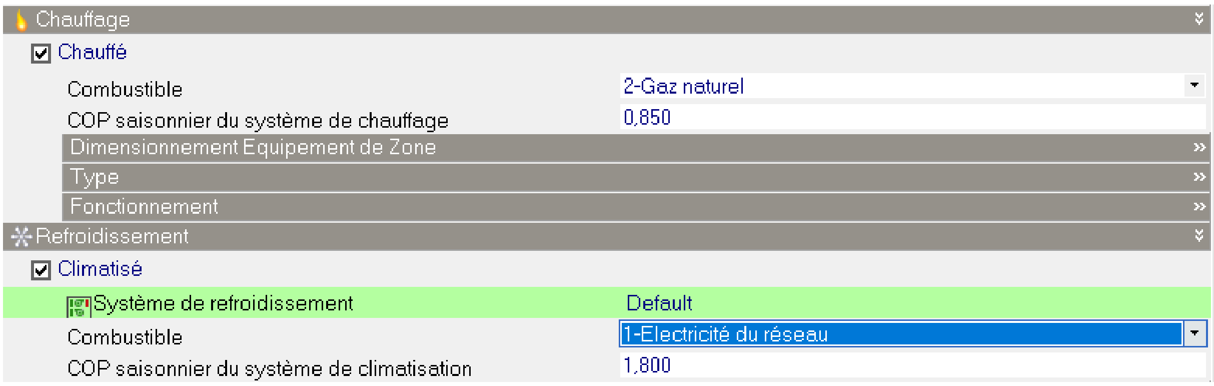


Figure 44 : HVAC system

3.5. Energy efficiency measures:

We will focus here on passive energy efficiency measures that do not require either energy assistance or the presence of occupants; these measures are related to the building envelope. The simulation will be done in five scenarios, taking these parameters into account :

- Types of windows.
- Glass surfaces.
- Types of construction materials.
- The impact of insulation.
- Permanent sun protection

3.5.1. Types of windows(without insulation) :

Table 17 : Types of windows(without insulation)

Composition	Kvn	Coéf. K winter	Coéf. K summer
Wood / Single glazed / -	Winter: 5,00 W/m².°C / Summer: 4,97 W/m².°C	5,00 W/m².°C	4,97 W/m².°C

3.5.2. Types of windows(with insulation) :

Table 18 : Types of windows(with insulation)

composition	Kvn	Coéf. K winter	Coéf. K summer
Metal / Double Glazing / 5 to 7	Winter: 4.00 W / m². ° C / Summer: 3.97 W / m². ° C	4,00 W/m².°C	3,97 W/m².°C

3.5.3. Presentation of the different constructive elements of the building:

The construction materials constituting the building envelope are in the following tables:

3.5.3.1. The envelop composition without insulation material:

a) The walls:

▪ Composition (from outside to inside)

Table 19 : composition of walls without insulation

Materials	Thickness [m]	Cond. Λ W/m.°C	Resistance (m².°C)/W
Cement mortar	0.02	1.40	0.01
Hollow brick	0.25	0,44	0.45
Cement mortar	0.02	1.40	0.01

b) Floors :

Table 20 : composition of floors

Material	Cond. λ	Thickness	Resistance
Bastard mortar	1,15 W/m.°C	0,05 m	0,04 (m².°C)/W
Hollow concrete blocks of heavy aggregates	1,10 W/m.°C	0,21 m	0,19 (m².°C)/W
Solid concrete	1,75 W/m.°C	0,05 m	0,03 (m².°C)/W
Marble tiles mosaic called "granito"	2,10 W/m.°C	0,03 m	0,01 (m².°C)/W

c) **Roof :**

Table 21 : composition of roof without insulation

Material	Cond. λ	Thickness	Resistance
Gravel	2,00 W/m.°C	0,05 m	0,03 (m².°C)/W
Felt and carpet boards, impregnated	0,23 W/m.°C	0,02 m	0,09 (m².°C)/W
Solid concrete	1,75 W/m.°C	0,07 m	0,04 (m².°C)/W
Hollow concrete blocks of heavy aggregates	1,10 W/m.°C	0,21 m	0,19 (m².°C)/W
Cement mortar	1,40 W/m.°C	0,02 m	0,01 (m².°C)/W

3.5.3.2. The envelop composition with insulation material:

a) **The walls :**

Table 22 : composition of walls with insuation

Materials	Thickness [m]	Cond. Λ W/m.°C	Resistance (m².°C)/W
Cement mortar	0,02	1,40	0,01
Expanded polystyrene	0,06	0,05	1,3
Hollow brick	0,25	0,44	0,45
Cement mortar	0,02	1,40	0,01

b) **Roof :**

Table 23 : composition of roofs with insuation

Material	Cond. λ	Thickness	Resistance
Gravel	2,00 W/m.°C	0,05 m	0,03 (m².°C)/W
Felt and carpet boards, impregnated	0,23 W/m.°C	0,02 m	0,09 (m².°C)/W
Solid concrete	1,75 W/m.°C	0,07 m	0,04 (m².°C)/W
Expanded polystyrene	0,05 W/m.°C	0,06 m	1,30 (m².°C)/W
Hollow concrete blocks of heavy aggregates	1,10 W/m.°C	0,21 m	0,19 (m².°C)/W
Cement mortar	1,40 W/m.°C	0,02 m	0,01 (m².°C)/W

3.5.4. The impact of insulation:

In this simulation, the effect of insulation would be important, in fact we only opted for expanded polystyrene as an insulation for conventional materials whose thermal characteristics are:

$\lambda = 0.141(KJ\ h\ m\ K/)$, $C = 1.38(KJ\ kg\ K\ /)$ et $d = 25$ (kg/m3)

The insulation will be used in several thicknesses varying between 1 cm and 10 cm, for the exterior facades, the roof and the low floor; in order to determine both the part to be insulated as a priority and the thickness of the insulation which guarantees an optimal energy requirement.

3.5.5. Permanent sun protection:

The first way chosen to reduce solar gain is to integrate a solar cap. We therefore offer a new function to the windows of the building.

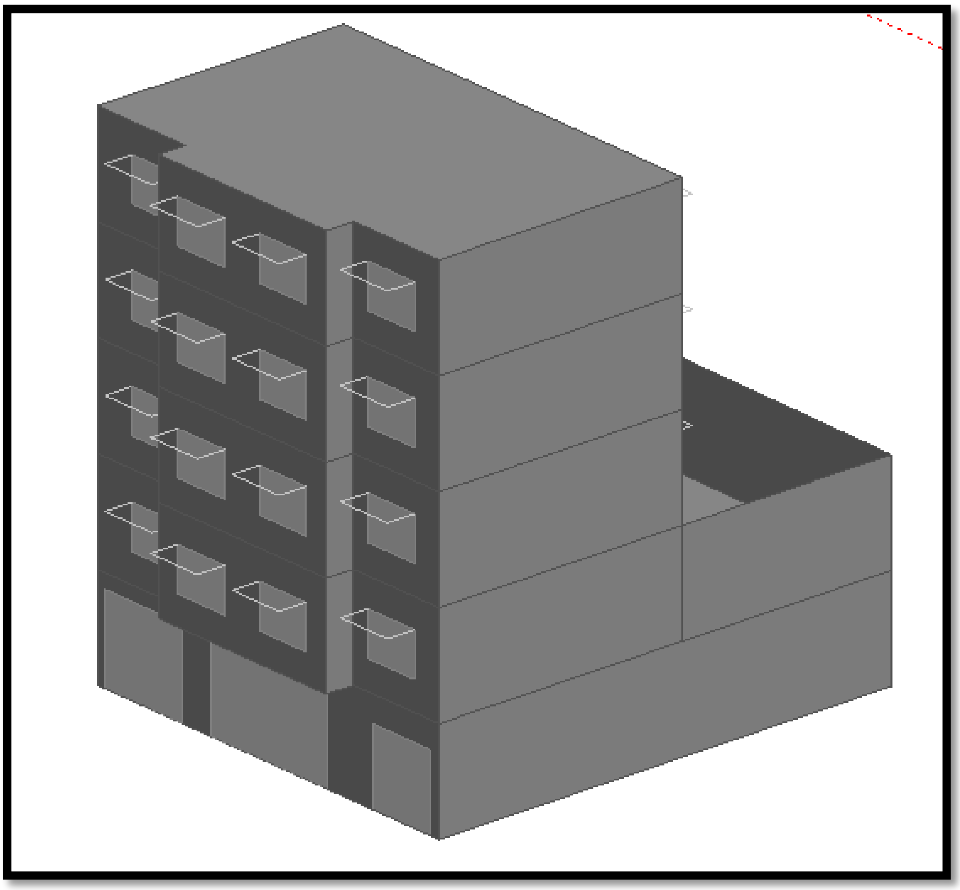


Figure 45 : sun protection

3.6. Results and Discussion:

3.6.1. Simulation results :

3.6.1.1. The envelop composition without insulation material:

Table 24: Proposed Composition of the building envelop without insulation.

	Wall	Roof	Floor
Layers	Outer surface Cement mortar — 0.02 m Hollow brick — 0.25 m Cement mortar — 0.02 m Inner surface	Outer surface Gravel — 0.05 m Felt and carpet boards — 0.02 m Solid concrete — 0.07 m Hollow concrete blocks — 0.21 m Cement mortar — 0.02 m Inner surface	Outer surface Bastard mortar — 0.05 m Hollow concrete blocks — 0.21 m Solid concrete — 0.05 m Granito — 0.03 m Inner surface

Results:

Table 25 : Energy consumption of the building without insulation (monthly)

Month	Room electricity	lighting	heating (Gas)	cooling (electricity)
	kWh	kWh	kWh	kWh
January	2803,467	2035,266	2914,811	0,050653
February	2449,522	1769,797	2308,563	1,964368
March	2589,976	1858,286	1670,293	2,638054
April	2685,486	1946,776	920,2555	20,05902
May	2803,467	2035,266	281,627	238,2368
June	2471,994	1769,797	7,338789	789,0204
July	2803,467	2035,266	0	2613,716
August	2696,722	1946,776	0	3391,771
September	2578,74	1858,286	0	1866,467
October	2803,467	2035,266	43,41023	585,2335
November	2578,74	1858,286	1083,509	112,9573
December	2696,722	1946,776	2317,971	4,145414

3.6.1.2. The envelop composition with insulation material:

Table 26: Proposed Composition of the building envelop with insulation.

	Wall	Roof	Floor
Layers	Outer surface Cement mortar 0.02 m Expanded polystyrene 0.06 m Hollow brick 0.25 m Cement mortar 0.02 m Inner surface	Outer surface Gravel 0.05 m Felt and carpet boards 0.02 m Solid concrete 0.07 m Expanded polystyrene 0.06 m Hollow concrete blocks 0.21 m Cement mortar 0.02 m Inner surface	Outer surface Bastard mortar 0.05 m Hollow concrete blocks 0.21 m Solid concrete 0.05 m Granito 0.03 m Inner surface

Results:

Table 27: Energy consumption of the building with insulation (monthly)

Month	Room electricity	lighting	heating (Gas)	cooling (electricity)
	kWh	kWh	kWh	kWh
January	2649,152	1923,236	3770,937	0
February	2314,689	1672,379	2152,646	0
March	2447,412	1755,998	1233,28	0
April	2537,664	1839,617	488,826	0
May	2649,152	1923,236	260,6497	95,35843
June	2335,924	1672,379	15,87388	511,9279
July	2649,152	1923,236	0	2280,613
August	2548,282	1839,617	0	3046,936
September	2436,794	1755,998	0	1523,191
October	2649,152	1923,236	69,6746	347,2347
November	2436,794	1755,998	697,451	33,5346
December	2548,282	1839,617	2401,28	0

3.6.2. Discussion:

The results are shown by the four activities consumption depending on the time(month and year).

3.6.2.1. Analysis per month :

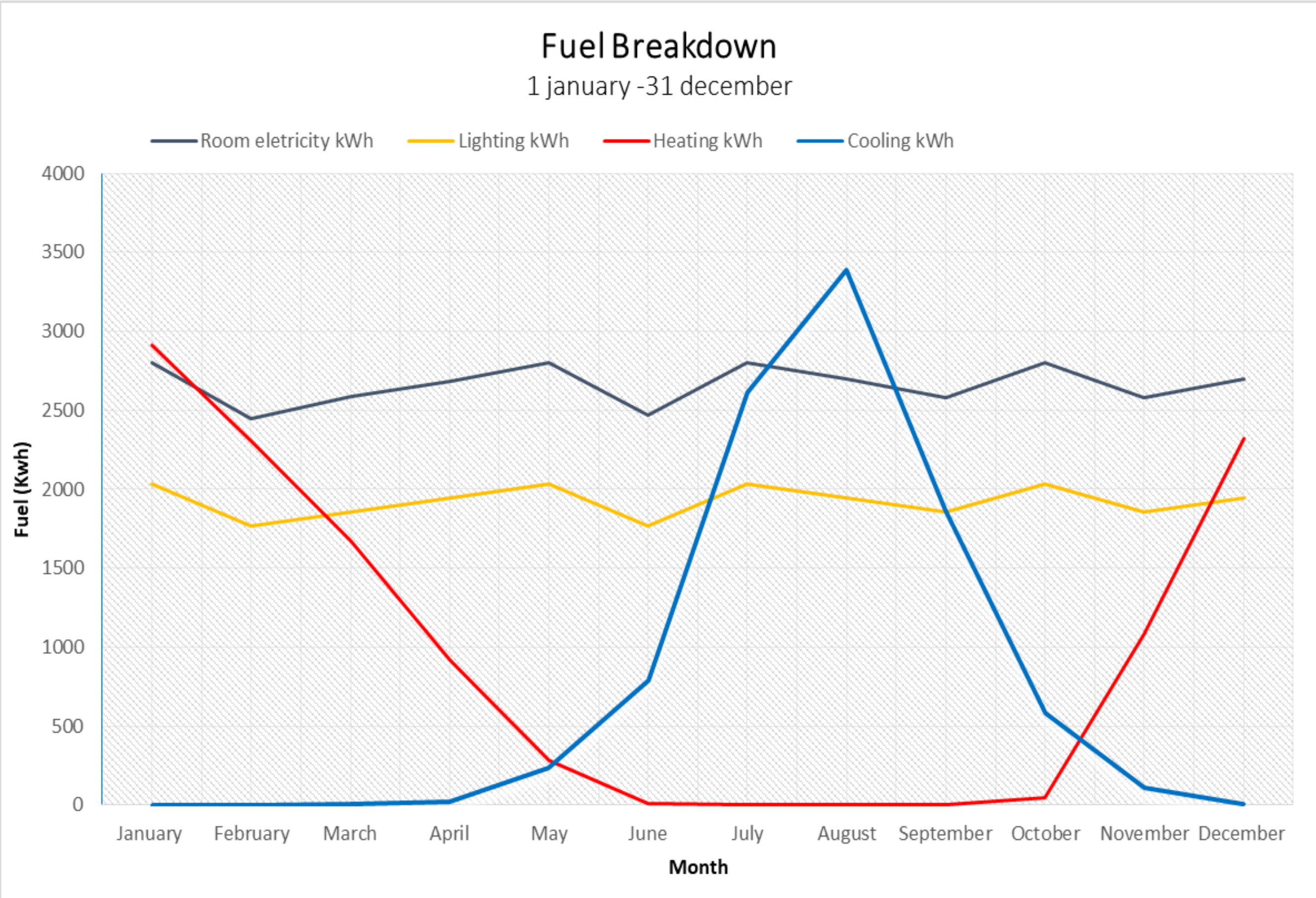


Figure 46 : Graph (a) : variety of combustibles without insulation

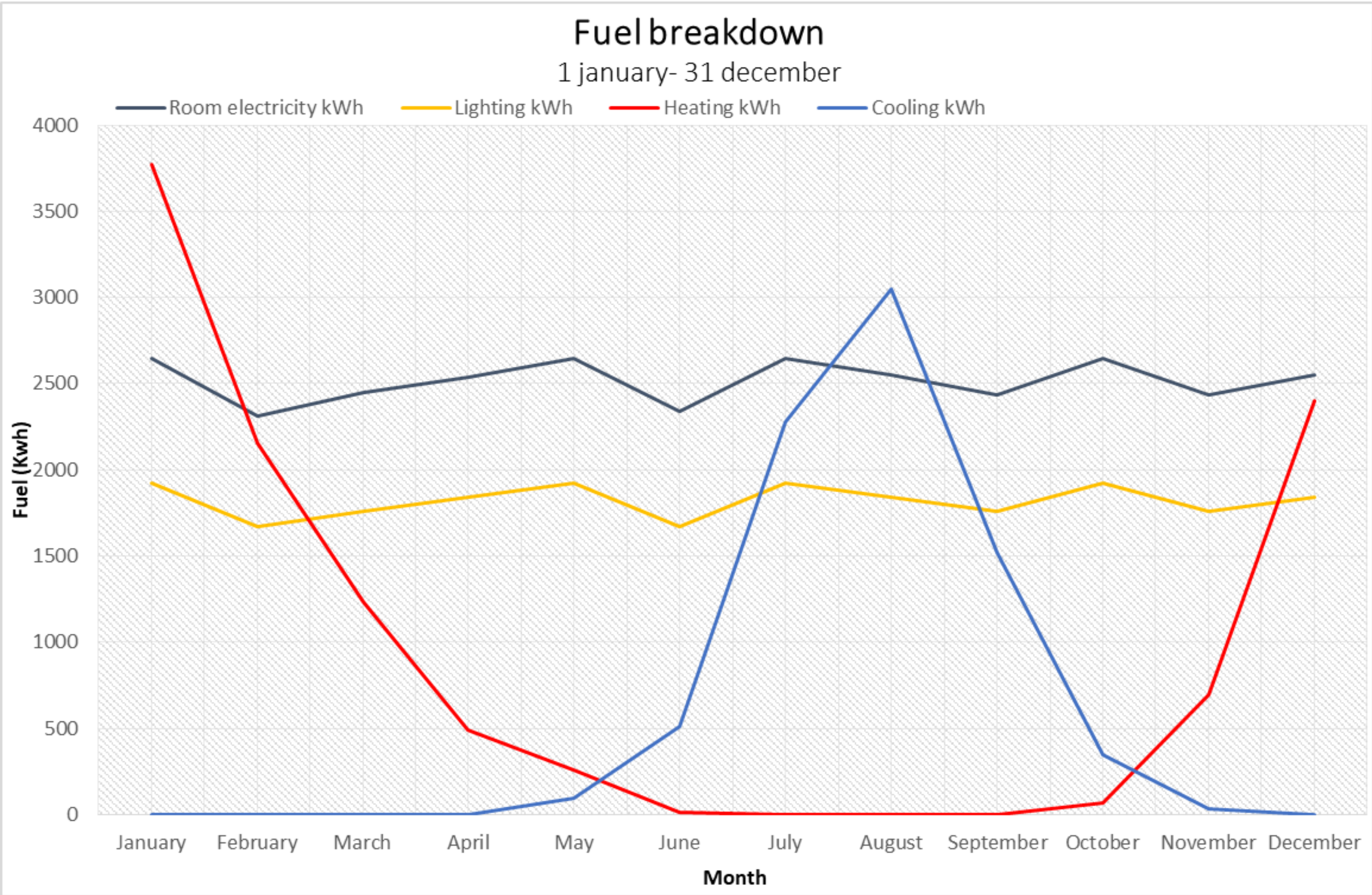


Figure 47 : Graph (b) : variety of combustibles with insulation

- **Activity1(room electricity)**
  - **Graph a :**

    Over the twelve months, there is daily use between (2803,467 ; 2471,994 **kwh**), which logically indicates that we use electricity for examples in household appliances, chargers ....
  - **Graph b :**

    we see the same for the curve a in terms of use except that the quantity consumed is more less (2649,152 ; 2314,689 **kwh**)
- **Activity 2 (lighting) :**

  as the lighting is also always used, we see the difference in terms of quantity Where in the curve a is around
  - **Graph a : max** 2035,266**(kwh)** ; **min** 1769,797 **(kwh)**
  - **Graph b : max** 1923,236 **(kwh) ;min** 1672,379 **(kwh)**

- **Actvity 3 (heating) :**

  during the winter months we have consumed a considerable quantity or we had a maximum value in the month of January where it decreases until it reaches zero in (June, July, August) and increases in harmonious growth until December has a value of

  - **Graph a :** maximum value in January 6670,937 **kwh** ; December value 5401,28 **kwh**
  - **Graph b :** maximum value in January 2914,811 **kwh** ; December value 2317,971**kwh**

- **Activity 4(cooling) :**

  Here in cooling we have three phases from

- **January to April**
  - **Graph a :** 0,050653- 20,059 **(kwh)**
  - **Graph b :** 0 **(kwh)**

- **April to the last of September :**
  - **Graph a :** 20,059-1866,**467 (kwh)**
  - **Graph b** : 0- 1523,191 **(kwh)**
- **October to december :**
  - **Graph a :** 585,2335- 4.14514 **(kwh)**
  - **Graph b :** 347,23- 0 **(kwh)**

3.6.2.2. Analysis per yer :

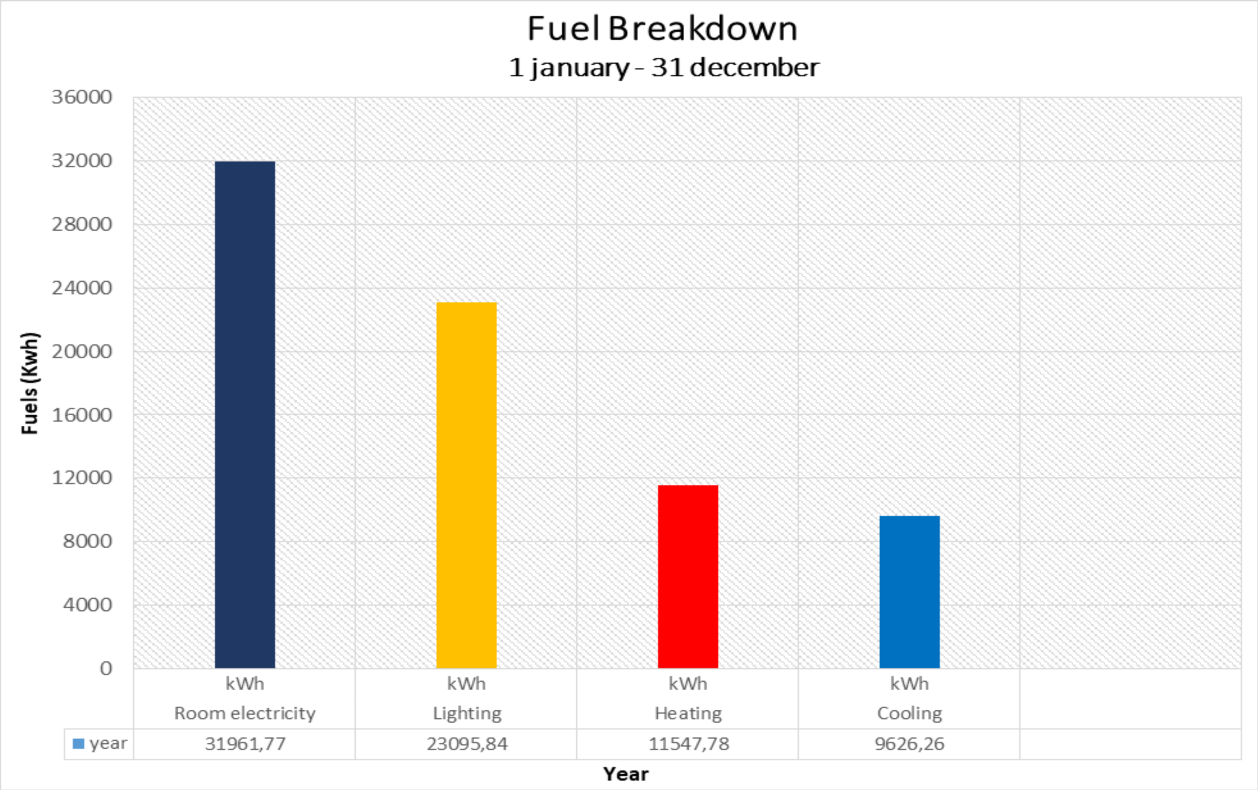


Figure 48 : Graph (a) : variety of combustibles without insulation

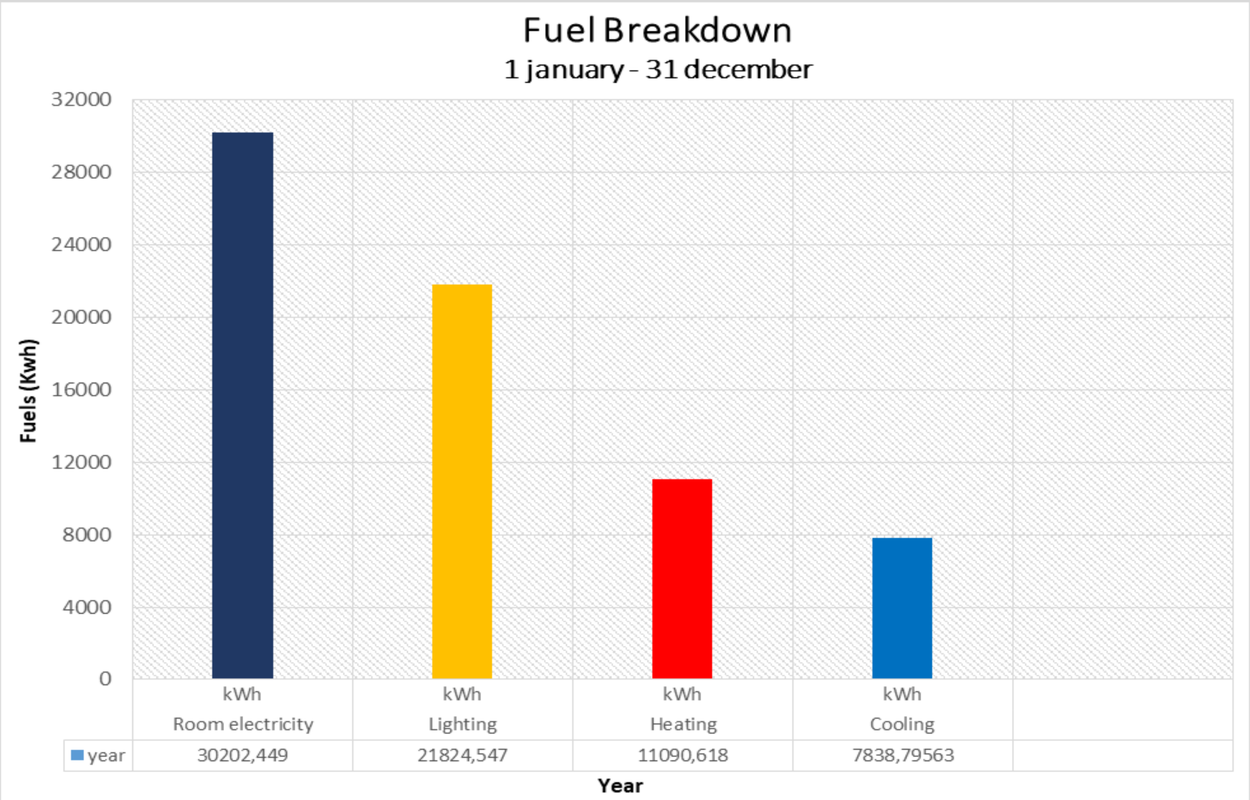


Figure 49 : Graph (b) : variety of combustibles with insulation

we notice that the electricity per zone and the lighting are the biggest parameters in terms of consumption, also that the quantities of power in the curve(a) is greater than that of the curve (b) :

- **Room electricity :**
  - **Graph (a) :**31961,77 **kWh**
  - **Graph (b) :**30202,449 **kWh**
- **Lighting :**
  - **Graph (a) :**23095,84 **kWh**
  - **Graph (b) :**21824,547 **kWh**

compared to heating and cooling , we see the heating is used more than the cooling in both cases except that we have a decrease in the quantity consumed :

- **Heating :**
  - **Graph(a) :**11547,78 **kWh**
  - **Graph(b) :**11090 ,618 **kWh**
- **Cooling :**
  - **Graph(a) :**9626,26 **kWh**
  - **Graph(b) :**7838,7956 **kWh**

3.7. Conclusion :

We can find a lot of results in Model Builder by using the App PlusEnergy. The energy consumption for the four key activities is given in the graph and tables. The buildings supply their heat from natural gas, electricity is used for the cooling.

Comparing both results, it is noticeable that all of the four main activities output has changed :

- **Electricity for room :** The gross non-isolating consumption is approximately 1,0583 that of insulation
- **Lighting :** The gross non-isolating consumption is approximately 1,058 that of insulation
- **Heating :** Approximately 2.389 gross non-isolating use is that of insulation
- **Cooling :** Approximately 1.9644 gross non-isolating use is that of insulation

These outputs depend on the building envelope and the timetables chosen, its already assumed that the building consumes less by applying some hypothesis, as we stated about the building composition and schedules .

- ✓ Electricity for room and lighting decreased due to the option of the lamp as we modified it from standard to LED and simple glazing to double glazing.
- ✓ it is noteworthy that heating and cooling we get a good results since there is no cooling in five months (winter season) and no heating (summer season) .the both have the highest gain approximation of energy consumption. This is due insulation from the outside , choosing an adequat schedules, using natural ventilation.
- ✓ We focused a little bit in schedules cooling and heating to get the energy performance, because to acheive this results we must highlighting comportement and behavior occupants .

Perspectives and recommandations :

Energy efficiency in the construction sector is an enormous benefit which makes us more aware of our vision in this field ,so as response in this major we recommend algerian authorities :

- Algerian regulations are reported against a minimum level of results, so it's time to lift the latter's bar and recompose the leading efficiency directors to establish competition in the general interest.
- Every building goes through an architectural design office, except that it takes into account only the architectural side and neglects the energetic dimension, because it fails to comply with its rules due to lack of follow-up.
- Architects who represent the designers of our projects in the field of energy efficiency should be encouraged whether by physical or moral rewards.
- We must implement all the regulations strictly and rigorously, as it is advantageous for individuals and countries.
- Sensitize people by giving lectures and advertising about the value of energy saving.
- sponsor markets to sell low-consumption lamps or LEDs and create a more favorable environment.

CONCLUSION:

The role of thermal reglomeration is very important in several levels, the whole country is affected by its regulations in the context of minimizing energy production which implies the reduction of greenhouse gases and the economic burden, especially in the case where the country subsidizes the consumption price.

Comparative analysis were performed in this research to pick one of the insulation materials and the best way in construction by stating the results from thermal simulations.

In Algeria, actions have been taken to reduce its subsidies, because the bill becomes heavy and prevents the development of the country.

Citizens are also concerned with the compliance of the legislation with the current Algerian energy policy, and the authority must be the example in the field of operation expressed in the energy reconstruction of state buildings.

The example chosen in this research highlights the value of building energy efficiency and with simple solutions we lower consumption and increase energy usage.

In the opposite case, the benefits gained would be in the general interest of the country, all this can only be possible by having an energetic efficiency specialist research committee which would have the authority to assess constuire permits in order to accept or reject projects while maintaining a decision margin.

This procedure will save us over 50 percent of energy sector spending and will channel its funds into growth.

Finally, this work aims to gather all relevant knowledge in the area of energy conservation in the building.

If we want a better life for life generations, then we must realize that we are all concerned to write our future pages.

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