THE REPUBLIC OF TURKEY
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CLIMATE AND ENERGY CONSCIOUS DESIGN PRINCIPLES FOR RESIDENTIAL BUILDINGS IN MOROCCO

Master's Thesis

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M. S. Thesis

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Prof. Dr. Emine Özen EYÜCE
Program Coordinator

This is to certify that we have read this thesis and we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Science.

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Istanbul, 2019 Imane OURHADJA

ABSTRACT

CLIMATE AND ENERGY CONSCIOUS DESIGN PRINCIPLES FOR RESIDENTIAL BUILDINGS IN MOROCCO

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Supervisor: Assoc. Prof. Dr. Emine Ümran TOPÇU

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The world is concerned with the menacing changes of the climate emergencies caused by CO2 emissions and energy reserves insufficiency. Climate change has become one of the most important topics to discuss at present and it is one of the most serious issues humanity is facing currently and must take fast and serious actions to overcome this dilemma. For this reason, humanity must rely more on renewable resources for energy production. The major energy consumers are buildings which represent 36percent of the total energy consumed around the world. Their energy consumption is expected to increase up to 30percent by 2030 (Held, 2013). This thesis highlights relevant cases of residential buildings that take into consideration best practices in terms of energy efficiency and the integration of renewable energies. It reflects the ability and ingenuity of building practitioners in Morocco to explore different means and passive systems for designing and implementing architecture based on a local climate. In fact, it is based on the contextualization of energy in buildings in relation to the specific environmental conditions of Morocco, which grants it an innovative character. Its development process has adopted a scientific methodology to evaluate or design a building in compliance with energy regulations and standards. In addition, this thesis helps to identify and understand the advantages and disadvantages inherent to energy aspects in the building by optimizing energy consumption and improving thermal comfort. This study seeks to remedy these problems by analysing and studying the available building techniques. Focusing on the energy performance and limiting the energy consumption by putting passive energy strategies into action, will help to assure the reduction of energy of the envelope of the building. Thus, through the diversity of the pilot buildings that it relates, this thesis will contribute to a better dissemination of energy efficiency and renewable energy technologies in the design of buildings.

Keywords: Energy Consumption, Energy Efficiency, Residential Buildings, Morocco, Climate.

ÖZET

FAS'TAKI KONUT YAPILARI İÇİN

İKLİM VE ENERJİ DUYARLI TASARIM İLKELERİ

Imane OURHADJA

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Dünya, CO_2 emisyonları ve enerji rezervleri yetersizliğinden kaynaklanan iklimle ilgili acil durumların tehdit edici değişiklikleriyle ilgilenmektedir. İklim değişikliği şu anda tartışılacak en önemli konulardan biri haline gelmiştir ve insanlığın şu anda karşılaştığı en ciddi konulardan biridir ve bu ikilemi aşmak için hızlı ve ciddi adımlar atılması gerekmektedir. Bu nedenle, insanlık enerji üretimi için yenilenebilir kaynaklara daha fazla güvenmelidir. En büyük enerji tüketicileri, dünya çapında tüketilen toplam enerjinin yüzde 36'sını temsil eden binalardır. Enerji tüketiminin 2030 yılına kadar yüzde 30'a kadar artması bekleniyor (Held, 2013). Bu tez, enerji verimliliği ve yenilenebilir enerji kaynaklarının entegrasyonu açısından en iyi uygulamaları göz önünde bulunduran, ilgili konut yapılarını vurgulamaktadır. Ayrıca, Fas'taki uygulayıcıların yerel bir iklime dayalı mimariyi tasarlamak ve uygulamak için farklı araçlar ve pasif sistemler keşfetme kabiliyetlerini ve ustalıklarını da yansıtmaktadır. Aslında, bu tez binalarda enerjinin bağlamsallaştırılmasına dayanır ve Fas'a özgü çevresel koşullara göre yenilikçi bir karakter kazandırır. Geliştirme süreci ise, bir binayı enerji düzenlemeleri ve standartlarına uygun olarak değerlendirmek veya tasarlamak için bilimsel bir metodoloji benimsemiştir. Ek olarak, bu tez, enerji tüketimini optimize ederek ve termal konforu artırarak binadaki enerji yönlerine özgü avantaj ve dezavantajları belirlemeye ve anlamaya yardımcı olur. Bu çalışma, mevcut bina tekniklerini analiz ederek ve inceleyerek bu sorunları gidermeyi amaçlamaktadır. Enerji performansına odaklanmak ve pasif enerji stratejilerini harekete geçirerek enerji tüketimini sınırlandırmak, bina zarfının enerjisinin azaltılmasını sağlamaya yardımcı olacaktır. Bu nedenle bu tez, ilgili pilot binaların ilgili olduğu çeşitlilik sayesinde, enerji verimliliğinin ve yenilenebilir enerji teknolojilerinin binaların tasarımında daha iyi yayılmasına katkıda bulunacaktır.

Anahtar Kelimeler: Enerji Tüketimi, Enerji Verimliliği, Konut Binaları, Fas, İklim.

CONTENTS

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ABBREVIATIONS

ADEME	:	French Environment and Energy Management Agency
ADEREE	:	Agency for the Environment and Energy Management
AMEE	:	Moroccan agency of energy efficiency
CDER	:	Renewable Energy Development Centre
CDM	:	Clean Development Mechanisms
CEEB	:	Building Energy Efficiency Code
CGDD	:	General Commissariat for Sustainable Development
COP	:	Conference of the Parties
DHW	:	Domestic Hot Water
EAHX	:	Earth-to-Air Heat Exchanger
EE	:	Energy Efficiency
EES	:	Energy Efficiency Solutions
EMC	:	Sustainable Construction Commission of the Cluster
EPS	:	Expanded Polystyrene Insulation
EU	:	European Union
FFEM	:	French Facility for Global Environment
FMCI	:	Moroccan Federation of Consulting and Engineering
GEF	:	Global Environment Facility
GEF	:	Global Environment Facility
GHG	:	Greenhouse Gas Emissions
HVAC	:	Heating, Ventilation and Air Conditioning
IAE	:	International Agency of Energy
IPCC	:	Intergovernmental Panel on Climate Change
JI	:	Joint Implementation

LED	:	Light-Emitting Diode
MHPV	:	The Ministry of Housing and City Planning
NDC	:	Nationally Determined Contribution
ONE	:	National Office of Electricity
PGES	:	Environmental and Social Management Plan
PNAP	:	National Priority Action Plan ()
PSE	:	Puget Sound Energy
PVC	:	Polymerizing Vinyl Chloride
RTCM	:	Thermal Building Regulations in Morocco
UNCED	:	United Nations Conference on Environment and Development
UNEP	:	United Nations Environment Program
UNFCCC	:	United Nations Framework Convention on Climate Change
UNDP	:	European Union Development Program
XPS	:	Extruded polystyrene insulation

1. INTRODUCTION

Almost every day, the media talks about climate emergency or global warming crisis. We have been informed about it for a long time. We are constantly terrified by the menacing changes of the climate emergencies caused by CO_2 emissions and energy reserves insufficiency. Their consumption will increase in the next years up to 30percent (Held, 2013). Minimizing energy consumption has become a fundamental survival strategy since we are living with the reality of the global warming threat and the decrease of fuels. The problem seems that these words are losing their meaning. What is the role of architecture in this crisis? Beyond indifference, mistrust towards architects seems to have developed in some sectors. The climate crisis is an opportunity to question our role.

According to the overwhelming scientific consensus of the Transition Pact, "*it is technologically, humanely and economically possible to limit global warming. The solution lies in our will* " (De Wrachien, 2017). However, the Moroccan government has begun to organize itself to limit greenhouse gas emissions. The reflection on the adaptation needed to climate change is often limited to improve the existing policy for preventing and managing the risks of natural disasters.

The building sector is the second largest energy consuming economic sector after transport, which accounts for 28percent of final energy consumption worldwide. In Morocco, this sector accounts for 25percent of the country's total energy consumption, of which 18percent is residential and 7percent is tertiary (COUNTRY PROFILE MOROCCO 2018 Renewable Energy Solutions for the Mediterranean & Africa RES4MED&Africa, n.d.). Moreover, energy consumption steadily grows in this sector with the rapid evolution of the housing stock. Therefore, the building sector represents a significant potential in terms of rationalization of energy consumption and an important source of greenhouse gas emissions reduction. Morocco adopted a thermal regulation of buildings in 2014 in order to register the building sector on the path of energy sobriety while emphasizing the thermal comfort of building users (“Morocco sets regulations for energy efficiency,” 2015). This regulation is an important step taken by Morocco, which indicates its will to reinforce the coherence between its strategy of renewable energies and its energy efficiency policy. In parallel, several public and private initiatives have emerged in recent years. It is highlighted through innovative, energy efficient, comfortable and aesthetic projects. Also, by good practices in the use of building elements, systems, and techniques adapted to climate diversity and uses. The main purpose of this thesis is to disseminate the good practices identified by the bearers of pilot cases, integrating energy efficiency and the renewable energies in the residential sector in Morocco.

The construction sector in Morocco accounts for more than a third of national final energy consumption, due to its high-energy consumption. It represents a significant source of energy savings through energy efficiency measures ("Buildings," 2019). For this reason, a thermal building regulation (RTCM) was adopted in 2014. Likewise, the building sector represents also a significant potential for integrating renewable energies with Morocco's energy strategy. Its major aim is to increase the share of renewable energy in terms of installed capacity to 52percent and to achieve 15percent energy savings by energy efficiency measures on the horizon of 2030 (UNDP/GEF PROJECT ENERGY EFFICIENCY CODES, 2013). This strategy contributes to the achievement of Morocco's climate commitments. It advocates an effective contribution to the efforts of the international community to reduce greenhouse gas emissions through a transition to low carbon development and resilience to climate change. In fact, Morocco's NDC projects a 42percent reduction in GHG emissions by 2030 ("Morocco," 2016). All sectors of high-energy consumption, including building, benefit from this reduction of GHG emissions according to their potential for greening. For the building sector, the aim is to minimize energy needs by ensuring proper building insulation and using renewable energy as much as possible to meet the residual energy needs. The combination of architecture and energy has always been a central element for the sustainability of a building, a neighborhood, a city, and even a territory.

1.1 RESEARCH AIM

Morocco, with its geographical and climatic diversity, represents a relevant example of empirical practices for adapting its built environment to its different natural environments. As a result, vernacular or traditional architecture, such as traditional medina-type houses, have always met certain environmental challenges by perfectly adapting to the different climates: humid, sub-humid, semi-arid, arid and desert. These architectural products are qualified as sustainable constructions using local materials such as earth, stone, and wood. Thick walls and massive flat roofs create inertia and comfort inside with well-ventilated environments designed to avoid overheating due to solar gains. These techniques, among others, show that Morocco has inherited an ancestral expertise that should be explored to promote sustainability and its issues today in order to guide its architectural production method. The correlation between architecture and energy is seen as a problem of different topics. It can be solved by finding solutions through the following questions:

a- Are social and cultural aspects important in energy management decisions for buildings?
b- Are the new technical means of energy efficiency applied to construction well developed and oriented?
c- Is energy saving in buildings related to the practice of architects?
d- How can architecture contribute to the reflection on the energy transition?
e- Are users aware of energy efficiency, renewable energies and thermal regulation in their building?

The main objective of this thesis is to disseminate the good practices identified and the lessons learned by the case studies that identify the best approaches and techniques for buildings which are both energy efficient and pleasant to live in. This thesis gives priority to the diversity of cases presented while taking into consideration the availability of documentation to characterize them.

1.2 METHODOLOGY

The methodological approach is the crucial point of the entire elaboration process for the integration of renewable energies and energy efficiency in Morocco. That is why it should be given the greatest attention. The objective of the elaboration is aimed at encouraging the use of energy efficiency techniques and renewable energies in the building.

The methodological approach by its content and the scope of its investigation, urges us to first adopt an analytical approach. It includes the analysis of the existing case studies in terms of documents, studies, and available data, in addition to the analysis of the interviews with the relevant population. This contextual approach is likely to lead us to analyse some buildings, depending on the availability of information and data. The study is based on contextual analysis, and adopts an analytical approach using three inputs (regulatory, conceptual, and technical) to analyse and measure the efficiency and effectiveness of these pilot cases.

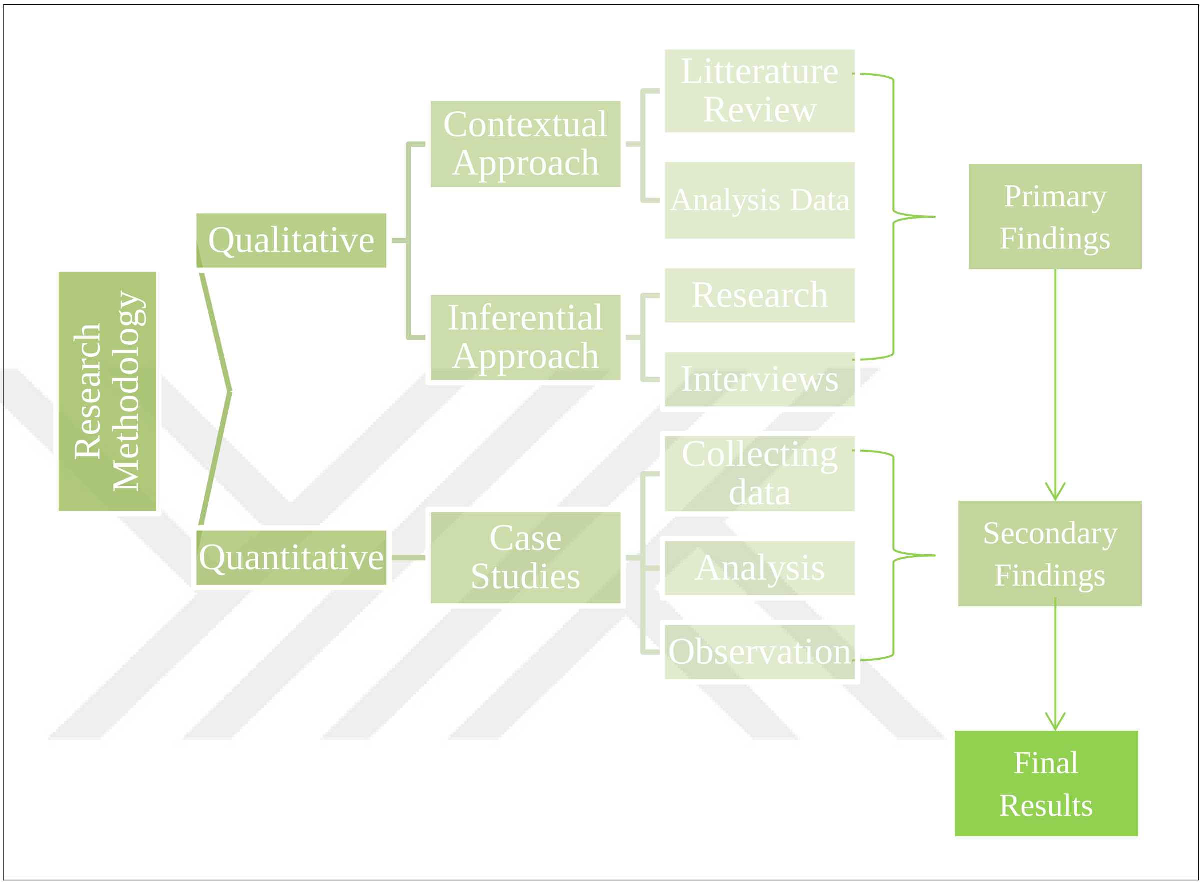
The energy aspect of residential habitats (individual housing and collective, social and economic housing), is analysed for a sample of buildings. The analysis takes into account criteria such as climate, singularity of the building, its design, its use and the availability of information. Thanks to qualitative, climatic, energetic and numerical simulations, the study is able to make the first approach to energy balance comfort to determine the impact of energy consumption on the environment, and to analyse these buildings at different scales (design equipment and energy management).

The second part is the qualitative inquiry; open-ended interviews are adopted for data gathering. Since, these interviews will help to understand the perception, of people on the integration of energy efficiency regulations into the building's envelope.

The collected data is subjected, analysed, and then discussed in reference to the related literature. Moreover, a concluding statement including general observations about the topic of the research, proposing research's extensive points to be studied further by other researchers. The methodology proposed makes it possible to identify, in a simple way, solutions for designing buildings with low energy consumption. The solutions are selected using tables defined by study cases. The determination of all these configurations would be difficult or even impossible to achieve directly using digital simulation. This methodology will allow us to compare different buildings built in different climates. With this knowledge, the established rules help the designer to create a building using less energy.

Finally, this methodology provides a strong basis for the development of support measures for the various actors in the building sector. Especially, the design approach of new buildings and the thermal renovation of existing buildings, according to the criteria of the low-energy consumption buildings.

Figure 1.1: Methodology of the thesis



1.3 LIMITATION

This issue is a challenge for architectural and urban practices, which over the past 20 years have evolved rapidly to reflect the principles of sustainable development. Hence, there is a need to find new ways to design and develop the space that seeks to reduce energy consumption, and to limit CO2 emissions. In addition, there is also a strong demand to improve the comfort of users, to propose modes of development more respectful of the environment and to offer sustainable solutions. As part of the national energy strategy, several actions have been initiated, including institutional and legal, which include:

•*‘‘Law No. 47-09’’* on energy efficiency.

• *‘‘Law No. 13-09’’* on renewable energies.

• *‘‘Law No. 58-15’’* amending and supplementing *‘‘Law No. 13-09’’* on Renewable Energies.

• The Code of Energy Efficiency in the Building Industry (CEEB), including the Building Thermal Regulation in Morocco (RTCM) setting the energy performance of buildings and establishing the National Energy Efficiency Committee in the Building.

• The guide of good practices for the energy control at the scale of the city and the habitat initiated by the Department of the Habitat and Urbanism.

Thus, the elaboration of this thesis aims to highlight the short, medium and long-term comparative advantages of energy-efficient buildings in the Moroccan context, and to identify and document the most relevant study cases.

For the sake of clarity, this thesis will be organized as follows:

- The first part: includes the introduction of the research, which explains climate emergencies caused from CO_2 emissions, energy reserves insufficiency and our need for energy that leads us to take some serious steps as a national duty. This part also illustrates the methodology, the aim of the study, in addition to the research question and the limitation of the study.

- The second part: within this chapter relevant former literature were analysed. It contains theoretical studies about the sources, Therefore the name Literature Review is given to this chapter. Various hypotheses are evaluated in the same manner.

- The third part: This chapter is devoted to the architectural and technical dimension by establishing relationships between architecture, thermal comfort, climate, and energy.

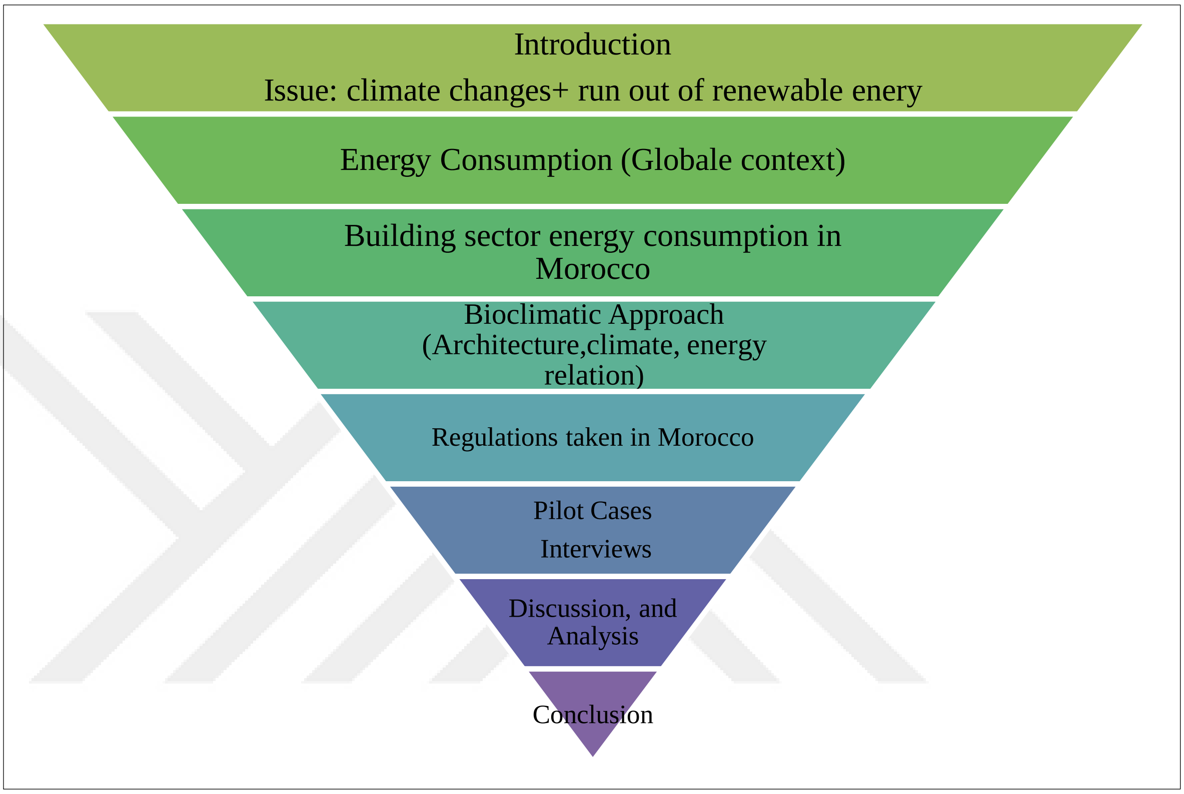
- The fourth part: It presents the regulatory framework in Morocco for energy efficiency, renewable energies and thermal regulation in buildings.

- The sixth part: presents some study cases in Morocco for the integration of renewable energy and energy efficiency.

- The seventh part: discusses the findings emerged in the analysis. Therefore, this section is named as Data Analysis and Discussion.

- The last part: is the conclusion, where further recommendations were proposed for decision makers and for future researches as well.

Figure 1.2: Thesis Structure



2. LITERATURE REVIEW

2.1 THE EARTH SUMMIT OF RIO: SUMMARY OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

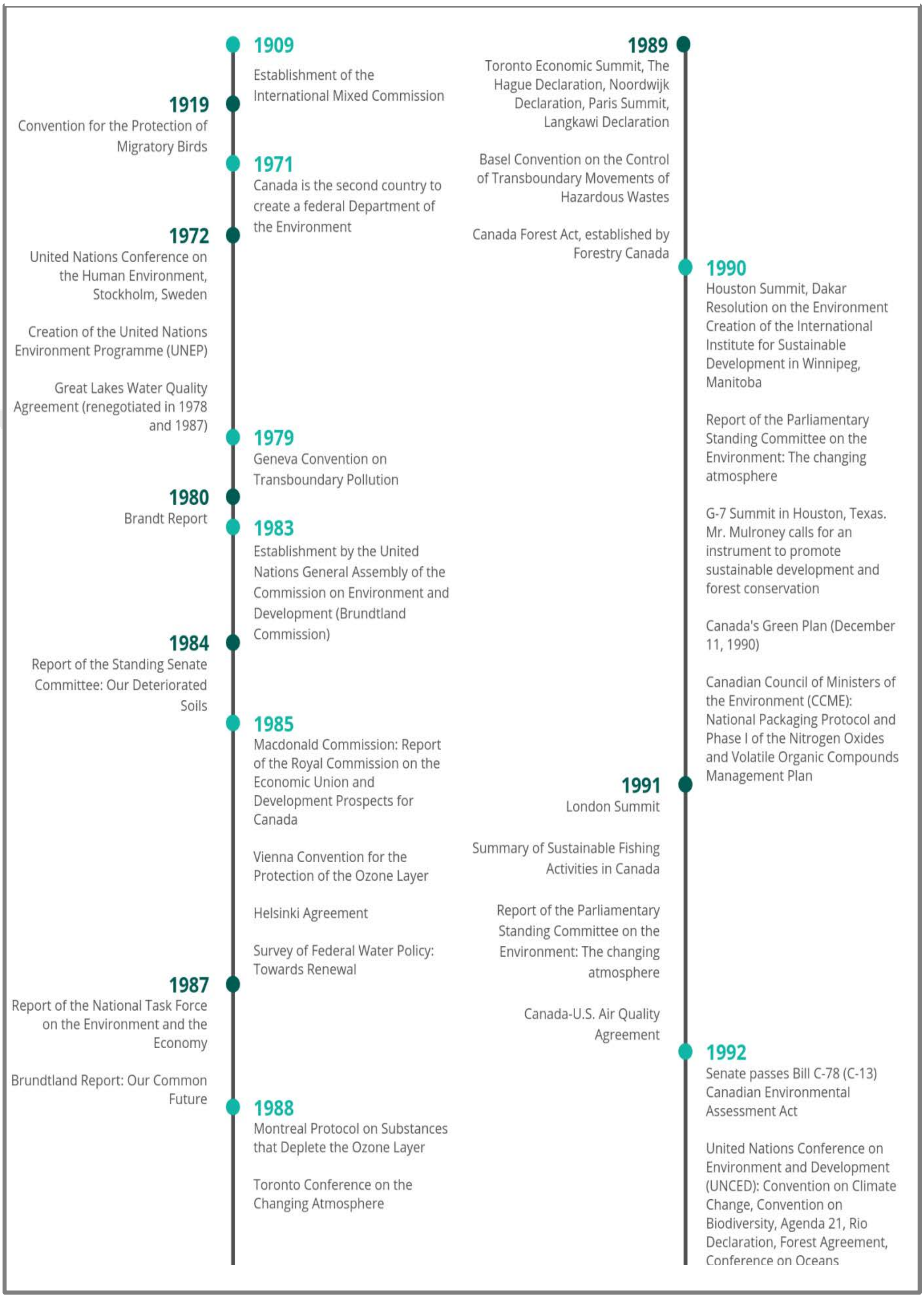
Gro Harlem Brundtland, Norwegian Prime Minister, claimed that: *"we do not inherit the land from our parents; we borrow it to our children"*. He added that: *"we cannot afford to betray future generations. They will judge us with a very severe eye if we fail at this crucial moment"* (Godlee, 1998). Furthermore, Boutros-Ghali, Secretary-General of the UN added: *"we will waste the planet's resources for a few more decades, but one day, the storm will hit our descendants hard. For them, it will be too late"* (Boutros Boutros-Ghali Appointed U.N. Secretary-General, 1992).

2.1.1 History

The UNCED's first "Earth Summit", was the result of two and a half years of global consultations aiming to show the importance of living responsibly (Raloff, 1992).

Many international environmental agreements and compliances have been concluded since 1972 till 1992, as follows:

Figure 2.1: Earth Summit Timeline



Source: Derived from *Sachs, 1978& Raloff, 1992*

2.1.2 The pre-Rio Summit ambitions

UNCED addressed many environmental issues, such as: air, land, and water protection; in addition to forests and natural resources conservation. This was a great chance to restrain and control human behavior that endangers the planet and causes pollution, drought, global warming, and damage of the ozone layer (Raloff, 1992a).

Other issues, which widened the gap between the countries of the North and the South, added to the issues already listed: development models that affect the environment, poverty in developing countries, economic growth, unsustainable consumption patterns, and demographic pressure including its impact on the international economy (Friends, 1992).

2.2 THE CLIMATE DEBATE SINCE THE EARTH SUMMIT IN RIO (1992 - 2018)

The June 1992 Conference in Rio de Janeiro marked the beginning of a major global program to combat climate change, biodiversity loss, desertification and the elimination of dangerous toxic products. In 2012, the Conference known as "Rio +20", whose main themes were the green economy and the reform of international institutions in charge of sustainable development. It concluded with a text that reaffirms good intentions. In December 2015, France chaired the Conference of the Parties to the 2015 United Nations Framework Convention on Climate Change (COP21), which summarizes the adoption of the Paris Agreement to contain the rise in global temperatures (Quarrie, 1992).

2.2.1 The COPs were born at the Earth Summit of Rio de Janeiro

Since 1995, more than 100 countries from all over the world have met each year at COPs to discuss climate and the fight against global warming. Due to the complexity of the subject and the issues behind it, it has been a long and challenging process that involves environmental, economic, social and diplomatic issues.

In 1992, more than 178 nations participated in Rio de Janeiro for the ONU Conference on Environment and Development. Significant progress has been made, such as the signing of the Rio de Janeiro Declaration on Environment and Development, which provides an "official" definition of sustainable development (A/CONF.151/26 (Vol. IV).

In this declaration, a climate convention is presented which supports the need to reduce greenhouse gas emissions in order to minimize the human impact on climate change. Every year, the countries having signed the Rio Summit's climate convention will meet to find realistic solutions to fight against climate change: it is the famous "Conference of the Parties" that will take place each year in a different city. Non-governmental actors will also take part (non-governmental organizations, companies, cities, citizens, etc.) in order to better represent the society that must fight against climate change (On, 1993).

2.2.2 The pre-Kyoto

The first COP took place in 1995 in Berlin. It sets for each country or region-specific targets for greenhouse gas emissions and the corresponding reductions to be achieved. This numerical commitment includes a series of measures and political commitments (Affan, 2019).

The second COP took place in Geneva in 1996. It took place just after the publication of the second report of the IPCC (Intergovernmental Panel on Climate Change), which reinforces the burden on the role of greenhouse gas emissions from anthropogenic sources. It states and acknowledges that "climate change is a danger to humanity".

2.2.3 Kyoto and its ratification

In 1997, the Conference of the Parties was held in Kyoto for its third year. For the first time in human history, a binding protocol has been formulated to regulate the CO2 emissions of more than a hundred countries. The objectives are quantified: to reduce global greenhouse gas emissions by 5.2percent by 2020, using 1990 as the reference year. For the European Union, this objective translates into a total reduction in emissions of 8percent (Affan, “Earth Summit: From Rio 1992 via Kyoto and Copenhagen, Back to Rio 2012”).

Flexibility mechanisms are also being explored to help signatory countries to reduce their own emissions. They will lead to the creation of Clean Development Mechanisms (CDMs) and Joint Implementation (JI).

To be able to become effective, the Kyoto Protocol had to be ratified in at least 55 countries. It couldn't be done until 2002 when Iceland commits to reduce its emissions. In other words, it took 5 years to implement this protocol! It was officially ratified in 2005 at COP11 in Montreal. The major disappointment of the Kyoto Protocol was that the world's two largest emitters of greenhouse gases did not ratify the agreement: the United States and China. Similarly, Canada did withdraw from the Kyoto Protocol in 2011(Affan,2012).

2.2.4 The post-Kyoto Protocol

One of the objectives of the COPs following COP11 in Montreal was to think about the post-Kyoto period. A second commitment period of the Kyoto Protocol was decided until 2020 in Doha at COP18.

It must be understood that the negotiators' great fear was to fail on finding a new binding agreement that could affect all countries, especially the most emitting ones. The COP15 in Copenhagen, for example, was a great disappointment because the expectations were so high. Finally, the United States and China refused to make their reduction targets binding, undermining a united fight against climate change. However, COP15 in Copenhagen affirmed that the nations of the world wanted to limit global warming to below +2°C (Grunewald and Martinez-Zarzoso, 2019).

Table 2.1: List of Conferences of the Parties since 1995

Year	COP	City	Country
1995	COP1	Berlin	Allemagne
1996	COP2	Genève	Suisse
1997	COP3	Kyoto	Japon
1998	COP4	Buenos Aires	Argentine
1999	COP5	Bonn	Allemagne
2000	COP6	La Hague	Pays-Bas
2001	COP6	Bonn	Allemagne
2001	COP7	Marrakech	Maroc
2002	COP8	New Delhi	Inde
2003	COP9	Milan	Italie
2004	COP10	Buenos Aires	Argentine
2005	COP11	Montréal	Canada

Year	COP	City	Country
2006	COP12	Nairobi	Kenya
2007	COP13	Bali	Indonésie
2008	COP14	Poznań	Pologne
2009	COP15	Copenhague	Danemark
2010	COP16	Cancún	Mexique
2011	COP17	Durban	Afrique du Sud
2012	COP18	Doha	Qatar
2013	COP19	Varsovie	Pologne
2014	COP20	Lima	Pérou
2015	COP21	Paris	France
2016	COP22	Marrakech	Maroc
2017	COP23	Bonn	Allemagne
2018	COP24	Katowice	Pologne

Source: Grunewald and Martinez-Zarzoso, 2019

2.3 TIMELINE OF THE MAJOR CHALLENGE OF CLIMATE CHANGE

This Timeline is retrieved from the following references: Global Warming Timeline, 2019, Witze, 2007, Donlon and Britain, 1992, Digumarti Bhaskara Rao, 1998

1992

Earth Summit in Rio de Janeiro, Brazil. 154 countries signed the Convention on Biological Diversity and adopted the United Nations Framework Convention on Climate Change (UNFCCC): its objective was to stabilize atmospheric concentrations of greenhouse gases by taking into account the differentiated responsibilities of industrialized and developing countries.

1994

Publication in OJ No 32 of Law No 94-106 of 5 February 1994 authorizing the ratification of the United Nations Framework Convention on Climate Change adopted on 9 May 1992 and signed by France on 13 June 1992. After its ratification by 50 States, the Convention entered into force on 21 March 1994.

1995

Communication to in the Council of Ministers the Berlin Conference on the Implementation of the International Convention on Climate Change concluded in 1992. In particular, the participants agreed to open new negotiations with a view to adopting, in 1997, new commitments valid for after the year 2000.

1997

In the Earth Summit of New York, the United Nations General Assembly Special Session (known as "Rio +5") reviews the commitments made in Rio five years ago and notes the disagreement between the European Union and the United States on the reduction of greenhouse gases. On 16 December in Luxembourg, EU Environment Ministers call on their partners in the Climate Change Convention to make ambitious proposals on reducing greenhouse gases before the International Conference in Kyoto (Japan) in December. On 22nd, US President Bill Clinton presented US proposals for reducing greenhouse gas emissions, including the objective of stabilizing emissions at their 1990 level around 2010, as well as the establishment of an international market for "rights to pollute".

2000

Between January and February , at the end of an inter-ministerial commission, presentation to the press by Lionel Jospin, Prime Minister, of a national program to combat the greenhouse effect comprising 96 measures, including the introduction of an ecological tax dissuasive. In March, the European Commission publishes a "Green Paper" presenting a draft "emissions trading scheme". And in November, UN Conference on Climate Change, The Hague, Netherlands, defined the modalities for implementing the 1997 Kyoto Protocol. Negotiators from the 182 countries represented failed to reach an agreement. In a statement on 20 November, President Jacques Chirac urged the United States to keep its commitments in the fight against global warming and proposed a "North-South partnership for sustainable development".

2001

- Promulgation of Act No. 2001-153 to make the fight against the greenhouse effect and the prevention of risks linked to global warming a national priority and to establish a national observatory on the effects of global warming.

- Mid-June, EU-US Summit in Gothenburg (Sweden). In a final declaration, the United States and EU countries agree on the need to launch a new round of trade negotiations in the WTO as soon as possible, acknowledging their disagreement on the 1997 Kyoto Protocol, but wishing to continue the dialogue on global warming.

- At the end of December, as part of the 1997 Kyoto Protocol, the French government launched a consultation with companies to enable them to make voluntary commitments to reduce their greenhouse gas emissions.

2002

- The European Union and its 15 Member States ratified the Kyoto Protocol. 4th Earth Summit, known as the "World Summit on Sustainable Development", in Johannesburg.

- UN Climate Change Conference in New Delhi, India, the final declaration of the conference, which brought together 185 countries, reiterated the need to ratify the Kyoto Protocol on the limitation of CO2 emissions.

- EU Environment Ministers, meeting in Brussels, have expressed strong support for the establishment by the European Union of the first carbon dioxide emissions trading scheme.

2003

- The European Parliament approves the establishment, on 1 January 2005, of a European market for carbon dioxide (CO2) emission rights, which aims to facilitate the European Union's (EU) compliance with the 1997 Kyoto Protocol.

- Meeting of the United Nations Climate Change Conference in Milan, Italy. The participants reaffirm their commitment to the Kyoto Protocol on the reduction of greenhouse gas emissions.

2004

Presentation of the 2004 Climate Plan by Serge Lepeltier, Minister of Ecology and Sustainable Development: launch of an information program of €3 million per year from 2004 and at least over 3 years, conducted by the Environment and Energy Management Agency.

2005

- Entry into force of the Kyoto Protocol. Signed in 1997, it aimed to reduce greenhouse gas emissions from industrialized countries to below 1990 levels during the period 2008-2012.
- Prime Minister Jean-Pierre Raffarin set up the National Council for Sustainable Development (CNDD), created in 2003 and renewed in 2005, which he asked to consider ways to reduce greenhouse gas emissions by a factor of four by 2050.
- Promulgation of a decree providing for a 40percent reduction in nitrogen oxide emissions and a 50percent reduction in sulphur dioxide emissions from petroleum refineries by 2010, with much stricter limits on dust emissions.
- From November 28 to December 9, meeting in Montreal of the UN climate conference bringing together the countries party to the 1992 Rio Convention (including the United States) and the countries acceding to the 1997 Kyoto Protocol to ensure a future beyond 2012 in the fight against climate change.

2007

- The European Commission presented a series of proposals setting ambitious greenhouse gas reduction targets: reducing developed countries' emissions by 30percent (compared to their 1990 levels) by 2020.
- reunited on February 3 in Paris at the initiative of French President Jacques Chirac, 46 countries were called for the creation of a United Nations Environment Organization, a project contested in particular by the United States and the major emerging countries.
- The European Council validated the greenhouse gas (GHG) emission reduction targets presented by the Commission on 10 January 2007.

2.3.1 Global warming highlighted by IPCC report

2007

- On the 6th of April, in a summary intended for world leaders, the IPCC made an alarming observation of the consequences of global warming.

- Establishment of the Major Economies Forum on Climate Change US President George W. Bush is launching the GEF (Major Economies Climate Forum) to compete with the United Nations-led negotiations.
- Intended to refund the politics of ecology in France, the Grenelle of the environment is spread over 4 months.
- The signing of the Montreal Agreement on the Elimination of Ozone Depleting HCFC (Hydro chlorofluorocarbons) Chemicals by 190 Countries plus the European Union.
- Trip to New York (United States) by Nicolas Sarkozy, President of France, on the occasion of the opening of the general debate of the 62nd session of the UN General Assembly.
- The appointment in Council of Ministers of Brice Lalonde, former environment minister and honorary president of Generation Ecology, as ambassador in charge of climate negotiations.
- UN Conference on Climate Change in Bali, Indonesia, on the 11th, the UN announces the launch of an adaptation fund, intended to help developing countries cope with the consequences of global warming.

2008

- The European Commission presents the Energy-Climate Package, proposals for action to achieve the objectives set by the European Council of 8 and 9 March 2008. The climate-energy package consists of a set of four texts:

a proposal for a directive to improve and extend the EU Emissions Trading Scheme (ETS),

a proposal for a decision imposing GHG emission reductions on economic sectors not covered by the ETS,

a proposal for a directive on the promotion of renewable energies,

a proposal for a Directive setting out the legal framework in which carbon capture and storage could be developed.

- Opening of new international climate change negotiations in Bangkok (Thailand) under the UN Framework Convention on Climate Change (UNFCCC) expected to culminate in an agreement at the December 2009 Copenhagen Conference global emissions reduction.

- Meeting in Poznan (Poland) of the UN Conference on Climate Change. An agreement is reached in extremis, after two weeks of difficult negotiations, on the "roadmap" which will culminate in 2009, in Copenhagen, to a new treaty. It will take over from the Kyoto Protocol on reducing greenhouse gas emissions, which expires in 2012.

2.3.2 EU adopts the climate-energy package

2008

- Adoption of the "climate-energy package" by the European Council: this is a plan to combat global warming for the 2013-2020 period.
- Promulgation of the finance law for 2009 which sets up a "green taxation": tax credits on loan interest and zero-rate loans in the case of purchase of housing complying with the "low energy building" standard.

2009

- Second negotiating session of the future agreement on climate change, Bonn, Germany. Delegates from 183 countries note their many disagreements by beginning to read the first negotiating text submitted to them.
- Meeting of the Major Economies Forum on Energy and Climate (FEM) in Jiutepec (Mexico). After a session in Washington on April 27 and 28, 2009, and in Paris on May 25 and 26, the Major Economies Forum holds its third round of preparations for the Copenhagen Conference in December 2009. The Mexican proposal established a Green Fund "fueled by a contribution from the richest countries to finance programs to combat global warming according to the needs of states is debated”. The GEF was relaunched in March 2009 by US President Barack Obama, who declared his country ready to lead the fight against climate change.
- Presentation of the report of the conference of experts and the round table on the Climate and Energy contribution, chaired by Michel Rocard.
- The introduction of a "climate-energy" contribution (CCE).
- The Law of 3 August 2009 on the programming relating to the implementation of the Grenelle de l'environnement, list of measures for the implementation of the Grenelle de l'environnement, some of which concern climate change.

- Summit on the fight against climate change, in New York (United States). At the initiative of UN Secretary-General Ban Ki-moon, a hundred or so heads of state meet to try to find a compromise in international negotiations on climate change deadlock for several months.
- Jean-Louis Borloo, Minister of Energy and Sustainable Development, in charge of climate negotiations, presents a plan called "Justice-climate": it is about mobilizing industrialized countries to help countries more vulnerable to climate change to finance the development of renewable energies.
- UN Climate Change Conference in Copenhagen (Denmark) with the goal of finding a global agreement on reducing greenhouse gas emissions for the post-2012 Kyoto Protocol expiry date. The Accord signed at the Conference affirms the need to limit global warming to 2 ° C compared to the pre-industrial era.
- Promulgation of the Finance Act for 2010. All the provisions concerning the introduction of a "carbon tax" provided for in the original text have been censored by the Constitutional Council.

2010

- A report by the United Nations Environment Program (UNEP) concludes that there are insufficient emission reduction commitments to meet the 2 ° C target.
- Signature of the Cancun Agreements on the occasion of the 16th Conference on Climate Change, held in Cancun, Mexico.

2011

- 17th Conference of the Parties to the United Nations Framework Convention on Climate Change, Durban, South Africa. With the Agreement signed at the Conference, all major greenhouse gas emitters agree to join an international agreement to reduce greenhouse gas emissions, to be adopted in 2015, to be effective from 2020.

2012

- United Nations Conference on Sustainable Development (Rio + 20), Rio de Janeiro, Brazil. Representatives from 193 countries together adopt a final declaration "the future we want" to launch a process leading to the establishment of Sustainable Development Goals (SDGs).

- International Climate Conference in Doha. The European Union, Australia, and more than 100 countries pledge to continue their efforts to reduce greenhouse gases by 2020 specify their financial commitments in Durban and adopt a roadmap for mark negotiations until 2015.

2014

- Presentation in Council of Ministers by Ségolène Royal, Minister of Ecology, Sustainable Development and Energy, a draft law on energy transition. It plans to reduce greenhouse gas emissions by 40percent by 2030 (75percent by 2050).
- UN climate summit in New York at the initiative of the Secretary-General, with the aim of mobilizing the heads of state and government and the actors of the civil society on this question.
- Publication of the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) that climate change could have irreversible and dangerous impacts, but options are still available to limit its effects.
- Adoption by the Council of the European Union of the 2030 Climate Change Package.
- Climate Agreement between China and the United States, signed in the margins of the Asia-Pacific Economic Cooperation Forum.
- 20th Climate Conference (COP20) in Lima (Peru). It leads to an agreement that constitutes a working basis for preparing Paris 2015 (COP 21).

2015

France chairs and hosts the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21 / CMP11).

2016

- Signature of the Paris climate agreement by 177 parties in New York.
- Promulgation of the law authorizing the ratification of the Paris Agreement adopted on 12 December 2015 (OJ of 16).

- Meeting of the 22nd United Nations Conference on Climate Change (COP 22), in Marrakech: setting the agenda for the coming years and in particular for 2018, the possible increase in the targets for reducing greenhouse gas emissions greenhouse gas from developed countries, a reminder of the goal of mobilizing the $ 100 billion a year pledged in Copenhagen in 2009 by developed countries to help the poorest countries to fight against climate change.

2017

- 23rd Conference (COP 23) of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), lead by Fiji.
- Climate Summit, "One Planet Summit", in Paris. Decided by Emmanuel Macron after the announcement by Donald Trump of the US withdrawal from the Paris Agreement and co-organized by the UN and the World Bank, this meeting focuses on the issue of financing climate action.

2018

- Publication by the Intergovernmental Panel on Climate Change (IPCC) of a special report on the consequences of global warming of 1.5 ° C.
- 24th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), known as COP24, in Katowice, Poland.

2.4 ADAPTATION TO THE CONSEQUENCES OF CLIMATE CHANGE

According to the Environment and Energy Management Agency, the world is changing as a result of climate change (Jackson, 2018). Its consequences are already visible in the world today (changes of rainfall and water regimes, longer periods of climatic extremes, seasonal shifts, sea level rise, desertification, etc.). Its anthropogenic origin is no longer debatable. It is up to us and local authorities to find an agreement to reduce greenhouse gas emissions despite the difficulties of such a policy.

While a climate, the agreement is essential to ensure the future of people. The effects of climate change are already being felt today, everywhere in the world, in both developed and developing countries. The greenhouse effect is an old and crucial phenomenon done by humans (“Expertise, Climate change – ADEME,” 2018). However, the increase in the concentration of greenhouse gases is a source of an additional greenhouse effect that causes global warming. A concentration largely due to the consumption of fossil fuels that different policies, national or international, are working to reduce in order to encourage a reduction in carbon emissions. To halt the increase in greenhouse gases and limit the effects of climate change, one of the major actions is to put in place an integrated policy for reducing energy needs, energy efficiency and the development of renewable energies. One of the key measures is, for example, the creation of energy saving certificates. Correlatively, it is claimed that we must also respond to the impacts of climate change already underway, by implementing an adaptation policy that reduces our exposure and vulnerability to these effects.

In line with climate change's ecological and energy transition, the impacts of this change affect us all and will change our environment and lifestyles. As several studies show, it is in our interest to anticipate the consequences of climate change by integrating this issue into our projects now. Planning and financing adaptation actions now will allow us to reduce the negative impacts of climate change and optimize the effectiveness of our investments. Adaptation actions can reduce the sensitivity of activities to the consequences of climate change. We can adjust activities, to optimize energy resource management through the control of its consumption, and choose a bioclimatic architecture for the design of a building, in order to benefit from a natural summer cooling. The reduction of greenhouse gas emissions can be achieved by supporting local authorities, developing new knowledge through the funding of research projects, and integrating the issue of adapting our actions in the building, urban organization, and other sectors to climate change.

2.5 FROM A TRADITIONAL HABITAT DESIGN TO THE CONCEPTION OF A CITY UNDER THE INFLUENCE OF CLIMATE AND HEALTH CONDITIONS

Roaf points out that "*buildings are our third skin*"; it is true that first designed to protect people and property from external climatic constraints and hazards, the building has seen and sees the extent of its functions expand as it evolves over time ("Adapting buildings and cities for climate change," 2005). Today, in addition to protecting us and our property from climatic events, it must be able to offer a pleasant environment, which means, for example, controlling the indoor environment (heating in winter, air conditioning in summer, etc.), but also paying attention to noise, light, etc., always taking into account cost constraints and limiting environmental impacts.

In recent decades, the issue of energy efficiency has also emerged with the introduction of increasingly ambitious thermal regulations. In addition to the economic constraints that motivated these actions, the prospect of climate change, closely linked to fossil fuel consumption, has also been added today. Several elements of climate are taken into account in the design of the building (solar radiation, temperature, winds, atmospheric humidity, precipitation, etc.). Each region has a traditional habitat whose design and form are closely linked to the climate. Givoni (1978), Griffiths (1976) and Escourrou (1991) noted and explained these differences. From dry and hot climates to cold climates, including hot and humid or Mediterranean-type climates, the choice of materials and the shape of the building are partly determined by climatic constraints. Local resources have also greatly influenced the choice of materials.

For hot and dry or Mediterranean climates (hot and dry summers, mild and humid winters), the objective is to let as less heat as possible penetrate the interior of the building. white or light-colored walls and roofs are preferred (this limits heat absorption by the walls through a greater reflection of solar radiation), walls are thick to slow heat diffusion and to absorb temperature variations indoors, the openings are small, and depending on the region, cool wells with vegetation and water can also be installed. Scientific knowledge has made it possible to gradually master many aspects of construction in relation to its climate and environment in a wider context. Since the middle of the 20th century, regulations have constantly taken into account new requirements to satisfy a certain level of comfort for occupants, preserve buildings, and reduce noise and energy consumption.

In Morocco, thermal regulations take into account different climatic zones. It is true that energy, or more precisely energy consumption, and climate are closely linked. This relationship is also strongly influenced by people's behavior, and their relationship to buildings and comfort, under pressure from economic resources. Today, technology makes it possible to overcome local climatic conditions and traditional skills to design buildings with a pleasant indoor atmosphere in all seasons. The city currently hosts many of these buildings with a pleasant interior atmosphere, but what about its own relationship with the climate?

Until very recently, the climate has not been a major concern for urban planners. As Adolphe et al (2002) point out that the actors in urban planning and spatial development have now lost this memory on the climatic effects of the urban form, on the regulatory influence of vegetation, or on the beneficial role of water spaces (river corridors, fountains, etc). These actors currently lack the basic tools and data needed to integrate the characteristics of the climate environment into their thinking at the three highly interlinked scales of regional climate, mesoclimate (at the urban scale), and microclimate (at the block scale). However, these tools and knowledge do exist, but they are the responsibility of specialists (on the one hand, architects and theoreticians on the energy behaviour of buildings with "High Environmental Quality", on the other hand, climatologists or aerialists).

The absence of climate concerns has not always been the case and various interventions have even had the stated objective of improving air quality or climate in the city as shown in his thesis Benzerzour et al.2011. Before the second half of the 20th century, developers did not yet talk about urban climate but became aware of the changes they could make.

2.6 TRADITIONAL BIOCLIMATIC ARCHITECTURE

In the current context, we can observe an increase in architectural concerns for energy, water consumption and the use of non-polluting materials. Among these concerns, bioclimatic architecture occupies an important place, especially at the cultural level of the regions, because it has a strong cultural heritage. It is indeed from traditional architecture that bioclimatic architecture develops certain techniques learned and evolved since the design of the shelter. In the 1970s, bioclimatic architecture studied the physical phenomena concerning the thermal comfort of traditional architecture in order to understand and reproduce them in a new architecture. In addition, with the emergence of sustainable development, concepts such as sustainable architecture and numerous environmental assessment methods have been created, giving different approaches and ways of approaching current environmental issues.

2.6.1 Hassan Fathy's Approach:

Egyptian pioneer of sustainable development, Hassan Fathy (1900-1989) was celebrated throughout the world during his lifetime. Convinced that it was necessary to offer the Egyptian people cheap and climate-friendly houses, made using traditional raw brick technology (tub il ahdar), he built a village on the west bank of Luxor, the New Gourna, in the late 1940s. He is known worldwide for his book Gourna, a Tale of two villages, published in English in Cairo in 1969 and translated into many languages, including French from 1970 under the title of "Building with the People ". However, his architectural work should not be underestimated or his other theoretical and political interventions on the extension of Cairo or more generally on urban planning underestimated. A graduate of the Department of Architecture at the Cairo Polytechnic School (1926), he obtained his first job in municipal administration (1926-1930), where he discovered rural poverty and proposed economical buildings built with a cheap and abundant material, raw earth brick (Fathy and Yana Kornel, 1970). His finely designed projects and creations reflect an incredible diversity of forms, which result both from his borrowing from traditional buildings, from simple rural settlements to medieval princely residences, and from his own research, particularly on vaults and domes.

Old and new village

The publication of his book on Gourna has given him an international reputation. It is based on the meaning of the French title, which implies that the author is a supporter of self-construction, vernacular architecture, and architecture without an architect, which borders on misinterpretation. With this "Tale of Two Villages", Hassan Fathy describes both the old and the new Gourna, for which he is responsible, with the ambition of writing a literary work and not just an architectural work. The anonymous editor of the biographical note on the Egyptian architect in the Universal Encyclopaedia agrees with this analysis, and notes that Hassan Fathy is "a paradoxical and controversial personality, held by some to be a true saint, a guru training many disciples in the world, but considered by others to be a mystical and retrograde illuminated man. "Hassan Bey" became interested very early on, at the end of the 1930s, in the indigenous traditions of his country and the cultural authenticity of the rural world, opposing them to the disorder and corruption that he perceived as a result of the techniques and models imported from the West.

His book does not present itself as a simple account of a construction site that has gone wrong; it is an initiation that is scrupulously described. Thus, the chronology of the project, the start and the incomplete implementation of the new village of Gourna, is interspersed with reflections that evoke Hassan Fathy's other professional experiences, past or present. He indicated his intention: *"It was to build a village where the fellahs would lead the kind of life I wanted for them"* (Fathy and Yana Kornel, Construire Avec Le Peuple, 1970) Given the economic conditions of country, Hassan Fathy opted for mud brick architecture with vaults without arches, to save wood. He points out that this does not mean that a poor architecture is not for the poor, but it is a question of simple materials that nevertheless allow a high quality aesthetic. *"The vault, the dome, the trunks and pendants, the arches and the walls provide the architect with an unlimited field of rational entanglements of curved lines going in all directions, with a harmonious passage from one to the other,"* he says. He recalls the exhibition he had mounted in 1937 on the uses of clay bricks and recounts a misadventure. A foundation asks him if he can build a village. He made it a point to build earthen houses, all different, for a unit price of 150 pounds and built one.

In December 9, 1982 in his Acceptance speech for the alternative Nobel Prize, Hassan Fathy said: *"How can we move from the system architect-builder to the self-constructing architect system? A man cannot build a house, but ten men can build ten houses very easily, even a hundred houses. We must submit technology and science to the economy of the poor and the cash-strapped. We must add the aesthetic factor"*.

It is certain that during the 1970s and 1980s, many architecture students around the world read and quote it. In France, it is mainly students from the Third World who make it a manifesto and transform its author into a spokesman for popular architecture. They are reinforced by the "spirit of the times". Indeed, the American architect of Austrian origin Bernard Rudofsky (1905-1988) published in 1964 Architecture without Architects: a short introduction to non-pedigreed architecture, a book that was very successful and oriented the spotlight towards the vernacular, self-construction. The English architect of libertarian sensitivity John Turner (born in 1926) observed spontaneous housing in Lima and Mexico City, also published in 1966 with Robert Fichter Freedom to Build, dweller control of storehouses process, and published in

1972, Housing by People: Towards autonomy in Building environments, translated into French in 1979 under the title, “Le Logement est votre affaire”. During this period, the French architect residing in Algeria, André Ravereau, worked hard to promote the M'Zab and its bioclimatic architecture. He asked Hassan Fathy to preface his book, Le M'Zab, a lesson in architecture. An exhibition on Earth Architecture was held in Beaubourg and the Grenoble School of Architecture created the CRA-Terre laboratory in 1979, an international centre for earth construction. At a more institutional level, the United Nations Conference on the Environment held in Stockholm in 1972 recommended "eco-development" and prepared the "Habitat 1" meeting, held in Vancouver in 1976, where participants exchanged methods, diagnoses, analyses and initiatives to make the world more livable. Finally, in May 1968, and its demands for more self-management and participation by the inhabitants, the action of neo-rurals with self-construction and catalogues of alternative architectures ("do it yourself!"), all this contributes confusingly to the "air of the times" and to the way Hassan Fathy's work is interpreted. We know that a book, once published, no longer belongs to its author but to its readers. This is where the French title can be misinterpreted, which was the case. In this after May 68 - the book was translated in 1970, the year in which the magazine Espaces et Sociétés was published, directed by the "Marxian" philosopher Henri Lefebvre, and by the architect and historian of modern architecture Anatole Kopp - "with the people" means "participation of the inhabitants", "basic democracy" means "egalitarianism", "experts at the service of the people", etc. However, we have seen it by closely following the book, the Egyptian architect built for the people, not with the people. His "for the people" means that he has in mind an image of the well-being of the people, which he wishes to transmit and apply. In a country with blatant economic inequalities, a strict social hierarchy, a pernickety and corrupt bureaucracy, elites fascinated by modernity from America and ready to systematically denigrate everything that appears local, in the absence of a social housing policy - a concept then unknown - and architects who are concerned about it, the situation is not favorable to such a full-scale experiment. Hassan Fathy is not an activist, he rejects inequity and believes that every human being has the right to a home, not only with basic comfort, but also beautiful, hence the intervention of the skilled man. Such a discourse hardly finds its echo in this disinherited campaign, at the end of a war that caused the shortage. John

Turner contributed to the reissue of Cities in Evolution in 1949 and summarizes his three principles: first, "The ways and means of building environments must increase people's control over their lives"; second, "The ways and means we use to build must generate and conserve material wealth where it is most needed, even when it is not possible to redistribute what already exists"; third, "The construction and maintenance of environments must make optimal use of abundant and renewable resources, and preserve those that are rare and polluting". As we can see, there is a kinship between Hassan Fathy's and John Turner's approach and conception, but this one is more political and ecological. However, Hassan Fathy refers in his book to the creation of an "informal" neighborhood near Lima in 1959. As for Turner, when he deals with adobe, he does not mention Fathy. On the other hand, Anne M. Meistersheim writes in her preface to the French translation (Rapoport, Meistersheim, & Maurin Schlumberger, 1972): *"If the problem of noble and popular architecture may seem to be an outdated conflict, the debate remains and is transposed to another level. Rapoport also emphasises the possible contribution of simple and traditional solutions to advanced technology and shows, as Hassan Fathy has also done, that traditional materials or techniques are often better answers than ours to the economic and technical problems of construction in Third World countries".* The same Rapoport, in Culture, Architecture and Design (Rapoport,2005), explains the failure of the New Gourna *"at least in part by the use of mud bricks and shapes from Nubia, a region of Egypt with a rather negative social connotation".* The earth material makes "exotic" for rich people's houses, but for those of the poor it stigmatizes their habitat and marks them as "less than nothing"...

2.6.2 Amos Rapaport's Approach

Amos Rapaport develops here a very broad vision of culture, which serves as a basis for all studies on the building. His perspective of anthropological analysis makes him approach the dwelling under all latitudes and as it is influenced by human values. An indefatigable traveler, he drew sketches on the way to illustrate his essays.

Rapaport also appears with an essential temporal characteristic of vernacular architecture. In this dense and well-documented little book (Rapaport, *Culture, Architecture, and Design, 2005*), A. Rapaport fights against all unilateral explanations of the phenomenon of "living in it". Noting the low numerical importance of the stylish building, created for and by an elite, the author looks at the popular habitat or "vernacular", the living environment of the majority of peoples, a bearer of a regulatory tradition, a certain ethics too, where respect for nature and the built environment seems to have a meaning.

Reviewing the various theories on the shape of the house, theories that invoke climate adaptation, constraints due to materials and technical knowledge, the nature of the site, needs related to the economy or the role of military strategy, and finally the importance of religious phenomena, Rapaport rejects them one by one by showing, with supporting evidence, their inadequacy.

For him there can be no unilateral explanation of the shape of the habitat and he criticizes in particular the theories of physical determinism. The immense variety of solutions and forms we see suggests that the physical environment provides opportunities or limitations within which each society makes a choice that is not the result of a single cause, *"but the consequence of a whole series of socio-cultural factors considered in their broadest extension; [....] what ultimately decides the form of a dwelling and shapes spaces and their relationship is a people's vision of the ideal life" (p. 65),* and which is also reflected in its economic, social and religious institutions. Each society makes a specific choice as to the norms and forms of its institutions; it interprets in a cultural way "basic needs" such as the need for shelter, food and social relations; it gives its own definition of time, poverty, intimacy and noise levels; it defines the status of women and children; all these correspond to different forms of housing and different provisions within the inhabited environment. Multiple solutions are therefore possible and even under the most severe ecological conditions a choice exists and nothing is inevitable.

However, Rapaport does not underestimate the importance of climatic and technical factors or the availability or scarcity of materials, but for him these are data that modify the form and not determine it. It attempts to define a scale of criticality of these factors and suggests that the lower the degree of criticality, the more socio-cultural and religious factors can act, but even in extreme cases they will always play an essential role. The shape of the habitat is therefore the result of the operation of several forces that combine because *"man may build to dominate his environment but it is as much the* *internal, social and religious environment as the physical environment that he dominates" (p. 83).* Having defined the essential factors; climate, available materials, and technological knowledge, to highlight the knowledge that traditional societies have of their environment and the degree of efficiency, even technical refinement and harmony, to which many of them arrive. In a short conclusion, he comes to a somewhat disenchanted look at the constructions of Western industrial societies (peasant housing being part of the traditional whole) and notes that we would have many lessons to learn from popular housing. We are faced with an excessive range of choices and our housing responses are increasingly linked to the fluctuations of fashion, the need for prestige, the influence of the mass media, a conquering way of conceiving our natural environment.

The book of A. Rapaport is enriching in the sense that it highlights the complexity of the determinants of the way of living and makes it clear that housing, as a visible framework, carries an infinity of invisible, social and symbolic elements, which must be discovered in order to understand it. Nor does it neglect the effects on traditional housing of colonization and the values it conveys (prestige of the tin roof, Western pavilion ideal) as well as the influence that the style building may have had on traditional housing (influence of Germanic Baroque on Austrian and Swiss farms).

It seems that its position is too idealistic: socio-cultural choices do not exist in themselves, but are part of a whole in which economic organization; production and power relations play a fundamental role. The fact that a village chief's house is larger, more ornate, that it is built collectively has a meaning that goes beyond the cultural, the symbolic. The fact that a habitat such as the Guadeloupean "hut" has been an almost unique and everlasting model for more than three centuries cannot be explained by the sole desire to build an ideal environment, but directly refers to the persistence of a mode of production and the need for a rural proletariat to supplement its meagre income with a self-sufficient economy.

2.6.3 Paolo Soleri’s Approach

Throughout his career, Paolo Soleri developed an architectural concept of a utopian city called Arcology. He applies it in various projects, including his Arcosanti project.

During these phases, Soleri carries out research on building forms that are more adapted to the climate in order to promote farming systems, and research on ways to make Arcosanti operate independently and autonomously: creation of a market (shops, fruit and vegetable production), a performing arts centre and an educational complex (school of architecture, school of urban planning and ecological design, etc.).

According to Soleri, the concept of arcology is the fusion between architecture and ecology; it proposes a three-dimensional urban form, compact and dense in contrast to the urban spread of space, energy and time consumption that cities have been demonstrating since 1970. A more complex and denser city allows the conservation of spaces and therefore resources. In addition, it offers a community life as opposed to the isolation of people caused by urban spread. Soleri abolishes the automobile within his city, this city has a mixed use in order to mix the populations living there. The land around the city is dedicated to agriculture and greenhouses are built. In the concept of "arcology", architectural design would promote the use of solar energy and reduce energy consumption (Paolo Soleri, 1974).

An organic city in the middle of the Arizona desert

Mesa City, a city that emerged from Paolo Soleri's imagination, was originally designed to accommodate 2,000,000 inhabitants. This "organic city" was created by Soleri and his students from drawings and enlarged models that remind us of the cuts of gigantic ant farms. One thing led to another, the sketch became a small hamlet lost on a 10 hectare site, surrounded by sovereign nature. Founded in 1970, in the state of Arizona, north of the city of Phoenix, Arcosanti represents a prototype of an organic city in accordance with the principles of Arcology (Ariz, 1979).

“Architecture must succeed in expressing this extremely important dimension of humanity: the community understood not as the separation of individual cells but as a combination of these individual cells in a more global system that represents the "superindividuality" of civilization” (Paolo Soleri, 1974).

Architecture and ecology in harmony

Born from the contraction of the terms architecture and ecology, Arcology is a principle that guides the establishment of housing and production units designed to minimize the impact of human activity on nature. The idea being to promote urban development that can be organic and no longer arbitrary, the main stakeholder emphasizes concepts such as self-management, good neighborliness or the organization of solidary and autonomous communities.

But there is more, since the concept of Arcology is inspired by the research carried out by giants such as Frank Lloyd Wright or Le Corbusier on the harmonious combination of measurement units with the natural properties of certain materials such as ceramic or concrete. Very early on, Soleri began to experiment with building materials, such as ceramics (Paolo Soleri, Arcology, 1969).

Successful workplaces

At the very beginning of his career, he built a revolutionary factory in Vietri sul Mare, Italy. The "Ceramica Artistica Solimene" is close to a museum and allows the different production units - both designers and craftsmen - to work together. Inspired by some of the Renaissance workshops, the architect wanted to make this ceramic component factory an inspiring place of design and production: everything but a systematically organized factory. The visionary architect had even used amphorae discovered on the site to use them for the plant's thermal insulation.

A new conception of housing

Already, when the Vietri sul Mare plant was designed, the foundations were laid for its future work on self-sufficient living spaces that would combine several functions necessary for social organization. Thus, places of residence, production and leisure could be - ideally - intertwined with each other, within "evolving" life complexes.

A visionary thinker and practitioner of architecture, Paolo Soleri claims to be inspired by the Italian civilization which, despite all its shortcomings, has succeeded in giving birth to an almost marvellous story, part of it resulting from the social and sentimental structure of the Italians.

In much the same way as Pier Luigi Nervi's experiments on concrete, Soleri works on the structural capacities of materials extracted from the earth, but also on the astonishing variations in shapes and patterns made possible by formwork or casting techniques. Throughout his work, we find this constant concern to incorporate traditional techniques with certain advanced technologies at work in the construction industry.

A structuralism in his approach, the visionary architect believes that humanity will have to overcome the selfishness that characterizes our current societies if it is to be able to survive. He says that "*the earth can do without us very well, but we will not be able to survive if we continue to develop the suburban cities of postmodernity*".

His architectural approach is strongly inspired by sociology and even anthropology. He believes that self-sufficiency is a myth and that, on the contrary, we need each other to survive in a context where our cities should adapt to the natural environment. It is important - always in accordance with its precepts - to recognize our total dependence on nature, which would imply conceiving technological development as a middle path between the activities of the human species and the natural environment.

Change of paradigm

In the long term, Soleri believes that culture would be the product of our intelligence's action on the natural environment. There is therefore a design in the form of a feedback loop that would make it possible to no longer oppose culture to nature. He takes this idea very far when he states that *"humanity has entered the technocratic or technological phase, a phase that implies that the process we are now seeking to accomplish is not natural... it is a process that goes beyond nature, a very risky thing, but that can open the universe to human intelligence".*

This approach reminds us of that of architects of the Italian Renaissance, when they tried to reconcile the measures of the human body with the organization and location of the cities of the future. However, Paolo Soleri's approach is not ethnocentric. And even less "naturalistic". He pointed out that we cannot stop progress, the future of human knowledge and its fields of application. But, of course, there are consumption habits or ways of doing things that he believes should be corrected.

The ideal city

Soleri's architectural and urban planning approach is in line with the ancient tradition of the utopian city. A tradition that would have fecundated two ramifications: utopias based on order and those that advocate freedom instead. In fact, utopian thinking would idealize an ideal city that would reconcile humans with nature and with their fellow human beings. While utopia may seem a dangerous chimera, it is nevertheless essential to the progress of humanity, since it acts as a powerful moral and intellectual stimulant.

It is undoubtedly the utopian city of Plato that poses a problem for many postmodernist thinkers. Indeed, this philosopher of antiquity wanted individuals to be replaced by citizens obeying the cosmic order of a "radiant" city. And, to achieve this form of organization, Plato advocated replacing the organic by the organization, as the engine of civilization. To make matters worse, Plato declared that it would be necessary to resolve to annihilate the family, perceived as a unit of life incompatible with the duties of citizenship.

This vision of a city functioning as a gigantic ant farm certainly inspired Charles Fourier to design his Theory of Universal Unity (Barnard, Zeldin, & Fourier, 1969). This early 19th century thinker advocated a complete reshaping of society based on the principles of association and cooperation. The basic cell of this idealized society would have been the phalanstery, a kind of community where almost total sharing would lead to "household associations". So, leave the family nucleus and this precursor of modern urban planning advocated the design of housing units that would be in conformity with the social system he intended to put in place.

However, Fourier's urban planning planned to harmonize industrial activities with those of the fields, a vision that anticipated the approach of garden cities that would announce the development of our famous suburbs at the beginning of the 20th century. It is perhaps here, on the question of the mix and proximity of human activities, that this thinker of "utopian socialism" joins Paolo Soleri's approach.

Sustainable development

Arcosanti has been in existence for about 40 years and has fewer than 200 volunteers. This means that there is a long way to go in front of the ideals of its founder. Nevertheless, this draft made it possible to test several initial hypotheses in situ. Thus, a

kind of "shell" was put in place - to use Soleri's words - leaving it to the participants to implement the type of programmes they wanted. Therefore, the authoritarian utopia, of the kind of community of followers surrounding a guru.
Despite some apparent failures, Arcosanti is a concrete illustration of this idea of a network of small towns, on a human scale, that would develop in harmony with their anchor site. The urban fabric reproduces, in a way, the sinuosities of the terrain and vice versa. The ideal of harmonious urban development - again according to this matrix - thus takes its place between the theories of linear cities, like Corbusier, and those of the endless suburbs, as in Frank Lloyd Wright's Broadacre city (Lapping, 1979). Frank Lloyd Wright's utopia is irreducibly opposing to TOD (transit oriented development), a development model that relies on public transport services to shape concentrated agglomerations along the railway or catenaries.

Paolo Soleri imagines a network of small "organic" cities, which would follow the sinuosities of the topography and develop according to the needs of the communities and inhabitants. However, there is not really any reflection in this approach on the interconnection between these small urban units and the need to establish larger production centres on the periphery, with public transport services that would allow citizens to communicate from one city to another.

2.6.4 Ken Yeang Approach

Ken is the Architect Director of Llewelyn Davies Yeang in Great Britain and T.R. Hamzah & Yeang in Malaysia and teaches at several universities around the world. According to Yeang, there is no one better approach to achieving an effective environmental design than others. On the contrary, there are many ways to achieve the same goal, namely a state of equilibrium in the global environment.

Integrating the natural environment

The approach is to consider environmental design as the harmonious and non-damaging bio-integration of the artificial (man-made) into the natural environment. Our difficulty in achieving this integration is at the root of environmental problems. In reality, if we are able to integrate our business processes and design in a homogeneous and seamless way, and everything we do or manufacture in our built environment, into the natural environment, any environmental problems of any kind will in principle disappear. Achieving this goal is of course easier said than done, but that is our challenge.

We could make an analogy between eco-design and prostheses in surgery. A medical prosthetic device must be integrated into its organic host, the human body. If integration is not successful, it can cause disruptions for both. By analogy, this is what eco-design should achieve in our built environment and in our activities: a total physical, systemic and temporal integration of our man-made environment into our organic host in a harmless and positive way. Environmental design is essentially that which integrates our artificial systems, both mechanically and organically, into their host system, i. e. ecosystems (Yeang, “Nanoenergy”, 1995).

Designing for bio-integration can be considered in three ways: physical, systemic and temporal. Physical and systemic integration requires a clear understanding of the site's ecology. We must first understand the local ecosystem before imposing any human activity on it. Each site has an ecology with a limited capacity to withstand the various stresses that, if pushed beyond this capacity, will be irreparably damaged. The consequences can range from minimal localized impact (clearing a small area to allow access), to devastation of an entire area.

We need to verify the structure and energy flow of its ecosystem, the diversity of its species and other ecological properties and processes. Next, we need to identify which parts of the site that have different types of structures and activities, and which parts are particularly sensitive. Finally, we must consider the likely impacts of the construction and its use.

This is, of course, a considerable undertaking. It must take place daily throughout the year and, in some cases, over several years. To reduce this long-term effort, landscape architects have developed a mapping technique, sieve mapping (revealing the constraints and opportunities offered by the landscape), to configure landscape design. We must be aware that this method generally treats the site ecosystem in a statistical way and may ignore the dynamic forces that play between layers and within an ecosystem. Between each of these layers there are complex interactions.

Another major design issue is the systemic integration of our built forms and their operational systems and internal processes into nature's ecosystems. This integration is crucial because, if our built systems and processes do not integrate with natural systems, then they will remain disparate, artificial elements and potential pollutants.

Time integration involves the conservation of both renewable and non-renewable resources to ensure that the latter remain available for future generations. This includes the design of systems built with low energy, less or not dependent on the use of non-renewable energy resources.

Restore existing systems

Eco-design is seen not only as the creation of new "living" artificial urban ecosystems or the rehabilitation of existing built environments and cities, but also as the restoration of damaged and devastated ecosystems locally present in the landscape.

For example, we should improve the ecological links between our designs and business processes and the surrounding landscape, both horizontally and vertically. Achieving these links ensures a higher level of species connectivity, interaction, mobility and resource sharing across borders. Such concrete improvements to the ecological network increase biodiversity and further increase habitat resilience and species survival.

We must integrate the inorganic aspects and processes of our built environment into the landscape so that they become mutually ecosystem-based. We need to create "artificial ecosystems" that are compatible with nature's ecological systems. In doing so, we increase the capacity of "artificial ecosystems" to support life in the biosphere (Yeang,2009).

Thinking global

The eco-design proposal considers that it is a matter of looking at the biosphere as a whole, monitoring the sustainability of the environment and its destruction by humans, natural disasters, buildings, activities and industries as sets of environmental interactions, and taking appropriate remedial measures to ensure global ecological stability.

Environmental design must go beyond conventional assessment systems, which are useful indicators for comparing the ecological character of building design, but are not effective as design tools. They are not comprehensive enough in addressing environmental design issues at the local, regional and global levels.

“Environmental design is still in its infancy. The building or the totally green city does not yet exist. We need a lot more theoretical work, technical research and invention, environmental studies before we can benefit from a truly green built environment. We must all continue this great adventure” (Yeang et al,2016.).

2.7 FROM VERNACULAR ARCHITECTURE TO NEWLY DEVELOPED TECHNOLOGIES

For Olgyay (1963), traditional or vernacular architecture plays an important role in the evolution of architecture, because it represents the cultural, social and political context of a society. The design of the shelter has reflected, throughout its history, different solutions for each period and context to solve problems determined for example by the adverse forces of cold, heat, wind, water and sun. Each era and each environment or culture seems to have had its own philosophy or vision of habitat design. The past thus offers us a rich experience, symbolized in the different types of architecture.

"As the shelter evolved, accumulated experience and ingenuity diversified it to meet the challenges of widely varying climates" (Olgyay, 1963). Vernacular architecture evolves in the technical context by taking the materials, the implementation technique and aesthetic codes surrounding the implantation site. It can be defined as the architecture specific to a country, a territory, a given area and to its inhabitants. Traditional architecture can be an important design guide, especially in regions that provide references on how to respond to local climatic conditions (Sobin & Olgyay, 1963). A representative example of these adaptations to climate influences is the igloo, a well-known solution to the problem of survival in extreme cold, created by the Inuit, the indigenous peoples of Canada's far north, with particular characteristics such as heat conservation, thanks to its compact shape, with a minimum of exposure surface. These hemispherical shelters made of snow blocks benefit from its insulating value. The smooth ice liner that forms on its inner surface is an effective seal against air infiltration, and the tunnel exits are oriented away from prevailing winds to reduce drafts and prevent hot air leakage (Olgyay, 1963).

Regional architecture became then the essential source leading to passive design approach contributing to the whim of comfort and getting over the survival mode by what we call now 'vernacular architecture'. The awareness of place, time and climatic conditions is not a new concept, but a buried one, re-appealed as a solution as said in the book *Architecture as Energy, 1997*. For instance, Matmata houses in the desert, were burying rooms underground to control heat during the day and cold at night, by using fibers in the exterior, which is so clever and works as a solar collector of nowadays. For instance, the case of Igloos, have a half-spherical shape and lower entrance tunnel that minimized the cold of the arctic wind. Architects are using this as a case study to develop their designs in a cold climate, especially in Normandy. By combining the old techniques and new technologies, consumption of energy can be reduced in buildings instead of depending on mechanical systems only. Actually, the design of a building form and dimensions can be led by the climate of an area. Thinking that buildings are an independent part of the environment is very wrong. They are indeed dependent on one another, energy-wise. According to Fernandez Galliano, Architecture and energy are fused and related to other disciplines. *''Matter and energy, architecture and fire, construction and combustion are once again placed in relation to one another'' (*Fire and Memory, 2019*).*

On the other hand, modern architecture wanted to break with tradition, by founding a new architecture. Thus, a new paradigm is presented in 1923 in a set of articles called "Towards an Architecture" published in the architecture journal "The New Spirit", which present the birth of a new paradigm: the era of technology. The new movement was inspired by the Chicago school, which in 1896 stated, "Form follows function. This is the law" (Bell, 2014). Le Corbusier, one of the leading theorists of modern movement interprets this discourse by comparing housing to a "living machine", where architectural elements must have a function, such as mobile architecture technology (car, boat, plane) (Morel Corrêa, Anzolch, & Fonseca Pedrotti, 2016). Thanks to the electrification of cities, new technologies such as air conditioning are taking place in the living machine. Thus, Le Corbusier's first works present industrialized solutions that can be exported everywhere. In 1929, with the Villa Savoye project, Le Corbusier integrated the independence of the site's conditions with a constant temperature of comfort obtained thanks to air conditioning, heating, and mechanical air renovation. Le Corbusier was convinced that he could make a home for all countries and all climates. Other projects include Centrosoyuz (1928) in Moscow and the City of Refuge (1929) in

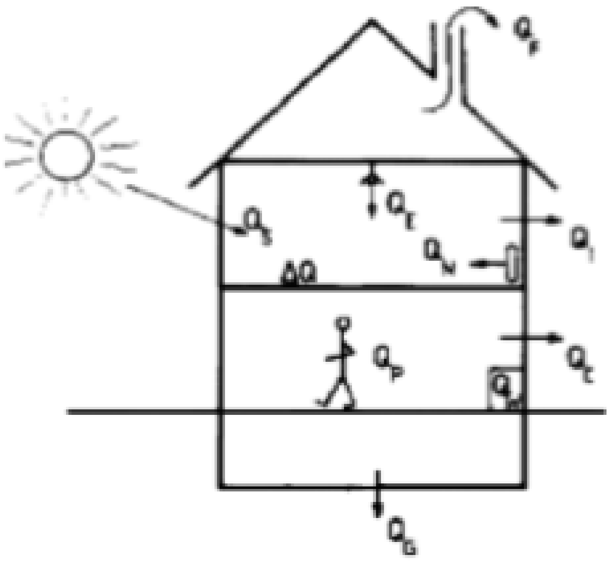
Paris were designed to be hermetically sealed buildings with two active concepts, which Le Corbusier called "Neutralizing Wall" and "Exact Breathing". The neutralizing wall consists of two layers of glass or stone with a closed air circuit in the middle: hot in winter or cold in summer. The exact breathing is what we call nowadays "controlled mechanical ventilation".

At the end of the Second World War, the architecture promoted to be seen from another angle and perspective, thanks to the architectural press, schools, and the critics that were done in that era, bringing another definition in terms of energy performance of buildings (amount of lighting, ventilation, cooling, heating…). New York faced brownouts and electricity was limited, that's when Richard Stein introduced his approach to reduce the overuse of energy and avoid its misuse through design. Dr. Lawrence Chartes also contributed by studying the amount of energy used (electricity, coal, oil…) to understand the energy demand. He made a questionnaire as a basis of the study, then took two buildings with the same surface area with different envelope materials (glass and aluminium) (Energy Technology Perspectives, 2017). As a result, the state office of general services made an energy conservation program and that's how they have been introduced lately to double glazing and solar collectors.

In his book 'Architecture and Energy', Richard Stein proposes to cut energy waste for different daily uses in the building (cooling, heating, lighting). He believes that through the energy production 50percent can be lost, and that *''the energy saved by conserving a building = energy produced by domestic sources''*. He concentrated his work on energy conservation through building design showing that the techniques to do so are available. He gave an example of a conventional office building in the USA starting by its orientation and analyses it through its façade *(*WATSON, 1977*).* It was irrespective to orientation and the use of glass façade on all sides required air conditioning. In other words, the need of lighting fixtures will increase because of the negligence of natural light and orientation during the design phase. Some buildings are designed to overuse energy, which deprives others who need it to survive.

According to EPJ conferences, to have fast results on the reduction of the consumption of energy, we need to raise awareness in a way to change the user's behavior in his either house or workspace, literally everywhere. (Especially when it comes to the use of electricity)The gain that can be held from this behavioral act can maybe save a small amount of energy today, which will be very valuable tomorrow. All we need is consciousness and a manner to conduct ourselves in a better way regarding the use of energy while attracting the attention to the methods and tips to do so, and getting motivated from its positive return. Building energy can be controlled if all climate, building envelope, services, maintenance, and occupants are taken into consideration. The data of a building design should include location, thermal zones, internal heat gain, usage profiles, and the used systems. To achieve a good result with good methods these data should be used even at a sketch phase before starting to design phase as shows Figure 2.2.

Figure 2.2: The building energy budget



QC +QG + QF + Ql −QP −QE −QS ±ΔQ = QN,
QC = heat loss by conduction to the outside air,
QG = heat loss by conduction to the ground,
QF = heat loss by mechanical ventilation,
Ql = heat loss by air leakage (infiltration),
QP = heat gain from occupants,
QE = heat gain from electric appliances,
QS = heat gain from solar irradiation,
ΔQ = heat storage in the building structure,
QN = net energy input needed.

Source: Sonetti, 2013

3. ARCHITECTURE, ENERGY AND CLIMATE

3.1 ROLE OF ARCHITECTURE AND ARCHITECTS

The way in which architecture is visually interpreted, from the perspective of forms, climatic and environmental concerns, may arise from the local as well as global understanding. Solar panels, sunshades, walls adobe, greenhouses, etc. are used as design elements in the contemporary buildings that are climatically adapted, so that the architectural expression of their functions becomes an important part of the building's aesthetics and character, which in turn are rationalized and justified by its environmental functions. In this way, the research and application of new technologies such as double glazed facades, new materials such as insulation and new techniques such as reinforced concrete column structures have been applied to international architectural projects, but have also been applied and made more common in vernacular projects where they have proven to be very effective. Indeed, the expansion of populations and modern communications has accelerated the exchange of ideas and technologies. It is with the concept of sustainable development that climate-conscious architects, regardless of their approach, achieve a more global vision of the environment. Thus, not only are climate and energy issues raised, but they are also complemented by new concerns about the health of occupants, the management of resources (energy, and materials) and the elimination of pollution.

As architects, we are supposed to find a way to optimize the relation architecture-energy through design, which is a mandatory stage. This relationship plays an intermediate role between the needs of the user, and the conditions of the surrounding environment. We are affecting the environment more than what we think, it’s more than the project that we are designing. As usually, ironically expressed *‘‘we are generalists that know a little about everything’’*, which put us into a position to find a remedy of any problem opposed to any situation. That is why our profession is under pressure of the responsibility that we should be capable to overcome it with reasonable and sustainable solutions. When we talk about design regarding energy or an energy conscious building it leads us to choose between renewable and non-renewable resources, which is about passive and active systems or to use them both by using the passive system as a principle design approach and the active system as a backup.

The role of architecture and architects here is to understand this relation, the seriousness of the situation and implicate it through the conceptual phase of design but unfortunately as Philip Johnson criticized it: *"I don't like all this energy business, for example, the growing tendency to use energy savings as a prime determinant of design, as in houses built with solar collectors. I think it is an excuse to get away from designing. There is some use for all of these things. .. But they are not architecture."*

The federal climate change action plan calls for the adoption of an energy code, with a "net zero energy ready" target for new buildings by 2030, and the achievement of carbon neutrality by 2050 (Guyatt, 2011). A new generation of architects is advocating an integrated approach to architectural design. It is an international passive building energy-efficiency label. It represents the best possible way to achieve real energy efficiency, the only responsible way to achieve "net zero" buildings (Guyatt, 2011). The beauty of the passive standard is that it requires highly creative responses and based on a collaborative approach from design to implementation.

It is time for architects to take responsibility, and finally to work together with project owners, engineers, academics, builders, community groups and citizen users to try to respond adequately to the climate emergency. Today, more than ever, we understand that a building is only an interface, but an area of exchange that we must better control to protect the natural and human ecosystems in which it is integrated. So, how can we get over the aftereffect of global warming? How can we optimize our buildings as architects to be a part and contribute to it? Should energy efficient buildings meet standards of efficiency of a building or beyond that to think about the impact on the inhabitants?

3.2 ENERGY AND ARCHITECTURE RELATIONSHIP

At present, the evolution of construction techniques has made it possible to design increasingly larger spaces. This has led to the need to integrate the thermal comfort component into the entire architectural design process. Using passive energy techniques such as convection, conduction, evaporation, and radiation, the architectural design makes it possible to propose solutions to thermal regulation requirements through natural means.

Indeed, thermal comfort must be the main objective of any architectural design and this, by exploring the different components of the building: the shape of the envelope, the thermal quality of the materials, the natural light and the modes of lighting, heating, ventilation, spatial articulation, the orientation of openings, etc.

To do this, all the existing potentials in the site, the spatial composition and the mode of construction must be explored in an intrinsic way from conception to realization. The architect, therefore, has a responsibility to protect natural environments and ecosystems, and cannot continue to follow the classical aesthetic approach of the genesis of fanciful forms that encourage the waste of resources.

This dimension of integration of energy measures in the architectural approach has been the subject of several studies and has aroused the interest of several practicing architects. As an example we can quote some testimonials:

Roberto Gonzalo and Karl J. Habermann, in Architecture and Energy Efficiency: Principles of Design and Construction, said: *"These buildings have to satisfy very complex energy requirements ... We have to worry at the same time about the temperature, the degree of hygrometry, illumination, sun protection devices and the quality of the development of the rooms" (*Gonzalo & Habermann, 2006*).*

Hassan Fathy, in Natural Energy & Vernacular Architecture, spoke about the importance of traditional architecture and vernacular architecture in generating natural energy solutions in contemporary architectural design.

Luis Fernandez-Galiano, in his book Fire and Memory on Architecture and Energy, has reconstructed the historical and theoretical relationship between architecture and energy, advocating a passive, bioclimatic, organic architecture, representing the optimistic side of thermodynamics.

In “The Architecture of the Well-Tempered Environment”, Reyner Banham identified three main modes of climate control: the conservative mode that uses materials and is suitable for most dry, hot or cold climates; the selective mode that acts on architectural elements to provide fresh air and evacuate stale air from damp indoor spaces; and the generative mode that uses the equipment for the energetic control of the ambiances (Banham, 2009).

In addition to these testimonials, research on renewable energy and especially solar energy are developed at the beginning of the twentieth century. The concept of solar architecture was thus introduced by the Americans by distinguishing between active architecture (or solarized architecture) and passive architecture (or bioclimatic architecture).

3.3 BIOCLIMATIC ARCHITECTURE: CONCEPT AND BASICS

Bioclimatic architecture can be defined as architecture that is sensitive to environmental problems by aiming to reconcile energy efficiency and occupant comfort with natural uses. It aims to make the most of the conditions of a site (climate and microclimate, geography and morphology) and its environment, with a set of architectural strategies, solutions and techniques that use as little non-renewable energy as possible and reduce the impacts on the natural environment and on the project's investment and operating costs (Alain Liébard & André De Herde, 2006). This type of architecture has evolved by integrating global concerns such as the ecological issues of the 1960s, which seek a more autonomous and natural way of life, the 1973 oil crisis and the energy crisis in Europe and North America, which has led to a concern to reduce, if not eliminate, dependence on non-renewable forms of energy in architecture", by developing passive, active solar architecture. Bioclimatic architecture is also influenced by other global concerns such as eco-development, first mentioned in 1972 at the first United Nations Conference on the Environment in Stockholm (“Environment: WAWF Supports Stockholm Conference,” 1972). In this conference, the environment is presented as an essential world heritage to be passed on to future generations. In 1980, the International Union for the Conservation of Nature and Natural Resources (IUCN) referred to the notion of "sustainable development" when it published its "World Conservation Strategy" concept, which was adopted in Rio in 1992, to take firm decisions mainly on climate change (Esmond Bradley Martin, World Wildlife Fund, & Union, 1980). Thus, it can be seen that bioclimatic architecture and sustainable architecture are two different approaches. Indeed, sustainable architecture is defined in relation to global environmental concerns, for example, the contribution of construction to the reduction of greenhouse gases, water pollution and, light pollution. As for bioclimatic architecture, it acts first and foremost to solve local problems: a good adaptation to the site (for example, obtaining comfort with low energy consumption, a good orientation towards the sun and wind, local and appropriate building materials, etc.). However, it is close to sustainable architecture in that the solutions adopted will contribute to global environmental objectives.

Bioclimatic architecture is a way of building with the environment. The overall concept is also called "climate architecture" or "natural architecture". When environmental considerations are also taken into account in the use of materials, greenhouse gas emissions, water or waste management, this type of architecture is called "ecological architecture", "sustainable architecture" or "green architecture". If integration into the environment is more specifically focused on the use of energy resources, and more specifically the sun, we talk about "solar architecture" or "passive architecture", and these two terms can be combined. The very nature of bioclimatic architecture, which is to adapt to the local environment, makes it impossible to define it more precisely and to detail general design principles. Indeed, the advice that can be found in bioclimatic architecture manuals is only applicable in a specific context and is usually based on empirical knowledge.

The main objective of this approach is to design buildings in a "natural" way, by fully integrating into their environment. A bioclimatic building must ,therefore, take into account the relief of the ground on which it is built, the vegetation surrounding it, the path of the sun throughout the day. In the northern hemisphere, it is therefore considered that living rooms, such as the living room and kitchen, should be oriented rather south (or east, or west), while buffer spaces (such as toilets or garage) can be provided along the north façade, which receives less sunlight than other orientations.

3.3.1 Architecture and the relation of the building with its environment and climate

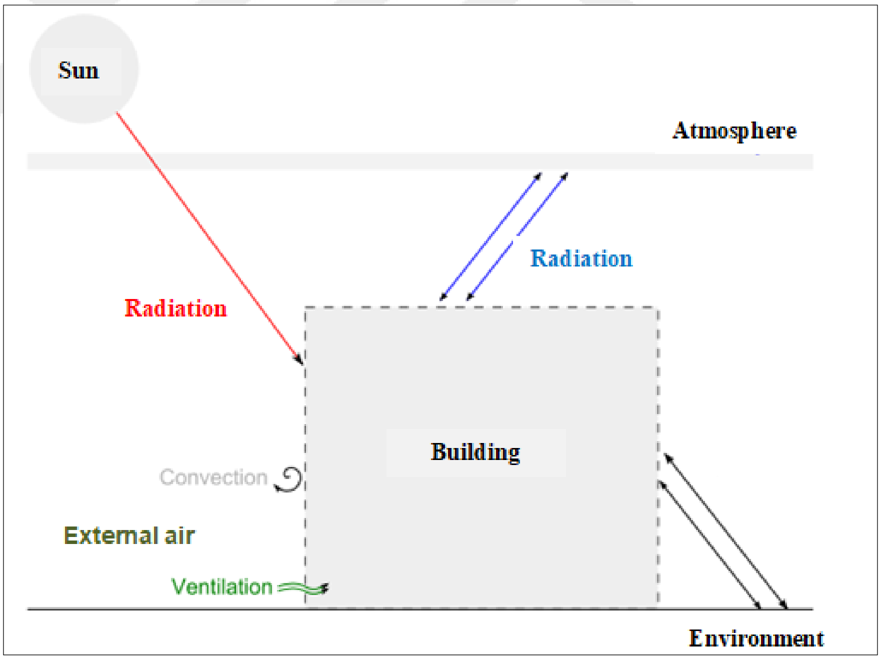
The environment surrounding the building from an energy point of view can be described by what is called climate. Multiple data (various temperatures, sunshine, cloud cover, wind direction and speed, air humidity, etc.) are collected in meteorological files, used in particular in building energy simulations.

Architectural choices have a very important impact on the thermal behavior of a building. Therefore, it is necessary to apply some principles from the pre-project phase.

It will reduce the loss of energy in a building during the winter, and will avoid overheating in the summer. The main recommendation concerns the orientation of the building and the presence of openings, which should make it possible to optimize the solar gains. There are other generally accepted rules of the art such as the compactness of the construction. It makes it possible to limit the volume surface of the walls in contact with the outside, and therefore the losses, but also the arrangement of the interior spaces .The architecture of the building must also anticipate comfort for the summer by providing protections for openings and windows.

Construction techniques and materials have continued to evolve to provide more comfort and energy savings. The principles and architectural rules are simple and easy to implement and adapt for each project to its particular environment.

Figure 3.1: Diagram of the energy interactions between a building and its environment



Source: Derived from from (Baruch Givoni & Izard, 1978)

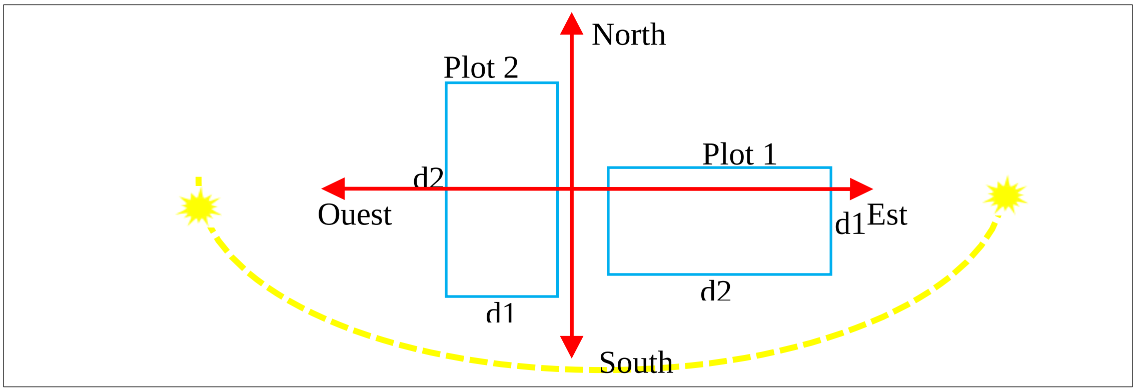
3.3.2 Orientation

The orientation of the building determines the quality of use of habitat and conditions its good insulation. An orientation to the south allows better control of the sunshine. The sun intervenes to dispense light and heat. An orientation adapted to the constraints of the building makes it possible to reduce the consumption of heating and lighting (Mirabelli, Economic Forum, & Energy Forum (6, 2011, Brixen, 2012).

These steps should be followed in order to get a better result:

- Study the site in detail: its physical and natural environment (relief, open or uneven areas...), urban planning (common area, shadows...) and climate (sunshine, winds, temperatures...);
- Use the location-specific solar diagram according to its latitude to determine the height of the sun at different times of the day, allowing designers to determine shading requirements and the choice of the type of solar protection systems.
- Ensure the orientation of the building: Orient the building to the south for maximum sunshine in winter. In fact, the sun is a source of light and heat. A south-facing orientation of the building, if possible, reduces energy consumption in terms of heating and lighting. The study of the sun's path through the solar diagram of the place in question makes it possible to determine the optimal orientation of the building on the ground and the correct layout of the rooms.
- Integrate sunlight into the design: opt, as far as possible, for an east-west orientation of the tracks, so that the location of the buildings is north/south, in order to benefit optimally from solar gains;
- Encourage the choice of a site that would allow the main facades to face south. A longitudinally shaped ground, with the main axis oriented east-west, is preferable as it allows for a larger south facade;

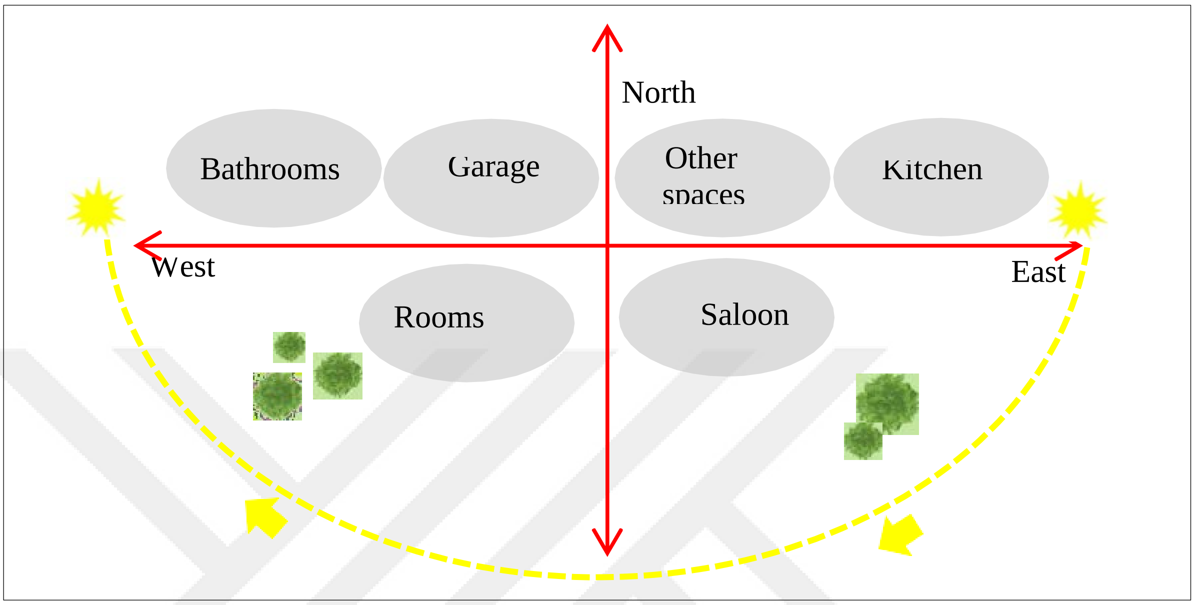
Figure 3.2: Orientation of the building



Source: Derived from (Document de Projet -Code EE du Bâtiment au Maroc Gouvernement Du Royaume du Maroc Programme des Nations Unies, n.d.), 2018.

For an equal area, plot 2 is better oriented than plot 1. On plot 2, the length of the south-facing façade d2 is longer than that of plot 1, d1. This allows you to benefit from the sun's contributions, all seasons combined.

Figure 3.3: Principle of composition of an interior plan of a dwelling



Source : Retrieved from (Document de Projet -Code EE du Bâtiment au Maroc Gouvernement Du Royaume du Maroc Programme des Nations Unies pour le Développement Document de Projet du PNUD, n.d.

As represented in Figure 3.3, we need to:

- ensure that the plot favors the location of buildings in a north/south orientation, giving the best compromise between heat input in winter and protection in summer with the possibility of evacuating the stored heat through natural ventilation;
- arrange the living rooms along the south facade to reduce heating needs during the winter;
- group wet and service rooms (kitchen, laundry room, garage, bathroom, cupboards,...) to the north; and protect the south façade by shading (protection of openings/ vegetation)

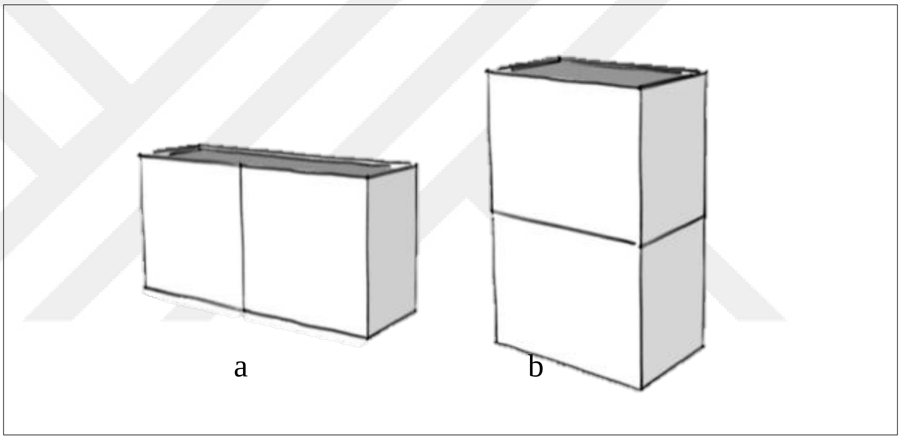
3.3.3 Form and Compactness

Compactness is generally a rule in bioclimatic architecture. It reduces losses through the envelope by minimizing the surfaces in contact with the outside.

The choice of the building's compactness is important to reduce energy consumption. Compactness is defined by the shape coefficient C = [(Front surface + Roof) /Volume]. The lower this coefficient, the more compact the building is and the less energy it consumes. It is therefore a matter of:

- favor a small "shape coefficient", less than 0.70 $m^2/m3$ (as an indication) to avoid thermal losses through the envelope surfaces during winter and limit heating consumption;
- Plan buildings that take advantage, as far as possible, of the common space, to increase compactness and reduce energy losses in winter.

Figure 3.4: Example of Building Compactness



From Figure 3.4. We can deduce that the building b is more Compact than building a.

In addition, the optimal shape of an envelope would correspond to that which would allow a minimum loss of heat in winter and a minimum gain in summer. The elongated shape in the east-west direction gives better results.

The characterization of the building's exterior envelope must address the nature as well as the physical and thermal specificities of the building materials and processes, at the level of exterior walls and openings including glazing, low floor, flat roof, and the thermal insulation of these walls.

3.3.4 Openings

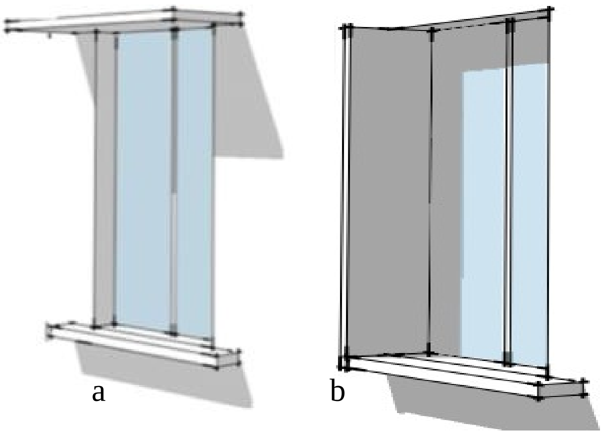
The south-facing openings receive the rays of the sun that warm the air, which permits capturing the heat of the sun by avoiding overheating. The air circulates naturally by convection or ventilation and then redistributes heat throughout the building. These openings help to reduce heating costs. A more affordable solution is to open large windows to the south. It is then necessary to use glazing with thermal insulation to limit thermal losses.

Paradoxically, the most difficult part is not to capture the heat of the sun but to protect itself in summer: the comfort temperature must not exceed a certain threshold in the indoor. External protections are required for the openings that are most exposed to the sun. But an overhang (horizontal and/or vertical) with a proper size or dimension can be much more efficient. It allows the sun to penetrate directly in winter and completely masks the summer.

We need to optimize sizing and the location of the openings by:

- reducing the dimensions of openings in the east, west and particularly in the north, in order to limit cold air intakes in winter;
- placing large openings to the south, as they allow incident solar radiation to penetrate in winter and can be easily protected in summer;
- Opting for the construction of a sun visor.

Figure 3.5: Window shadings (Cap/Flank)



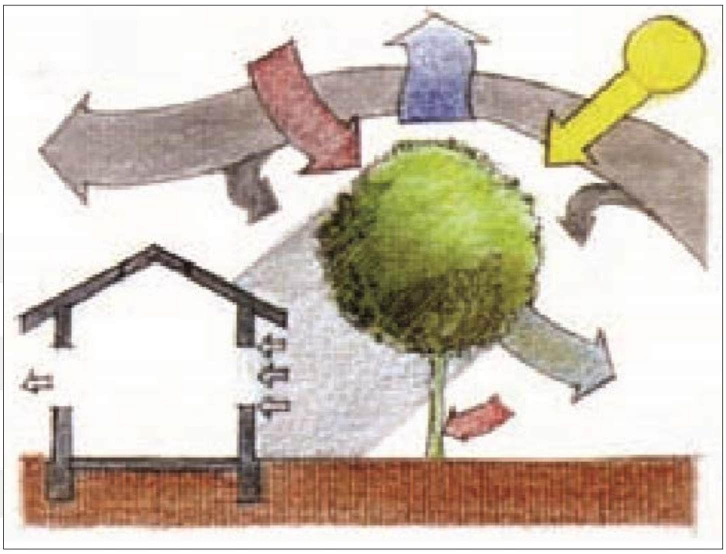
a- The cap is an advance above the opening.

Source: Derived from RTCM, 2017, Imane Ourhadja, 2019

When it comes to opening protection supplements, we need to opt for an adjustable shading device or blinds. Without forgetting, that we can use deciduous foliage vegetation that will maximize solar gain in winter and minimize it in summer. Such as Jacaranda, Catalpa, Micocoulier, Platane, Tipuana tipu, Vine, Acer, Albizia, Carpinus...

The plant protections in the south shade the facades but also filter the dust, protect from hot winds, oxygenate the air and cool it by vapour-transpiration.

Figure 3.6: Illustration of the vegetation shading



Source: Retrieved from (World Energy Perspectives ENERGY EFFICIENCY : ASTRAIGHT PATH TOWARDS ENERGY SUSTAINABILITY In Partnership with ADEME 1, n.d.), Imane Ourhadja, 2019

The outside air is introduced into the buildings either by the voluntary effect of the ventilation or by infiltration in the right of the sealing defects of the envelope. The ventilation techniques are dimensioned to respect the comfort of the occupant. On the other hand, the infiltration of the air in the building is likely to produce situations of discomfort as soon as a defect of execution is responsible for a draft. Outdoor air introduced into the building through ventilation or infiltration must be heated or cooled to bring it to the indoor comfort temperature. Closed rooms should be avoided where the air is confined. The circulation of air in the house will be favored by a mechanical system or by a natural chimney effect.

3.3.5 Thermal inertia

The main quality of the thermal inertia of a building is to absorb the strong daily thermal variations by creating a phase shift. On hot days, the heavy envelope (stone construction, thick wall of raw earth) accumulates heat therefore limiting the risk of overheating. During the night, when the outside temperature decreases, all the heat accumulated during the day is transmitted inside the building, which avoids the use of possible additional heating.
Accumulation and phase shift constitutes the thermal inertia.

To increase the thermal inertia we need to:

- Make an appropriate choice of construction materials resulting in a good overall thermal inertia of the building allowing a better thermal phase shift. For example, clay materials (adobe, adobe, clay brick) have remarkable thermal qualities as well as high thermal inertia and a longer phase shift time.
- Use heavy and thick roofs and walls in climatic zones with high-temperature variations. This contributes significantly to the thermal comfort of buildings and energy savings.

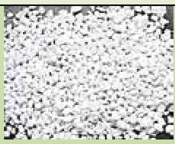
3.3.6 Materials

In climates with high daily temperature variation, materials with low diffusivity and high effectivity will be favored. The outer walls of the building envelope allow the control of the amplitude between the internal and external temperature. Thanks to the inertia of the material that the duration of the heat transfer is delayed, and it therefore acts on the amplitude and the phase shift. Therefore it acts on the amplitude and the phase shift. The thermal inertia of the wall is proportional to the thickness of the wall and inversely proportional to the thermal conductivity coefficient of the material. The phase shift time expressed in hours is a function of the thickness as well as the thermal conductivity of the materials (λ) expressed in W / m.K.

3.3.7 Thermal insulation

The thermal inertia is complemented by the insulation of the building envelope, against both low temperatures and high temperatures. The thermal quality of an envelope (wall, roof, window) is evaluated by the surface transmission coefficient or the U value, expressed in W / m².K. The opaque wall will be more efficient than its U value will be very small (according to *RTCM,2018* U should be between 0.4 and 1.2 W / m².K, while this value is less than 0.15 W / m².K for the envelope of a passive building located in a relevant climatic environment). We need to select the best insulating materials with very low thermal conductivity and define the most appropriate thickness for the roof and walls of the envelope while treating thermal bridges.

Table 3.1: Materials and their thermal conductivity

Material	**Appearance**	**Density kg/m3**	**Thermal conductivity W/m2.K**	**Water vapour resistance m**	**Fire behaviour**	**Compressive strength kg/cm2**
Rock wool		20 to 150	0,034 to 0,040	0,8 to 2,2	Non flammable	0,7 to 1,3
Glass wool		13 to 60	0,034 to 0,045	1 to 2 3 to 4	Low combustible	0,2
Polyurethan		28 to 50	0,022 to 0,028	100	Medium flammable fuel	1,6 to 3,5
Cork		80 to 140	0,032 to 0,045	10 to 13	Low flammability	0,2
Polystyrene		(PSE) 15 to 65 (XPS) 20 to 30	(PSE) 0,03 to 0,04 (XPS) 0,028	20 to 225	Moderately flammable	(PSE) 0,7 to 3,5 (XPS) 3 to 7
Polystyrene concrete		500 to 1200	0,8 to 2,2	6 to 8	Non-flammable	5 to 8
Expanded perlite		90 to 170	0,045 to 0,050	6 to 10	Non-combustible	3,5

Perlite concrete		450 to 600	0,15 to 0,31	4 to 6	Non-combustibl e	11
Aerated concrete		350 to 550	0,10 to 0,18	6 to 10	Non-combustibl e and non-flammable	11

Sources: Retrieved from" Experimental Study on the Thermal Conductivity of Thermal Insulation Materials Used in Residential Buildings",(Jeong, 2014) ," Environmentally Sustainable Construction Products and Materials ", (Tiainen & Christina, 2014) ; Imane Ourhadja, 2019.

Note: expanded polystyrene, cork and glass wool are the most widely used insulating materials in Morocco, depending on their cost.

3.3.8 Tools to assist Bioclimatic Architectural Design: Giovani Diagram

They are a tool to help in the overall decision-making process of the bioclimatic project to achieve thermal comfort in buildings. These methods, which integrate the meteorological factors that determine the design, are based on knowledge of the climate and climate variables (temperature, winds, precipitation, and humidity) of the geographical location in question.

The bioclimatic diagram of Givoni (*L'homme, le climat et l'Architecture, 1978*) is based on a psychrometric diagram (also called the humid air diagram). It identifies the optimal thermal comfort for the different months of the year through the main options and modes of intervention such as thermal inertia, ventilation, passive heating by internal inputs, cooling by evaporation, then heating or air conditioning in extreme cases. They are not precise project sizing tools, as digital simulation tools can be, but they are a guide to help the architect make the right decisions during the sketching phase.

As part of a sustainable development approach, bioclimatic architecture is a design method that consists in finding the best balance between the building, the surrounding climate and the thermal comfort of the inhabitants.

It is based on the following principles:

1. Minimize energy losses by adapting to the surrounding climate to:

- favor the compactness of the building;

- provide effective insulation to conserve heat;
- Reduce sashes and glass surfaces on facades exposed to cold or bad weather.

2. favor natural winter thermal inputs to:

- prefer openings and glazing on façades exposed to the sun;
- store heat in heavy masonry;
- plan solar designs that favor air heating (example of a combination of walls with dark coatings plus glazing resulting in natural thermal air circulation, such as TROMBE walls).
- provide solar installations for domestic hot water heating.

3. Favor the use of natural light:

- integrate well-positioned elements transparent to incident solar radiation into the envelope;
- choose appropriate materials and colors.

4. Favor natural cooling in summer:

- provide fixed, mobile or natural solar protection (roof projections, vegetation, etc.);
- provide natural ventilation that can cause draughts at night;
- choose materials with appropriate thermal inertia.

Table 3.2: Mandatory principles to be implemented in each project

ORIENTATION	FORM AND COMPACITY
OPENINGS	MATERIALS, SKIN, COATING
THERMAL INERTIA	THERMAL INSULATION OF THE ENVELOPE (WALLS, ROOF, WINDOWS ...)
INNER ATMOSPHERE (Use, Thermal Comfort)	ENERGY • Renewable energy (solar, thermal, photovoltaic, ...) • Energy management and performance according to the regulations in force (RTCM)

Source: Retrieved from L'Homme, l'Architecture et le Climat, 1978, Imane Ourhadja, 2019.

4. ENERGY CONSUMPTION AND ENERGY EFFICIENCY

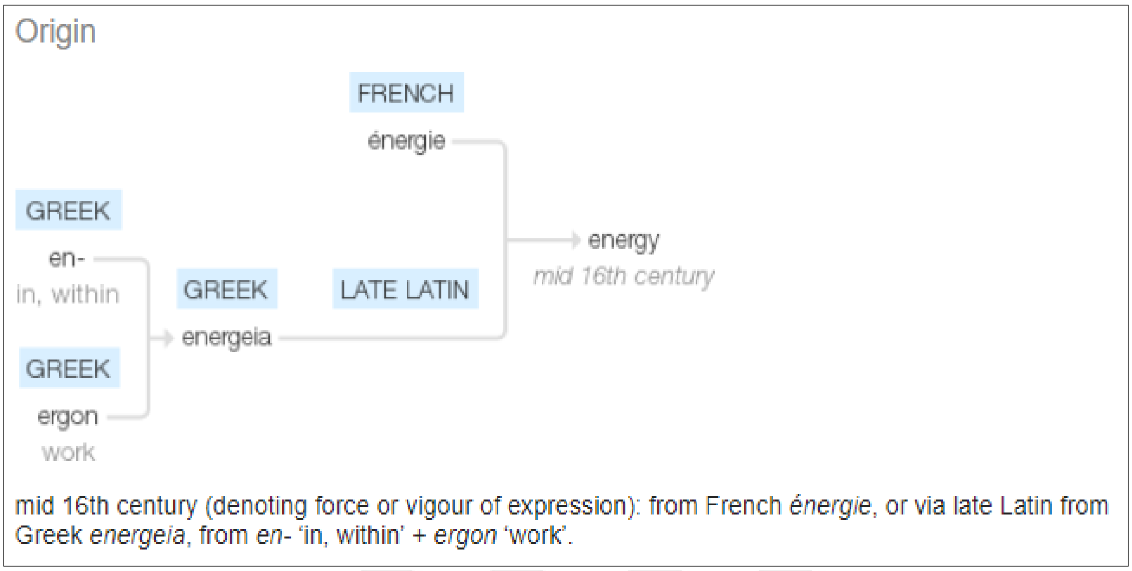
4.1 CONCEPTS AND DEFINITIONS

Figure 4.1: Definitions of energy

- Primary energy: not transformed after extraction (coal, lignite, crude oil, natural gas, primary electricity). Primary electricity: electricity from nuclear, hydro, wind, solar photovoltaic and geothermal (high temperature) sources. -Secondary or derived energy: any energy obtained by the transformation of primary energy (in particular: electricity of thermal origin). Final or available energy: energy delivered to the consumer for final consumption (petrol at the pump, electricity at home...). -Final energy consumption: final energy consumption - net of distribution losses - of all branches of the economy, with the exception of quantities consumed by energy producers and transformers. -Final energy consumption: final energy consumption excluding energy used as a raw material (examples: naphtha for plastics, bitumen for roads, natural gas for fertilizer production, etc.). -Primary energy consumption: final consumption + losses + consumption of energy producers and transformers. Primary energy consumption measures the national energy independence rate, while final energy consumption is used to track the penetration of various forms of energy into sectors of the economy. -Consumption adjusted for climatic variations: consumption calculated by taking into account a climatic severity index, making it possible to obtain consumption under "normal" climatic conditions. The consumption observed before any correction is, in general, called real consumption.

Sources: "Définitions | Insee," 2017

Figure 4.2: Etymology of the word Energy



Source: Etymonline.com. (2018).

The word ''Energeia'' first appeared in the 4th century with Aristotle, as a philosophical concept meaning Operation or Activity. It developed in the late 17th century with Gottfried who developed it to ''Energy'' and defined it as the product of the mass of an object (*En.wikiyy.com, 2018).* It took another direction with the physics researches where energy is the qualitative property transferred to work or heat an object and it may exist in various forms such as kinetic, chemical, nuclear, electrical and thermal, etc.

Unlike fossil fuels (natural gas, oil, coal), renewable energies are inexhaustible and do not emit greenhouse gases. Energy can be provided by non-renewable or renewable resources which are provided by nature and used constantly, while they are inexhaustible such as biomass, solar, wind, hydropower, and geothermal energies *(Sorensen, B. 1991).* Opposite to renewable resources, non-renewable ones are limited and harmful to nature and its habitants, such as nuclear energy and fossil fuels; natural gas, coal, and oil *(Non-renewable energy, Toronto, 1980).*

Table 4.1: Non-renewable and renewable resources differences

	Non-Renewable Resources	Renewable Resources
Source	Present underground layers of the earth.	Present in the atmosphere of the earth.
Replace ability	Cannot be replaced by nature.	Can be replaced by nature itself
Availability	Not available in an abundant manner in nature.	Available and abundant in nature.
Cost	Very expensive	Free
Pollution effect	Release of a huge amount of pollutants	No effect and no release of pollutants
Environmental effect	Cause climate changes	Don’t cause any harm
Effect on atmosphere	Release Greenhouse gases (Global warming)	Don’t cause any harm
Effect on health	Release smoke and radiations	Don’t cause any health problems
Effect on nature	Disturbs the balance of nature	Encourage balance and habitat on earth

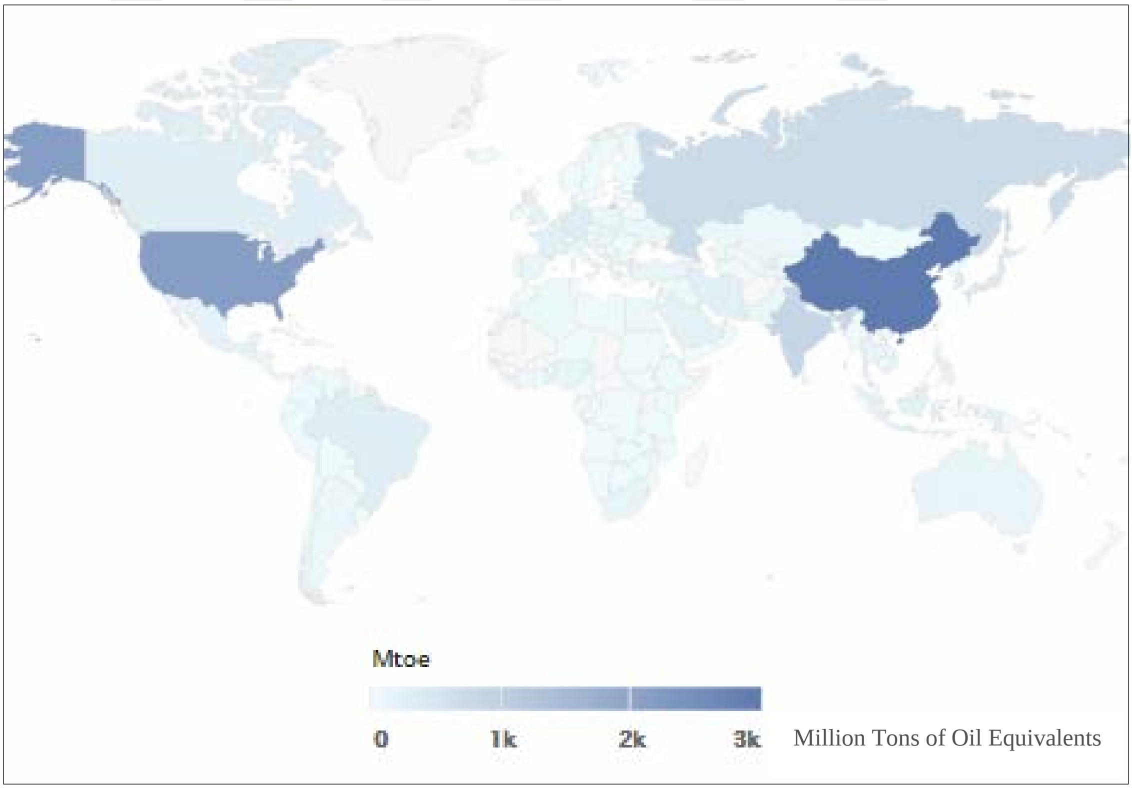
Source: Derived from two sources; Stein, R. 1997& Architecture as Energy, 1977, Imane Ourhadja,2019

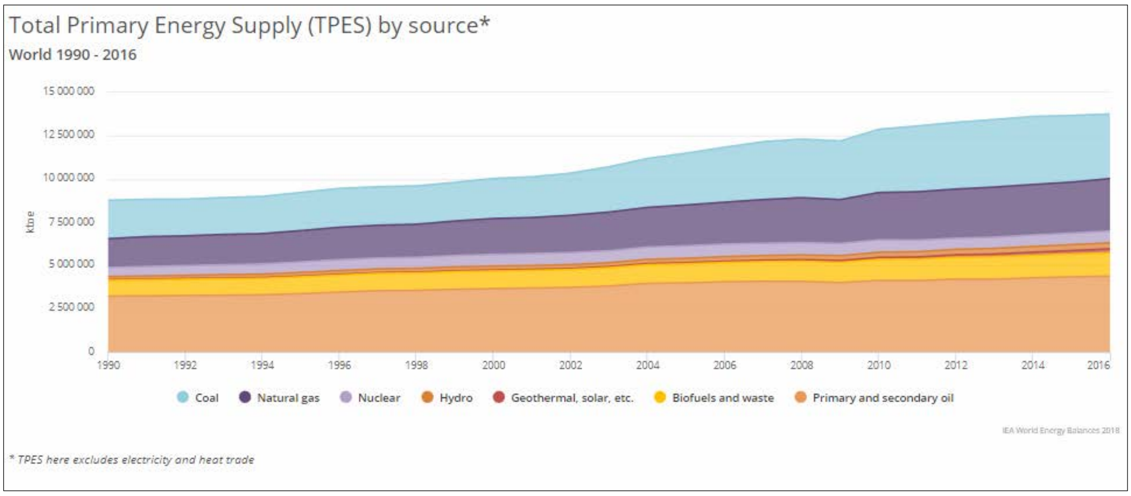
4.2 ENERGY CONSUMPTION

4.2.1 The World energy consumption

Over the years, since the primitive ages, humans used multiple resources in different ways to provide energy. After the industrial revolution which began in the 18th century, the world started consuming a very large amount of fuel, causing a huge amount of CO_2 and greenhouse gases, which by its turn leads to global warming *(Stein, R. 1997& Architecture as Energy, 1977)*. According to the General Commission for Sustainable Development, during the period 1960-1973, the growth in energy demand had been closely linked to economic growth. But between 1973 and the end of the 1980s, the price increases and uncertainties of supply caused by the oil shocks had called into question energy decisions, by encouraging people to control consumption and direct it to other sources(CGDD, 2011).

Figure 4.3: The World's Energy Consumption and Total Energy Supply

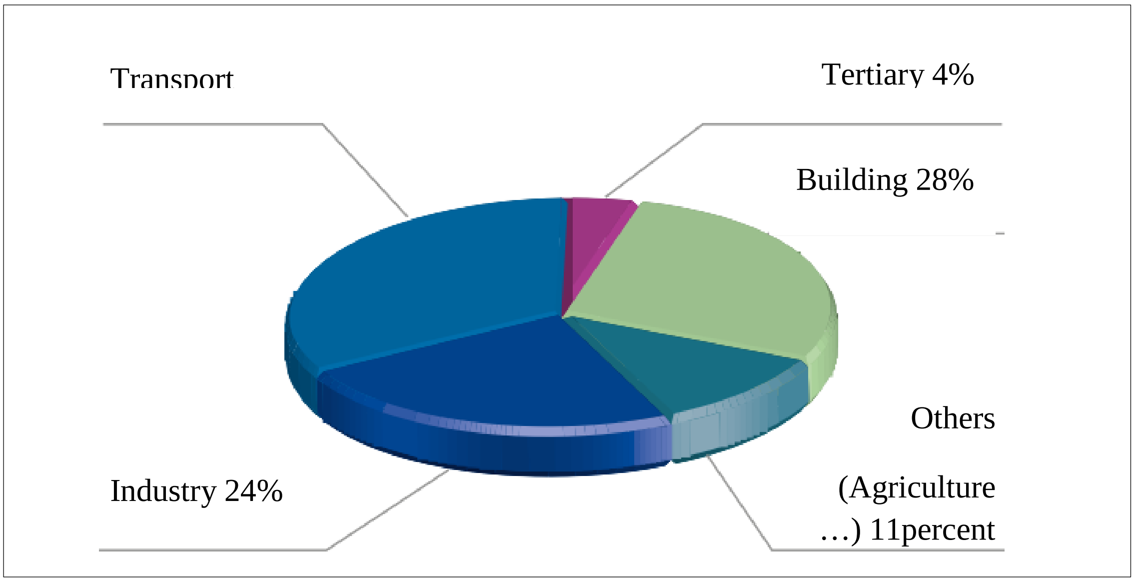




Source: IAE, World Energy Balance, 2018.

In 2018, global energy consumption has increased; it doubled the average rate of growth since 2010, guided by economic issues due to higher heating and cooling needs in the world. The demand for fuels increased; China, the United States, and India together accounted for nearly 70percent of the rise in energy demand. According to IAE, weather conditions are also responsible for almost 20percent of the increase in global energy demand.

Figure 4.4: Global energy consumption by sector in the World



Source: Derived from Beyond 450: Why the IEA's 'Climate Scenario' Falls Short - Oil Change International," 2016, *Imane Ourhadja, 2019.*

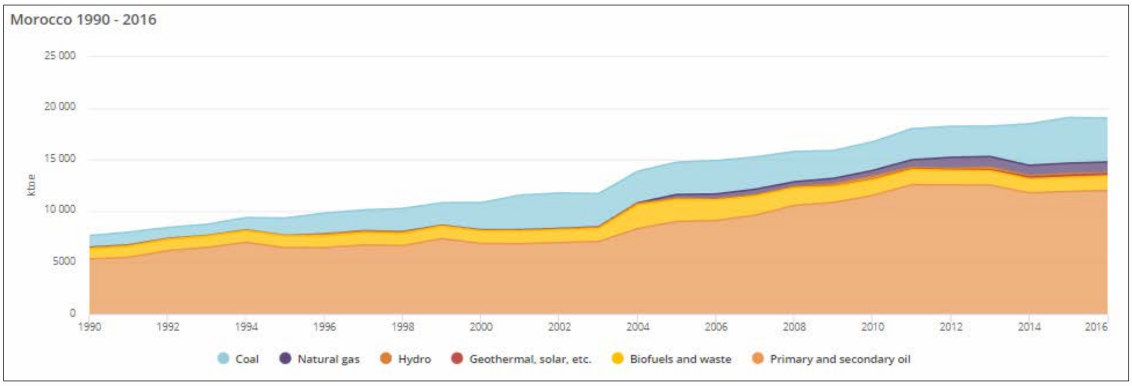
Globally, the building sector alone accounts for around 28percent of final energy consumption and contributes about a third of CO_2 emissions as shown in the graph. It is estimated that the energy saving potential in this sector worldwide is around 40percent, largely through economically viable measures. It is also an eminently strategic sector because of the long life span of buildings: today's constructions will have a lasting impact on tomorrow's consumption. A well-designed building will always be more efficient and less expensive than a retrofitted building.

The energy demand is nearly 40percent of total CO_2 emissions, and in the recent years the global use of energy in buildings has been increasing by 1percent per year, and can increase to 30percent by the end of 2060 if no action is taken (*Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector GLOBAL STATUS REPORT 2017*). To solve this problem, the use of renewables also grew, but not enough to meet the demand for energy around the world. To get the amount needed of energy without harming the planet, using clean energy is fundamental. The world can be saved with a switch toward renewable sources. However, if all the countries concentrate on energy-efficient buildings, the demand for energy can be controlled and decrease. The improvement and the development toward energy efficient buildings are progressing, yet they are trying to keep up with the escalating demand for energy and fast-growing buildings sector.

4.2.2 Energy consumption in Morocco

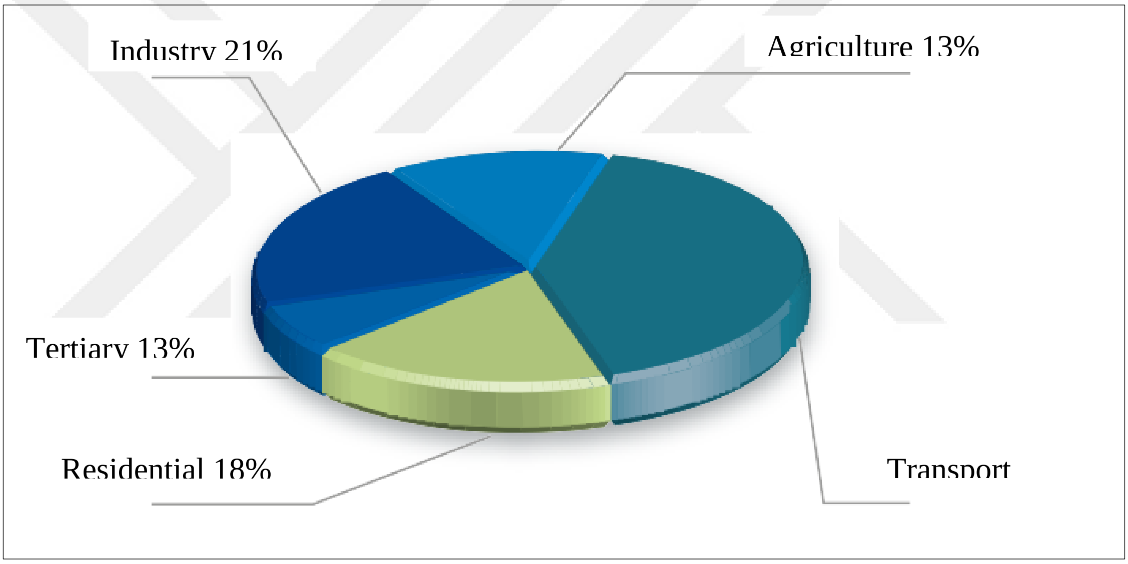
In Morocco, like all countries, energy is the main driver of economic and social development. To meet the growing energy needs of its growing economy and population, the country currently imports more than 97percent of its energy supplies due to the scarcity of its own resources. For that, the country is considered as the largest energy importer in Northern Africa. During the last years, the energy sector is undergoing an evident transition period in Morocco.

Figure 4.5: Total Primary Energy Supply by source in Morocco



Source: IAE, World Energy Balance, 2018.

Figure 4.6: Energy consumption by sector in Morocco



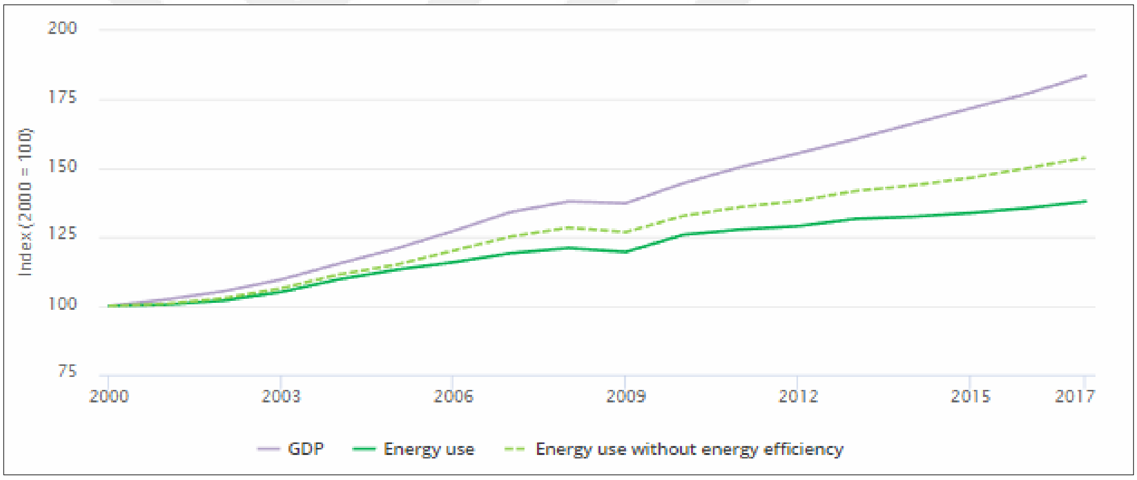
Source: Derived from Morocco Energy Situation - energypedia.info,2019, Imane Ourhadja, 2019.

The objective announced by the Moroccan Government is to achieve a primary energy saving of about 12percent to 15percent by 2020 through the implementation of an energy efficiency plan in the various economic sectors. Among these sectors, buildings that are the second largest consumer of energy, accounting for 25percent of the country's total energy consumption, 18percent of which are reserved for residential use and the rest for the tertiary sector (Développement ADEREE,2017).

4.3 ENERGY EFFICIENCY

Energy Efficiency is the rational use of energy resources: it consists in reducing energy consumption to a minimum in order to provide the same service (*IEA, 2018*). Controlling energy consumption means implementing good practices to reduce energy costs. It is considered to be the building's ability to control its energy consumption for the same level of comfort (*"AMEE - Agence Marocaine Pour l'Efficacité Energétique",2019*). This is technically feasible through architectural design, building envelope optimization, appropriate material selection and the use of energy-efficient technologies. As the IAE stated, it can be considered as the 1st fuel of a sustainable energy system.

Figure 4.7: Global Energy use with and without energy efficiency (2000-2017)



Source: IAE, World Energy Balance, 2018.

From the previous chart, we can deduce that the global energy demand increased by 1.9percent since 2010. Energy intensity fell by just 1.7percent in 2017 and is predicted that it can be ameliorated by 3percent per year until 2040 by taking the cost-effective energy efficiency opportunities in consideration. According to Dr. Fatih Birol, the executive director of IEA; *"The Efficiency can enable economic growth, reduce emissions and improve energy security. The right efficiency policies could enable the world to achieve more than 40percent of the emissions cuts needed to reach its climate goals without new technology"*. Energy Efficiency can mitigate climate change, improve energy security, and grow economies while delivering environmental and social benefits (*IEA,2019*). Brian Motherway, the Head of IEA, claims that: "*Energy efficiency is the cornerstone of a global response to climate change.*"

4.3.1 Energy Efficiency in Morocco

Morocco turns out to be the 1st country in North Africa and the Middle East to work with the IEA's Association. It has plentiful renewable energy resources, essentially solar, wind and hydro-power. (In 2020 will represent 42percent of total energy). Between the 1st countries to introduce energy efficiency measures, Morocco is a regional leader in deploying clean energy technologies. (Compared to 2011, saving up to 12percent of consumed energy by 2020 and 25 - 30percent in 2030) (*IAE, 2018*).

Energy efficiency and renewable energy potentials in Morocco

Energy Efficiency is defined according to *Article 1 of Law No. 47-09 on Energy Efficiency* as "*Any action positively affecting energy consumption, whatever the activity of the sector concerned, tending to an optimal management of energy resources, as well as the control of energy demand and increasing the competitiveness of economic activity. By maintaining the results, service, product or quality of energy obtained at an equivalent level*" ("Law 47-09 on Energy efficiency Morocco 2011 - Policy database," 2011).

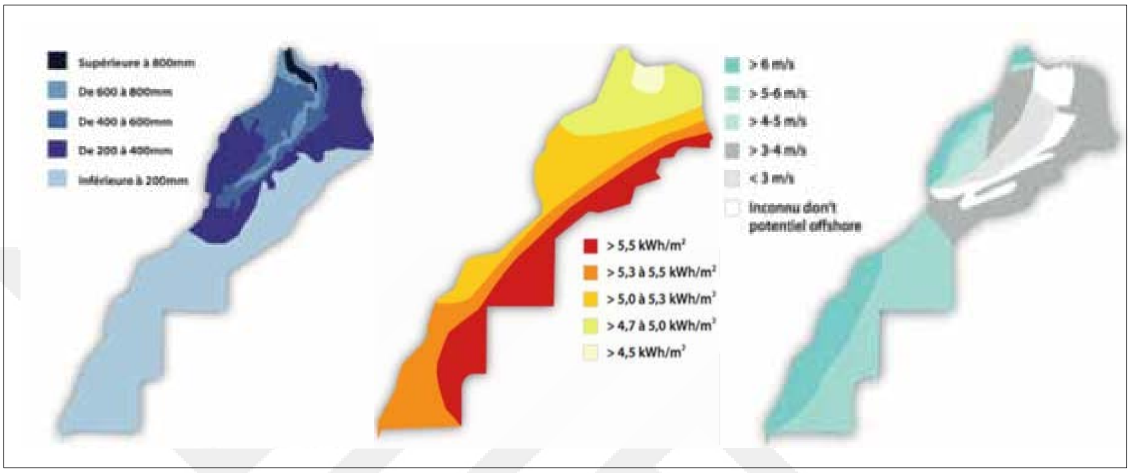
Renewable energies are defined according to Law No. 13-09 on renewable energies as "*All sources of energy that are renewed naturally or through human action, including solar, wind, geothermal, wave and tidal energy, as well as energy from biomass, landfill gas, sewage treatment plant gas, and biogas*" (El Bachtiri, R, El, & Matagne, 2015).

As reported by Mr. Aziz Rabbah, Morocco's Minister of Energy**:** "*Morocco's leadership and commitment to expanding the deployment of renewable energy and weaning itself off imported fossil fuel are to be commended.*"

Morocco has all the resources to reach 100percent renewable energy, according to a study published this month by Stanford University in California. The latter, cited by the website of the French monthly magazine Sciences Et Avenir, is based on data from energy systems provided by 139 countries and on a series of studies that look closely at the development potential of renewable energies to develop scenarios for the development of energy systems.

Morocco is nominated to become a major energy producer thanks to its geographical position that has an important potential in terms of wind and solar power.

Figure 4.8: Solar, Wind and Hydropower Potential in Morocco



*Sources:*Retrived from” Morocco poised to become a solar superpower with launch of desert mega-project” Neslen, 2018, Imane Ourhadja, 2019

Thanks to the variety of Morocco’s landscape, with its two maritime facades totalling more than 3500 km including 500 km in the Mediterranean, its climate benefits from significant solar radiation. Morocco is hosting important renewable energy sources, particularly for solar and wind energy in coastal areas. Solar energy is estimated 20,000 MW within3000 hours of sunshine a year what is estimated to be between 5.5 kW per meter squared to 4.5 kW per meter squared. The expectations of wind speed are between 9.5 to11 m/s, that's why the wind potential is estimated to be 25 GB of which 6 GW could be installed in 2030.Thanks to the hydroelectric structure morocco have covered its basic needs in 2015 by reaching the capacity of 1770 MW which is estimated to reach 3800 MW (Neslen, 2018).

Our daily activities whether it is a matter of heating and cooling products, lighting or irrigating that our consumption patterns and practices are energy consuming. These activities have an impact on our environment, climate change and quality of life. Controlling energy, the main driver of economic and social growth, has become Morocco's priority objective. There are solutions to reduce our energy consumption for greater efficiency and respect for our environment. Energy efficiency must be promoted by the citizen, civil society, the private sector and the Moroccan State as a national issue. It calls for collective awareness and a change in mentality. Thus, for nearly a decade, Morocco has been embarking an ambitious program of energy reinforcement and diversification in favour of the environment and the climate, accompanied by a proactive policy for better energy efficiency.

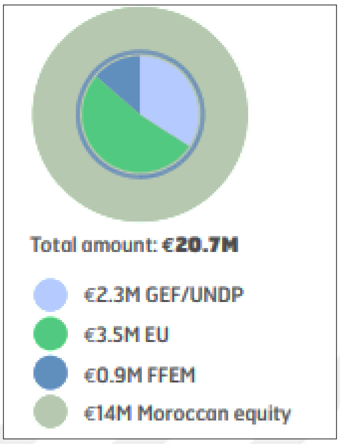
4.3.2 Improving Energy Efficiency in the Building sector in Morocco

In order to reduce its energy bill, Morocco has adopted a national energy efficiency strategy. It aims to achieve an energy saving of about 20percent by 2030 through better use of energy in all areas of economic and social activity (wfc.goodpolicies, 2016).

Buildings are one of the major energy consuming sectors in Morocco, accounting for 33percent of final energy consumption and recording strong growth in annual energy consumption ("REEEP - Morocco (2014)," 2013). The integration of energy efficiency and renewable energy technologies in the construction sector is one of the levers that will enable the Kingdom to meet its energy challenges and achieve its objectives in the fight against climate change (ADEREE, 2019). According to the Moroccan law 47-09/2009 of energy efficiency, *"Morocco's development process is leading to a steady increase in energy demand which can only be met by increasing supply and controlling energy consumption''*.

That's when a project held sustained by the FFEM, and ADEREE (ADEREE became AMEE in 2016) __FFEM the French Facility for Global Environment, AMEE the Moroccan agency of energy efficiency, and ADEREE the Agency for the Environment and Energy Management __, took place to proclaim the progress made regarding the financial support furnished by several international funding agencies for the Moroccan authorities building energy efficiency program. This program is launched in February 2010 and benefited from an investment strategy to get a better return on the employed Capital, held by the GEF through UNDP__ the Global Environment Facility, and the European Union development program __. The investment reached about 20.7 M € over just 6 years and the FFEM made a commitment to share its experience and knowledge regarding energy efficiency in buildings, to support new projects and to reinforce the skills of AMEE to develop building sector.

Figure 4.9: Funds committed for 2010-2016 (in millions of euros)

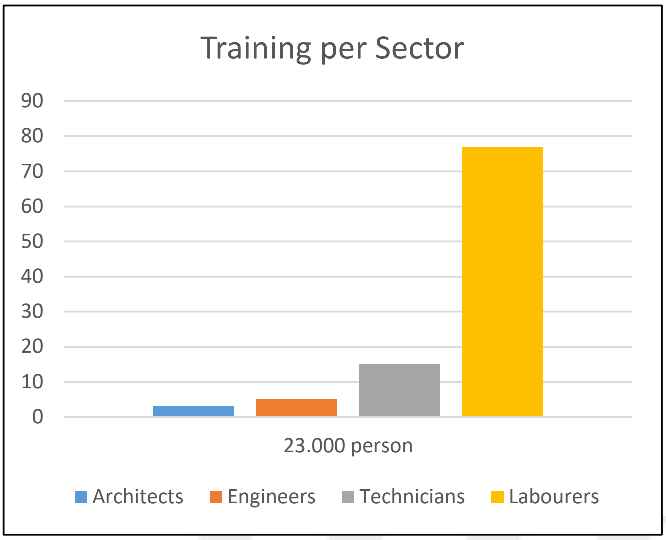


Source: "Morocco | FFEM – Fonds Français pour l'Environnement Mondial," 2016

As reported by DOMINIQUE CAMPANA the director of ADEME, the CEEB (Building energy efficiency code) program, launched in 2010, generated other regulations starting by the thermal code of construction in Morocco in 2015. This project is not only concerned by energy issues but also environmental, social and economic problems in order to improve the condition of living, developing skills to produce new facilities and provide job opportunities. Morocco's energy strategy is mainly about controlling and regulating energy consumption in the building sector because the country is extremely energy dependent, where building sector consumes 25percent of the whole energy (in 2016 was about 6,4 million residential buildings), as stated in the survey done by the *Minister of housing and urban policy MHPV,2015.*

According to the National Energy Efficiency strategy, energy consumption will be reduced by 12percent at the end of 2020 and by 15percent in 2030. For it, MHPV sat a plan consisting of energy efficiency elements for 3 categories: social housing (around 50-80 $m^{2,}$ 250.000 MAD), Middle-class housing (around 80-140 m^2, 7200 MAD/m^2), and Low-cost housing(less than140.000 MAD).

Table 4.2: Training Program per Sector



Source: Derived from ("ENERGY EFFICIENCY IN BUILDINGS IN MOROCCO | FFEM - Fonds Français pour l'Environnement Mondial," 2018), Imane Ourhadja, 2019.

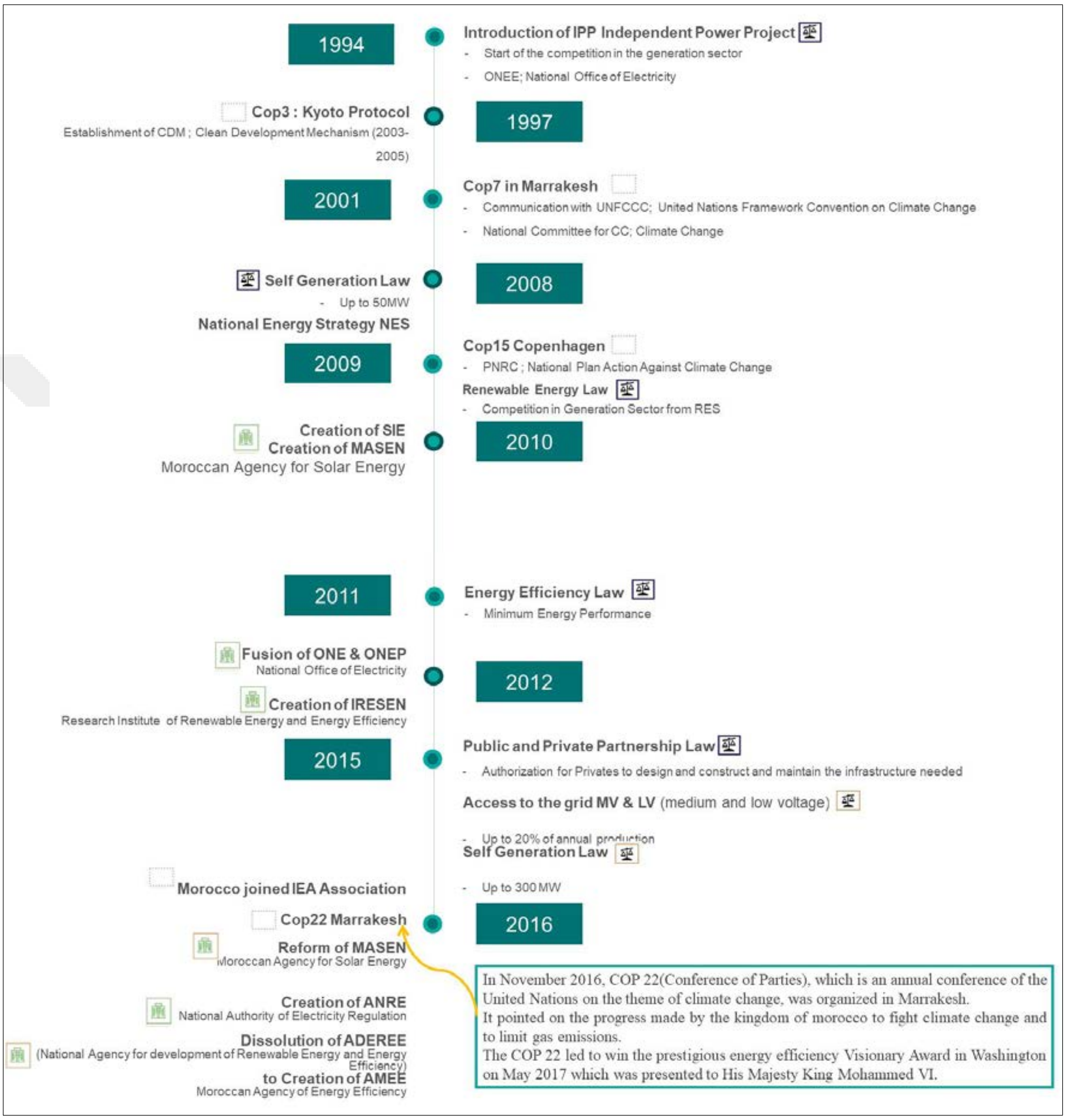
The priority of all of these programs was training to construct more energy efficient buildings. In 2011, the initial training started by surveys, and the supply of needed equipment. It was estimated to train the third out of 720.000 persons including engineers, architects, contractors, and laborers all over Morocco. (23.000 person/year). Another system FORMABAT came after two years in 2013 as a complementary program, which is a professional one specialized for instructors to give better education educating. It started later on in 2015 after many researches, surveys and analysis. It consists of 18 days of theory sessions and training sessions.

The opinion of BADRE KANOUNI, the chairman of the executive board of AL Omrane Group was that *''Energy Efficiency is something that concerns us all…An energy-efficient dwelling is above all a well-designed, oriented, ventilated and insulated one''*.

The support of FFEM to enrich the Energy efficiency program in Morocco can be explained in the words of DOMINIQUE RICHARD, the project manager of climate and energy project, FFEM *''The Kingdom of Morocco did not have thermal in place for buildings. However, the country was and is still seeing very rapid growth in this sector (housing, tourism, public buildings including hospitals), a high energy consumer which is responsible for a quarter of the country's CO2 emissions. Putting in place to set regulation, certifications, standards, and guides aimed at improving energy efficiency in* *the building sector is a way to reduce Morocco's gas emissions and lower its energy dependence.''*

5. REGULATORY LAW AND FRAMEWORK IN MOROCCO

Figure 5.1: Timeline of regulatory framework in Morocco



Source: IAE 2019 &ADEREE, 2018& FFEM, 2017, Imane Ourhadja, 2019

To guide this building sector AMEE took the step to support it, especially when it's assisted by UNDP and FFEM. Conforming to SAID MOULINE, the general director of AMEE ''*when regulatory technical training and financial issues are tackled together, it is possible to change habits and achieve decisive results in terms of energy efficiency…*

Improving energy efficiency relies on changing the attitudes of citizens and on the building sector being fully aware of the environmental and energy-related implications of the new regulations''.

Figure 5.2: Moroccan Laws regarding Building Energy efficiency

Law 13-09 Renewable Energies:

- The project indeed offers the possibility to investors to :
- Create structures dedicated to the production of electrical energy from renewable energy sources
- Exportability
- prior authorization if their power is equal to or greater than 2 MW.
- prior declaration for plants with a power of between 20 KW and 2 MW,

Law 47-09 Energy Efficiency

- Recently enacted aims at integrating EE code measures into the building
- The law also provides for the obligation of energy audits by decree from a certain threshold of energy consumption defined by decree.
- Financial support measures are also planned

Law 16-09 on ADEREE

- The transformation of the CDER into a National Agency for Renewable Energies and Energy Efficiency (ADEREE)

CEEB & RTCM

- The Code of Energy Efficiency in the Building industry, including the Building Thermal Regulation in Morocco (RTCM) : setting the energy performance of buildings and establishing the National Energy Efficiency Committee in the Building.

Source: Derived from"Département de l'Habitat et de la Politique de la Ville," 2017, Imane Ourhadja, 2019

5.1 CONSTRUCTION REGULATIONS IN GENERAL

The issue of climate change is at the heart of the Ministry of Housing's concerns and the City Policy, which places a strong emphasis on sustainability in its development, in order to ensure strong and sustainable economic growth and development Integrated Human Resources.

Energy efficiency is a priority axis of the State's action, aimed at motivating all stakeholders to operators and stakeholders in favor of limiting global warming and controlling climate change energy demand, with the objective of achieving an energy saving of 12percent by 2020 and 15percent by 2030.

As a major energy consumer in Morocco, the building sector must undergo a major transformation. In this sense and in order to initiate the construction of low-energy buildings, regulations are necessary to reduce the energy consumption of buildings while improving the comfort of the occupants.

In this context, the Ministry of Housing and Urban Policy, the Ministry of Energy, Mines, Water and Environment and the National Agency for the Development of Renewable Energies and Energy Efficiency have drawn up General Building Regulations setting out the Rules of Energy Performance of Buildings, this regulation has also been approved by the Ministry of The Ministry of the Interior, the Ministry of Urban and Regional Planning and the Ministry of Public Works, Transport and Logistics.

These general building regulations, which aim to produce a new generation of buildings, focus on to stimulate significant technological and industrial development in the field of and will help to promote the economic competitiveness of engineering, technology and construction.

The Decree No. 213874 of 20 hija 1435 (15 October 2014) approves the general building the regulations setting out the rules on the performance of buildings and establishing the national committee on energy efficiency in buildings:

Article 1: The general building regulations sets out the rules for the energy performance of buildings.

Article 2: For the application of the general building regulations defining the energy performance rules for buildings, in accordance with the climatic zoning defined by this Regulation, the national territory shall be divided.
Any modification or revision of climate zoning must be the subject of a joint order by the government authorities responsible for urban planning, the interior, housing, equipment and energy.

Article 3: The general building regulations setting out the rules for the energy performance of buildings shall apply residential and tertiary buildings to be built.

For the purposes of this Decree, the following definitions shall be applied:

- Residential building: any building whose residential spaces constitute more than 80percent of its surface area,
- Tertiary building: all public facilities and buildings in the tertiary sector tourism, health, education and teaching, trade and services.

Article 4: The provisions of this Decree shall not apply to:
§ buildings existing before the entry into force of this decree.
§ buildings for agricultural, craft or industrial use, other than premises used for housing in the same premises.
§ buildings used for manufacturing, industrial and storage operations.
§ buildings or parts of buildings that require indoor conditions such as greenhouses, or warehouses.

Article 5: A committee known as the "National Committee for Energy Efficiency in Buildings" is set up to: propose and give its opinion on the revision or modification of climate zoning, as provided for in Article 2 of this Decree.
It studies the amendments and proposes improvements to be made to the General Building Regulations laying down the rules on the energy performance of buildings annexed to this Decree, taking into account developments in knowledge and techniques relating to energy efficiency and renewable energy.

Article 6: This committee is composed, under the chairmanship of the government authority in charge of energy, of:
§ the government authority in charge of urban planning.
§ the governmental authority in charge of the interior.
§ the government authority in charge of housing.
§ the government authority in charge of the equipment.
§ the government authority responsible for industry.
§ the government authority responsible for scientific research.

§ the national agency for the development of renewable energies and energy efficiency.
This committee may be joined by anybody or expert whose participation is deemed useful, at the request of its chairman.
The said committee shall meet once a year and whenever necessary at the request of its chairman.

5.2 THE THERMAL REGULATION OF CONSTRUCTIONS IN MOROCCO

The Thermal Building Regulations in Morocco (RTCM) is a set of rules that essentially aim to improve the thermal performance of buildings, reduce heating and cooling needs, and improve the thermal comfort of users. In particular, it encourages building professionals, architects, engineers and prime contractors to adopt efficient thermal design approaches for the building envelope. It sets performance levels for building envelope components according to established climate zoning, and minimum energy performance levels for heating, ventilation and air conditioning (HVAC) systems. This approach promotes efficient equipment.

By specifying the required performance thresholds, the RTCM is a basic document that can be used from the design stage, as a basis for specifications developed for construction or renovation projects. Compliance with these regulations will make it possible to generate substantial savings on household electricity bills and contribute to more optimized consumption at national level.

As part of the implementation of Law 47-09, the Ministry of Energy, Mines, Water and Environment, in partnership with the Ministry of Housing, Urban Planning and Urban Policy, and the National Agency for the Development of Renewable Energies and Energy Efficiency, have prepared the draft decree approving the thermal building regulations in Morocco (RTCM), applicable to buildings, establishing the energy performance rules for buildings and establishing the National Energy Efficiency Committee.
This Regulation works to integrate energy considerations into buildings within key sectors of development policy. It concerns both the passive component of the building (bioclimatic, envelope, orientation, etc.) and the active component (HVAC, DHW,

lighting, heating, air conditioning, etc.) in the residential and tertiary sectors, with the main objectives.

The Thermal Building Regulations define the minimum technical specifications for the thermal performance of buildings to be met, both in the residential and tertiary sectors, in order to obtain the following results:

- Reduce air conditioning needs: heating and cooling;
- Improve thermal comfort;
- Optimize the design of the building envelope, independent of the building's energy installations.
- Encourage architects and owners to use the thermal performance approach in the design of the building envelope.
- Support the performance of energy diagnostics and audits of existing buildings, by establishing desired reference levels and providing software that allows the simulation of alternative solutions.

The Thermal Regulations apply to all new buildings. Existing buildings are evaluated through energy audits for future implementation of the appropriate measures identified, with a view to adapting them to the new Regulation. The methodology used to develop the RTCM is a process involving the main actors in the construction sector. In agreement with MAJIDA EL OUARDIRHI, the director of quality and technical affairs in MHPV, she claims that ‘‘*the energy efficiency regulations for construction represent an opportunity to tap the energy-saving potential of the construction sector. They aim to reduce the heating and air conditioning requirements of buildings while at the same time improving thermal comfort and optimizing the design of the building envelope.*’’ The Thermal Building Regulations in Morocco (RTCM) provide a solution to the problem of excessive energy consumption in the building sector, both in terms of construction and in the operation of electrical equipment. The acceleration of new housing construction, and the expansion of the heating, ventilation and air conditioning (HVAC) fleet, has a significant impact on the country's overall energy consumption. The implementation of this regulation (RTCM) provides for the development of the technical specifications of the thermal regulations. It leads to the implementation of a strategic plan and appropriate communication tools for mobilizing and raising awareness among stakeholders, including administrations and companies, energy efficiency in buildings. In addition, it helps to create a favorable climate for investment in energy efficiency.

5.3 CLIMATIC ZONING IN MOROCCO

For an easy and efficient application of the Thermal Building Regulations in Morocco, ADEREE has developed a climate-zoning map including six climate zones. They are represented climatically by the following cities:

Table 5.1: Climatic Zones According to ADEREE

Zone 1	**North Atlantic Zone,** Agadir, Casablanca, Rabat
Zone 2	**Doukkala and Souss lowlands,** Tanger, Al Hoceima, Nador
Zone 3	**Mediterranean coastline and countryside - Rif,** Fes, Meknes, Oujda
Zone 4	**Middle and High Atlas,** Ifrane, Midelt
Zone 5	**Anti-Atlas,** Marrakech
Zone 6	**Saharan zone,** Errachidia , Ouarzazate

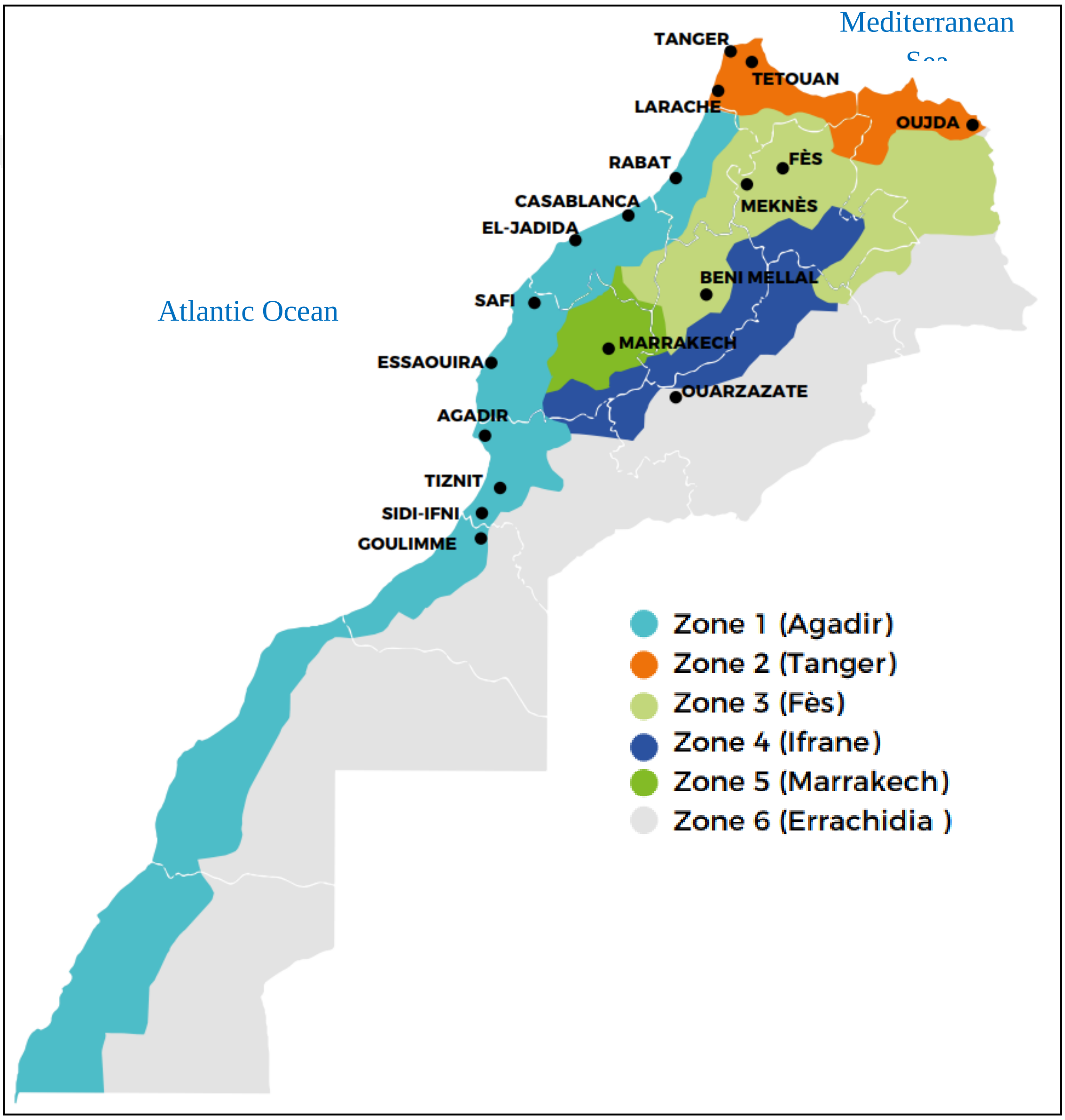
Source: Derived from “Département de l’Habitat et de la Politique de la Ville,” 2017, Imane Ourhadja, 2019

The RTCM system was a good solution since Morocco is divided to different climate zones. It is based on joining the thermal performance requirements for buildings with climate zoning. It has two approaches related to each other; the first relies on the performance setting the maximum energy that a building can consume, and the second on the target, by predicting the thermal properties of the building envelope according to its climatic zone.

The RTCM needs to be implemented into every project in Morocco. Therefore, it is mandatory to raise public awareness, give information about RTCM to the concerned stakeholders, starting by contractors, clients, and architects to use it to check their designs and plans. The RTCM request also indirectly to develop the technical construction materials, and push the manufacturers to make sufficient products.

Confirming to it MERIEM TAHIRI, the Vice-President of the National Council of the Order of Architects ‘‘*A building’s design must consider the climate zone, orient the building correctly and use building materials that comply with the regulatory thermal* *performance requirements. These new measures relating to the design of architectural spaces should lead to innovation in building techniques that will contribute to sustainable environmental performance more widely''.* Project owners, project managers, building professionals and potential users are called upon to adopt good practices and actions to comply with the requirements of the Thermal Building Regulations in Morocco for each climatic zone.

Figure 5.3: Map of Morocco's Climate zoning



Source: Derived From "LE CLIMAT DU MAROC | Maroc Météo," 2019, Imane Ourhadja, 2019

The Thermal Regulation of Constructions in Morocco adopts the climate-zoning map comprising six climate zones with different climates: humid, sub humid, semi-arid, arid and desert, circumscribed within the administrative boundaries, for an easy and effective application.

5.4 ENERGY EFFICIENCY LAW N° 47-09

Morocco's development momentum, highlighted by the major projects completed or under way in all economic and social sectors, particularly in the areas of port and airport infrastructure, motorways, industry, agriculture, tourism and the creation of new cities, has led to sustained growth in energy demand, which can only be met by strengthening supply and controlling energy consumption.

Energy efficiency is now considered a fourth energy after fossil fuels, renewable energies and energy nuclear. The Kingdom of Morocco's ambition is to ensure a better energy use in all areas of economic activity and social, considering the need to rationalize and improve the energy consumption to meet energy needs of our country.

In a context of almost total energy dependence of the country on from abroad and a significant fluctuation in energy prices, it has become the need to implement an ambitious energy efficiency policy as part of its new energy strategy, aimed at exploiting Morocco's significant potential for energy efficiency.

This policy aims to clarify the relationship between the administration and operators by establishing an institutionalized system of governance of energy efficiency, an adequate legislative and regulatory framework and appropriate norms and standards.

The purpose of this Act is to increase energy efficiency in the use of energy sources, avoid waste, reduce the burden of energy costs on the national economy and contribute to development sustainable. Its implementation is mainly based on the principles of the energy performance, energy efficiency requirements, energy impact studies, mandatory energy audit and technical inspection.

It also aims to integrate energy efficiency techniques in a sustainable way into all sectoral development programs, encourage industrial companies to rationalize their energy consumption, generalize energy audits, set up sector-specific energy efficiency codes, promote the development of solar water heaters, and generalize the use of low-energy lamps and equipment adapted to public lighting.

In order to strengthen energy efficiency in key sectors of the national economy, means and incentives will be put in place.

In addition, training, further training, vocational training, scientific research and demonstration of techniques in all sectors must be implemented to promote energy efficiency and energy saving.

6. STUDY CASES FOR THE INTEGRATION OF ENERGY EFFICIENCY IN RESIDENTIAL BUILDINGS IN DIFFERENT ZONES IN MOROCCO

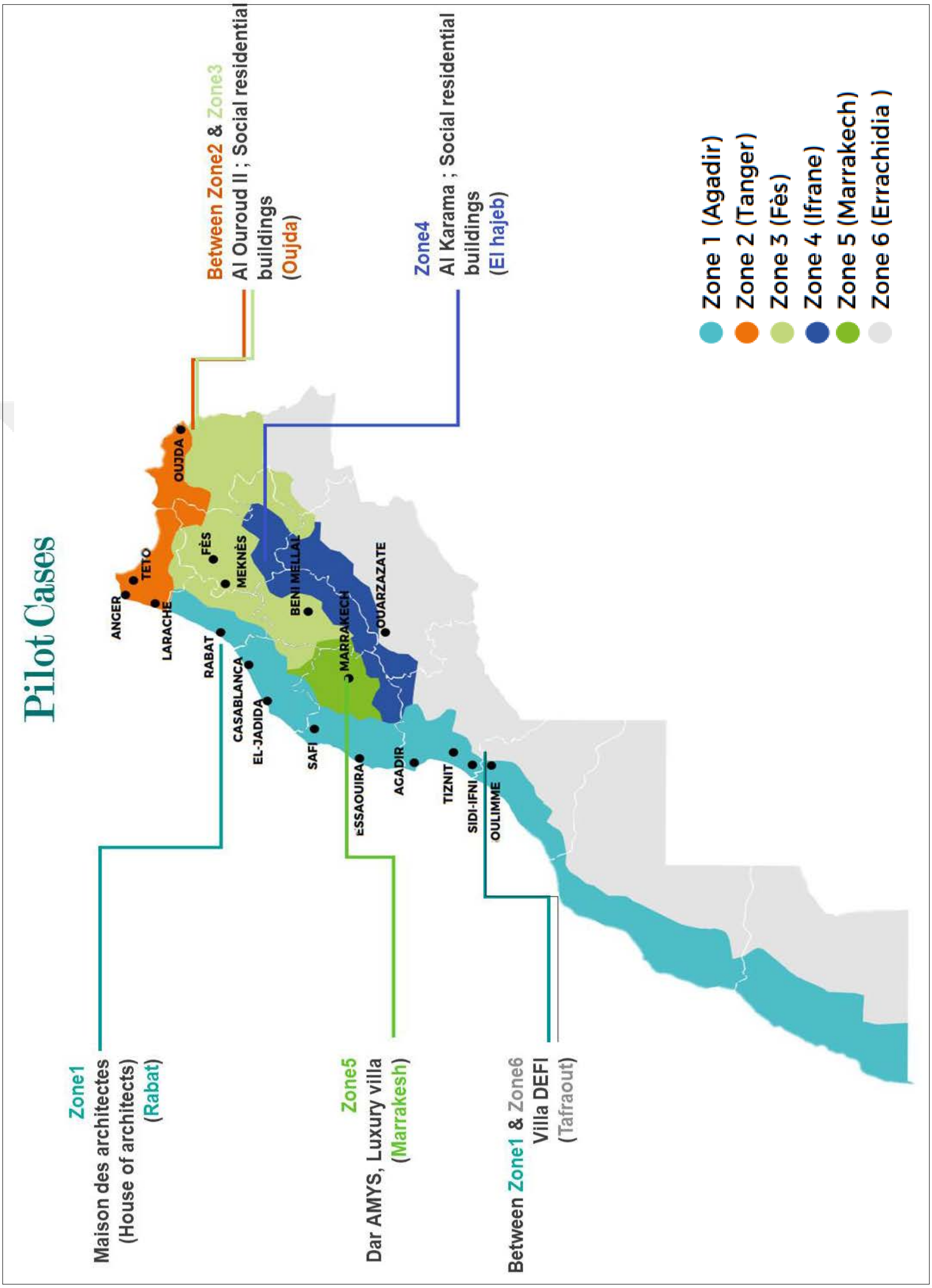
The objective of the demonstration projects is to demonstrate energy efficiency measures on real cases of new or renovated residential or tertiary buildings. In addition, to demonstrate the feasibility of technical solutions that improves the thermal performance and comfort of buildings at lower cost. All the projects are realized in a framework of thermal regulation of housing, taking into account the capacities of the Moroccan market and companies.

Table 6.1: Study Cases

Project designation	Project owner	Architect	Location	Climatic zone	Project type
LA MAISON DES ARCHITECTS	Myriam Soussan et Laurent Moulin	Myriam Soussan et Laurent Moulin	RABAT	Z1	Old Building
AL OUROUD 2	Al Omrane Oujda	Ahmed Barhdadi	Al Arrouit	Z2-Z3	Social Housing
AL KARAMA	Al Omrane Meknes	Alla El Hassan & Claire Patteet	El Hajeb	Z4	Social Housing
Dar AMYS	Amin Bennouna	Mohamed El Anbassi	Marrakech	Z5	Villa haut standing
CHRAFATE	AL ANSARY	Mohamed El Mankibi	Tafraout	Z1-Z6	Villa

This study cases (Table 6.1) present the essential elements of institutional and regulatory information and technical solutions. In order to enable new housing construction programs to be undertaken by integrating appropriate principles and technologies to rationalize energy consumption.

Figure 6.1: Location map of Study Cases



6.1 ZONE 1: MAISON DES ARCHITECTES (HOUSE OF ARCHITECTS IN RABAT)

Climatic zone	Project Type	Project owner	Architect
Z1 RABAT	House of architects (Renovation of an Old building)	Myriam Soussan et Laurent Moulin	Propriétaires Myriam Soussan et Laurent Moulin

"House of architects" is a very important building in terms of energy conservation. It is a modular triplex 100percent autonomous, and eco-responsible in terms of energy, water, and waste. It is located in the heart of the Medina of Rabat.

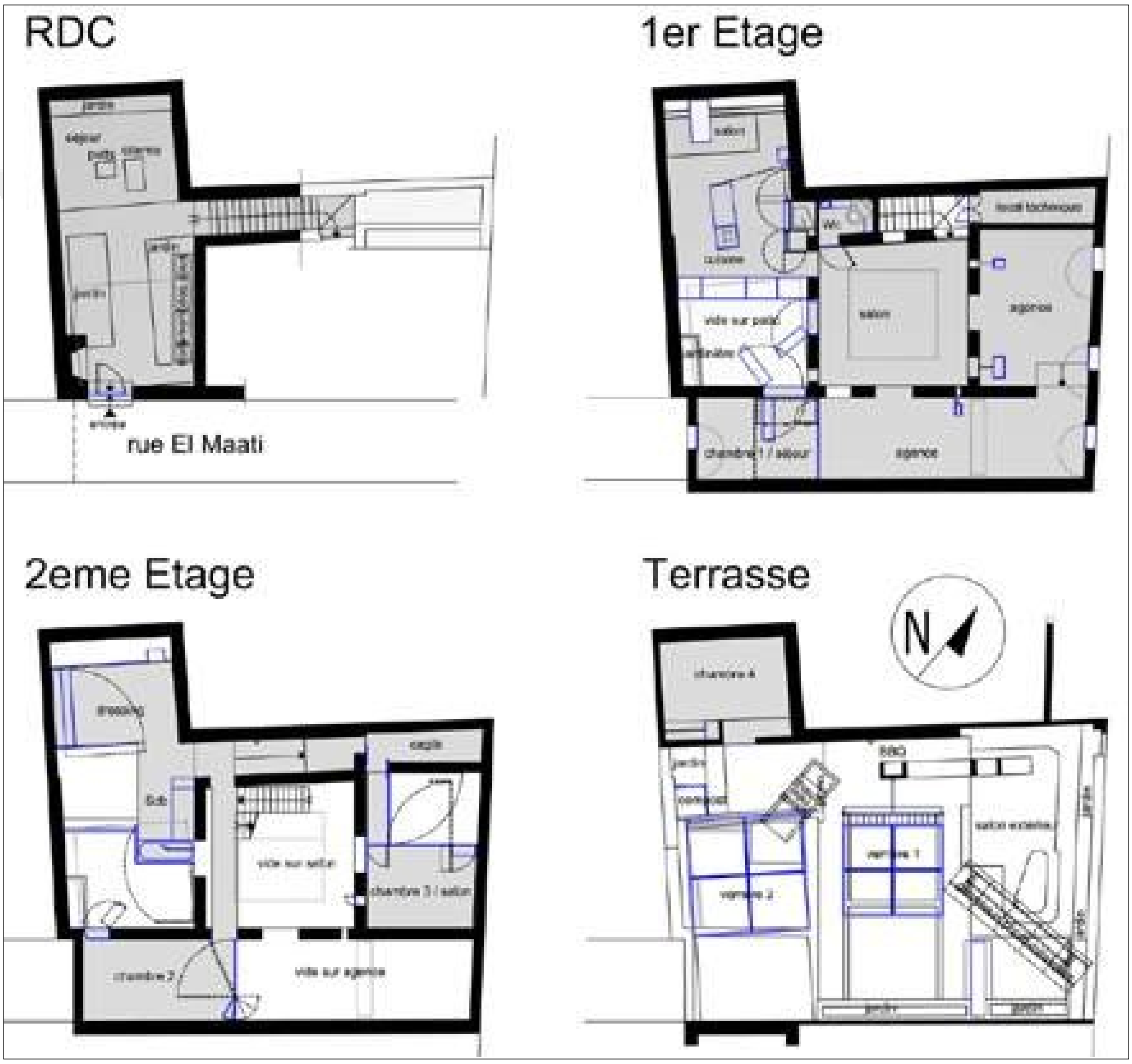
Figure 6.2: Old Street of La Maison des architectes.

The house interior design of this house in the Medina of Rabat is inspired by a research for a Moroccan architectural model, contemporary and bio-climatic. The first challenge was to achieve a small-scale and accelerated reproduction of natural cycles (water cycle, organic material cycle, energy cycle). The second challenge was to merge and combine different devices related to the development of these cycles into an innovative architecture in terms of space use. In response to current environmental problems, various processes have been implemented. They considered rainwater recovery and solar process, including the proper management of waste and organic materials. The energy autonomy combined with the flexibility of the space provided a unique system. Such an approach ensures the cohesion and balance of the different elements of the architecture it governs.

The pilot project of the two architects thus ensures, on a housing scale, an architectural and environmental harmony.

6.1.1 Orientation and Form

Figure 6.3: Plans of La Maison des Architects



Source: "aMush," 2017

The building is located in the old Medina, on a narrow street. It is juxtaposed to other old buildings oriented east west with a disorientation of 25°-30 °.

Figure 6.4: Entry photos of the House of Architects

Source: Imane Ourhadja, 2019

To access this autonomous house, you have to use one of the large gates of the ramparts. After crossing Bab Chellah, just walk along the widest street in the area to reach Souika/ shops. Once in the heart of the turmoil, there is a maze that leads to Sidi Maâti Street. Apart from the noise of children during recess, calm reigns over this old city, which is not very popular with tourists. Part of the riad is next to the local school. A whitewashed door opens onto a small garden. A chair tells you to take off your shoes. As soon as you enter, the color is announced. In the middle of the cobblestones and wild vegetation, the wooden staircase leads directly to the first floor.

Flexibility

This modular architecture allows a real nomadic lifestyle, according to needs (change of use, transformation or reduction of spaces), seasons, or the number of occupants (modification of the partitioning). There is no fixed space to which a function is assigned: in this house, everything is transformed and moved.

- **Multiplicity of functions by elements.**

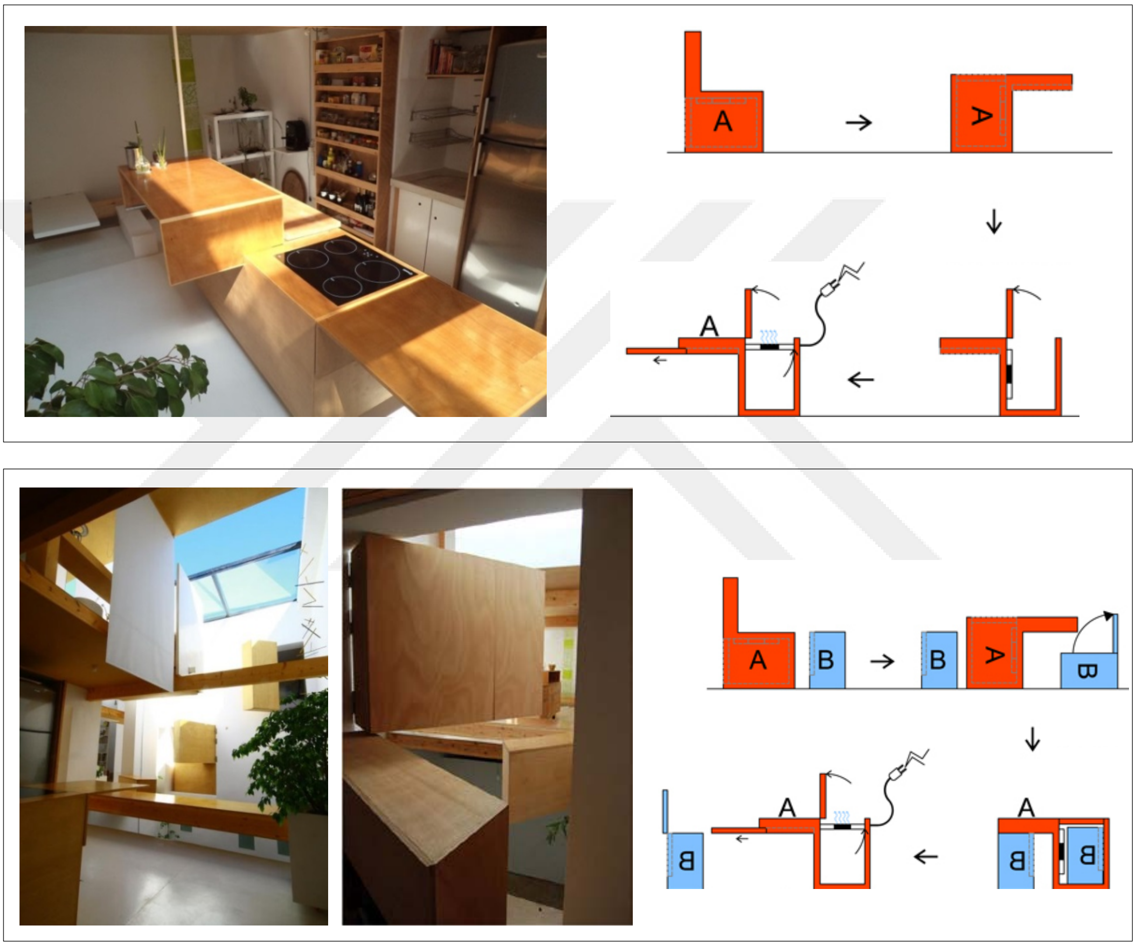
From chair to table to box to an addition to the kitchen as in Figure 6.1.4.

- **Associativity of the elements.**

Modularity inside the house allows a real nomadism through transformation, variation, addition or reduction of spaces. It also enables the modification of the division according to the number of occupants. Everything can be changed and moved inside the house because nothing is fixed, in order to increase chances to diverse and multiple the combinations.

- **Mobility of the elements and convertibility of spaces**

Figure 6.5: Photos from the interior of the House of Architects



Source: Taken from "aMush," 2017, Imane Ourhadja, 2019

Figure 6.6: Photos from the interior of the House of Architects

Source: Taken from "aMush," 2017, Imane Ourhadja, 2019

6.1.2 Materials, skin, and coating

Table 6.2: Materials used in House of Architects

ENVELOPE WALLS (Existing walls)	ROOF	INTERMEDIATE FLOOR
Existing earth/stone walls	Concrete Wood Cork insulation Double glazing with Steel joinery	Intermediate wooden floors

Source: Derived from Smisek, 2019, Imane Ourhadja, 2019

Cork insulation is 100percent natural insulation, carbon negative, used as a passive house material, because of ıts high efficiency.

6.1.3 Openings

In the 1st floor only three windows on south east and only one on the opposed wall which represents a small percentage on the overall area.

Figure 6.7: Photos from the interior of the House of Architects

Source: "aMush," 2017

The two major openings in this case are located on the roof representing 28percent and allowing natural ventilation.

6.1.4 Thermal insulation of the envelope

Envelope walls are characterized with high thermal inertia (earth/stone). Insulation of the roof is made of cork, while the intermediate floors are made of wood. Moreover, all windows are double glazed. Two glass roofs are totaling almost 24 m² with double glazing for winter heating.

6.1.5 Thermal Comfort

The temperature is around 20 degrees all year round thanks to these removable bays and awnings. Energy autonomy, photovoltaic solar panels, double glazing, rainwater harvesting in a cistern, filters to obtain quality water for kitchens and bathrooms, greywater treated with "phyto-purification", dry toilets with dehydration, organic materials and composted waste on the terrace, compost for plants and vegetable gardens... everything has been designed to preserve the planet without neglecting the practical or aesthetic aspect.

6.1.6 Energy

The pilot project of the two architects ensures an architectural and environmental harmony on a housing scale. In response to current environmental problems, various processes have been implemented, ranging from rainwater harvesting to solar processes, as well as good waste and organic matter management. The energy autonomy combined with the modularity of the space sets up a real system. Such an approach ensures the cohesion and balance of the different elements of the architecture it governs. These elements, by their formal simplicity, open up multiple combinations, as if not to interfere with the different possibilities that architecture offers.

- **Water**:

Rainwater is theoretically, the only source. Collected from the terrace, they are collected and stored in the existing traditional cistern, with a volume of 60 m³. It corresponds precisely to the amount used water in the house each year. The well, which has also been preserved, will be able to provide additional power if necessary. (See Appendices)

- Preliminary treatment: a series of filters provides bathing quality water that supplies the kitchen and bathrooms. Additional micro-filtration provides drinking water for a drinking water valve.

Figure 6.8: Water Treatment

Source: "aMush," 2017

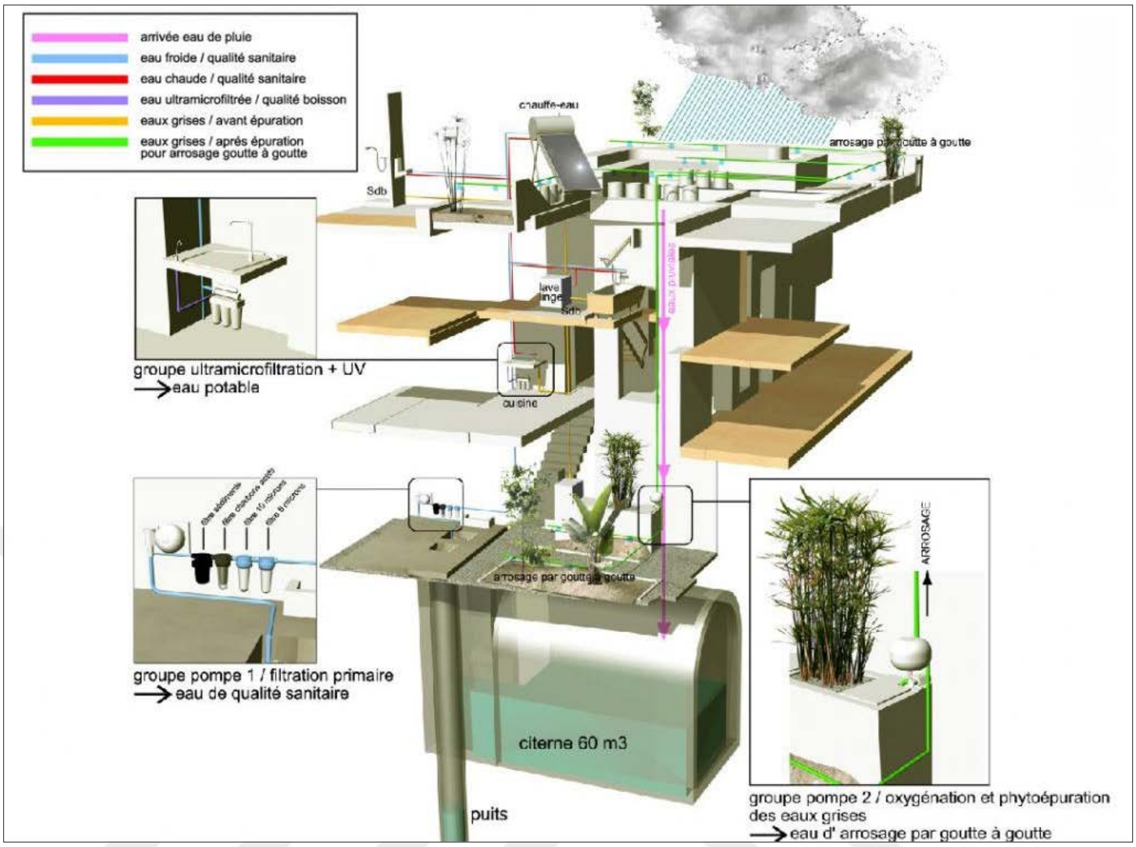
- Optimized consumption: the choice of economical taps and the presence of dry toilets with dehydration allow a consumption of 40 liters/person/day. This should ensure autonomy of 2 years once the tank is full.

- Downstream treatment: which means dry toilets, means the absence of black water (black water) which, let us recall, is usually the heaviest burden to treat (phosphates, nitrates, pathogens) So only grey water (kitchen, bathrooms) remains; it is treated by phytol-purification. The filter consists of a grease filter, a tank with bubbles (oxygenation), a filter planted with reeds, and a storage tank. This treated water then feeds the vegetables in the terrace gardens.

Figure 6.9: Vegetation on the roof

Source: "aMush," 2017

Figure 6.10: Illustration of Water as energy Source

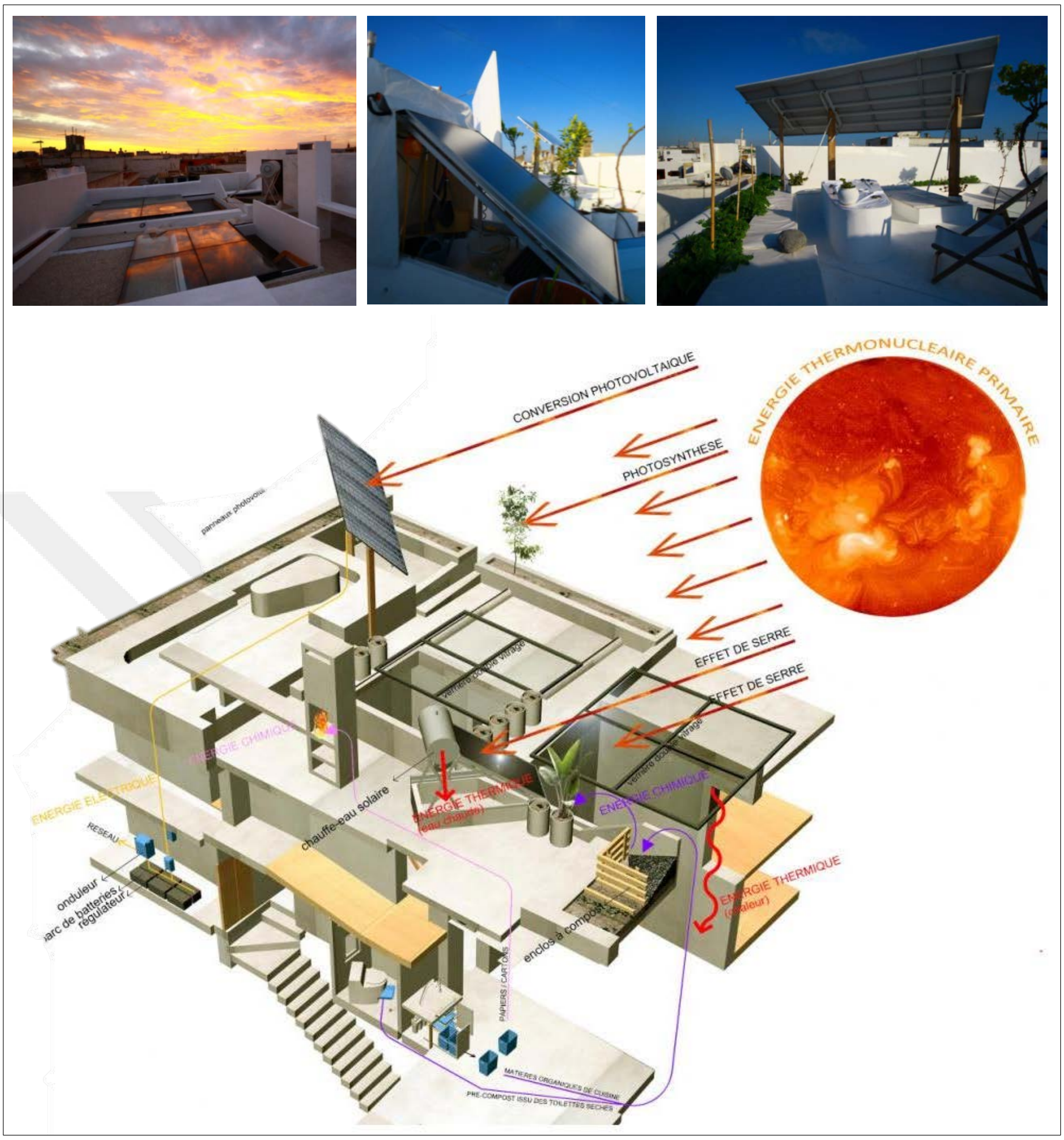


Source: “arcVision.org,” 2016

- **Light, Heat, and Electricity:**

The bioclimatic architecture implemented makes it possible to reduce the needs of the habitat significantly. On the envelope side, as it is a Riad of the medina (semi-detached, mesa-climate...) only the flat roof has been improved by 4 cm of expanded cork panel insulation. On the opening side, each window was equipped with double-glazing and shutters. As for the two patios, usually open and highly water-repellent, they are closed with large removable bays and double glazing, which makes all the difference. Indeed, these two bays heat almost all volumes in the cold season, while preserving precious energy. Only a mobile backup (gas) is used on days of extreme cold. In the hot season, the use of awnings, combined with the night opening of the bays, which creates efficient ventilation, makes it possible to eliminate the need for artificial air conditioning.

Figure 6.11: Photos of the PV Panels used on the roof and Illustration of the heat



Sources: Derived from “arcVision.org,” : “*aMush,*” , 2018

As far as lighting is concerned, natural lighting has been treated with small onions, resulting in an "abnormally" bright riad. In addition, low-energy artificial lighting is provided in all rooms (Fluocopmacts, LEDs). For heating, 1075Wc of photovoltaic panels, a 150V / 70A max regulator, 5kVA UPS (220V), 6 batteries totaling 1320Ah.

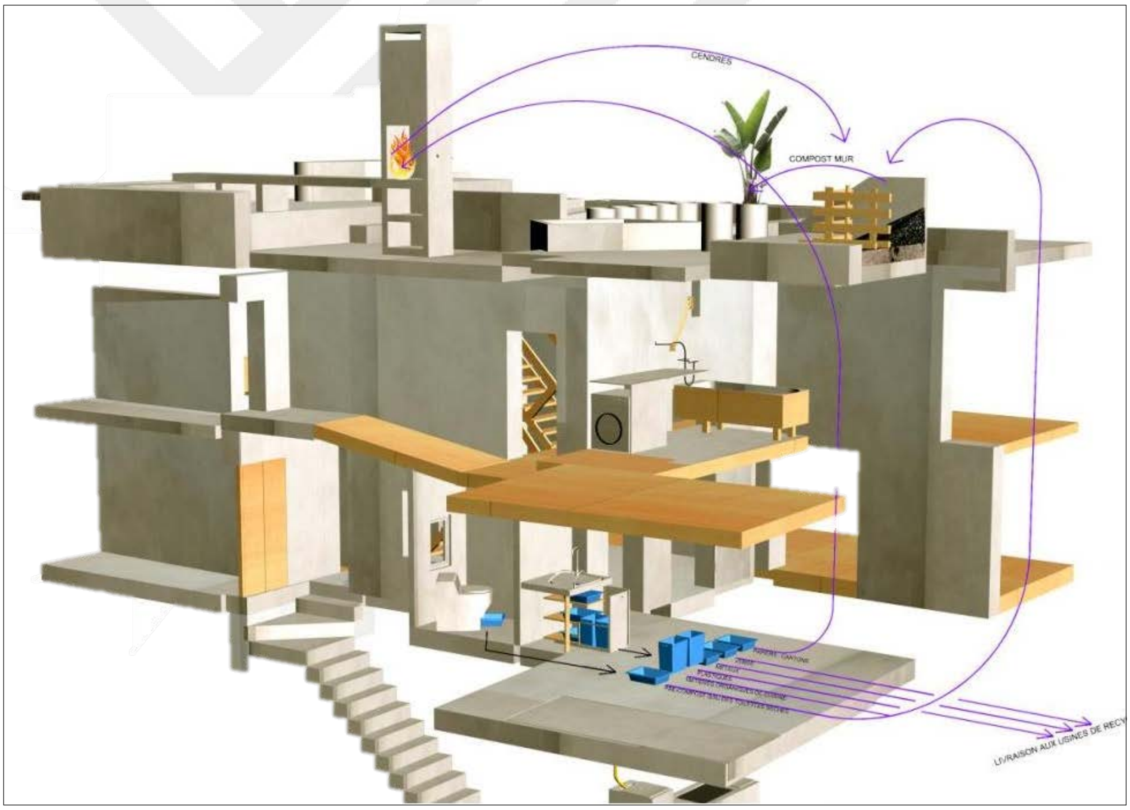
As for household appliances, a refrigerator and washing machine was used and powered by the CES. On the other hand, electric ovens (the solar oven integrated in the kitchen is under study). Local production: electricity is produced by photovoltaic panels (8m²).

Electricity is stored in batteries, as grid connection is not yet on the agenda in Morocco. Despite the induction heaters and additional equipment (iron, oven,etc.) the autonomy is total, even in winter! Seasonal optimization is simply carried out by manually changing the angle of the panels (the azimuth is fixed), by fetching the sun.

- Organic materials and waste

The habitants are fighting against the over packaging and plastic bags that invade us every day. They think that we need to return to the good old bags and small boxes to go shopping. Downstream is composted on the terrace, mixed with the premix from the dry toilets. Moreover, if you look at the size of the compost pile after more than a year of occupancy, you can feel the expertise of the house owners in managing this precious natural cycle. This compost will eventually feed the plants on the terrace and patio.

Figure 6.12: Representation of Organic Material Waste



Source: Amush, 2018

6.1.7 Feedback

The riad was surprisingly simple. The hall where our guests welcome us is made up of soft ground and some immaculate white furniture. *"A real return to the ancestor of the*

Moroccan salon, which has nothing to do with the one we see everywhere today," *according to Laurent. It is a minimalist shelter, modular and multi-functional, with a piece of sky as a ceiling. Laurent evokes the disaster of real estate development. "Architecture is none other than a synthetic profession"* says Laurent, she continues: *“We must allow people to live together. And to do this, we must work on everything that can bring nature ın order to simply achieve coherence. The path the world is taking in terms of urban planning and housing is just frightening when you know that 80percent of the world's population is deforested, that there are no longer any unpolluted rivers..."(Appendices)*

A tour with the owner is enough to understand that if such a feat was possible in the middle of the medina, with such a high density, seems easy to build green cities all over Morocco.

A riad renovated like a triplex loft that was designed by architects, it offers open and modular spaces and infinite space configurations in the heart of the medina and equipped with a Small garden and a large terrace. The distribution is done on three levels in an area of 250 m²:

- Ground floor: Entrance with small bamboo grove composing a small garden lit by a large glass roof, a well and a rainwater-harvesting tank. If you look up, you would notice different levels, as if the walls were removed so you can discover the spaces. It is connected with a staircase taking you to the upper floor.

- 1st floor: A beautiful reception, lounge, dining room, office area, TV lounge area + fireplace area, a kitchen open to the entrance of the house with a view of the garden. All the spaces are convertible and connected by walkways.

- 2nd floor: 1 bathroom floating above the garden, with possibility of a clear view of the garden at the entrance, two bedrooms and a large dressing room that can be folded and disappears to leave space ,and a shower.

- Roof terrace: A fourth bedroom on the roof with bathroom, garden, solarium, barbecue, and garden furniture. The photovoltaic panels are used also as canopy for the dining area.

Figure 6.13: 3D of the House of Architects

Source: "aMush,", 2018

The architects' house is perfectly integrated into the traditional urban fabric such as the medina. Its bioclimatic approach is also in perfect harmony with the three cycles of water, waste and energy. It is a modular and innovative architecture in terms of space use strategy, thanks to sustainable technicality and bioclimatic processes using the efficient energy measures of the envelope: double glazing for winter heating, walls with very high thermal inertia (earth/stone), cork roof insulation, photovoltaic power supply, solar water heater (solar thermal), natural ventilation, high energy performance household appliances, very low consumption lamps. Compared to the climate of Rabat, the atmosphere of the architects' house offers the best thermal comfort, 20°C in winter and 25°C in summer.

There is No heating system used, and No air conditioning system but instead Natural ventilation and the use of Renewable energies is applied by using Solar photovoltaic and Thermal solar energy systems as follows:

- Use of double-glazing for all windows and Cork as an insulation material

- Photovoltaic power supply (5200 W/h/day).

- Solar water heater 200 L,

- Rainwater collection in a cistern (40 m^3) to supply the entire house, after filtration and UV treatment.

- Grey water filtration (aerobic reactor). Reuse of treated water for terrace watering (drip irrigation).

- Automatic dry toilets (ventilation and compost heating).

- Low water consumption faucets (infrared).

- Terrace garden providing half of the vegetable consumption.

-Washing machine supplied with solar hot water (reduction of 2/3 of electricity consumption).

- High energy efficiency refrigerator (300 W/h/day).

- Very low consumption lamps (with yellow light).

According to the architects, the concept of the house is based on sustainable development approach and autonomy in terms of water, energy, and waste. The main idea is to show and to prove that the majority of the needs can be provided on a local level. Energy autonomy, food and water self-sufficiency are important factors that can lead to a global stability. According to Soussan, after years of research, this 100percent autonomous house was no more a goal but it was achieved. It offers interesting, joyful and comfortable spaces at a very low cost compared to what it provides. This step permits us to consider not only an autonomous house but a whole city with a bioclimatic approach.

6.2 ZONE 2- ZONE 3: AL OUROUD II SOCIAL HOUSING

Climatic zone	Project Type	Project owner	Architect
Between Z2-Z3 Al Arrouit, Nador	Social housing buildings Al Ouroud II	Ahmed Barhdadi	Al Omrane Oujda

The Al Omrane group is committed to the government's program to support the development of living spaces that are socially inclusive and economically productive while integrating the environment to improve the quality of life of residents. The group also plans to make its expertise available to the regions for accelerated territorial development. This is illustrated by its commitment to build new and sustainable cities. This is what happened in the Oriental region precisely in Al Arrouit, Nador province. Through the Al Ouroud project, Al Omrane is delivering a new anchor for sustainability. This project, which is currently being delivered, is part of the 5 projects proposed by the group and which have been selected to benefit from the financial support of the European Union and distinguished by its energy efficiency.

Figure 6.14: Photo of Al Ouroud II project

Source: AL Omrane Oujda, 2018

6.2.1 Orientation and Form

Figure 6.15: Site Plan and Photos of Al Ouroud Social Housing

Source: AL Omrane, 2018

This project involves 140 social housing units at 250,000 dirhams, with insulation of the roofs and low deck with injected polyurethane. The walls are made of double wall with 5 cm thick polystyrene panels. Al Omrane has installed PVC double glazing in this project. The group has also installed presence detectors in the corridors to control the switching period. Committed to sustainable development, Al Omrane is implementing new principles and instruments to guide its interventions and activities in order to bring them into line with the objectives of the National Charter for the Environment and Sustainable Development. This has led the group to adopt, first and foremost, a charter that sets out Al Omrane's commitments to sustainable development. Subsequently, the group developed and implemented its Environmental and Social Management Plan, in the same way as an Environmental and Social Management System. An approach that aims to design housing that integrates architectural, urban planning, environmental, technical and constructive solutions that offer residents optimal conditions for living and well-being environment that guarantees a maximum reduction in energy consumption. From an environmental point of view, the programs integrate the building into its immediate environment while seeking visual, aesthetic and landscape comfort with specific green spaces on the side facades as well as an event esplanade. At the architectural level, the approach consists in designing flexible housing types adapted to the target population. The method of grouping housing is designed to allow semi-private spaces to function properly and to minimize the circulation areas in order to create interior courtyards for better ventilation.

6.2.2 Materials, skin, and coating

Table 6.3: Materials used in Al Ouroud

ENVELOPE WALLS (OR EXTERIOR WALLS)	INTERIOR WALLS	ROOF	INTERMEDIATE FLOOR
PLASTER		PLASTER	PLASTER
Interior Agglo		HOURDI	HOURDI
POLYSTERENE PANEL	Concrete brick (filled with sand on the ground floor)	REINFORCED CONCRETE	REINFORCED CONCRETE
AIR GAP		POLYURETHANE FOAM	POLYURETHANE
Outdoor Agglo			

Source: Retrieved from Al Omrane, Imane Ourhadja,2019

6.2.3 Openings

The main entrances of the residential building are on the southern part. From the Northern part of the buildings, the ground floor is used as garages either for commercial purposes or as parking spaces.

Figure 6.16: Photos of Facade of Al Ouroud

Source: AL Omrane, 2018

6.2.4 Thermal insulation of the envelope

In order to create better treat thermal bridges and keep the building fresh, they used Polystyrene for thermal insulation of wall and designed the plan openings to limit electricity consumption.

Table 6.4: Materials used in the Exterior Walls in Ouroud

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
INTERIOR AGGLO	7	2,55	0.5-0.4 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM
POLYSTERENE PANEL	4		
AIR GAP	4		
Outdoor Agglo	15		

Source: Derived from AL Omrane, 2018, Imane Ourhadja, 2019

Table 6.5: Materials used in the Intermediate Floor in Ouroud

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,37	<0.65 instead of the maximum U of 0.80 set by the RTCM
HOURDI	16		
REINFORCED CONCRETE	5		
POLYURETHANE	5		
CEMENT MORTAR	4		

Source: Derived from AL Omrane, 2018, Imane Ourhadja, 2019

The high thermal performance of polyurethane will allow achieving compliant heat transfer coefficients. Better than the regulatory limit requirements for the thermal characteristics of residential building envelopes for Climate Zone 2: U less than 0.65 W/m².K instead of the maximum U of 0.80 set by the RTCM.

Table 6.6: Materials used on the roof in Ouroud

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,67	0.48 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM.
Hourdi	15		
REINFORCED CONCRETE	5		
POLYURETHANE	5		

Source: Derived from Construction21 and Al Omrane2018, Imane Ourhadja, 2019

For roofs, Polyurethane is used to limit exchanges by radiation or conduction, thus it helps increasing thermal comfort and limiting heating or air conditioning requirements.

- **Insulation of walls**

The walls overlooking the exterior are insulated with a layer of 4 cm thick expanded polystyrene insulation and an air gap.

- **Insulation of the Roofs**

The roofs consist of a slab of concrete, insulated with a 5 cm thick layer of polyurethane.

- **Insulation of the transparent openings**

High performance double glazing is used to ensure the thermal tightness of the envelope.

Double glazing 4/16/4 (with U=1.4 W/m².K and 60percent solar factor) on aluminum joinery

Figure 6.17: Sun Brakers used in Al Oroud Project

Source: AL Omrane Oujda, 2018

In addition the use of Sun barkers, which are composed of aluminum blades: The position of the protection is horizontal, perpendicular to the plane of the window to limit the summer solar gain. The use of outdoor blinds on the glazing purpose is to limit summer solar gain and allow it to penetrate during the winter season.

6.2.5 Thermal comfort

It is about Social Housing composed of 144 units with a total project area of 9.360 m². Each apartment has an average surface area of 60-80 m² including:

Figure 6.18: Photos from the inside of Ouroud Project

Source: AL Omrane, 2017

- Hall
- Salon.
- A living room.
- Two bedrooms.
- A bathroom.
- And a kitchen

Energy efficiency measures implemented:

- Installation of external shading devices and high-performance glazing.

- Insulation under the floors, walls and roofs.

- Installation of hydro-economical systems to avoid over-consumption of water in flushing toilets by using single lever mixers and dual key flush toilets

- Installation of sensors for occupancy in circulation which, when placed in circulation, avoid any omission of switch-off or lighting activated unnecessarily in corridors, stairs, and entrance halls.

- Installation of solar water heaters to save electrical energy

6.2.6 Energy

Figure 6.19: Solar water heaters on the rooftop of Al Ouroud

Source: AL Omrane, 2017

6.2.7 Feedback

This 144-unit social housing program, located in the new Al Arrouit district, has taken into account the energy efficiency measures required by the thermal regulations, while aiming to optimize user comfort. The project also showed that solar hot water production can contribute to satisfying more than 75percent of the users' average annual domestic hot water needs, for an investment of 13,000 Dirhams (this investment including an auxiliary electric water heater).

However, the economic interest of this solar hot water production is still limited compared to gas-fired hot water production. This is due to the high cost of equipment on the one hand, and the very low cost of butane for domestic use on the other. Al Omrane Nador Agency has developed technical expertise in the integration of energy efficiency in buildings. This approach could be integrated into social housing, without compromising the financial balance of the project while respecting the social objective of low-cost production.

The extra cost is estimated at about 2605€ equal to 27.000 DH /Apartment (Solar Water Heater 1280€+ Wall insulations 70 €+ Double Glazing 245€+ Roof Insulations 120€+Intermediate floors insulation 25€+ Projection shutters 405€+ Simple shutters 265€+ Presence detectors 25€+ Hydro economic systems 170€) *(AL Omrane, 2018).*

In addition to Al Ouroud, two other projects are part of the same approach. These are Al Karama in El Hajeb and Jacaranda in Tamansourt. Through these concepts, Al Omrane places environmental and social concerns at the heart of its strategy. This is illustrated by the implementation of a long-term strategy to promote the implementation of an environmental and social management plan "PGES" at the level of all its subsidiaries. Through these new buildings, Al Omrane is demonstrating energy efficiency in social housing programs. The aim is to be part of a proactive approach by Morocco to move towards an energy saving policy and the improvement of the energy performance of buildings. These various programs aim to demonstrate the feasibility of technical solutions that improve the thermal performance and comfort of buildings at the lowest cost, with a perspective of implementing thermal regulation of the habitat.

6.3 ZONE 4: AL KARAMA SOCIAL HOUSING

Climatic zone	Project Type	Project owner	Architect
Z4 El Hajeb	Social housing buildings Al Karama	Alla El Hassan Claire Patteet	Al Omrane Meknès

In total, nine projects of the Al Omrane group were proposed according to the climate zoning defined by the Aderee. Only 5 projects out of 9 were selected, including 3 other social housing projects in Tamansourt, Agadir, Oujda and a tertiary building project. These buildings have all been designed with a sustainable approach. Each has particular features and characteristics for the insulation of the building envelope (walls, floor, roof and openings) in order to provide indoor thermal comfort without energy consumption and thus reduce the energy bill of households. The final and ultimate objective of this social action is to demonstrate the feasibility at a lower cost and to spread these practices in order to reduce the country's energy consumption, or at least that related to housing. *"Our social commitment on this path allows us to play a leading role in this field, mainly in a sector considered to be a major consumer of land, water and energy, such as city planning construction,"* concludes Al Omrane's CEO. The Al Omrane manager highlighted that sustainable development is a priority for his group. It should be remembered that (in June 2011); Al Omrane Meknès participated and responded to the call for proposals launched by the European Union as a part of the national program for energy efficiency in buildings. This project is being carried out jointly with Aderee in order to be able to benefit from the support and grant. It aims to carry out the implementation of large-scale energy efficiency projects based on the technical elements of thermal regulation developed by the Aderee program.

Figure 6.20: Photo of Al Karama Project

Source: Al Omrane Meknès, 2017

6.3.1 Orientation and Form

Figure 6.21: Site plan of Al Karama

Source: Al Omrane Meknès, 2017

Longline design building oriented east-west so that its large dimensions are facing south (disorientation of 23 ° was tolerated).

Figure 6.22: Plan and Construction phase of Al karama

Source: Al Omrane Meknès, 2016

Al karama residence is a group of (R+3) 4 story buildings located in the city of El Hajeb constructed by Al Omrane group. It is said that this regional initiative also seeks to showcase and demonstrate Al Omrane’s actions in terms of sustainable development and more particularly in terms of energy efficiency. This project has been carried out in partnership with Aderee and financed by the European Union. It is considered as a model of energy efficiency in the region. The design of housing is offering architectural, environmental, technical and constructive solutions. All aimed to provide an optimal living and well-being environment while guaranteeing a maximum reduction in energy consumption. Indeed, Al Karama project consists of a little less than a hundred social housing unit at 250,000 DH. It integrates energy efficiency solutions (EES), with immediate benefits for residents. This project is the first of its kind in this region known for its harsh winters. It intends to become an example for the entire region to be followed. According to Badr Kanouni, the Chairman of the Board of Directors of the Al Omrane development holding company, *"This innovative citizen-oriented project* *creates an attractive living environment thanks to the architectural design of housing. Moreover it minimizes energy consumption".*

6.3.2 Materials, skin, and coating

Table 6.7: Materials used in Al Karama Project

ENVELOPE WALLS (OR EXTERIOR WALLS)	INTERIOR WALLS	ROOF	INTERMEDIATE FLOOR
PLASTER	Concrete brick (filled with sand on the ground floor)	PLASTER	PLASTER
6T HOLLOW BRICK		HOURDI	HOURDI
POLYSTERENE PANEL		REINFORCED CONCRETE	REINFORCED CONCRETE
AIR GAP		POLYURETHANE FOAM	POLYURETHANE
6T HOLLOW BRICK		CEMENT MORTAR	CEMENT MORTAR
		FLOOR TILE	

Source: Derived from AL Omrane Meknes, 2018, Imane Ourhadja, 2019

6.3.3 Openings

The main entrances of the residential building are on the southern part. From the Northern part of the buildings, the ground floor is used as garages either for commercial purposes or as parking spaces.

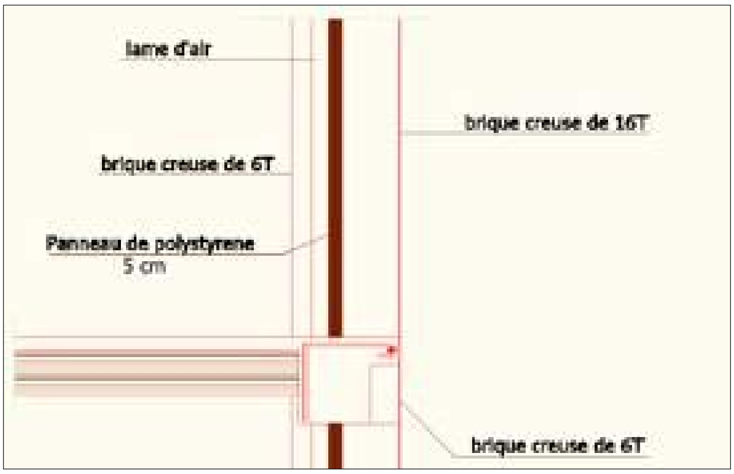
Figure 6.23: Facade of Al Karama

Source: Al Omrane Meknès, 2017

6.3.4 Thermal insulation of the envelope

Table 6.8: Materials used on the Exterior walls in Al Karama

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
6T HOLLOW BRICK	20	2,55	0.5-0.4 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM
POLYSTERENE PANEL	5		
AIR GAP	1		
6T HOLLOW BRICK	14		



Source: Derived from AL Omrane Meknes, 2018, Imane Ourhadja, 2019

The thermal performance of polystyrene and brick as well as the high thickness of double wall walls (up to 40 cm thick) make it possible to achieve compliant heat transfer coefficients. Better than the regulatory limit requirements for the thermal characteristics of residential building envelopes for Climate Zone 4: U from 0.50 to 0.40 W/m².K instead of the maximum U of 0.60 set by the RTCM.

Table 6.9: Materials used on the Inner walls in Al Karama

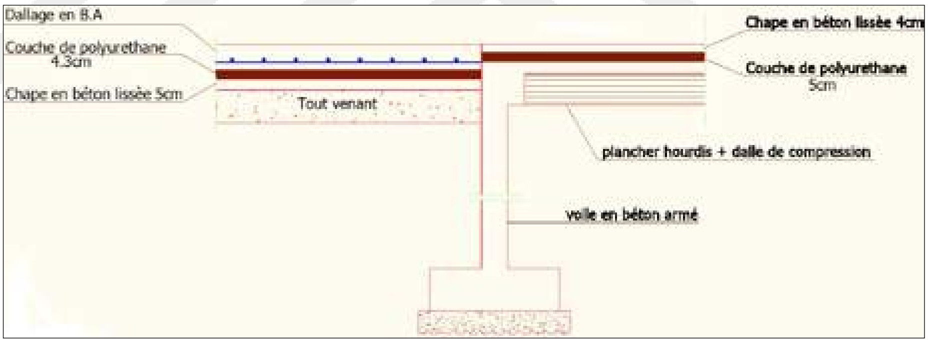
LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,37	0.42 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM.
Hourdi	16		
REINFORCED CONCRETE	5		
CEMENT MORTAR	6		

Source: Derived from AL Omrane Meknes, 2018, Imane Ourhadja, 2019

Table 6.10: Materials used on the Intermediate floor in Al Karama

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,37	<0.65 instead of the maximum U of 0.80 set by the RTCM
HOURDI	16		
REINFORCED CONCRETE	5		
POLYURETHANE	5		
CEMENT MORTAR	4		

Source: Derived from AL Omrane Meknes, 2018, Imane Ourhadja, 2019



The high thermal performance of polyurethane will allow achieving compliant heat transfer coefficients. Better than the regulatory limit requirements for the thermal characteristics of residential building envelopes for Climate Zone 4: U less than 0.65 W/m².K instead of the maximum U of 0.80 set by the RTCM.

Table 6.11: Materials used on the roof in Al Karama

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,67	0.48 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM.
Hourdi	16		
REINFORCED CONCRETE	5		
POLYURETHANE FOAM	6		
CEMENT MORTAR	6		
FLOOR TILE	2		

Source: Derived from AL Omrane Meknes, 2018, Imane Ourhadja, 2019

The high thermal performance of the polyurethane projected onto a vapor barrier above the slab and protected by the waterproofing complex and terrace coating will allow a compliant heat transfer coefficient to be achieved. Better than the regulatory limit requirements for the thermal characteristics of residential building envelopes for Climate Zone 4: U of about 0.48 W/m².K instead of the maximum U of 0.55 set by the RTCM.

- **Insulation of walls**

The walls overlooking the exterior and circulation walls (entrance corridor and stairwell) with a double partition are insulated with a layer of 5 cm thick expanded polystyrene insulation and an air gap.

The polystyrene panels measuring 1 m x 0.5 m are glued to the outer wall with a suitable TT 0Padhesive. The inner wall is mounted leaving an air gap between it and the insulation.

Figure 6.24: Insulation of the Walls in Al Karama

Source: AL Omrane Meknes, 2017

- **Insulation of the Roofs**

Figure 6.25: Polyurethane on the roof of Al Karama

Source: AL Omrane Meknes, 2016

The roofs consist of a slab of concrete, insulated with a 5 cm thick layer of polyurethane.

- **Insulation of the transparent openings**

Figure 6.26: Transparent Openings in Al

Source: Groupe AL OMRANE, 2019

All the windows are equipped with double glazing, 4/12/4 in order to reduce their thermal transmission coefficient. The use of a low-emissivity glass that reflects 96percent of the solar radiation to the exterior led to a low solar factor of 0.6 to limit the energy transmitted by the glass inside.

- **Insulation of intermediate floors**

Figure 6.27: Polyurethane insulation used in the intermediate floors

Source: AL Omrane Meknes, 2014

Insulate all externally facing floors with a layer of polyurethane insulation:

- 4 cm thick layer under the paving stones on solid ground.

- 5 cm thick layer on floor slabs on crawl space.

6.3.5 Thermal comfort

Energy efficiency measures implemented:

- Installation of external shading devices.
- Insulation under the floors.
- Wall insulation.
- Roof insulation.
- Installation of high-performance glazing.
- Installation of hydro-economical systems.
- Installation of sensors for occupancy in circulation.
- Installation of solar water heaters.

Social housing in R+3 buildings grouped into 4 units per level. Average surface area of 65 m² including a living room, two bedrooms, a bathroom, and a kitchen with laundry room

Figure 6.28: Floor Plan Examples of Al Karama

Source: AL Omrane Meknes, 2016

6.3.6 Energy

Figure 6.29: Solar Water Heaters used in Al Karama on the roof Tops

Source: AL Omrane Meknes, 2016

The hot water circuit of each dwelling will be connected to an individual thermosiphon solar water heater (associated collector and storage tank), or forced circulation installed on the roof of the building. Residents will be able to install a heat supplement (gas water heater) in the laundry room of their apartment between the solar water heater and the hot water circuit of the apartment in order to complete the system.

6.3.7 Feedback

This is one of the projects demonstrating energy efficiency in the building located in Climate Zone 4. To fight against the cold in winter and thus reduce heating energy consumption, the project integrated the following measures: insulation of the envelope (polyurethane projected on a vapor barrier above the slab and protected by the waterproofing complex and the terrace covering, polystyrene in double-walled walls), including glazing (double glazing with low emissivity) and the low-floor floor (projected polyurethane), solar protection, solar water heater (solar thermal), etc.

These measures have made it possible to achieve energy performance and are generally in compliance with thermal regulations.

6.4 ZONE 5: DAR AMYS, LUXURY VILLA (MARRAKESH)

Climatic zone	Project Type	Architect	Project owner
Z5 Marrakech	Dar AMYS, Villa haut standing	Mohamed El Anbassi	Amin Bennouna

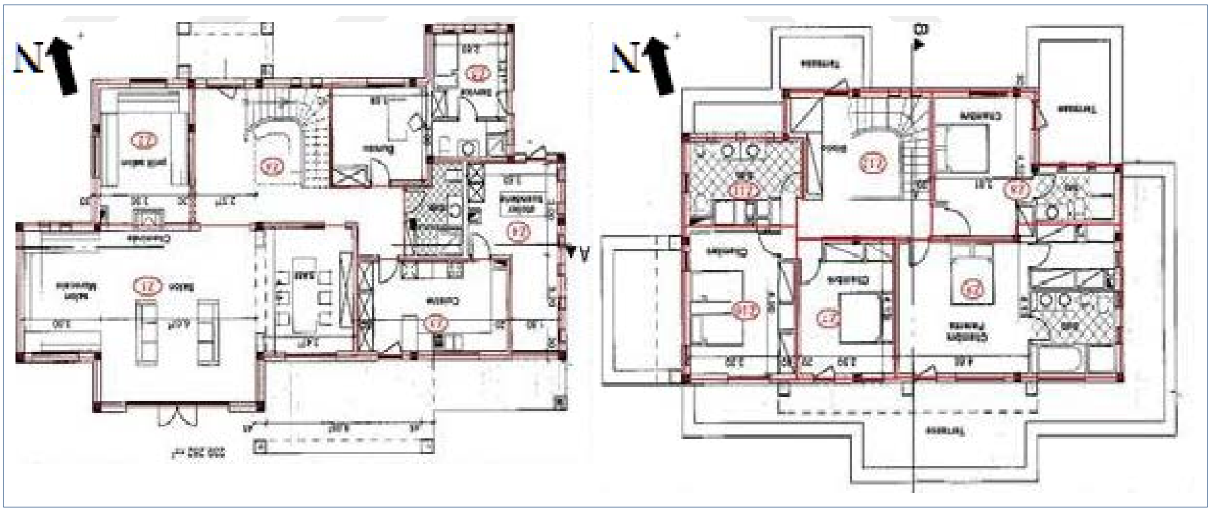
This building is taking an important position in terms of energy consumption around the world. This is particularly the case in Morocco, where consumption in the building sector accounts for 29percent of total national energy consumption and 33percent of electricity consumption *(ONE, National Office of Electricity 2010).* Air conditioning represents a significant part of this consumption, mainly in summer. Indeed, the Electric Peak occurs during the hottest months (July-August). Thus, the reduction of energy consumption in the building has become a priority in the national energy strategy. A program has been dedicated to this *(CEEB National Program for Energy Efficiency in Buildings, 2011)* with the aim of setting up a code for energy. One of the measures of this program is the introduction of thermal regulation through the introduction of passive systems to reduce the thermal load of the building *(ADEREE, Agency for the Development of Renewable Energy and Energy Efficiency, 2011).* It should be noted that in the traditional Moroccan way of life, people have developed empirical, architectural and mental accounting solutions to produce climate-friendly homes with minimal thermal comfort. The requirements of thermal comfort are met by means of very energy-intensive electric air conditioning systems. It is known that acceptable thermal comfort can be achieved in a building by a suitable architectural design that takes into account the climate *(GIVONI, Climate and Architecture, 1976).* For a hot and arid climate, such as Marrakech, profiting from the benefit of free solar gain in winter while avoiding overheating summer and taking advantage of the night cooling is the keystone of energy efficiency in the building (*GHRAB-MORCOS, Energy and Buildings, 2005).* Therefore, it is obvious that the thermal insulation of the envelope reduces the heating load. However, the outdoor temperature in summer is often lower than what is required in the building. Thus, the thermal insulation of the walls will prevent the nocturnal evacuation of the heat stored during the day *(MANOJ KUMAR, Energy and Buildings, 2007).*

6.4.1 Orientation and Form

Longline design building oriented east-west so that its large dimensions are facing south (disorientation of 17 ° was tolerated).

Figure 6.30: Photos of the AMYS house

Figure 6.31: Plan Photos of the AMYS house (left: Ground floor and right: first floor)



Sources: Dynamic Modelling and Monitoring of a Passive House in Marrakech, 2015

The house studied, known as AMYS, is a villa type with four facades and built on a ground surface of 168m², on a bare ground (large garden without trees). The house consists of a ground floor (dining room, small living room, large living room, kitchen, laundry room, and office and service room) and a first floor (4 bedrooms, 3 bathrooms and a corridor).

Figure 6.32: Photos of the AMYS house (left: SOUTH view and right: NORTH view)

Source: Imane Ourhadja, 2019

The South façade is characterized by a high percentage of glass surfaces.

6.4.2 Materials, skin, and coating

Table 6.12: Materials used in AMYS Project

ENVELOPE WALLS (OR EXTERIOR WALLS)	INTERIOR WALLS	ROOF	INTERMEDIATE FLOOR
Plaster		Plaster	Plaster
Cinder Block		Hourdi	Hourdi
Glass wool	Concrete brick (filled with sand on the ground floor)	Reinforced concrete	Reinforced concrete
Terracotta brick		Polyurethane foam	Mortar
Cement mortar		Mortar	Floor tile
		Floor tile	

Source: Derived from Energy Performances of a Passive Building in Marrakech: Parametric Study,Imane Ourhadja,2019

6.4.3 Openings

The south walls are characterized by a large percentage of glazed area. This percentage is 36percent for the ground floor and 18percent for the floor. A horizontal canopy overhangs the floor over the entire length of the south facade above the large terrace; its depth is 1.20 m.

Figure 6.33: Photos of the AMYS house (showing the openings)

Sources: Dynamic Modelling and Monitoring of a Passive House in Marrakech, 2015

THERMAL INERTIA

Table 6.13: Materials used on the External Walls in AMYS

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,55	0.39 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM
PARPAING	15		
GLASS WOOL	1		
BRICK OF TERRE CUITE	15		
CEMENT MORTAR	1,5		

Source: Derived from Energy Performances of a Passive Building in Marrakech: Parametric Study,Imane Ourhadja,2019

Concrete brick (filled with sand on the ground floor). Its thermal conductivity is 1.4 W / make.

Table 6.14: Materials used on the Inner Walls in AMYS

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,37	0.42 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM.
Hourdi	16		
REINFORCED CONCRETE	5		
CEMENT MORTAR	6		
FLOOR TILE	2		

Source: Derived from Energy Performances of a Passive Building in Marrakech: Parametric Study,Imane Ourhadja,2019

Table 6.15: Materials used on the roof in AMYS

LAYERS	THICKNESS (CM)	TOTAL THERMAL RESISTANCE R (M².K / W)	THERMAL TRANSMISSION COEFFICIENT U (W / M².K)
PLASTER	1	2,67	0.37 The proposed wall is very efficient because the value of U is lower than the regulatory limit requirements set by the RTCM.
Hourdi	16		
REINFORCED CONCRETE	5		
POLYURETHANE FOAM	6		
CEMENT MORTAR	6		
FLOOR TILE	2		

Source: Derived from Energy Performances of a Passive Building in Marrakech,Imane Ourhadja,2019

The external walls and roof are thermally insulated, so the external walls are 42.5cm thick. They consist of five layers: 1cm of plaster, 15cm of cinder block, 1cm of glass wool, 15cm of terracotta brick and 1.5cm of cement mortar. Its thermal resistance is calculated from the standard data of the components, it is 2.55m².K.W-1. The roof of the house is composed of six layers: 1cm of plaster, 16cm of Hourdi, 5cm of reinforced concrete, 6cm of polyurethane foam, 6cm of mortar and 2cm of tiles. The equivalent thermal resistance of the roof is estimated at 2.67m².K.W-1. We notice that the exterior walls and the roof have practically the same thermal resistance. The ground floor slab is composed of five layers: 1cm of plaster, 16cm of Hourdi, 5cm of reinforced concrete, 6cm of mortar and 2cm of tiles. The thermal resistance of this slab is estimated at 2.37m².K.W-1. The inertia of the ground floor's internal walls is reinforced by the filling of the bricks with sand (solid brick). In addition, the house is connected to a ground-to-air heat exchanger (Canadian well) composed of 3 PVC pipes each 70m long. This exchanger is buried at a depth of 2-3 m in the villa's garden.

6.4.4 Thermal insulation of the envelope

- **Insulation of walls**

Figure 6.34: External Wall Composition of AMYS

Source: Qadi Ayyad University 2019

The walls are made of terracotta honeycomb bricks of 15 cm, 10 cm of Rockwool, and a block of 15 cm on the inside.

- **Insulation of the transparent openings**

Apart from the small French-style windows, all the other transparent openings are double-glazed sliding and equipped with roller blinds in foamed aluminum.

- **Insulation of the Terrace**

The terrace consists of a slab of concrete and slabs, 6 cm of injected polyurethane foam and a sloping form of slab reinforced with 3.5 mm welded mesh.

Figure 6.35: Insulation used on the terraces

Source: Qadi Ayyad University 2019

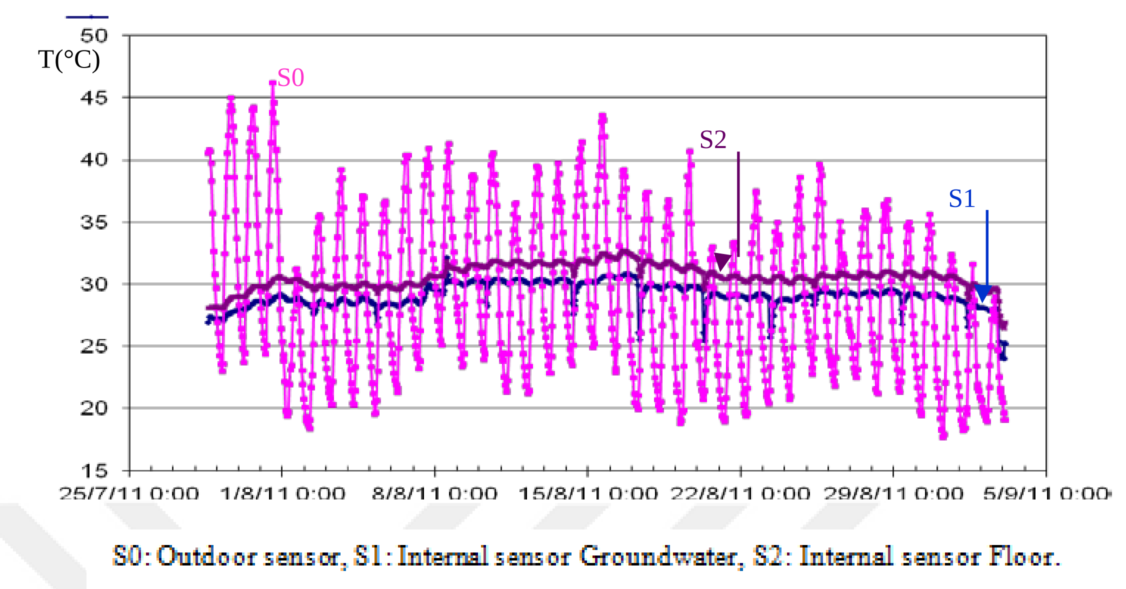
6.4.5 Thermal comfort

Figure 6.36: Meteorological Measurement Equipment

Source: Energy Performances of a Passive Building in Marrakech2014

The house is equipped with an Oregon Scientific measurement station with wireless receiving base, ambient data measured by four indoor sensors and one exterior (photo shows outdoor anemometer, wind vane, thermometer, hygrometer and barometer) . **Meteorological data (See Appendices)**

Figure 6.37: Monitoring of the AMYS house (See Appendices)



Source: Qadi Ayyad University 2019

6.4.6 Energy

Figure 6.38: Solar Water Heaters and EAHX Systems used in AMYS

Source: Qadi Ayyad University 2019

Two solar water heaters with heat exchanger (because of the limestone and the risk of frost) totalling 4 m² ensure the supply of hot water to the bathrooms and the kitchen.

Earth-to-Air Heat Exchanger (EAHX)/ CANADIAN WELL

The house is air-conditioned by a Canadian well made up of 3 tubes down to 3.50 m deep that provide 500 m³ / h of air at 24 ° C in summer and 19 ° C in winter (in fact, the use in winter is useless). Earth to Air Heat Exchangers (EAHX), are also known as underground air tunnels or buried pipe systems. They are used worldwide for their highly energy efficiency response in comparison with the current ordinary heating and cooling systems. Centuries ago, the soil was used as a heat sink. For instance, Iranians used underground air tunnels and wind towers as a solution for passive cooling (Ozgener, 2011). Important and effective researches were carried out around the world about the use of EAHX for air cooling and preheating in buildings. It was performed in cold, mild and hot climates around the world (Santamouris&Kolokotsa, 2013; Hollmuller&Lachal, 2014; Santamouris et al., 2007). The results proved the benefits of the EAHX in many regions in the world for both heating and cooling. Yet, it depends on climate and soil conditions. The context of climatic, soil and building load conditions needs to be analyzed and studied. The EAHX installed in villa Amy's is , buried at 3.2 m depth, constituted of 3 parallel and identical PVC pipes (72 m length 15/16 cm inside/outside diameter) equipped by a 44-90 W fan. Two pipes are connected to the first floor and the third is connected to the second floor of the villa.

Figure 6.39: Schematic diagram of the EAHX and its implementation details.

Source: Qadi Ayyad University 2019

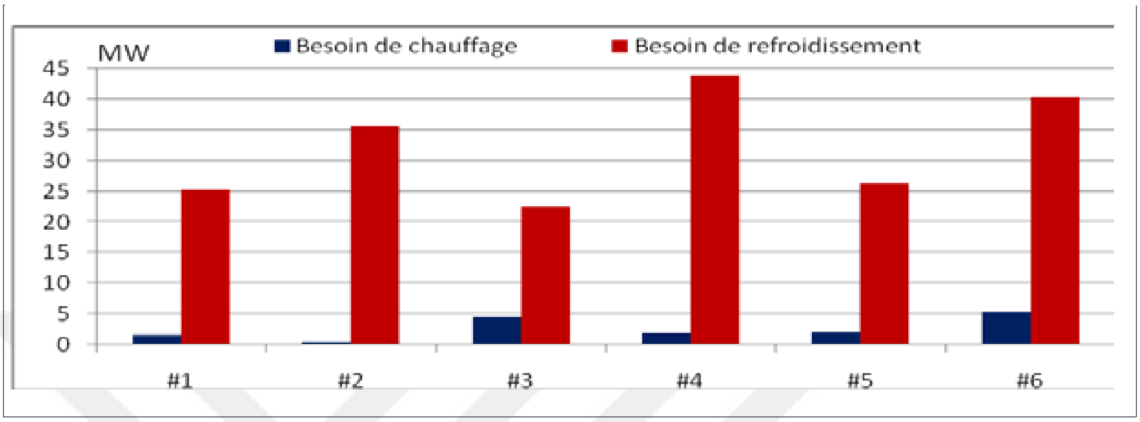
The figure above represents a sketch of the connection of EAHX to the villa, and presents the details of its implementation.

6.4.7 Feedback

- Energy needs for the building environment without insulation: In winter, it is almost 40 kWh / m² of heating that would be required to maintain 20 ° C continuously. In summer, to maintain at 26 ° C, it is close to 65 kWh / m². That is nearly 105 kWh / year per m².

• Energy needs of the building environment with insulation of the terrace, wall, transparent openings, and thermal bridges: In winter, 15 kWh / m² of heating suffices to maintain 20 ° C continuously. In summer, it costs only 23 kWh / m² to maintain 26 ° C. That is, 38 kWh / year per m² of living space and 2/3 of energy saved.

Table 6.16: Annual air conditioning requirements for different configurations.



Source: Qadi Ayyad University 2019

This study case is illustrating perfectly good practices in energy efficiency, renewable energy and thermal comfort. It demonstrates that the strategy adopted for its design has achieved its objective: its envelope and its interior environments meet the requirements of a reference system that more than meets the thermal regulations in terms of heating / cooling needs and in terms of thermal comfort.

The villa combines the ability to store the heat of the sun, through the south-facing openings, and the ability to regulate the ambient temperature thanks to its great thermal inertia. The insulation of the roof and the walls is a very important measure which makes it possible to reduce the contributions and the losses of heat. This device, reinforced by vegetation, functioning in deciduous leaves during the winter period, thus allowing a maximum of solar radiation inside, and by a shading effect in the spring-summer: during this period, the leaves still persistent on trees, intercept intense solar radiation.

A swimming pool is placed voluntarily on the side of the south facade, plays the role of thermal regulator by its ability to absorb heat. This case shows that the thermal insulation of the roof is necessary for the climate of Marrakech. In fact, this insulation reduces the need for air conditioning by 42percent for cooling and by 18percent for heating. The house is air-conditioned by an EAHX Canadian well; the air is blown in the rooms at 24 ° C in summer and 19 ° C in winter. However, the use in winter is useless (the thermal difference blown, is not significant). These measures do not have to be fixed prescriptions. This will allow more flexibility for architects, engineers and builders to act on the different parameters necessary for the development of sustainable and energy efficient buildings.

6.5 ZONE 1- 6: DEFI INDIVIDUAL VILLA (EXPERIMENTAL PROJECT) FOR THE EVALUATION OF LOW IMPACT USAGES.

Climatic zone	Project Type	Architect	Project owner
Z1- Z6 Tafraout	DEFI Villa	Mohamed El Mankibi	AL ANSARY

One of the projects that Morocco intends to get the Green Building Solutions Awards is DEFI this award is only given if the project provide this followings: Zero Energy Building, Energy Renovation, Bio-sourced & Recycled Materials, Renewable Energies, Smart Buildings, Health and Comfort). In order to show and reward the variety of possible solutions for creating sustainable buildings that contributes to the fight against climate change.

DEFI means CHALLENGE: Experimental system for the evaluation of low impact uses.

The building "DEFI" is a residential building and an experimental platform in same time. It was designed and implemented as part of a Franco-Moroccan-Italian partnership involving the National School of Public Works from Lyon-France, the Directorate of Public Facilities from Rabat-Morocco, and Politecnico di Torino from Turin-Italy.

Figure 6.40: Photo of Villa DEFI

Source: Construction21, le média social du bâtiment et de la ville durable 2019

6.5.1 Orientation and Form

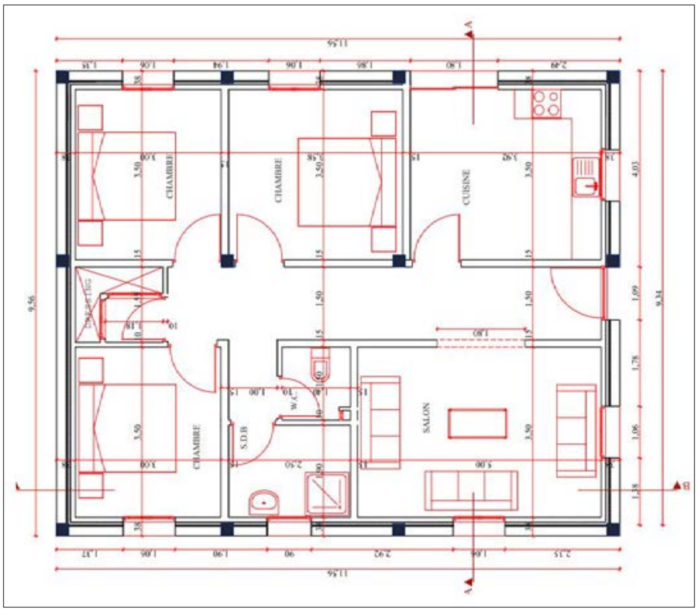
Figure 6.41: 3D perspective of Villa DEFI

Source: Construction21, le média social du bâtiment et de la ville durable," 2019

The building is oriented South-East in order to enjoy sunshine in winter and avoid morning overheating in summer.

"DEFI" is located in Tafraout in southern Morocco. It represents a multi-zone residential building (ground floor) with 4 rooms including a living room, a kitchen, two wet areas (toilet and bathroom), and an additional room to control the integrated systems. The building is a reinforced concrete construction in accordance with Moroccan seismic rules. It is also designed in compliance with the draft thermal regulations proposed by ADEREE – ADEME.

Figure 6.42: Floor plan of Villa DEFI



The "CHALLENGE" platform is a reinforced concrete building in accordance with Moroccan seismic rules. Different architectural consideration was taken into account to improve Energy efficiency.

6.5.2 Materials, skin, and coating

Table 6.17: Materials used in AMYS Project

ENVELOPE WALLS (OR EXTERIOR WALLS)	INTERIOR WALLS	ROOF	INTERMEDIATE FLOOR
PLASTER	CONCRETE BRICK	ROOF PAINTING BOARD	PLASTER
SANDWICH WALLS BLOCK		HOURDI	HOURDI
EXPANDED POLYSTERENE		REINFORCED CONCRETE	REINFORCED CONCRETE
BLOCK x2		POLYURETHANE FOAM	POLYURETHANE

Source: Derived from “le média social du bâtiment et de la ville durable,” Imane Ourhadja,2019

6.5.3 Openings

One of the challenges is the openings on the West façade on level ground floor. It is to avoid overheating in summer morning and enjoy the temperature rise to less over-ventilation. The second challenge was to reduce the openings of the thermal envelope over 20percent.

Figure 6.43: Entry of Villa DEFI

Source : Construction21, le média social du bâtiment et de la ville durable 2019

6.5.4 Thermal insulation of the envelope

Exterior Walls

In order to create better treat thermal bridges and keep the temperature inside the building stable, they used Polystyrene as a thermal insulation and designed the plan openings to avoid overheating in summer morning and enjoy the temperature rise to less over-ventilation.

Roof

For roofs Polyurethane is used to limit exchanges by radiation or conduction, in addition to a roof painting board to reduce gains radiation in summer.

- **Insulation of walls**

The walls overlooking the exterior are insulated with a layer of expanded polystyrene insulation and an air gap.

- **Insulation of the Roofs**

The roofs consist of a slab of concrete, insulated with a thick layer of polyurethane and a roof painting board.

- **Insulation of the transparent openings**

The double-glazing 4/16/4 is used with Argon filling Systems to ensure the thermal tightness of the envelope. A reinforced insulation glazing (VIR) is provided with a treatment that opposes infrared radiation and forms a thermal barrier, without constituting a too important obstacle to visible light. Therefore, it prevents heat from coming out in winter and back in summer.

Figure 6.44: Wall Insulation in Villa DEFI

Source: Construction21, le média social du bâtiment et de la ville durable 2019

INNER ATHMOSPHERE

It is about an individual building with a total project area of 110 m².

It represents a multi-zone residential building:

- A living room.
- 4 rooms
- A kitchen
- 2 toilets.
- Central corridor 1.6m width (for ventilation efficiency and Gain energy)

Figure 6.45: Photos from the interior of Villa DEFI

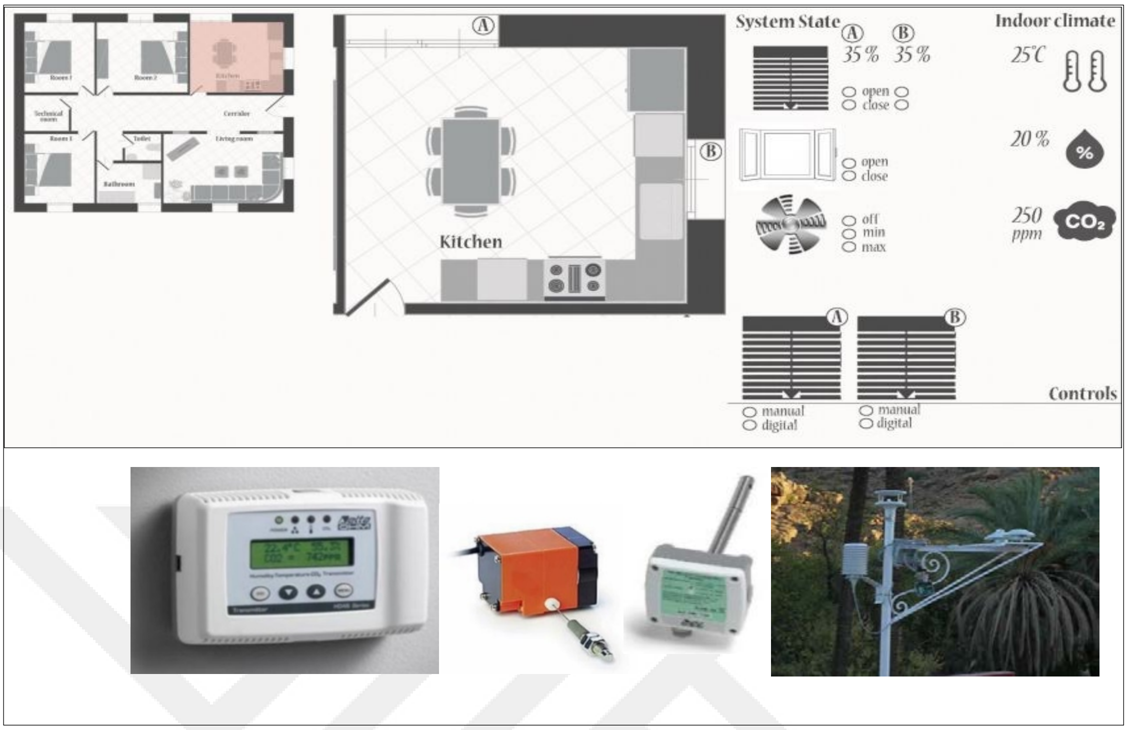
Source: Derived from "le média social du bâtiment et de la ville durable," 2018

6.5.5 Thermal comfort

Energy efficiency measures implemented are :

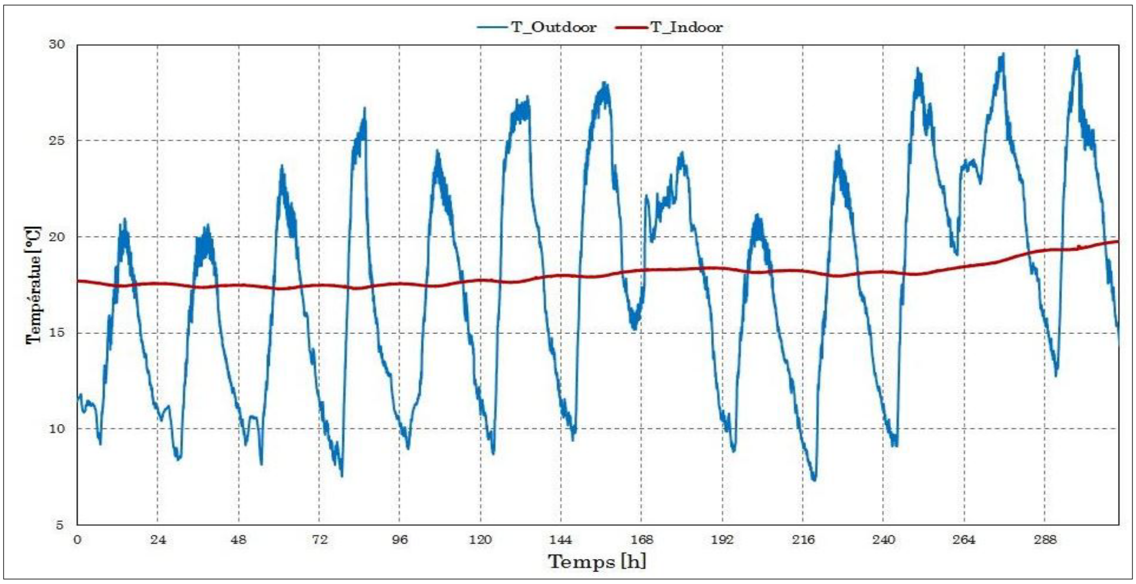
- Air temperature, CO2 and relative humidity sensors per room
- Sensors for opening and closing windows
- Blinds position sensors
- Air temperature, relative humidity and air velocity sensors at the inlets and outlets of ventilation systems and the Air to Land exchanger
- Meteorological station: Air temperature, Wind speed and direction, Relative humidity and global solar radiation
- Consumption monitoring sensors (one sensor per station)
- Sensors for measuring domestic hot water consumption
- Earth temperature sensors

Figure 6.46: Energy efficiency measures implemented in Villa DEFI



Source: Derived from "le média social du bâtiment et de la ville durable," Imane Ourhadja,2019

Figure 6.47: Outdoor and indoor temperatures (Without heating or air conditioning)



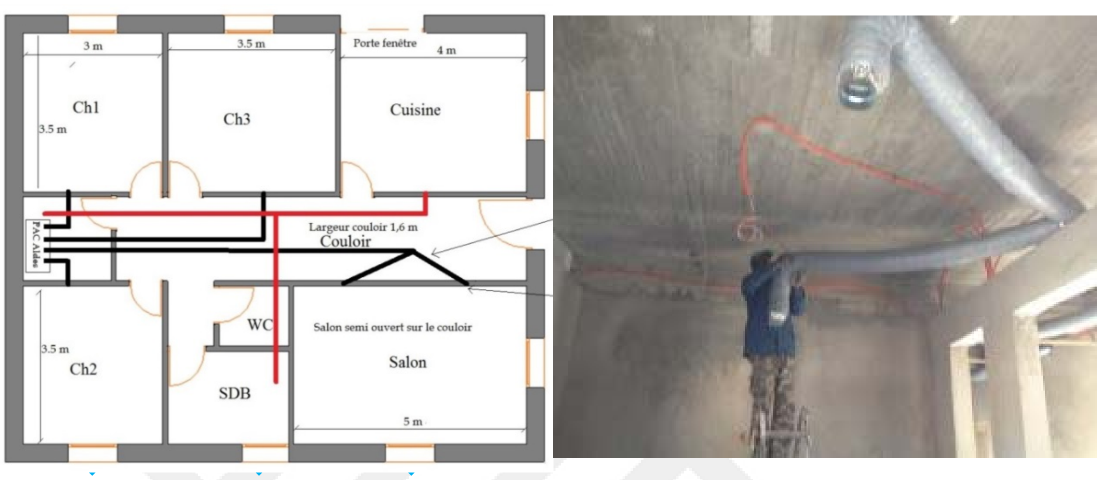
Source: Derived from "le média social du bâtiment et de la ville durable," Imane Ourhadja,2019

6.5.6 Energy

The "DEFI" platform is equipped with the following systems:

- Dual flow ventilation system with a specific fan for each zone

Figure 6.48: Dual Flow ventilation system in DEFI



Source: Derived from "le média social du bâtiment et de la ville durable," Imane Ourhadja,2019

-Air-to-Earth Exchanger

Figure 6.49: Canadian well and Heat pump photos from DEFI

Source: Derived from "le média social du bâtiment et de la ville durable," Imane Ourhadja,2019

The house is connected to a ground-to-air heat exchanger (Canadian well) composed of 3 PVC pipes each. The air-to-ground heat exchanger is used to supply a building with air by circulating it previously in an underground duct, which, depending on the climatic conditions, cools or preheats it using the thermal inertia of the ground.

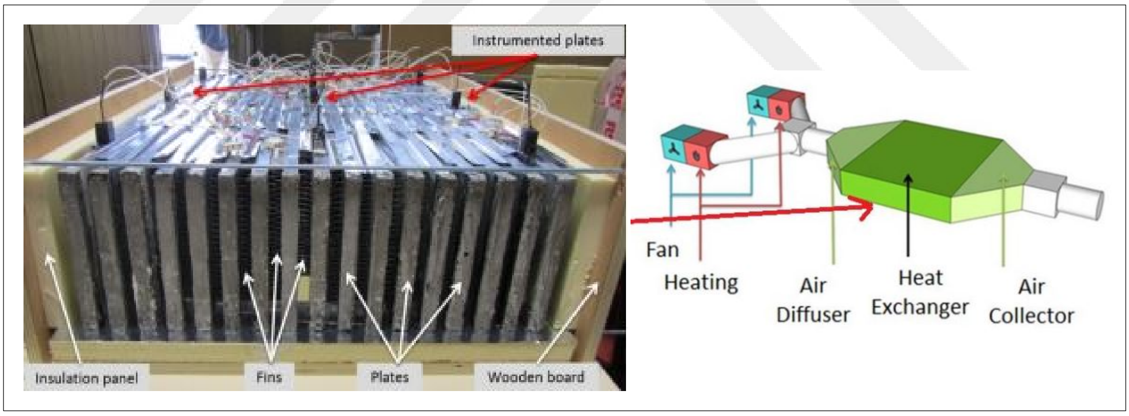
The Provencal well, although mainly used as a natural cooling system, can also be used in winter to preheat incoming air or to keep a home frost-free. The same applies to the Canadian well.

- Active heating and cooling (Air-to-air heat pump)

T.ONE is an individual heating solution for all types of homes that also provides cooling in summer. This system uses an air-to-air heat pump coupled to a distribution plenum and motorized vents. Exclusive to Aldes, the T.One system features a piece-by-piece regulation for better comfort management and greater economy, by adjusting the heat pump capacity and supply air flow rate. In addition to its exceptionally low consumption, this solution is distinguished by its low noise level. The products in the T.ONE range consist of an indoor unit and an outdoor unit combined with a regulation and a complete range of air conditioning accessories.

- Air-Materials exchanger with phase change Metrology.

Figure 6.50: Air-Materials exchanger



Source: Derived from "le média social du bâtiment et de la ville durable," Imane Ourhadja,2019

The Phase Change Air-Materials exchanger is used to heat the building during the winter; it will be coupled to a solar chimney.

6.5.7 Feedback

The principle of design and construction approach respects the Moroccan thermal regulation and allows demonstrating the reproducibility on a large scale (individual houses). The principle of purchase and information system of the house DEFI allows both the experience feedback on the building behavior and the adoption of best practices by occupants. It is indeed a study case of the International Energy Agency's "ANNEX 58" project and the support for theses of research work at ENTPE-DEP. It also provides experimental support for publications in international conferences and journals.

Figure 6.51: Photo taken during experiments

Source: Derived from “le média social du bâtiment et de la ville durable,” Imane Ourhadja,2019

The objective of this project is to provide some tools and methodologies for designing and characterizing the general performance of buildings. This structure is one of the approaches to start a study research in Morocco as to contribute in improving the energy effectiveness of structures and help for guidance. It is about a real scale experimental building, aiming to support using hybrid ventilation systems, passive heating and cooling, and phase change exchangers. It helps evaluating the potential and relevance of solar systems, and the impact of occupant behavior on indoor environments and overall consumption.

7. DISCUSSION

For the building sector that is the subject of this study and according to the regulations in force, Morocco has set itself the objectives of saving primary energy through the implementation of an energy efficiency plan in various economic sectors.

Today, the implementation of the general building regulations setting the energy performance rules is an economic and social priority in view of the growth in energy demand and the considerable bill. The energy-environment issue should lead to a transition towards an optimal use of energy in the operation of buildings by using urban climate design methods, the principles of bioclimatic architecture, renewable energies and sustainable practices more appropriate and most conducive to energy savings.

Among the objectives of urban climate design in any urban development, and those of bioclimatic architecture at the scale of the building, we can cite:

• Improving the comfort of urban spaces, which also improves the comfort inside the housing.

• Reducing energy consumption, including the optimization of energy requirements for heating during the winter and cooling during the summer.

• Reducing carbon emissions

Through these study projects, it shows that the implementation of thermal regulation in low-cost housing can be achieved under acceptable financial conditions. One of the objectives of the demonstration projects is to show that the requirements imposed by the new thermal regulations could be implemented at a lower cost. Also, it proves that the actors in the construction industry (architects, design offices, builders) are able to implement the thermal regulations and does not affect the construction techniques usually used. Building companies have adapted to these requirements without too much difficulty from their own resources for the installation of standard insulation, or by subcontracting. (See Appendices)

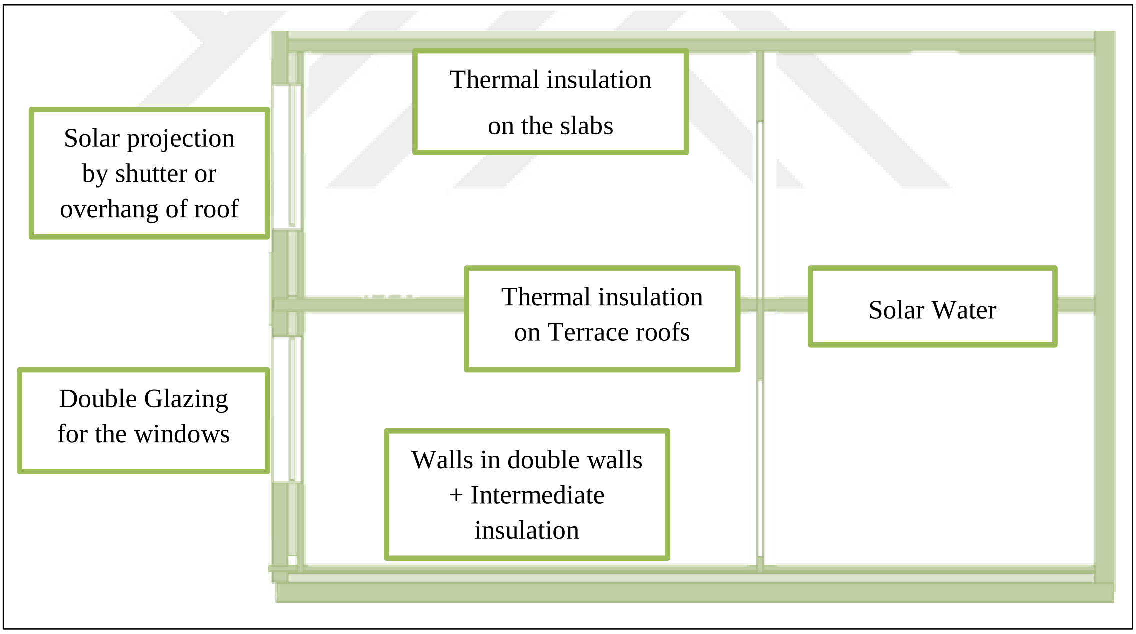
The compliance with the requirements of the thermal regulations can be simply ensured by adding insulation in the double wall, on the roof and possibly on the floor, the installation of double glazing if necessary, without it being necessary to touch the architectural provisions. In this approach, regulation contributes to increasing the grey energy of the construction, since it is necessary to add the grey energy of the insulators. Thermal regulations have little impact on the energy budget of households in social and economic housing. Under these conditions, the impact of the implementation of regulatory isolation measures is mainly related to the improvement of the indoor comfort of homes.

Performance approach:

The requirement for the overall thermal performance characterizes the maximum annual heat exchanges through the building envelope. It is established for each climatic zone taking into account the comfort temperatures inside the dwellings:

- Indoor design temperature for heating requirements: 18° C
- Indoor design temperature and for cooling requirements: 26 °C

Figure 7.1: Interpretation of the used techniques in the study cases



Source: Derived from the studied study cases, Imane Ourhadja, 2019

The study mainly summarizes the answer of “How to act on the building envelope to reduce energy consumption?”

From the study cases, we can deduce the implemented techniques organised in the following tables:

Table 7.1: Implemented techniques on the study cases

	House of Architects	Al Ouroud II	Al Karama	Villa AMYS	DEFI
Roof Insulation	✖	✖	✖	✖	✖
External wall Insulation	✖	✖	✖	✖	✖
Ground Floor Insulation	✖	✖	✖	✖	✖
Double Glazing	✖	✖	✖	✖	✖
Sun blocker		✖		✖	
Roller shutters		✖		✖	✖
Solar Water Heaters	✖	✖	✖	✖	✖
Awnings	✖		✖	✖	
Presence Sensor in circulation areas			✖	✖	✖
Air to water heat pump	✖			✖	✖
Air to air heat pump					✖
Canadian Well			✖	✖	✖

Table 7.2: The best technical solutions implemented

	Roofing	Walls	Floors	Double glazing	Carpentry	Sun protection
Type	Extruded polystyrene	Glass wool	Polyurethane spray	Clear 4/12/4	PVC French opening	Projection shutters

Figure 7.2: Representation of the used principles

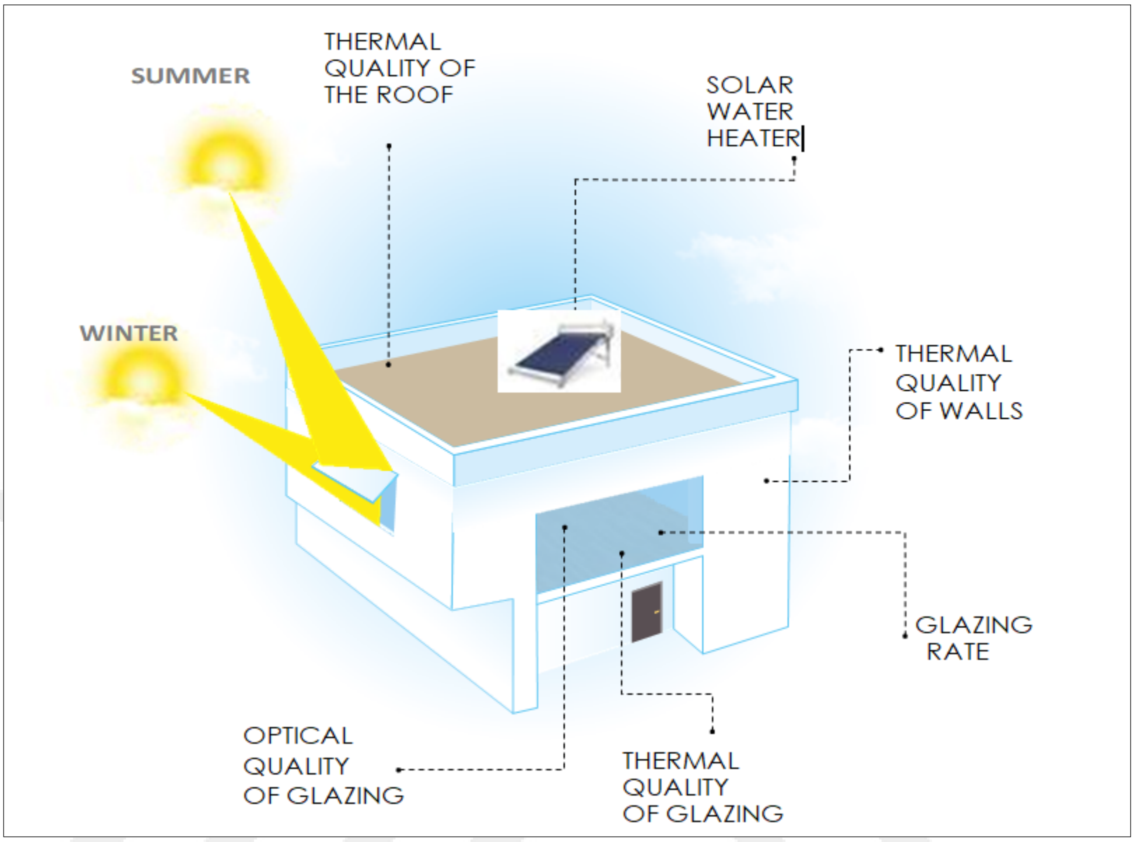


Table 7.3: Choice of insulation according to the wall

Types of insulation	Walls	Partition walls	Ceilings	Roofs and low floors
Glass wool	Yes	Yes	Yes	No
Rockwool	Yes	Yes	Yes	Yes
Expanded polystyrene (EPS)	Yes	Yes	No	No
Extruded Polystyrene (XPS)	No	Yes	No	Yes
Polyurethane	Yes	No	No	Yes
Hemp wool	Yes	Yes	Yes	No
Perlite	No	No	No	Yes
Expanded cork	Yes	Yes	Yes	Yes

8. GENERAL CONCLUSION

Morocco is engaged in a major process of implementing vast housing production programs: 180,000 units planned per year to meet the current deficit and additional needs, the creation of new cities and new urban centers. The country is also particularly concerned by energy issues since it imports more than 95percent of its needs. The energy bill has continued to increase and exceeded 100 billion dirhams in 2012. The building sector alone consumes about 36percent of the country's total energy, of which nearly 29percent is residential and 7percent tertiary (“Département de l’Habitat et de La Politique de La Ville”, *2018*).

The importance of the needs in the building sector, combined with the environmental challenges and the increase in the price of energy, have prompted the public authorities to implement accompanying institutional, legislative and regulatory measures. In particular, the laws on renewable energies No. 13-09, energy efficiency No. 47-09, water No. 10-95, waste management and their disposal and the general building regulations laying down the rules for the energy performance of buildings.

Moroccan cities face multiple issues and challenges, related on the one hand to the threats and risks caused by climate change and environmental degradation. On the other hand, it’s related to the urban complexity that characterizes the development of cities. Today's cities are in fact, very emitting greenhouse gases, very energy and resource-intensive, and their development involve several scales (commune, district, subdivision, housing, etc.) that require a global and integrated approach (housing, infrastructure, public facilities and services, transport, etc.). At the same time, the city has an important potential for sustainable development and the capacity to create new resources and new technologies. It has an essential role to play in the fight against climate change and in promoting green growth. In this regard, to enable our cities to be sustainable and energy efficient, it is essential to take into consideration several elements before any action is taken to develop them, particularly in terms of controlling energy consumption and promoting renewable energies.

It is worth mentioning that “Energy-conscious building” is a structure whose main principle is based on the positive balance between the energy produced and the energy consumed. The objective is to reduce energy requirements, maintain pleasant temperatures, control humidity and promote natural lighting. "*Through these achievements, we wanted to ensure that thermal and acoustic comfort in the housing is within the reach of all Moroccan citizens*," says Ahmed Belamine, President of the Sustainable Construction Commission of the EMC Cluster. The positioning of those projects ensures thermal inertia, guaranteeing comfort for occupants in both winter and summer, providing optimal hygiene and health conditions for the inhabitants. These projects are inaugurated by His Majesty King Mohammed VI unifying tool in the field of sustainable construction in the Kingdom.

This thesis is intended to be as a reference framework illustrating buildings that are relevant and representative of climate zones in Morocco, taking into consideration best practices in terms of energy efficiency and the integration of renewable energies. To develop it, a series of visits, researches and interviews with the stakeholders concerned were carried out to enable the leaders of these innovative projects to communicate on their projects in terms of architectural design, good practices, intelligent solutions adopted and feedback from experience.

From a habitat level, Demonstration projects advocates a design based on the principles of bioclimatic architecture. It also invites promoters and project managers to act on the building envelope in order to optimize energy consumption while integrating of the most energy-efficient equipment. Finally, it contributes to facilitating the progressive use of thermal regulations for buildings.

The study cases studied showed that the building sector represents a significant potential for energy savings. The relevance of passive systems for thermal comfort is well established: layout, building architecture, bioclimatic approach (optimal orientation, openings, solar entrances, and natural lighting, appropriate choice of materials, high-performance insulation, use of renewable energies, etc.) The diversity of solutions provided and the wide range of possibilities for adapting to the specificities of local climates offer great opportunities for innovation. Water and vegetation do not only respond to new logics, but they have also always been deployed to help reduce heat. The solutions adopted by each study case to achieve energy savings, improve thermal comfort and at the same time minimize the impact on the environment are described in this document.

Some processes do not seem to be adapted to certain climatic zones, due to their specificities and the antagonistic effects between the summer and winter or day/night strategy. The bioclimatic design of a building consists of building with the climate. It is based on knowledge of the climate context, the natural environment of the site and the human factor and its uses. The additional cost of integrating energy efficiency and renewable energy into buildings has often been criticized as a barrier to the development of good practices. However, this thesis shows that thanks to the rigor and quality of the design approach, the additional cost can be reduced to less than 7percent of the overall cost (Badre Kanouni, 2019).

Some projects had to overcome several difficulties, linked in particular to the lack of technical know-how of companies, low consumer awareness and a poorly organized market that should adapt to new products. These projects were led by men and women professionals, who were able to adapt the most appropriate solutions to the reality of the context.

The theme of this thesis addresses the environmental and energy challenges that Moroccan cities will face in the coming years. These challenges must be addressed both at the level of buildings and in larger contexts. These new approaches to spatial design and planning seek to reduce energy consumption, limit CO2 emissions, improve user comfort, propose more environmentally friendly development methods and offer sustainable solutions to urban problems.

REFERENCES

Books

Alain Liébard, & André De Herde. (2006). **Traité d'architecture et d'urbanisme bioclimatiques*. Paris: Moniteur.

Ariz, S. (1979). *Arcosanti workshops, 1979.* Scottsdale, Ariz.: Cosanti Foundation.

Banham, R. (2009). *The architecture of the well-tempered environment*. Chicago: University Of Chicago Press.

Baruch Givoni. (1978). *L'homme, l'architecture et le climat*. Paris: Éditions Du Moniteur.

Baruch Givoni. (1998). *Climate considerations in building and urban design*. Retrieved from https://www.wiley.com/en-us/Climate+Considerations+in+Building+and+Urban+Design-p-9780471291770

Baruch Givoni, & Izard, J.-L. (1978). *L'homme, l'architecture et le climat.* Paris: Ed. Du Moniteur.

Digumarti Bhaskara Rao. (1998). *Earth Summit*. New Delhi: Discovery Pub.

Donlon, N., & Britain., G. (1992). *The Earth Summit*. London: House Of Commons Library, Research Division.

Esmond Bradley Martin, World Wildlife Fund, & Union, I. (1980). *The international trade in rhinoceros products : a report for the World Wildlife Fund (WWF) and International Union for Conservation of Nature and Natural Resources (IUCN), December 1979*. Gland, Switzerland: Iucn/Wwf.

Fathy, H., & Yana Kornel. (1970a). *Construire avec le peuple*. Paris: Editions Jérôme Martineau.

Fathy, H., & Yana Kornel. (1970b). *Construire avec le peuple* (p. 23). Paris: Editions Jérôme Martineau.

For, O. (2017). *ENERGY TECHNOLOGY PERSPECTIVES 2017 : catalysing energy technology transformations.* Place Of Publication Not Identified], Oecd.

Gonzalo, R., & Habermann, K. J. (2006). *Energy efficient architecture : basics for planning and construction*. Basel: Birkhäuser ; London.

Griffiths, J. F. (1976). *Climate and the environment*. Boulder - Col: Westview Press.

Gisèle Escourrou. (1991). *Le climat et la ville*. Paris: Nathan.

On, C. (1993). *Report of the United Nations Conference on Environment and Development : Rio de Janeiro, 3-14 June 1992. 3 Statements made by heads of State or government at the Summit Segment of the Conference.*New York.

Paolo Soleri. (1969). *Arcology: the city in the image af man.* Cambridge Mit Press.

Paolo Soleri. (1974). *Arcology : the city in the image of man*. Cambridge, Mass.: Mit Press.

Rapoport, A. (1985). *Pour une anthropologie de la maison*. Paris ; Montréal: Dunod.

Rapoport, A., Meistersheim, A. M., & Maurin Schlumberger. (1972). *Pour une anthropologie de la maison*. Paris: Dunod.

Rapoport, A. (2005). *Culture, architecture, and design*. Chicago: Locke Science Pub. Co.

Quarrie, J. (1992). *Earth summit 1992*. London: Regency Press

Villecco, M. (1977). *Architecture as energy*. Minneapolis: Walker Art Center.

Yeang, K., Shireen Jahnkassim, Humaedah Rosly, & Powell, R. (2016). *Constructed ecosystems : ideas and subsystems in the work of Ken Yeang*. Novato, Ca: Applied Research And Design Publishing.

Periodicals

Affan, F. B. (2017a). Earth Summit: From Rio 1992 via Kyoto and Copenhagen, Back to Rio 2012. *Journal of Ecosystem & Ecography*, *07*(01). https://doi.org/10.4172/2157-7625.1000229

Adapting buildings and cities for climate change: a 21st century survival guide. (2005). *Choice Reviews Online*, *43*(01), 43-0117-43-0117. https://doi.org/10.5860/choice.43-0117

Adolphe, L., A. Chatelet, K. Ait Ameur, A. Boussoualim, A. Barlet, JL. Izard, K. Lehtihet and A. Casal, 2002, SAGACités, Système d'Aide à la Gestion des Ambiances urbaines, Rapport final, MENRT, Action Concertée Incitative Ville.

Barnard, H. C., Zeldin, D., & Fourier, C. (1969). The Educational Ideas of Charles Fourier (1773-1837). *British Journal of Educational Studies*, *17*(2), 220. https://doi.org/10.2307/3119264

Bell, L. (2014). Brave New Worlds: Reaching Towards a New Era of Space Architecture. *Architectural Design, 84*(6), 118–121. https://doi.org/10.1002/ad.1842

Benhamou, B., & Bennouna, A. (2013). Energy Performances of a Passive Building in Marrakech: Parametric Study. *Energy Procedia, 42,* 624–632. https://doi.org/10.1016/j.egypro.2013.11.064

Benzerzour, M., Masson, V., Groleau, D., & Lemonsu, A. (2011). Simulation of the urban climate variations in connection with the transformations of the city of Nantes since the 17th century. *Building and Environment*, *46*(8), 1545–1557. https://doi.org/10.1016/j.buildenv.2011.01.014

Boutros Boutros-Ghali Appointed U.N. Secretary-General. (1992). *Foreign Policy Bulletin*, *2*(4–5), 132–132. https://doi.org/10.1017/s105270360000842x

COUNTRY PROFILE MOROCCO 2018 Renewable Energy Solutions for the Mediterranean & Africa RES4MED&Africa. (n.d.). Retrieved from https://www.res4med.org/wp-content/uploads/2018/06/Country-profile-Marocco-2.pdf

De Wrachien, D. (2017). Impacts of Global Warming on Irrigation and Drainage Development: Perspectives Challenges and Solutions. *SciFed Journal of Global Warming*, *1*(1). https://doi.org/10.23959/sfjgw-1000003

Document de Projet -Code EE du Bâtiment au Maroc Gouvernement Du Royaume du Maroc Programme des Nations Unies pour le Développement Document de Projet du PNUD. (n.d.). Retrieved from https://www.undp.org/content/dam/morocco/docs/prodocs/Prodoc_CEEB.pdf

Environment: WAWF Supports Stockholm Conference. (1972). *Nature*, *236*(5342), 90–90. https://doi.org/10.1038/236090b0

Friends. (1992). *The last chance to save the planet? : the 1992 Earth Summit.* Friends Of The Earth.

Godlee, F. (1998). Dr Gro Harlem Brundtland is a former prime minister of Norway and has been a leading voice on the environment. *BMJ*, *316*(7124), 7–7. https://doi.org/10.1136/bmj.316.7124.7k

Grondin, Y.-A., & Charbonneau, L. (1994). La participation et la mise en oeuvre des conventions et engagements du Sommet Planète-Terre de Rio par le Québec. *Revue Générale de Droit*, *25*(4), 537. https://doi.org/10.7202/1056272ar

Grunewald, N., & Martinez-Zarzoso, I. (2015). Did the Kyoto Protocol fail? An evaluation of the effect of the Kyoto Protocol on CO2 emissions. *Environment and Development Economics*, *21*(1), 1–22. https://doi.org/10.1017/s1355770x15000091

Guyatt, D. J. (2011). Climate Change Scenarios – Implications for Strategic Asset Allocation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1911824

Held, H. (2013). Climate policy options and the transformation of the energy system. *EPJ Web of Conferences*, *54*, 01002. https://doi.org/10.1051/epjconf/20135401002

Jeong, Y. S. (2014). Experimental Study on the Thermal Conductivity of Thermal Insulation Materials Used in Residential Buildings. *Advanced Materials Research*, *1025–1026*, 535–538. https://doi.org/10.4028/www.scientific.net/amr.1025-1026.535

Lapping, M. B. (1979). Toward A Social Theory of the Built Environment: Frank Lloyd Wright and Broadacre City. *Environmental History Review*, *3*(3), 11–23. https://doi.org/10.2307/3984040

MID-TERM EVALUATION REPORT ON THE UNDP/GEF PROJECT ENERGY EFFICIENCY CODES IN RESIDENTIAL BUILDINGS AND ENERGY EFFICIENCY IMPROVEMENT IN COMMERCIAL AND HOSPITAL BUILDINGS IN MOROCCO. (2013). Retrieved from http://procurement-notices.undp.org/view_file.cfm?doc_id=35481

Morel Corrêa, D. A. S., Anzolch, D. A. R., & Fonseca Pedrotti, R. (2016). El brise–soleil o la doble fachada de Le Corbusier. *ARQUISUR*, (10), 108–123. https://doi.org/10.14409/ar.v0i10.6190

Raloff, J. (1992a). Rio Summit Launches Two “Earth” Treaties. *Science News*, *141*(25), 407. https://doi.org/10.2307/3976574

Raloff, J. (1992b). Rio Summit Launches Two “Earth” Treaties. *Science News*, *141*(25), 407. https://doi.org/10.2307/3976574

Paquot, T. (2009). Hassan Fathy, construire avec ou pour le peuple? *Cahiers d'histoire. Revue d'histoire Critique*, (109), 15–25. https://doi.org/http://journals.openedition.org/chrhc/1907

Sachs, I. (1994). Le développement reconsidéré : quelques réflexions inspirées par le Sommet de la Terre. *Tiers-Monde*, *35*(137), 53–60. https://doi.org/10.3406/tiers.1994.4848

Sobin, H. J., & Olgyay, V. (1963). Design with Climate: Bioclimatic Approach to Architectural Regionalism. *Journal of Architectural Education (1947-1974)*, *18*(3), 43. https://doi.org/10.2307/1424217

Sonetti, G. (2013). Energy and architecture — An overview. *EPJ Web of Conferences*, *54*, 02004. https://doi.org/10.1051/epjconf/20135402004

Sørensen, Bent. "Renewable Energy." *Energy Policy*, vol. 19, no. 4, May 1991, pp. 386–391, 10.1016/0301-4215(91)90061-r. Accessed 25 January 2019.

Stein, R. G. (1977). Observations on Energy Use in Buildings. *JAE*, *30*(3), 36. https://doi.org/10.2307/1424307

Tiainen, J., & Christina, V. (2014). *Environmentally Sustainable Construction Products and Materials – Assessment of release*. Retrieved from http://www.nordicinnovation.org/Global/_Publications/Reports/2014/Environmentallypercent20Sustainable%20Construction%20Products%20and%20Materials_Final_report.pdf

Vigneau, J.-P. (2016). Escourrou (G.), 1991. — Le climat et la ville. *Norois*, *162*(1), 358–359. https://doi.org/noroi_0029-182x_1994_num_162_1_6566_t1_0358_0000_2

WATSON, D. (1977). Energy Use and Building Design. *Science*, *198*(4315), 391–392. https://doi.org/10.1126/science.198.4315.391

World Energy Perspectives ENERGY EFFICIENCY : A STRAIGHT PATH TOWARDS ENERGY SUSTAINABILITY In Partnership with ADEME 1. (n.d.). Retrieved from https://www.ademe.fr/sites/default/files/assets/documents/energy-efficiency-astraight-path-4thnov.pdf

Witze, A. (2007). A timeline of Earth observation. *Nature*. https://doi.org/10.1038/news.2007.320.

Yeang, K. (2009). Nanoenergy. *Architectural Design*, *79*(1), 124–125. https://doi.org/10.1002/ad.832

Other Publications

A/CONF.151/26 (Vol. IV) REPORT OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT*. (2019). Retrieved June 25, 2019, from Un.org website: https://www.un.org/documents/ga/conf151/aconf15126-4.htm

AMEE - Agence Marocaine pour l’Efficacité Energétique. (2019). Retrieved from Amee.ma website: http://www.amee.ma/

aMush. (2017). Retrieved May 8, 2019, from aMush website: http://www.amush.org/

arcVision.org. (2016). Retrieved January 8, 2019, from arcVision.org website: http://arcvision.org

Beyond 450: Why the IEA’s “Climate Scenario” Falls Short - Oil Change International. (2016, April 6). Retrieved May 8, 2019, from Oil Change International website: http://priceofoil.org/2016/04/06/beyond-450-why-the-iea-climate-scenario-falls-short/

Buildings. (2019). Retrieved March 10, 2018, from Iea.org website: https://www.iea.org/topics/energyefficiency/buildings/

Construction21, le média social du bâtiment et de la ville durable. (2019). Retrieved April 8, 2019, from construction21.org website: http://construction21.org/maroc

Définitions | Insee. (2017). Retrieved May 8, 2019, from Insee.fr website: https://www.insee.fr/en/metadonnees/definitions

Département de l'Habitat et de la Politique de la Ville. (2017). Retrieved April 28, 2019, from Mhpv.gov.ma website: http://www.mhpv.gov.ma/

Département de l'Habitat et de la Politique de la Ville. (2017). Retrieved from Mhpv.gov.ma website: http://www.mhpv.gov.ma/

Développement, le. (2017). www.Aderee.ma | Aderee - ADEREE - L'Agence Nationale pour le Développement ... Retrieved June 01, 2019, from comprsites.net website: https://www.comprsite.net/www/aderee.ma

Expertise, Climate change – ADEME. (2018). Retrieved April 25, 2019, from ADEME website: https://www.ademe.fr/en/expertise/climate-change

El Bachtiri, R, El, B. R., & Matagne, E. (2015). A technical reading of the 13-09 law on renewable energy in Morocco. Retrieved May 8, 2019, from 2013 International Renewable and Sustainable Energy Conference (IRSEC) website: https://www.academia.edu/29135687/A_technical_reading_of_the_13-09_law_on_renewable_energy_in_Morocco

energy | Origin and meaning of energy by Online Etymology Dictionary. (2019). Retrieved October 17, 2010, from Etymonline.com website: https://www.etymonline.com/word/energy

ENERGY EFFICIENCY IN BUILDINGS IN MOROCCO | FFEM - Fonds Français pour l'Environnement Mondial. (2018, September). Retrieved from Ffem.fr website: https://www.ffem.fr/en/energy-efficiency-buildings-morocco

Expertise, Climate change – ADEME. (2018). Retrieved April 28, 2018, from ADEME website: https://www.ademe.fr/en/expertise/climate-change

Fire and Memory. (2019). Retrieved March 6, 2018, from Google Books website: https://books.google.com.tr/books?id=Svmc_uZqwcEC&pg=PA13&lpg=PA13&d

q=Matter+and+energy,+architecture+and+fire,+construction+and+combustion+are+once+again+placed+in+relation+to+one+another&source=bl&ots=dM3RuPJtrU&sig=ACfU3U3B4e_NwDjFevFwM53dpnHmvk0bOw&hl=en&sa=X&ved=2ahUKEwjjj4L_-IriAhUoMuwKHaSzDx8Q6AEwAHoECAkQAQ#v=onepage&q=Matter%20and%20energy%2C%20architecture%20and%20fire%2C%20construction%20and%20combustion%20are%20once%20again%20placed%20in%20relation%20to%20one%20another&f=false

Global Warming Timeline. (2019). Retrieved april 23, 2019, from Aip.org website: https://history.aip.org/climate/timeline.htm

Groupe AL OMRANE. (2019a). Groupe AL OMRANE - Al Omrane Meknès. Retrieved February 8, 2019, from Alomrane.gov.ma website: http://www.alomrane.gov.ma/Reseau/Al-omrane-meknes

Groupe AL OMRANE. (2019b). Groupe AL OMRANE - Al Omrane Région de l'Oriental. Retrieved February 8, 2019, from Alomrane.gov.ma website: http://www.alomrane.gov.ma/Reseau/Al-omrane-region-de-l-oriental

https://www.facebook.com/wfc.goodpolicies. (2016, November 21). After COP22, Morocco to implement 100% RE. Retrieved February 13, 2019, from World Future Council website: https://www.worldfuturecouncil.org/cop22-morocco-implement-100-re/

IEA World Energy Balances. (2019). Retrieved May 8, 2019, from Iea.org website: https://www.iea.org/statistics/balances/

Jackson, R. (2018, November 28). Global Climate Change: Effects. Retrieved April 11, 2018, from Climate Change: Vital Signs of the Planet website: https://climate.nasa.gov/effects/

Law 47-09 on Energy efficiency Morocco 2011 - Policy database. (2011). Retrieved January 8, 2019, from Climatepolicydatabase.org website: http://climatepolicydatabase.org/index.php/Law_47-09_on_Energy_efficiency_Morocco_2011

LE CLIMAT DU MAROC | Maroc Météo. (2019). Retrieved May 8, 2019, from Marocmeteo.ma website: http://www.marocmeteo.ma/?q=fr/climat_maroc

Mirabelli, A., Economic Forum, & Energy Forum (6, 2011, Brixen. (2012). *Solar building skins : [conference proceedings]*. Munich: Economic Forum.

Morocco. (2016). Retrieved February 7, 2019, from Undp.org website: https://www.ndcs.undp.org/content/ndc-support-programme/en/home/our-work/geographic/arab-states/morocco.html

Morocco | FFEM - Fonds Français pour l'Environnement Mondial. (2016). Retrieved March 2, 2019, from Ffem.fr website: http://www.ffem.fr/en/region-country-page/morocco

Morocco Energy Situation - energypedia.info. (2019). Retrieved from Energypedia.info website: https://energypedia.info/wiki/Morocco_Energy_Situation

Morocco sets regulations for energy efficiency. (2015, September 16). Retrieved February 8, 2018, from Oxford Business Group website: https://oxfordbusinessgroup.com/analysis/morocco-sets-regulations-energy-efficiency

Neslen, A. (2018, August 8). Morocco poised to become a solar superpower with launch of desert mega-project. Retrieved April 8, 2019, from the Guardian website: https://www.theguardian.com/environment/2015/oct/26/morocco-poised-to-become-a-solar-superpower-with-launch-of-desert-mega-project

REEEP - Morocco (2014). (2013, October 11). Retrieved January 1, 2019, from REEEP website: https://www.reeep.org/morocco-2014

Smisek, P. (2019, May 7). In the bag: new retail-interior concepts. Retrieved April 8, 2019, from Architonic.com website: https://www.architonic.com/

Towards a zero-emission, efficient, and resilient buildings and construction sector GLOBAL STATUS REPORT 2017. (n.d.). Retrieved from https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf

APPENDICES

APPENDIX A.1 INTERVIEW1

Name: Said MOULINE-

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- How do you define the concept of energy transition at the local level, taking into account Morocco's commitments in the context of global climate action?

The new national energy strategy and policy places sustainable development, renewable energies and energy efficiency at the heart of its concerns. Energy efficiency goes hand in hand with current sustainable development strategies. The scope is vast and implementation is carried out through a series of public policies and actions ranging, for example, from the implementation of large-scale national and regional programmes, to raising awareness of eco-gestures among stakeholders, the implementation of financial support schemes, the development of eco-mobility solutions and the consideration of these issues in urban forms and spatial planning. While the supply-side lever has been addressed, it has so far mainly taken the form of actions to give priority to energy production programmes based on renewable resources, but also by proposing measures to rationalise national and regional energy consumption and to support the emergence and development of local solutions. Local and regional authorities are then invited to support this approach, particularly in the local management and consolidation of economic, organisational and governance models in favour of the energy transition, as well as in the integration of this transition at the heart of local development plans.

- Within the framework of the National Energy Strategy adopted by Morocco in 2009, what progress has been made so far in legal and institutional terms?

The first energy efficiency actions were carried out within the framework of the National Priority Action Plan (PNAP), launched during the 2008-2012 period, with a view to implementing the first energy saving measures on the scale of supply and demand. Other measures and actions were subsequently initiated and implemented at legislative, regulatory and institutional levels. Reforms have been undertaken such as Law No. 47-09 on energy efficiency, laws relating to the creation of new structures, which in 2016 divided the two axes of the energy transition between the Moroccan Solar Energy Agency (MASEN) for renewable power energies and the AMEE for energy efficiency, the general building regulation fixing the energy performance of buildings published in the Official Gazette, as well as several decrees in the field of renewable energies and energy efficiency. Several other decrees are in the approval phase, such as the decree on mandatory and periodic energy audits.

- What is the place given to biomass energy in national programs?

Biomass in the form of firewood and its derivatives represents nearly 7percent of the national primary energy consumption, or nearly 1.4 million toes. It is used by the entire rural population mainly for cooking and heating purposes, and remains very present in some artisanal sectors in the city (hammams and bakery ovens in particular). Every year, several million tons of wood are used, of which nearly 53percent comes from the forest. In Morocco, the supply of firewood remains very modest, thwarted by the climatic conditions of our country, in view of a significant and growing demand. Biomass, in the form of residues and by-products, resulting mainly from agricultural, agro-industrial and urban activity, of which Morocco has a great potential that is not well developed, constitutes a new energy opportunity. To this end, in 2010, regional studies were launched to provide an overview of the available potential, its regional distribution and the technical possibilities for its energy recovery. Companies have developed to condition its waste used today by certain industries as fuel instead of fuel or diesel. Energy production such as Biogas can come mainly from agricultural installations; organic waste, urban wastewater treatment plants (WWTPs) or household landfills. The potential is very high, particularly in the energy use of landfills and WWTPs. The cities of Oujda and Fez are transforming the Biogas from their landfills into electricity. This practice, which has a significant impact, must be generalized, particularly through the reduction of local and national energy bills, the reuse of waste and biomass, and the reduction of greenhouse gases (GHGs).

- The building sector is a major energy consumer (25percent nationally). How do you think architecture can contribute to the promotion of renewable energies and the transition to a lower carbon footprint and better preservation of our natural resources?

Aware of the potential for efficiency that it represents, AMEE has been working since 2010 on the characterisation of the building sector with the proposal for thermal technical requirements for a new decree on thermal regulation in buildings, published in the B.O. in November 2014 and implemented in November 2015. Among the thermal compliance provisions, the architecture of the building or the architect plays a fundamental role. The exploitation of local resources and materials in construction, as well as the development of traditional construction methods that have been upgraded and adapted, have been encouraged through study projects. It should also be noted that AMEE has launched and renews every year national training and awareness-raising campaigns for the main actors involved in the building permit process to raise their awareness of these aspects and their impact on the environment and energy saving.

- What actions does AMEE take with professionals in the real estate sector to encourage them to put into practice the standards and regulations resulting from our Energy Efficiency Code in the building sector?

Law 47-09 presented the overall framework for the development of energy efficiency at the national level. A provision of this law has been applied by regulation through the decree on the thermal regulation of construction in Morocco (RTCM). In this context, AMEE has conducted a series of training and upgrading campaigns for all stakeholders at sector: professional real estate federations, public departments and agencies, architects, as well as local authorities. Specific action plans link us to the profession to disseminate good practices more widely and to further clarify the provisions of the regulations.

- Despite the implementation of some laws, such as the RTCM (Réglementation thermique des constructions au Maroc) published in the Official Bulletin in 2014, energy efficiency in buildings faces many difficulties, including the lack of awareness and training of some architects. What is the place given to these two components within AMEE?

These are fewer difficulties than a normal process of implementing new regulations in a structuring sector of the national economy. There are support programmes and measures to be put in place to achieve this transition. All the technical tools set up by AMEE, such as the national software " Binayate " and the database of construction materials are made available to professionals and architects. An annual training programme is planned and carried out with the sector, including targeted practical training actions, sectoral guides, the development of an energy performance label in the building, etc.

- Architects are criticized for not making their clients sufficiently aware of the comparative advantages of a low-energy building. What do you think of that?

Particular attention is currently being paid by AMEE to this aspect. Architects are now sufficiently aware to intervene at different phases of the construction process in order to propose and advise the best technical solutions capable of offering building occupants thermal comfort and energy-efficient buildings. Moreover, it is necessary to further strengthen communication actions for the general public to help citizens adopt energy saving measures in their daily lives. It is much more a matter of changing user behaviour.

- At the COP 23 event in Bonn in November 2017, Morocco presented projects cited as African models for the implementation of a proactive State policy at the highest level, the results of which we are now beginning to see today. Does this confirm Morocco's current approach? In other words, have we met the challenge of energy transition?

The energy transition defines the framework for the different sectoral strategies needed to ensure sustainable development and a reduction in our energy consumption. Energy efficiency occupies a prominent place in the objectives of the Nationally Determined

Contribution (NDC) formulated by Morocco and presented to the UNFCCC Secretariat, with specific objectives relating to energy savings of around 15percent compared to the trend by 2030 and with programmes identified in the various energy consuming sectors (transport, construction, industry, agriculture, etc.). Already at COP22, Morocco presented its experience in implementing its strategy to combat climate change and highlighted possible opportunities for South-South cooperation, particularly with the African continent. AMEE now has several African partners with whom we share our experiences and help build capacity. It is also to be welcomed that the Green Climate Fund has been allocated 21 projects for Morocco out of 54 projects allocated to Africa.

- Mobility is an important issue in the energy transition. What are the ongoing projects being carried out by AMEE in this sector?

The transport sector accounts for nearly 39percent of national energy consumption and contributes to more than 23percent of GHG emissions. This sector depends almost exclusively on petroleum products, which are imported in their entirety and weigh heavily on our trade balance. Sustainable mobility is one of the main pillars of our strategy. AMEE presented several measures to reduce vehicle fuel consumption, which are being implemented, such as tax incentives for hybrid and electric cars, the promotion of soft mobility within certain cities and municipalities, the promotion of public transport and urban travel plans, and the establishment of the basis for regulations to improve the quality of vehicles and tyres on the market. A communication and training component is also addressed, in particular eco-driving or the training of professionals. Concerning the electric mobility that is developing worldwide, AMEE has brought together in a consortium of manufacturers, importers and developers to optimize the deployment of this technology in stages. In addition, since COP 22, we have been founding members of the coalition of electric sports with Formula E and other partners. The Formula E Marrakech Prize at COP 22, which is now part of the Federation's global programme (the next grand prize will take place on 13 January 2018 in Marrakech), is a perfect opportunity to demonstrate that electric mobility has reached an excellent level of maturity and that its development depends on the policies established by the states. The Kingdom of Morocco is introducing electric mobility in Africa where there are significant opportunities. The launch before the Head of State of the electric car and bus factories, as well as the battery factories with the world leader, shows just how committed our country is.

- How can users be made aware of the challenges of climate and energy efficiency in their living environment in general, taking into account the cultural and social specificities of Morocco?

A communication effort for the general public should be conducted and strengthened. More awareness-raising and demonstration actions are needed to highlight the major interest of sustainable development with its energy, economic, social and environmental components. Thousands of local and regional actions must be carried out in the private and public sectors, but also at the primary education level, at school. To this end, we have annual programmes with the Mohammed VI Foundation for the Protection of the Environment, the various ministerial departments and the professional sectors of industry, construction, transport and agriculture to demonstrate the major interest that energy efficiency and climate issues represent in the economic and social development of our country.

APPENDIX A.1 INTERVIEW2

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- You built the first autonomous house in Morocco. Can you explain what this concept means?

It is a house disconnected from all networks (except the Internet!). It produces the electricity it needs thanks to photovoltaic panels. The water comes from the recovery of rainwater which is stored in a tank and then filtered before use. Grey water is treated by phyto-purification and used to water the vegetable garden. The autonomy in this house also involves food since a vegetable garden is installed on the terrace, benefiting from fertilizer from the dry toilets and organic waste. All other waste is recyclable, provided of course that only products sold in glass or without packaging are purchased. To sum up, this house operates and functions in a closed cycle.

- The concept has something to appeal to. You have built an autonomous house in Rabat but is it possible on a large scale?

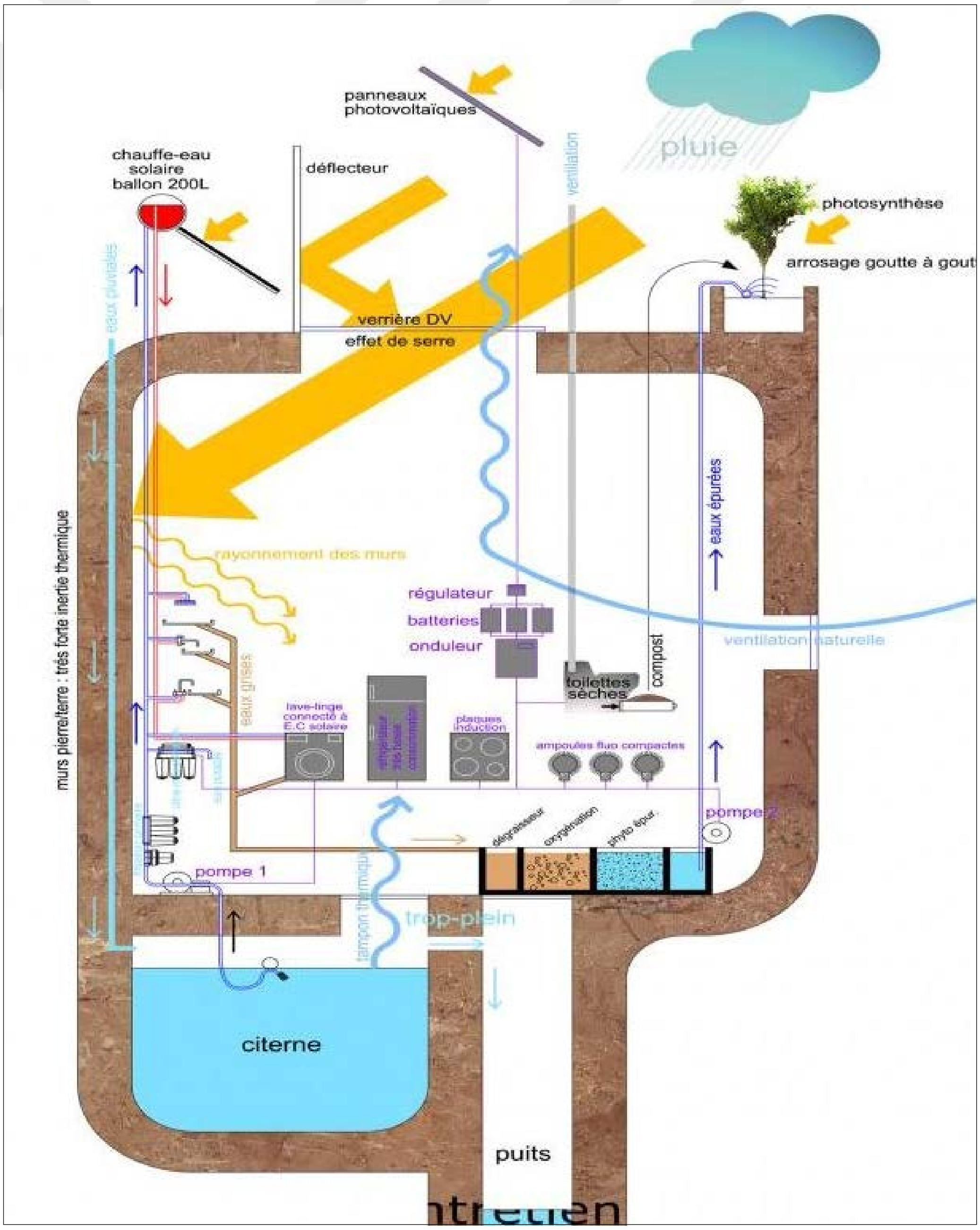
Ofcourse. We have developed an autonomous building model by reusing the same systems and are also working on an autonomous city concept.

- You have also opened an "archibionic" guest house in the Essaouira region with a very avant-garde look. How do visitors react?

Visitors discover it at the end of a 6 km track, after crossing a forest of argan trees. They are always surprised to find themselves in front of this white cube, set in this natural environment and which unfolds in all its dimensions, over the hours and seasons. They are also pleasantly surprised to find all the comfort to which they are accustomed and familiar with. In general, they leave convinced of this approach... and relaxed after this stop, disconnected from the networks but reconnected to nature!

- In your opinion, what are the first steps that each of us can take to effectively participate in the effort to preserve the environment?

-Reduce energy consumption by switching to fully LED lighting and choose very low-energy household appliances.
-Install double glazing on windows and a solar water heater.
-Reduce waste by avoiding buying packaged products (bulk or glass).
-Produce its own composition with the organic waste from the kitchen.
- Reduce water consumption by installing water reducers at faucets or installing infrared faucets. In houses with gardens, collect rainwater for watering.



APPENDIX A.2 INTERVIEW3

Interview with Nabil BENAZZOUZ,

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- As President of the FMCI Moroccan Federation of Consulting and Engineering, what is your definition of the concept of the energy transition?

Beyond the concept that the whole world is experiencing at various degrees of urgency, the energy transition in Morocco is a strategic choice dictated, on the one hand, by a desire to develop abundant and diversified renewable clean energies that preserve the national, regional and universal environment. And on the other hand, by a need to mitigate without further delay on the impact of the continuously increasing energy bill with the country's economic growth and unpredictable fluctuations in hydrocarbons.

- What role does FMCI play in this process and how is it preparing for the energetic transition?

Nearly 600 companies operate in consulting and engineering and generate a business volume of about 4.5 billion dirhams per year. More than 250 of the largest of these companies, which account for 90percent of this volume of business, belong to the Moroccan Federation of Council and Engineering (FMCI). They employ nearly 10,000 people, 65percent of whom are engineers and university managers, and are located throughout the country with a concentration of 65percent for the two regions of Rabat and Casablanca.
Consulting and engineering are involved in all investment projects in the form of studies, technical assistance, control or tests on the feasibility, design, implementation, and management of projects, since their implementation until their commissioning, or even

their operation and maintenance. Since 2010, the FMCI has self-imposed a voluntary commitment to preserving the environment and sustainable development.
In terms of energy transition and sustainable development in general, and by the nature of its services, the Council and engineering are at the heart of any effort to preserve and enhance urban and infrastructural heritage. FMCI has naturally and voluntarily committed, since March 2010, to the preservation of the environment and sustainable development. This commitment is shared with other professionals within the framework of the National Alliance for Sustainable Building, initiated at the COP21 by the Ministry of Housing and Urban Policy by bringing together all construction professionals: the CNOA, the FMCI, the FNBTP, the FNPI and concretized at the COP22 held in Marrakech. Within its national office, activates a commission dedicated to innovation and sustainable development. A convention had been signed with the former ADEREE (current AMEE) for training in the field of energy efficiency.
The FMCI is a member of the Economic and Social Economic Council "CESE" and therefore the force of proposal texts and provisions in relation to the various strategic plans, including the energy transition.

- What progress do you think Morocco has made, particularly in the field of housing?

Energy efficiency is now considered as the fourth energy after fossil fuels, renewable energies, and nuclear energy. The ambition of the Kingdom of Morocco is to ensure better use of energy in all areas of economic and social activity, given the need to rationalize and improve energy consumption to meet the needs increasing the energy of our country.
Globally the building sector accounts for 28percent of final energy consumption. The building is the second most energy-efficient sector after transportation. In Morocco, it accounts for 25percent of the country's total energy consumption, of which 18percent is residential and 7percent is tertiary.
This energy consumption is expected to increase rapidly in the future, following the evolution of the housing stock induced by the major projects programmed: Azur plan of the hotel industry, emergency program of the national education, program of 150 000 housing per year, hospital rehabilitation program, etc.

Energy Efficiency is the rational use of energy resources: it consists of minimizing energy consumption to provide the same service. Controlling energy consumption means putting in place good practices to reduce the energy bill.

AMEE, in collaboration with other partners, has developed an Energy Efficiency Code including Thermal Regulation of Construction in Morocco. This new code concerns both the passive component of the building setting the energy performance requirements of the envelope (thermal insulation of the walls, orientation, building materials, etc.) and the active component (lighting, air conditioning, electrical appliances, etc.).

For an easy and efficient application of the RTCM, the Moroccan Agency for Energy Efficiency (AMEE) has developed a climate zonation map comprising six distinct climatic zones. It has also developed a guide to good practices in energy efficiency in the building, for owners, contractors, building professionals, and any potential user. It groups together a range of practices and actions stemming from the RTCM, relating in particular to the choice of thermal insulation, to the orientation of the buildings, to the ventilation, to the heating and air-conditioning systems, to the lighting, to the heaters. solar thermal water, as well as the choice and use of household appliances.

These good practices and gestures of energy efficiency will ultimately allow a harmonious implementation of the RTCM. They will guarantee in the residential and tertiary sector a reduction in the electricity bill, a reduction in the environmental impact while promoting an optimal living comfort for residents and users.

Planning legislation, "general building regulations" must also set the energy performance rules of buildings to ensure a better energy balance of buildings by climate zones by addressing, in particular, the orientation, the lighting, insulation and heat flow, , as well as renewable energy inputs to enhance the performance levels of buildings to be built or modified.

Public administrations and establishments, as well as local authorities, must comply with the energy efficiency standards laid down by law during public procurement, the list of which will be set by regulation.

- What would be the real opportunities for Morocco to serve the power of the continent?

The energy transition in Morocco is a strategic decision with important challenges. They are obviously political since it is a question of achieving greater energy autonomy for our country and ensuring balanced development for all its regions. They are also economic, as our country aims to ensure strong and sustainable economic growth and human development that benefits all its citizens. The challenges are also social, because it is a question of ensuring general access to energy and controlling its cost so that Moroccan citizens are the least affected by any price rises.

And finally, the challenges are environmental, since the approach aims to place our country at the forefront of environmental preservation and the fight against the effects of climate change.

In this regard, it is important to share common energy issues with European countries that have committed to increasing the share of renewable energy in final energy consumption, increasing energy efficiency and reducing CO2 emissions by 2020.

In this context, Morocco has chosen to take the lead by implementing, from 2009, an energy strategy through several actions: the implementation of a diversified and optimized energy mix, the large-scale development of renewable energies (solar and wind), the promotion of energy efficiency and the mobilization of national fossil resources. Other countries have also adopted targets: Senegal with 15percent renewable energy penetration in 2020, followed by Ghana and Mali with 10percent penetration in 2020 and 2022 respectively. Nigeria, for its part, is targeting a target of 10percent of installed electricity capacity by 2020, and Côte d'Ivoire was forecasting a 5percent penetration of renewable energy by 2015.

In 2010, Morocco set a new framework for the deployment of renewable energies, which must represent 20percent of electricity production by 2020. The country has created a national body: the Moroccan Solar Energy Agency (MASEN) to manage calls for tenders, with a view to achieving the objective of 2,000 MW of solar energy. The tender procedure for the 500 MW power plant in Ouarzazate, perhaps one of the largest concentrated solar thermal energy projects (combined with photovoltaic solar energy), has been completed.

Characterized by economic backwardness, the vast majority of African States are engaged in development dynamics to keep pace with globalization. As a result, many have set a course for their emergence by 2025-2035. Given that access to energy is the pillar of economic development because it conditions basic needs (access to water, agricultural and industrial productivity, health, education, etc.), its availability appears to be crucial for development. Moreover, the World Energy Council, aware of this, has predicted "a tripling of electricity demand in Africa between now and 2035".

- What could Morocco contribute on a technical level?

Morocco is committed naturally and historically to a process of sharing complementary assets with the countries of the region and the continent. Its experience will be greatly appreciated as it will be developed in a socio-economic environment closer to the reality of the continent.
In this sense, it will be able to provide its expertise in the fields of:

. Assistance in the drafting of regulatory texts,

. Assistance in the governance of energy projects,

. Energy impact studies,

. Assistance in the devolution of international offers for renewable energy installations,

. Sizing, installation and maintenance of local solar stations,

. Sustainable construction of residential and public housing,

. Energy diagnosis and audits to reduce energy consumption.

Construction Sites of Morocco which concern the news of the construction sector in Morocco

communication@archimedia.ma

Do you apply thermal building regulations in Morocco (RTBM)?

- No (51percent, 27 Votes)

- Yes (49percent, 26 Votes)

Total Voters: 53Voting

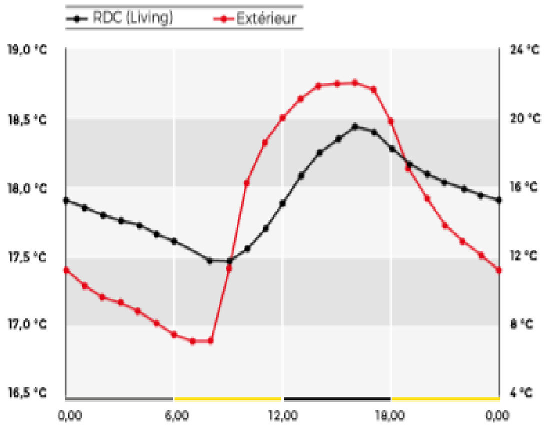
APPENDIX A.3 METEOROIDAL DATA OF VILLA AMYS

Table: Some meteorological data measured in Marrakech in 2018 (Agdal-Marrakech weather station).

Months	Maximum temperature (°C)	Minimum temperature (°C)	Average Temperature (°C)	Global solar irradiation (kWh.m-²)
January	21.4	-1.8	8.6	92.86
February	25.0	1.8	11.8	104.53
March	30.9	4.4	15.3	138.22
April	33.9	4.8	16.4	188.94
May	34.7	8.2	20.7	205.25
June	40.9	12.0	24.5	198.17
July	44.0	14.5	28.7	214.42
August	42.5	15.8	27.0	204.77
September	36.0	11.4	21.9	158.08
October	34.6	11.4	21.3	138.41
November	30.4	4.6	15.8	102.54
December	24.3	0.8	12.7	85.68

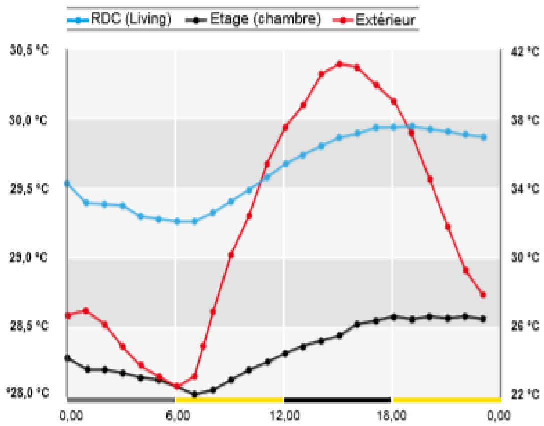
AMYS is located in the suburbs of Marrakech (31°37' N in latitude and 8°2' E in longitude and 468m of altitude). This city is characterized by a dry and warm continental climate in summer and cool in winter. The meteorological data used in this study are those for 2018, measured at the Agdal-Marrakech metrological station. These data were measured with a 30-minute time step and include: temperature, humidity, global solar radiation, wind speed and direction. Table 1 presents some characteristic data on the climate. It should be noted that the minimum temperature for this year was recorded in January (-1.8°C) although this month is sunnier than December. In February and December the minimum temperature is around 0°C. Thus, the coldest months are January, February and December. On the other hand, the maximum temperature reached its highest value in July (44°C) which is the sunniest month. The climate of Marrakech in 2018 begins to get hot from March, with temperatures above 30°C. Indeed, the average temperature of this month increases abruptly by 3.5°C compared to February. It is important to note the large amplitude of temperature oscillations, which is a characteristic of the continental climate of Marrakech. The monthly amplitude of these oscillations reaches 14.4°C (in July). The minimum of this amplitude is 12.8°C and occurs in January, February and September. Table 1 show that global solar radiation is significant. Its average daily value varies between 2.76kW.m-2 /day and 6.92 kW.m-2 /day.

MEASURED TEMPERATURE - WINTER



While the outdoor temperature was between 7 and 23 ° C, the indoor temperature of the house (doors, windows and closed shutters) was very stable at 18 ± 0.5 ° C. The opening of the shutters during the day can earn 1 to 2 ° C more.

MEASURED TEMPERATURE - SUMMER



The house being completely closed (shutters included), while the outside temperature was between 23 and 41 ° C, the indoor temperature was very stable at 28.3 ± 0.3 ° C on the ground floor and 29.6 ± 0.3 ° C on the floor.