PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

UNIVERSITY BLIDA 01

INSTITUT OF ARCHITECTURE AND URBAN PLANNING
Architecture department

Thesis of the master's degree in architecture

Option: Architecture, Environment and Technology

P.F.E: Scientific city , Renewable energy research centre

Nature lessons: biomimicry architecture, a solution to enhance thermal comfort in hot arid climates

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Academic year: 2023/2024

Gratitude

الحمد لله الذي بنعمته تتم الصالحات

بسم الله والصلاة والسلام على محمد صلى الله عليه وسلم

In the name of Allah, the Most Gracious, the Most Merciful,

At the end of this work, we would like to thank "Allah Almighty" who gave us the strength to successfully complete this scientific study. Furthermore, this thesis represents only a summary of a long university course (Bachelor/Master) blessed by His Majesty. On the other hand, it reflects the great support and assistance of several people in this work

Dear parents, may God bless them, who have always supported us materially and spiritually, and constantly provided us with prayers and strength to successfully complete this project. Without them, this work would not have been possible.

We would like to express our deep gratitude and special appreciation to thank our supervisors. A big thank you to Dr.KAOULA Dalel, Dr. BENCHEKROUNE Marwa, and Dr. BABASLIMANE Nour El-Houda for their great availability, moral and physical support, wise advice, and immense kindness throughout this work, enabling us to develop this theme and join the ranks of architects.

A big thanks is also extended to the jury members who agreed to examine this work.

More generally, we extend our gratitude to all the teaching staff of the Institute of Architecture and Urbanism at the University of Blida 1, who contributed to our education.

Finally, we thank everyone who contributed, directly or indirectly, to the completion of our final project.

DJELID Chaima , ELKHIR Amira Ouidad

Dedication

With appreciation, respect and love I dedicate this work:

-To the one who gave me life, the symbol of tenderness, who sacrificed herself for my happiness and my success "**my dear mother**". I would like to dedicate this thesis to you, the source of my strength and my inspiration. Throughout my life and studies, you have been my idol, supporting me with all your heart. The sacrifices you made to help me complete my adventure will never be forgotten. May these few words reflect the love and gratitude I have for you, my beloved mother. I love you from the bottom of my heart and I will always be grateful for everything you have done and continue to do for me.

- The person who has waited for this moment , the bravest and most magnificent in my eyes: "**my dear father**", whom God protects and thanks for all your sacrifices for your daughter's well-being, as well as all your work and efforts to instil trust in me.

- To my older sister, the bravest person I know and the source of my happiness **Khawla**

-To the best sister ever, the most inspiring, my little **Malak.**

- My dearest and only brother, **Yacine**, for always being by my side.

-To **my family** many thanks. your encouragement, prayers, advice, orientation, and education have been extremely valuable throughout my studies and for the past 17 years.May God provide you with protection, blessing, and long life.

-To my friends. **Sana**, **Baya**, **Rima**, **Asma**, **Soumia**, **Yacmine**, Without forgetting the "girls" **Lilya , Amel, Radhia, Wissal , Inasse, Amina, Ikram , Abir**...

-I'd want to express my heartfelt gratitude to my sister ,my lovely binôme **ELKHIR Amira ouided.**

Finally, to all the people who believed in me and supported me throughout this academic journey this graduation project represents the culmination of support and encouragement throughout throughout my educational life.

CHAIMA

I am extremely grateful to you

Dedication

الحمدلله اللذي بنعمتة تتم الصالحات

This thesis is dedicated with gratitude to the many individuals who have supported, guided, and inspired me throughout my academic journey.

-To my beloved **parents**, whose unwavering support, boundless love, and prayers have been the cornerstone of my success. Their sacrifices, encouragement, and unwavering belief in me have given me the strength to persevere through every challenge. They are my greatest source of inspiration and my most steadfast supporters. I owe every achievement to the values and resilience they instilled in me. Thank you for your endless patience, wisdom, and unwavering faith in me.

-To my brothers and sisters: **Maliko**, my right hand; **Ikram**, the most patient and sweet sister anyone could ever have; **Rouida**, my partner in both good and challenging times. And to my lovely **twins**, I hope to see them all reach the highest ranks.

-To the one whose endless kindness and generosity have been a blessing, my second mom, **Aunt Yezza**.

-To all my family members, with special thanks to my uncle, **Abd El Karim**, who has been an external mentor and invaluable support. With deepest gratitude, I dedicate this thesis to you.

-To all **my teachers** throughout my academic career—this is the fruit of your dedication and hard work.

-To **my friends**, who have always stood by my side "**J.S ladies", "Bnat la cité"** and "**girls"**.

-To my **workshop colleagues**, who made learning a fun and enriching experience. A special mention to my partner, **CHAIMA**; her patience, ambition, support, and motivation have been my guiding light through every challenge.

-To all the creative souls of my blue family "**Ibdaa club**"

To all the **Palestinian souls** and individuals who couldn't complete their studies and experience these moments.

To all the dreamers, lovers of challenges and seekers of success, this thesis and PFE are dedicated to you.

Last but not least ;

AMIRA OUIDAD

I.1.1.1.1 Abstract:

Algeria has abundant natural resources, including coastlines, deserts, mountains, and plains. The Saoura region in southwest Algeria, where the province of Béchar is located, it is particularly noted for its vital oases that require protection. In response, our initiative has focused on establishing a scientific city, emphasizing the role of renewable resources in sustainable development. These efforts aim to meet Béchar's essential scientific needs, crucial for the country's progress.

The design of the scientific city integrates architectural principles such as bioclimatic studies to efficiently utilize local resources, reduce environmental impact, and lower energy consumption.

A priority has been given to creating public-friendly spaces and promoting community participation, ensuring inclusivity and educational opportunities.

Our architectural design has been guided by biomimetic principles, deriving sustainable solutions from natural processes, where a tools like the Givoni chart have facilitated thermal comfort studies and air cooling , enabling us to ensure thermal comfort and environmental sustainability through simulation software. This approach creates a welcoming environment that encourages public interaction and learning.

Keywords: Biomimicry architecture; scientific city; bioclimatic architecture; Public-friendly; thermal comfort; energy efficiency; aride climate.

Résumé :

L'Algérie dispose de ressources naturelles abondantes, notamment des côtes, des déserts, des montagnes et des plaines. La région de Saoura, située dans le sud-ouest de l'Algérie, où se trouve la wilaya de Béchar, est particulièrement célèbre pour ses oasis vitales nécessitant une protection. En réponse à cela, notre initiative se concentre sur la création d'une cité scientifique, mettant l'accent sur le rôle des énergies renouvelables dans le développement durable. Ces efforts visent à répondre aux besoins scientifiques essentiels de Béchar et à promouvoir le progrès du pays.

Le design de la cité scientifique intègre des principes architecturaux tels que les études bioclimatiques pour une utilisation efficace des ressources locales, la réduction de l'empreinte environnementale et la diminution de la consommation énergétique. Une priorité est accordée à la convivialité et à la participation communautaire, assurant ainsi l'inclusivité et des opportunités éducatives, où les principes de biomimétisme ont guidé notre conception architecturale, tirant des solutions durables des processus naturels. Des outils comme le diagramme de Givoni ont facilité l'étude et l'amélioration du confort thermique, permettant l'adoption de stratégies de refroidissement. Par l'utilisation d'un logiciel de simulation, nous avons garanti le confort thermique et la durabilité environnementale, créant ainsi un environnement accueillant qui encourage l'interaction publique et l'apprentissage.

Mots clés : architecture biomimétisme ; cité scientifique ; architecture bioclimatique ; confort thermique ; convivial pour le publique ; climat aride.

ملخص

تمتع الجزائر بموارد طبيعية وفيرة، بما في ذلك السواحل والصحارى والجبال والسهول. يُذكر بشكل خاص منطقة الساورة في جنوب غرب الجزائر، حيث تقع ولاية بشار، والمعروفة بواحاتها الحيوية التي تحتاج إلى حماية. إستجابة لذلك، ركزت مبادرتنا على إنشاء مدينة علمية، مع التركيز على دور الطاقة المتجددة الحيوي في التنمية المستدامة.

تهدف هذه الجهود إلى تلبية احتياجات بشار العلمية، الأساسية لتقدم البلاد

يدمج تصميم المدينة العلمية مبادئ معمارية مثل الدراسات البيومناخية لاستغلال الموارد المحلية بكفاءة، وتقليل التأثير البيئي، وخفض استهلاك الطاقة. تم إيلاء أولوية لمفهوم الود العام والمشاركة المجتمعية، مما يضمن الشمولية والفرص التعليمية حيث قادت مبادئ التقليد الحيوي التصميم المعماري الخاص بنا، مستمدة بذلك حلولاً مستدامة من العمليات الطبيعية اين ساعدت الأدوات مثل جدول جيفوني في تسهيل و دراسة الراحة الحرارية، مما أتاح اعتماد استراتيجيات للتبريد. ومن خلال استخدام برنامج للمحاكاة تمكننا من ضمان الراحة الحرارية والاستدامة البيئية كله من اجل إنشاء بيئة ترحيبية تشجع على التفاعل العام والتعلم.

الكلمات الرئيسية: بنية المحاكاة الحيوية ; المدينة العلمية ;الود العام; العمارة المناخية الحيوية ; الراحة الحرارية .;

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I CHAPTER ONE: INTRODUCTORY CHAPTER

I.1 INTRODUCTION GENERALE

Dans un monde de plus en plus conscient de l'impact environnemental de ses activités, l'architecture occupe une position centrale dans la quête d'un développement durable. L'option architecture, environnement et technologie vise à répondre aux défis contemporains en intégrant des pratiques respectueuses de l'environnement tout en assurant un niveau de confort élevé répondant aux nouveaux standards. Le secteur de la construction est responsable d'une part significative des émissions de gaz à effet de serre, de la consommation d'énergie et de l'exploitation des ressources naturelles. Il est donc impératif d'adopter des approches innovantes et durables dans la conception et la construction des bâtiments.

L'atelier E-Cow Built est une initiative pédagogique intégrée dans le cadre du Master 2 visant à fournir aux étudiants des compétences pratiques et théoriques dans le domaine de l'architecture durable, de la construction écologique et des technologies de pointe. Cet atelier est conçu pour combiner les aspects théoriques avec des expériences pratiques, tout en mettant un accent particulier sur l'innovation et la durabilité.

Cet atelier se concentre sur deux aspects ayant pour objectif l'optimisation de l'efficacité énergétique, et ne se limitant pas seulement à la construction de nouveaux bâtiments. La réhabilitation énergétique des bâtiments existants est tout aussi cruciale, car elle implique la rénovation des structures pour améliorer leur performance thermique et énergétique. Cela peut comprendre l'isolation des murs, des toits et des planchers, le remplacement des fenêtres par des modèles à haute performance énergétique, et l'installation de systèmes de chauffage, de ventilation et de climatisation plus efficaces. C'est pour cette raison que certaines thématiques traitent de la modernisation des bâtiments anciens, permettant non seulement de prolonger leur durée de vie, mais aussi d'améliorer le confort des occupants et de réduire les coûts énergétiques.

Les thématiques traitées par les différents étudiants se focalisent sur le confort des occupants, qui est un aspect indissociable de cette démarche, d'autres se concentrent sur les certifications LEED (Leadership in Energy and Environmental Design) ou BREEAM (Building Research Establishment Environmental Assessment Method), mettant l'accent sur la qualité de vie à l'intérieur des bâtiments. Cela inclut le contrôle de la température, de la qualité de l'air, de l'acoustique et de l'éclairage naturel. Des technologies avancées permettent de réguler ces paramètres de manière intelligente, créant ainsi des environnements de vie et de travail agréables tout en réduisant la consommation énergétique.

Les différents objectifs de cet atelier visent l’intégration dès la conception les principes de durabilité et de haute performance énergétique, et ainsi choisir dès le départ des matériaux à faible impact environnemental, concevoir des structures optimisées pour l'efficacité énergétique et intégrer des systèmes de gestion de l'énergie. Sensibiliser les étudiants sur les stratégies passives tels que l'orientation des bâtiments, leur forme et l'utilisation de technologies comme les panneaux solaires ou les pompes à chaleur jouant un rôle crucial dans la réduction de l'empreinte écologique. De plus, la construction modulaire et les techniques de préfabrication peuvent réduire les déchets de construction et améliorer l'efficacité du processus.

L’atelier se concentre également sur l’utilisation des outils numériques, tels que la modélisation des informations du bâtiment (BIM) et la simulation des performances énergétiques des bâtiments, afin d’optimiser leur conception pour maximiser l’efficacité énergétique et évaluer l’impact environnemental à travers ces différents outils.

Cette démarche permet d'anticiper et de réduire les impacts environnementaux dès les phases de conception et de construction, car ces technologies offrent une vision globale du projet et facilitent la prise de décisions éclairées en matière de durabilité.

L'option architecture, environnement et technologie ne se limite pas à l'adoption de nouvelles techniques de construction ou à la réhabilitation énergétique. Elle inclut également une réflexion plus large sur l'urbanisme et la planification territoriale. Les éco-quartiers et les villes intelligentes émergent comme des réponses intégrées aux défis du développement durable, s’évertuant à optimiser l'utilisation des ressources, à réduire les déplacements en voiture grâce à une mixité fonctionnelle et à favoriser les modes de transport doux.

En conclusion, l'intégration de l'architecture, de l'environnement et de la technologie représente une réponse nécessaire et ambitieuse aux défis du changement climatique et de la transition énergétique. Elle exige une approche holistique, combinant la construction neuve et la réhabilitation des bâtiments existants, pour créer des environnements bâtis qui sont à la fois durables, confortables et résilients.

Dr.BENCHEKROUN Marwa

I.2 GENERAL THEMATIC

The planet we inhabit, with its exquisite details that attribute to divine creation, is currently grappling with a substantial climate transformation. This change is a direct result of human intervention in the planet's intricate ecosystems, a scenario that once seemed unfathomable humans altering the fundamental physical and chemical characteristics of this vast world. The manifestation of this transformation is strikingly evident in the disintegration of colossal glacier masses, as they fracture and dissolve into the world's oceans, serving as a conspicuous symptom of Earth's escalating temperatures.

As per the Intergovernmental Panel on Climate Change IPCC[1], the average temperature over land for the 2006–2015 period showed a 1.53°C increase compared to the 1850–1900 timeframe, surpassing the global mean temperature change by 0.66°C. These elevated temperatures, accompanied by shifting precipitation patterns, have impacted the commencement and conclusion of growing seasons, leading to regional crop yield reductions, diminished freshwater resources, heightened stress on biodiversity, and increased strain on trees. Meanwhile, rising atmospheric CO2 levels have contributed to enhanced plant growth and expanded woody plant cover in grasslands and savannahs.

So as we can see, human activities have been a major contributor to the global warming crisis, with estimates suggesting an increase of approximately 1.0°C above pre-industrial levels, potentially ranging from 0.8°C to 1.2°C. This concerning trajectory indicates that global warming may reach 1.5°C between 2030 and 2052 if we continue along the current path[2].

To address these pressing climate challenges and promote sustainability, Elkington's[3] exploration of the 'triple bottom line' concept from his 1997 work becomes highly relevant. Elkington's concept encompasses economic prosperity, environmental quality, and social justice as integral components. He underlines the vital importance of social sustainability, recognizing that human actions and economic activities significantly impact the environment. Elkington's critique of traditional economics for failing to assign value to natural resources, such as air and water, which are often regarded as free, underscores the

[1] IPCC: Intergovernmental panel on climate change. The main activity of the IPCC is the preparation of reports assessing the state of knowledge of climate change...

[2] Present level of global warming is defined as the average of a 30-year period centred on 2017 asming the recent rate of warming continue -

[3] John Elkington is a world authority on corporate responsibility and sustainable capitalism, a bestselling author and serial entrepreneur.

critical need for a paradigm shift. In this context, there is a call for a profound transformation in our current values, political values, and daily behavior. This transformation ranges from shifting focus from economic efficiency to social equity, individual rights to collective obligations, selfishness to community, quantity to quality, and more. These changes in values and behavior are not only essential for addressing global warming but also for achieving genuine sustainability that benefits us all, as they align with the goal of mitigating the impacts of human activities on climate change while fostering a more equitable and sustainable world. (Sturges,2019)

This vision needs to line with architecture, contemporary buildings have been primarily driven by the pursuit of energy efficiency. However, this singular focus often unintentionally exacerbates a different challenge such as overheating during scorching summer months. This dilemma necessitates innovative and sustainable solutions, where scientist and architects collaborate to find a solution and create more sustainable buildings, until they reached to biomimicry, a concept rooted in drawing inspiration from nature's ingenious designs and intricate systems. Our exploration focuses on the practical application of biomimicry within the field of architecture, with the specific goal of reducing energy consumption and enhancing the thermal comfort of buildings.

Biomimicry, a term introduced by Otto Herbert Schmitt and developed by Benyus, revolves around observing nature and drawing inspiration from it to solve human problems. It embodies an extensive reflection of nature. Interest in biomimetic architecture has been steadily growing since the 1970s (Aykal and all, 2022) driven by factors such as the energy crisis, environmental awareness, and successful biomimetic projects.

Iconic biomimetic projects, especially in Europe, have been founded, such as the West German Pavilion, self-cleaning surfaces, and self-ventilation systems. These projects initially generated high expectations but also faced challenges, particularly in obtaining and understanding biological data, leading to a phase of disillusionment.

Over the following decades, the field of biomimetics saw the development of numerous methods and tools, including international standards like ISO 2015:18458[4]. Tools like

[4] ISO 2015:18458: international Standard confirmed, provides a framework for the terminology on biomimetics in scientific, industrial, and educational purposes.

Genius of Biome[5], BioGen[6], and ESA[7] were created to assist architects and designers in applying biomimicry.

Furthermore, the establishment of incubators, research centers, and funding programs dedicated to biomimetics played a crucial role in overcoming disillusionment phases and advancing to the current stage of enlightenment. This approach not only aligns with the vision of societal transformation outlined earlier but also offers a promising solution to architectural challenges in the pursuit of sustainability and enhanced living environments.

The choice of a biological theme in this study is motivated by the striking parallels between well-crafted human creations and the astonishing efficiency of biological organisms. By exploring this connection, we not only aim to address the immediate issue of overheating in modern buildings but also trace the historical link between architecture and biology, underscoring the age-old inspiration drawn from the natural world in the pursuit of sustainable and harmonious built environments.

Biomimicry finds relevance in desert countries and arid regions, such as the Middle East, where the demand for energy-efficient, thermally comfortable, and environmentally responsible and sustainable buildings is pressing. It extends beyond immediate challenges to encompass the creation of harmonious built environments, making it a promising and widely applicable approach in desertic zones and beyond.

I.3 GENERAL PROBLEMATIC

Algeria, hosting a population of over 45 million people, ranks as the eleventh largest nation globally. This vast country, grappling with severe desertification, faces heightened susceptibility to the diverse repercussions of climate change, which pose a significant threat to its economic and social progress. currently deeply involved in advancing the renewable energy sector through substantial and well-funded projects. These initiatives are essential for sustaining economic growth in the western regions of Algeria.

Algeria maintains a significant presence in the global energy landscape. Its confirmed oil reserves stand at a substantial 12.2 billion barrels, securing its position as a notable player in the petroleum industry. With an impressive 4.56 trillion cubic feet of proven natural gas reserves, Algeria ranks among the top 10 nations worldwide, further highlighting its energy

[5] Genius of Biome: describes the strategies and designs adopted by living organisms found in the temperate broadleaf forest biome

[6] BioGen: is an American multinational biotechnology company based in Cambridge

[7] ESA: the European Space Agency

potential. The nation faces a rapidly rising demand for electricity, with an annual growth rate ranging from 5%.

Sonelgaz[8] anticipates a substantial need for increased capacity in the years to come, given the current installed power generation capacity of around 6,000 MW, which has proven inadequate during peak cooling periods in the scorching summer months. The government launched the hydrocarbon law in July 2011 to increase competitiveness by easing taxes and encouraging import and export to attract foreign investment.

Moreover, Algeria has many oil refineries and gas treatment center projects that have been kicked off under the supervision of the national oil company Sonatrach[9]. Currently, the Algerian government is seeking to minimize the energy reliance on hydrocarbons, which represent 99.4% of the country's power generation sources under the petroleum crisis.

Algeria indeed possesses abundant solar and wind resources due to its favorable geographic location and climate conditions. The country is characterized by vast desert regions and long coastlines, both of which offer significant potential for harnessing renewable energy sources such as solar and wind power, the potential for power generation is enormous compared to regional and global energy demands—roughly 10% of the Algerian Sahara Desert could meet the EU demand

However, despite this wealth of renewable energy resources, Algeria has historically relied heavily on fossil fuels, particularly natural gas and oil, for electricity generation. This heavy dependence on fossil fuels has been a primary source of energy in the country for many years, partly due to the availability of these resources domestically. In recent years, there has been a growing recognition of the need to transition towards a more sustainable and diversified energy mix, with a greater focus on renewable energy sources.

Algeria has initiated various projects and policies to promote the development of renewable energy, including solar and wind power, to reduce its reliance on fossil fuels and mitigate the environmental impact of its energy sector. Efforts are being made to increase the share of renewable energy in the electricity generation mix, aiming to enhance energy security, reduce greenhouse gas emissions, and support long-term sustainability. These initiatives are essential for addressing both the environmental challenges and the economic opportunities

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[8] National Company for Electricity and Gas) is a state-owned utility in charge of electricity and natural gas distribution in Algeria. It was established in 1969

[9] Sonatrach is the national state-owned oil company of Algeria. Founded in 1963, it is known today to be the largest company in Africa with 154 subsidiaries, and often referred as the first African oil "major.

associated with renewable energy in Algeria. Energy efficiency has always been at the core of how Algeria conceives and utilizes energy resources. It is the linchpin in securing a sustainable energy supply, reducing costs, and preserving the environment. Nevertheless, the inefficiency of energy systems in Algeria can have a profound impact on its valuable resources, the quality of life, and the ecological footprint.

Algeria, as a nation prone to harsh weather conditions, should prioritize solutions that maintain optimal thermal comfort within buildings while minimizing energy consumption. Buildings are major energy consumers, and since people spend the majority of their time indoors, it's imperative to integrate energy efficiency into architectural design, creating comfortable and welcoming spaces.

Given the climatic conditions of the country, diversity and the richness in fauna and flora well adapted to the environmental and to solve these problems of energy consumption and take account of environmental problems resulting , they innovative approach that draws inspiration from nature to address various challenges which is Biomimicry in Building Design, also known as biomimetic architecture, effectively, interdisciplinary collaboration between architects, biologists, engineers, and local communities is crucial. Research into the specific fauna and flora adapted to the country's conditions should guide the design process. Government policies and incentives can also play a role in promoting and supporting these innovative approaches to building design, ultimately contributing to energy efficiency and environmental sustainability.

The government is planning to start a new renewable energy development plan, according to Algeria's Energy Minister Youcef Yousfi who said, ''It's a huge program and a huge challenge. The government will work alongside and assist operators in its implementation'' primarily relying on air conditioning for thermal comfort, while outdoor spaces remain underutilized due to inhospitable weather conditions and a lack of refreshing urban infrastructure and comfortable gathering areas. Therefore, it's essential to ask a fundamental question:

How can Algeria apply the principles and strategies of sustainability to develop buildings that enhance energy efficiency, considering the unique climatic challenges and social needs of its various regions using biomimicry architecture?

I.4 SPECIFIC PROBLEMATIC

One of the most significant design challenges in architecture is the creation of environmentally friendly buildings in hot and arid regions. Therefore, we have selected

Bechar, situated in the southern part of Algeria, as case of study. The chosen area (Altitude: 772 m, Latitude: 31°.37, Longitude: -2°.14) is known for its extended periods of extreme heat, resulting in significant discomfort. An analysis of the monthly temperature and relative humidity distribution in Bechar reveals that a considerable portion of the year falls outside the comfort zone.

In this region, there is a strong recommendation for incorporating sustainable design principles, particularly focusing on minimizing a building's energy usage and optimizing energy efficiency. Although Bechar benefits from ample sunlight, efficiently harnessing solar energy and integrating it into innovative building designs may pose technical and logistical difficulties. The distinct climate and environmental factors in Bechar must be taken into account when developing buildings that draw inspiration from nature and effectively harness solar energy as emulating natural structures like bones and shells for efficient load-bearing designs and designing buildings that mimic natural processes, such as passive solar heating or cooling or developing new construction materials inspired by nature's materials, like spider silk inspired by the structure and stability of sand dunes, incorporating their natural curves and wind-sculpted forms for both aesthetics and energy efficiency.

Interdisciplinary collaboration is indeed a crucial aspect of biomimicry architecture. Architects, biologists, engineers, and local communities need to work together to ensure the successful implementation of biomimetic designs Facilitating effective interdisciplinary collaboration can be a complex process, requiring effective communication and coordination among different disciplines.

Bechar grapples with the challenges of an arid desert climate marked by scorching temperatures, minimal humidity the summers are sweltering, arid, and clear and the winters are cold, dry, and mostly clear, and recurrent dust and sandstorms. These environmental conditions pose hurdles for achieving thermal comfort, water conservation, efficient energy use, and structural protection in building design. To address these issues, the region can draw inspiration from natural adaptations of desert organisms for temperature regulation, optimize building materials and ventilation systems, manage water resources innovatively, improve solar energy capture and storage, and protect structures from sandstorms. Additionally, making these designs economically viable, establishing efficient supply chains, and enacting supportive policies are essential steps. Community engagement is pivotal for gaining local acceptance and ensuring designs align with community values.

These challenges highlight the complexities and considerations involved in implementing biomimicry architecture in Bechar. They serve as areas of focus for further research and development in this field, aiming to overcome technical, logistical, regulatory, community, and financial barriers by addressing these challenges, biomimicry architecture can contribute to sustainable and innovative building designs in Bechar and beyond.

What strategies and measures can Bechar implement to integrate biomimicry principles effectively into its architectural projects, promoting the construction of environmentally-friendly and thermally comfortable buildings?

I.5 HYPOTHESIS OF THE RESEARCH

Based on our review of multiple sources, we propose the following hypothesis:

- Integrating passive strategies of biomimicry architecture at the project level can enhance the level of thermal comfort of a building under aride climate.
- The integration of passive and low-energy active strategies, inspired by biomimetic architecture, may be necessary to ensure an optimal comfort of a building at the project level.
- local materials help to improve thermal comfort in a building, despite its harsh climate.

I.6 RESEARCH OBJECTIVES

The aim of this research is to establish a connection between two emerging fields: Biomimicry and architectural design. It seeks to investigate their potential for enhancing the sustainability of a region's architectural methods, particularly in hot and arid areas. To achieve this objective, we are striving to:

- Promotion of biomimetic architectural design to discover sustainable, natural solutions for all aspects of a building (form, function, structure), with a focus on reducing energy consumption.
- Evaluate the current energy consumption patterns and environmental challenges in Bechar
- Prioritizing nature-inspired design to create cost-effective solutions.
- Highlighting the necessity to minimize the ecological footprint of buildings on the environment.
- Encouraging the utilization of local resources, materials, and renewable energy sources to promote building sustainability in Bechar.

I.7 METHODOLOGY OF THE RESEARCH

Our methodology reflects the approach taken to address our research problem and achieve our objectives. It consists of two parts:

I.7.1 Theoretical Part:

In this part, we have expanded our knowledge by defining key concepts and understanding different measures of energy efficiency a building. This is based on a literature review and analysis of examples.

- An urban and historical analysis: Firstly, we will establish a status report for our case study, Bechar, and emphasize key moments in the city's urban evolution.
- A theoretical framework: After that, we will delve into the topic and become acquainted with key concepts (biomimicry architecture, energy efficiency, renewable energy, etc.).
- A examples analysis: This theoretical part will conclude with a presentation of global examples comparable to the Algerian case.

I.7.2 Operational Part :

This part involves first conducting a diagnostic assessment of Bechar and the project area using environmental methods. Then, a thematic research related to the project is carried out to ultimately lead to its design programmes

- Surveys and Questionnaires: Design and administer surveys or questionnaires to gather quantitative data. This can be useful for collecting information from a broad audience about their preferences, opinions, or behaviours related to architectural design.
- Site Visits and Observations: Visit the architectural site or locations relevant to our thesis and make detailed observations. Document architectural features, environmental conditions, spatial use, and user interactions.
- Photography and Visualization: Using photography and visualization techniques to document architectural details, spatial qualities, and visual representations of our thesis project or research.
- Interviews: Conduct structured or semi-structured interviews with experts, stakeholders, or potential users to gain in-depth insights and qualitative data about your architectural project. These interviews can provide valuable contextual information.

- Data Analysis Software: Utilize specialized architectural software for tasks such as Building Information Modeling (BIM) analysis, design builder, climate-consult, GIS[10] or other architectural simulations to generate data and insights.

[10] GIS : Geographic Information Systems

I.8 WORKING PLAN OF THESIS

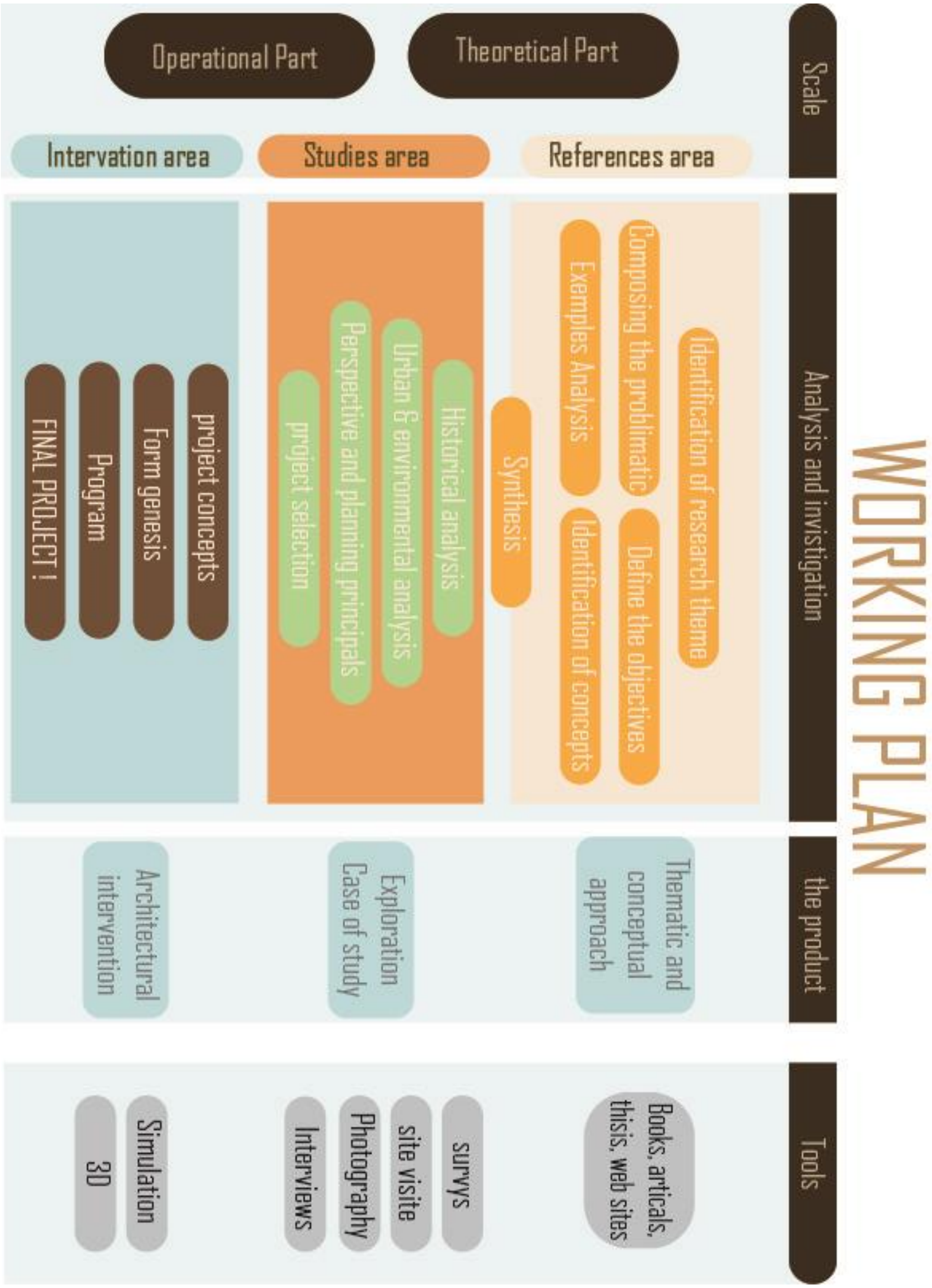


FIGURE 1 : WORKING PLAN OF THESIS , (SOURCE AUTHORS)

II CHAPTER TWO: STATE OF THE ART

II.1 INTRODUCTION

Thematic studies hold a pivotal position in architectural design, serving because the cornerstone for knowledgeable and impactful creations. In this chapter, we embark on a rigorous adventure aimed toward delineating the problematic conceptual framework that underpins our theoretical exploration. Our venture is twofold: to meticulously dissect the essential principles that lay the foundation for our medical studies theme, and to shed mild at the profound dating among biomimicry and sustainability. As we navigate the problematic terrain of those principles, our goal extends past mere comprehension in their character significance. We aspire to unearth the synergies and interdependencies that intricately weave biomimicry and sustainability together. Recognizing their capacity to now no longer simplest supplement however additionally increases every other`s impact, we enterprise to resolve the symbiotic dance among those pillars of innovation. Through this exploration, our goal is to chart a path closer to pioneering medical practices that draw idea from the innate expertise of nature. By embracing biomimicry and sustainability as guiding principles, we are seeking to domesticate a harmonious coexistence with our environment, making sure a legacy of stewardship for generations to come.

II.2 SUSTAINABILITY ARCHITECTURE

II.2.1 Introduction

A comprehensive approach to planning and erecting structures that reduce their negative effects on the environment while improving the quality of life for residents and communities is known as sustainable architecture. It includes a range of ideas, tactics, and technological advancements intended to lower energy use, preserve natural resources, and advance social justice. The fundamental tenets of sustainable architecture are social responsibility, economic viability, and environmental care. By combining techniques that lower energy use, lessen carbon emissions, and preserve natural resources, it aims to reduce the environmental impact of infrastructure and buildings. This frequently entails cutting-edge methods to lessen dependency on fossil fuels and greenhouse gas emissions, such as energy-efficient HVAC systems, high-performance insulation, and passive solar design. Furthermore, social justice and cultural context are fundamental components of sustainable architecture. It places a strong emphasis on involving the community, obtaining materials locally, and designing inclusive areas that enhance everyone's health and well-being. Sustainable design is essentially a paradigm change toward more resilient, equitable, and regenerative built environments. It pushes established approaches to design and construction to be reconsidered and creative solutions that strike a balance between environmental imperatives and human needs to be adopted by legislators, developers, planners, and architects. Sustainable architecture provides a novel vision for our cities and communities by encouraging teamwork, innovation, and a strong feeling of responsibility

II.2.2 Sustainability

The terms sustainability has been used since the 1990s to refer to a configuration of human society that enables it to ensure its sustainability. Such a human organization is based on the maintenance of a viable environment, enabling economic and social development on a global scale, and, from the point of view, on a fair social organization

The World Commission on Environment and Development defines sustainability as ensuring present development meets needs without jeopardizing future generations' ability to meet theirs.

Translating this intricate concept to architecture involves crafting designs that foster healthy living environments while minimizing adverse environmental impacts, energy consumption, and human resource use.

Sustainable architecture encompasses a building's materials, construction methods, resource utilization, and overall design. It must enable sustainable operation throughout its life cycle, including eventual disposal, while also prioritizing functionality and aesthetic appeal. The design ethos should aim for long-term energy and resource efficiency

Also known as green or environmental architecture, sustainable architecture challenges architects to create intelligent designs and employ available technologies to minimize structures' harmful effects on ecosystems and communities.

Understanding this concept might be challenging for those outside the construction realm, so let's simplify it: Imagine you want to build your house on a plot of land conveniently located for you, but it's home to 100 trees, the last of their kind. Without sustainability in mind, you might clear the space by cutting down all the trees, using their lumber for your house, regardless of the impact on future generations.

II.2.3 Is sustainability important?

Buildings and construction contribute to over 35% of global final energy use and nearly 40% of energy-related CO_2 emissions, as highlighted by the UN Environment Global Status

Report 2017[11]. As cities expand relentlessly, the finite nature of Earth's resources becomes increasingly apparent. Developing new habitats constantly demands substantial natural resources, putting a strain on our environment. While there's been progress in raising awareness about sustainability since 2010, there's still a considerable journey ahead.

Nowadays, designing a building's form and function must go hand in hand with considerations of building services, materials, and environmental impact. Achieving sustainable development requires a delicate balance between a building's design, functionality, and its interaction with the surrounding environment.

Embracing sustainable architecture offers not only environmental benefits but also economic and social advantages, whether in new constructions or retrofitting existing ones.

II.2.4 Definition of Sustainable Development

Sustainable development has become the buzzword in development discourse, having been associated with different definitions, meanings and interpretations. Taken literally, SD would simply mean: development that can be continued either indefinitely or for the given time period. (Stoddart, 2011). Structurally, the concept can be seen as a phrase consisting of two words, "sustainable" and "development." Just as each of the two words that combine to form the concept of SD, has been defined variously from various perspectives, it has also been looked at from various angles, leading to a plethora of definitions of the concept. Although definitions abound with respect to SD, the most often cited definition of the concept is the one proposed by the Brundtland Commission[12] Report. The Report defines SD as development that meets the needs of the current generation without compromising the ability of future generations to meets their own needs. (Schaefer &Crane, 2005)

The objective of sustainable development is to define viable patterns that reconcile the three aspects: economic, social, and environmental, of human activities.

II.2.5 The pillars of Sustainable Development:

Sustainable development is based on three major pillars (Marechal, 2001):

[11] The UN Environment Global Status Report 2017

[12] The Brundtland Commission: formerly the World Commission on Environment and Development, was a sub-organization of the United Nations that aimed to unite countries in pursuit of sustainable development

II.2.5.1 Social Dimension :

The factors of sustainable development (SD) include access to education, housing, and food in order to:

- Meet the essential needs of populations.
- Combat exclusion in all its forms (social, professional).
- Stabilize demographic growth.
- Manage urban growth and migration flows.

II.2.5.2 Economic Dimension :

Sustainable development depends, in particular, on:

- Economic development that respects natural environments, the source of basic resources.
- A profound change in international economic relations to promote fair trade.
- The cancellation of debt for poor countries and an increase in investments, enabling them to avoid opting for short-term profits that contradict sustainable development for both the country and the planet.

II.2.5.3 Environmental Dimension :

Achieving the goal of sustainable development involves respecting the following key conditions:

- The sustainable use and management of natural resources and human knowledge.
- Maintaining a certain number of major natural balances:
- The economy of non-renewable resources (oil, gas, coal, minerals...).

II.3 DIFFUSION OF BIOMIMICRY IN THE BUILT WORLD, TOWARDS MORE SUSTAINABILITY.

II.3.1 Introduction

Biomimicry is the science that involves studying, imitating, or drawing inspiration from nature. It provides models and methods for solving human problems. This approach is not new, but it is only recently that researchers have started taking the subject of biomimicry seriously. Scientifically, the applications of biomimicry are broad and varied, spanning across technical and industrial domains. From agriculture to industry and through architecture, the innovation potential is promising.

II.3.2 Biomimicry unveiled

II.3.2.1 Terms, Definitions, and Related Fields

Biomimicry: is a word that means imitation of life.

It comes from the Greek roots bios (life) and mimikos (imitation).

Biomimicry, as defined by Benyus,[13] (Janine M, nd) is the science that studies nature's models and the imitation of their designs and processes to solve human problems. A good definition would be "'innovation inspired by nature"

II.3.2.2 Clarifying terms: Bionics, and Biomimetics

Biomes are very large ecological areas on the earth's surface, with fauna and flora (animals and plants) adapting to their environment. Biomes are often defined by Abiotic factors such as climate, relief, geology, soils, and vegetation. A biome is not an ecosystem, although in a way it looks like a massive ecosystem.

The term bionic (Bioink): is a combination of two terms:

- Biology, the science of life.
- Technology, the constructive relation of products, devise, and processes by using the materials and forces of nature, considering the laws of nature (j.biotechadv.2016).

So bioink is: The science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues (Nachtigall and al , 1997).

Biomimetics: Modelled on or resembling a natural biological material, process, etc.; (of a synthetic method) that mimics biochemical processes. (OED 1960).

Many people around the planet have been honored with it because biomimicry is an inspiring source of innovation possibilities and offers the potential to create a more sustainable and just world.

Renewable built environment. Biomimicry, the imitation of animals, fauna, or entire ecosystems as a basis for design, is a growing field of research in the fields of architecture and engineering.

[13] Benyus: is an American natural sciences writer, innovation consultant, and author. After writing books on wildlife and animal behavior, she coined the term Biomimicry to describe intentional problem-solving design inspired by nature.

II.3.3 Historical Background and Evolution of Biomimicry

The idea of biomimicry has undoubtedly existed for thousands of years, it is not possible to track exactly at which point humans started to look at nature for solutions. However, there are several well-known examples throughout history (Figure *).

One of the first examples of biomimicry is the study of bird flight by Abbas ibn Fernas (810-887) and then by Leonardo da Vinci (1452-1519). An example of architecture from the same period is the dome of the Florence Cathedral designed by Filippo Brunelleschi with reliance on the study of the forms of eggshells. (Routledge and al, 2019)

Copying natural figures on building façades was the first application of biomimicry in architecture from thousands of years. 2100 years ago, the roman architect Vitruvius opened a new dimension in biomimicry by comparing the propositions of temples with the dimensions of human body. He focused on inspiring propositions from nature. Eight centuries ago in China, rural populations of Hongcun village are considered the first bionic architects. They designed their village, giving it the form of a caw, while creating a hydrologic network water system in the form of its digestive system. Copying figures, forms, and propositions continued till the end of the 18th century as the only application of biomimicry in architecture. The industrial revolution added new dimension in this field which is copying construction systems found in plants and animals, this approach opens the way to a huge number of new construction designs. The Lily House in Strasbourg and the crystal palace in London designed by Joseph Paxton are examples of such inspired constructions. In the middle of the 20 century, Robert Le Ricolais, a French professor at the University of Pennsylvania, developed new structural models through copying biological structure models drawn by Germane biologist called Haeckel during the 19th century (Guillot and Meyer, 2008, p.15).

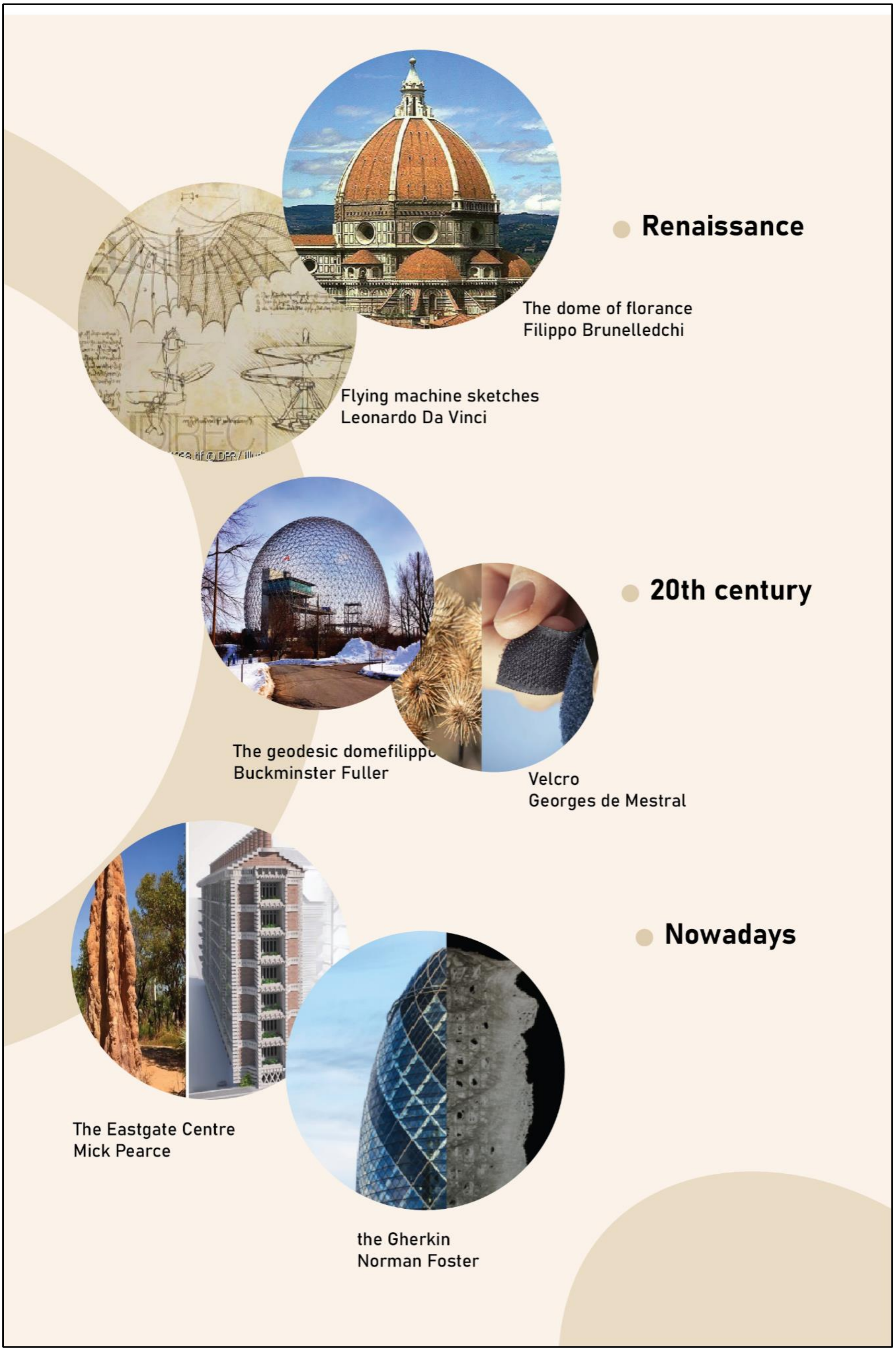


FIGURE 2: BIOMIMICRY HISTORIC TIMELINE. (SOURCE: AUTHOR)

II.3.4 Motivations for Biomimicry

Today, due to the technological advances, humans are able to explore and study the living world and all-natural phenomena in more detail. The study of biomimicry and the emergence of biomimicry as a field of research has improved human's abilities to understand and imitate nature.

Maibrit Pedersen Zali[14] said: "*Biological and ecological imitation is a growing field of research in both academic and design discourses."* In her opinion, there are three main motivations for studying biomimicry:

Biomimicry for innovation: Biomimicry can be seen as a source of innovation that accommodates new materials and technologies. Most biomimetic research is related to this reason and does not necessarily aim to improve the ecological performance of human technologies. Rather, new approaches to solving technical problems and improving performance are important. This type of research is particularly relevant to robotics, computing, and materials technologies that do not focus on sustainability issues.

Biomimicry for sustainability: There is growing interest in the potential of biomimicry to create more sustainable materials, products, built environments (Pawlyn 2011) , and technological solutions. Biomimicry improves the environmental performance of human technology and the built environment. Mimicking biology in design is itself a means to achieving greater sustainability. One of the key differences between biomimicry for sustainability and biomimicry for innovation is that the first one focuses on the underlying processes, strategies, and systems of ecosystems, not just living organisms. They tend to recognize the importance of imitation. Leading to more sustainable results. Biomimicry for sustainability does not just focus on creating new and novel technologies, but rather on changing the fundamentals underlying design.

Biomimicry for human well-being: A third motivation for studying biomimicry stems from considering whether designs based on an understanding of the biological world can contribute to improving human psychological well-being due to its inherent relationship to the concept of biophilia[15].(Zari 2012)

[14] Maibritt Pedersen Zari: is a Senior Lecturer in Sustainable Architecture and Interior Architecture at Victoria University's School of Architecture, New Zealand.
[15] Biophilia: originates from the Greek, 'philia' meaning 'love of'. It means a love of life and the connection with nature.

II.3.5 Objectives of Biomimetic Architecture

It's no longer just about giving shape and dimension to space, but also about arranging it. There exists a synergistic relationship between a building and its environment—something heuristic. The approach of biomimicry involves infusing architecture with a vitality that extends beyond mere essence, transcending the mechanical vision of life.

Biomimetic architecture could be the catalyst for a transformation in societal roles. Architects are transitioning from controlling nature to continuous participation within it.

II.3.6 Different Approaches to Biomimicry in Architecture

A comparative study of the current practice of biomimicry shows distinct approaches to architectural design. Each approach inherently has its own advantages and disadvantages. Approaches to biomimicry as a design process typically fall into two categories: Problem-Based Approach and Solution-Based Approach explained in the following paragraphs.

II.3.6.1 Problem-Based Approach

Throughout literature review, this approach was found to have different naming, such as ―Design looking to biology‖ (Pedersen Zari, M. 2007), Top-down Approach‖ (Jean Knippers 2009) and Problem-Driven Biologically Inspired Design (Michael Helms, Swaroop S. Vattam.)

The pattern of problem-driven biologically inspired design follows a progression of steps which, in practice, is non-linear and dynamic in the sense that output from later stages frequently influences previous stages, providing iterative feedback and refinement loops. (Goel et al, 2009) An example of such an approach is DaimlerChrysler’s prototype Bionic Car (fig.3).

FIGURE 3 : DAIMLERCHRYSLER'S PROTOTYPE BIONIC CAR (SOURCE : MOTOR1)

In order to create a large volume, small wheel base car, the design for the car was based on the boxfish (ostracion meleagris), a surprisingly aerodynamic fish given its box like shape. The chassis and structure of the car are also biomimetic, having been designed using a computer modelling method based upon how trees are able to grow in a way that minimises stress concentrations. The resulting structure looks almost skeletal, as material is allocated only to the places where it is most needed. (Vincent et al., 2006)

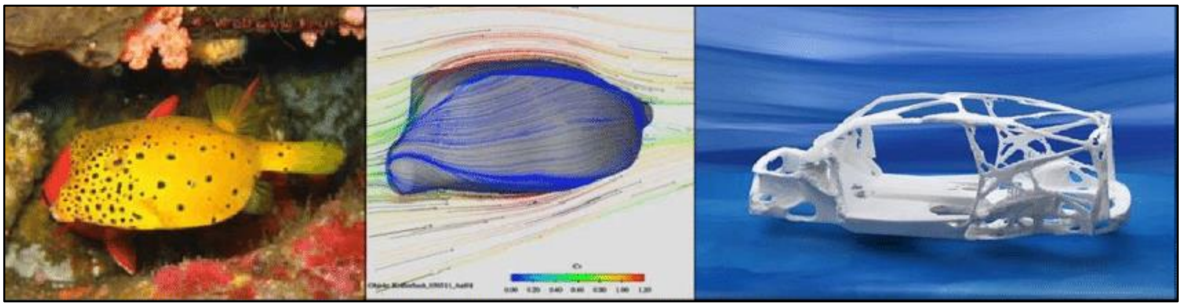


FIGURE 4 : DAIMLERCRYSLER BIONIC CAR INSPIRED BY THE BOX FISH AND TREE GROWTH PATTERNS. (STUDYLIB)

The possible implications of architectural design where biological analogues are matched with human identified design problems are that the fundamental approach to solving a problem and the issue of how buildings relate to each other and the ecosystems they are part of is not examined. The underlying causes of a non-sustainable or even degenerative built environment are not therefore necessarily addressed with such an approach.

The Bionic Car illustrates the point. It is more efficient in terms of fuel use because the body is more aerodynamic due to the mimicking of the box fish. It is also more materials efficient due to the mimicking of tree growth patterns to identify the minimum amount of material need in the structure of the car. The car itself is however not a new approach to transport. Instead, small improvements have been made to existing technology without a re-examination of the idea of the car itself as an answer to personal transport. (Pedersen Zari, M. 2007).

Designers are able to research potential biomimetic solutions without an in depth scientific understanding or even collaboration with a biologist or ecologist if they are able to observe organisms or ecosystems or are able to access available biological research. With a limited scientific understanding however, translation of such biological knowledge to a human design setting has the potential to remain at a shallow level. It is for example easy to mimic forms and certain mechanical aspects of organisms but difficult to mimic other aspects such as chemical processes without scientific collaboration. (Pedersen Zari, M. 2007)

Despite these disadvantages, such an approach might be a way to begin transitioning the built environment from an unsustainable to efficient to effective paradigm. (McDonough, 2002)

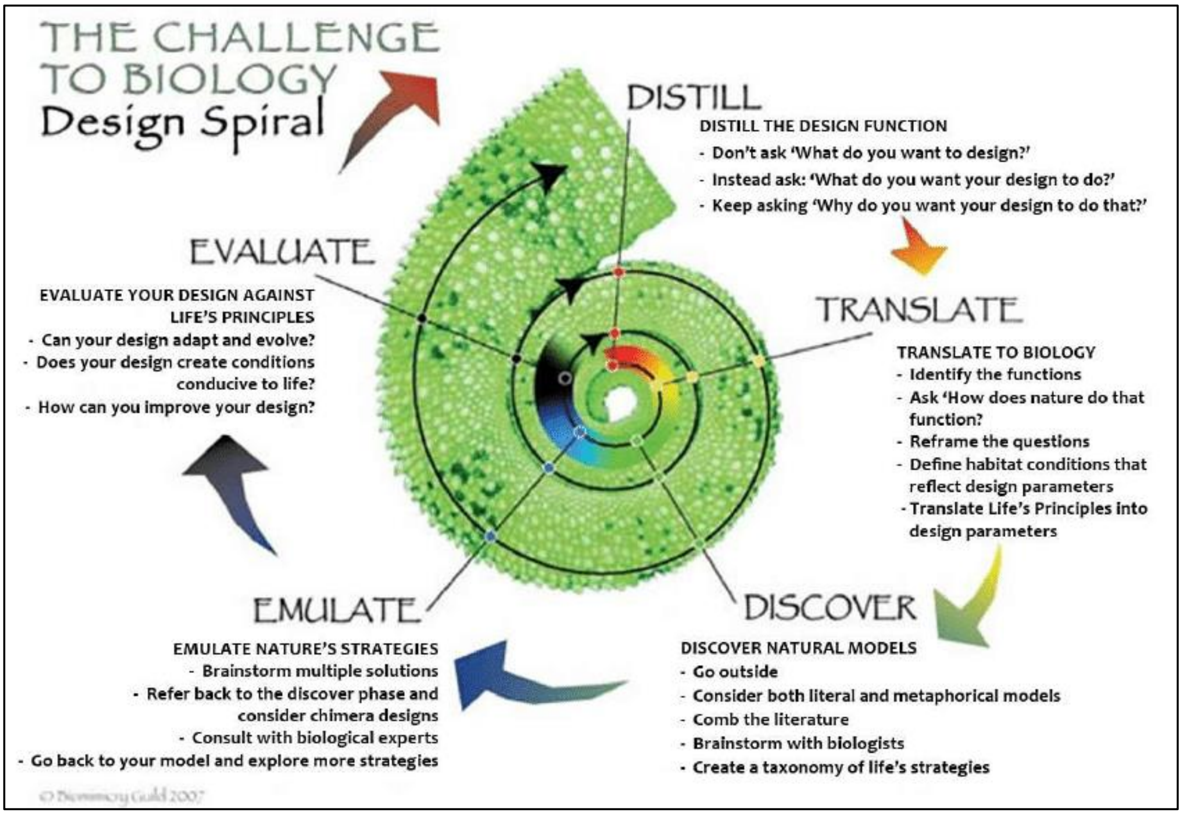


FIGURE 5 : BIOMIMICRY DESIGN SPIRAL. (SOURCE: © 2007 BIOMIMICRY GUILD.)

The Biomimicry Institute has referred to this design approach and explained it through the Challenge to Biology Design Spiral‖ as illustrated in fig*.

Research held in Georgia Institute of Technology by Michael Helms, Swaroop S.Vattam and Ashok K. Goel, at the Design Intelligence Lab in 2006, also defined this approach through 6 definite steps, which are very similar to those defined by the Biomimicry Institute: (Goel, 2009)

Step 1: problem definition.

- Step 2: reframe the problem.
- Step 3: biological solution search.
- Step 4: define the biological solution.
- Step 5: principle extraction.
- Step 6: principle application.

II.3.6.2 Solution-Based Approach

As stated in the previous approach, this approach was also found to have different naming such as Biology Influencing Design, Bottom-Up Approach and Solution-Driven Biologically Inspired Design. When biological knowledge influences human design, the collaborative design process is initially dependent on people having knowledge of relevant biological or ecological research rather than on determined human design problems. A popular example is the scientific analysis of the lotus flower emerging clean from swampy waters, which led to many design innovations as detailed by Baumeister (2007a), including Sto's Lotusan paint which enables buildings to be self-cleaning.

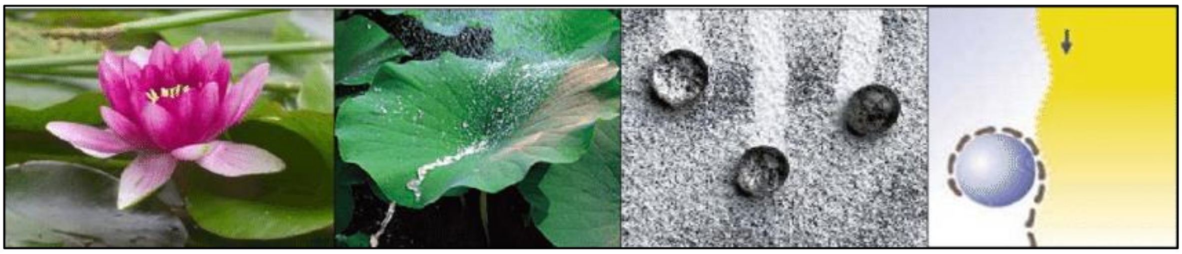


FIGURE 6 : LOTUS INSPIRED LOTUSAN PAINT (SOURCE: PEDERSEN ZARI, M. 2007)

An advantage of this approach therefore is that biology may influence humans in ways that might be outside a predetermined design problem, resulting in previously unthought-of technologies or systems or even approaches to design solutions. The potential for true shifts in the way humans design and what is focused on as a solution to a problem, exists with such an approach to biomimetic design. (Vincent et al., 2005)

A disadvantage from a design point of view with this approach is that biological research must be conducted and then identified as relevant to a design context. Biologists and ecologists must therefore be able to recognise the potential of their research in the creation of novel applications. Research held in Georgia Institute of Technology by Michael Helms, Swaroop S. Vattam and Ashok K. Goel, at the Design Intelligence Lab in 2006, also defined this approach through 7 definite steps:

Step 1: biological solution identification Here, designers start with a particular biological solution in mind.

Step 2: define the biological solution

Step 3: principle extraction

Step 4: reframe the solution In thins case, reframing forces designers to think in terms of how humans might view the usefulness of the biological function being achieved.

Step 5: problem search Whereas search in the biological domain includes search through some finite space of documented biological solutions, problem search may include defining entirely new problems. This is much different than the solution search step in the problem-driven process.

Step 6: problem definition

Step 7: principal application

II.3.7 Levels of Biomimicry in Architecture

Biomimetic design processes in architecture reveal three levels possible of imitation: the level of organism, behavior and ecosystem (Figure 07).

The organism level refers to a specific being such as a plant or animal and can involve imitating part of the organism or the whole.

The behavior level refers to behaviour or a being and may include the translation of an aspect of the behavior of the organism and possibly its relation to a context wider.

The ecosystem level is the imitation of the principles that allow the function to be performed successfully.

Within each of those three levels, five additional dimensions of imitation exist:

The design can be biomimetic for example in terms of what it looks like (shape), how it's made (construction), how it works (process) or what does it do (function)

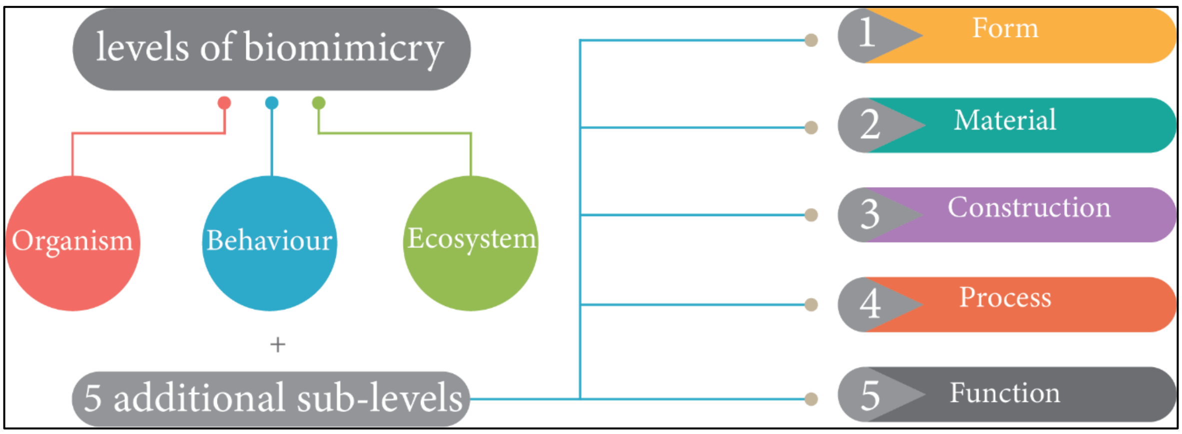


FIGURE 7 : THE LEVELS OF BIOMIMICRY. (SOURCE: THE AUTHOR)

Example:

Behavior level (Mimicry of how an organism behaves or relates to its larger context)

Form: looks like it was made by an organism.
Material: made from similar materials that an organism builds with.
Construction: made in the same way that an organism would build in.
Process: works in the same way as an organism mound would.

Function: functions in the same way that it would if made by organism

II.3.7.1 The organism levels

Species of living organisms have undergone evolution for millions of years. The organisms present on Earth today possess survival mechanisms that have endured and adapted to continual changes over time. As Baumeister (2007a) emphasizes, "the research and development have been done." Consequently, humans have an extensive repertoire of examples to draw upon in solving societal problems, many of which organisms may have already addressed, typically in energy- and materials-efficient ways.

This proves advantageous for humans, especially as resource accessibility fluctuates, the climate undergoes changes, and our understanding deepens regarding the adverse environmental impact of current human activities on numerous ecosystems worldwide. (Alberti et al., 2003)An illustration of this concept is the emulation of the Namibian desert beetle, Stenocara. (Garrod et al., 2007).

This beetle resides in a desert characterized by minimal rainfall. Despite the arid environment, it efficiently captures moisture from swiftly moving fog by orienting its body into the wind. Droplets condense on the beetle's back and wings, featuring an alternating hydrophilic and hydrophobic rough surface, and then trickle down into its mouth. (Parker and Lawrence, 2001)

Matthew Parkes, from KSS Architects, exemplifies organism-level biomimicry inspired by this beetle. His proposed fog-catcher design for the Hydrological Center at the University of Namibia (Fig. /) demonstrates the application of this process (Killeen, 2002). Discussing a more focused aspect of material biomimicry at the organism level, Ravilious (2007) and Knight (2001) delve into the study and replication of the beetle's surface. This biomimetic approach opens doors to potential applications such as enhancing visibility on airport runways by clearing fog and improving dehumidification equipment.

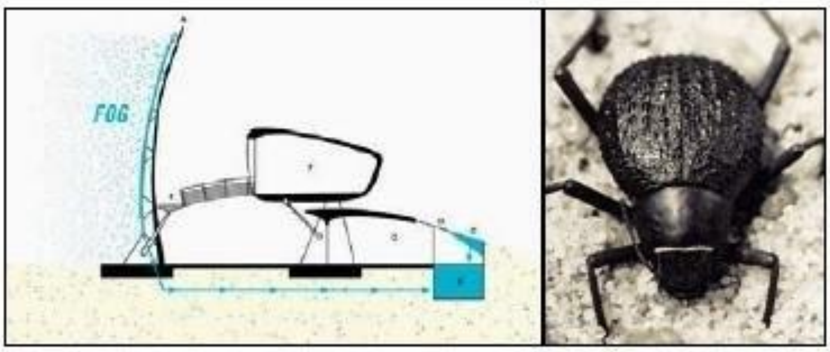


FIGURE 8 : MATTHEW PARKES7 HYDROLOGICAL CENTRE(SOURCE : DERGIPARK)

The design created by Nicholas Grimshaw & Partners for the Waterloo International Terminal serves as an illustration of form and process biomimicry at the organism level (Fig. 09). This terminal required the capability to respond to changes in air pressure during the arrival and departure of trains. The structure's glass panel fixings imitate the flexible scale arrangement of the Pangolin, enabling them to move in response to the applied air pressure forces (Aldersey-Williams, 2003).

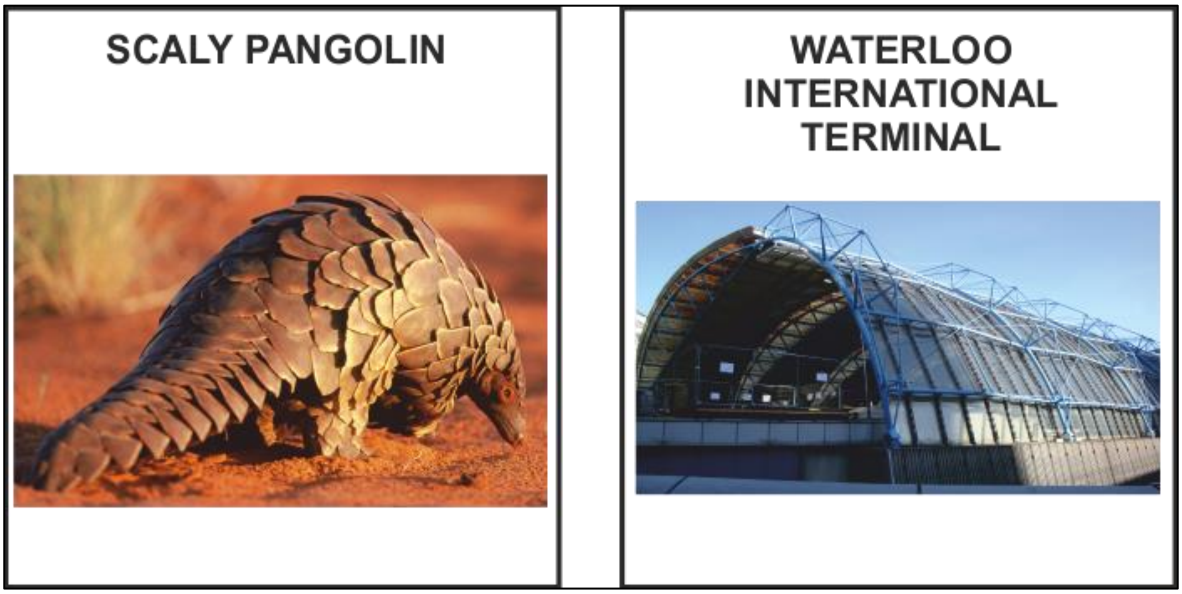


FIGURE 9 : NICHOLAS GRIMSHAW & PARTNERS. WATERLOO, INTERNATIONAL TERMINAL, AND THE PANGOLIN.(SOURCE : PINTEREST)

However, solely mimicking an organism without considering its involvement and contribution to the broader ecosystem has the potential to generate designs that are either conventional or below average in terms of environmental impact. (Reap et al., 2005)

Given that organism mimicking often focuses on specific features rather than entire systems, there is a risk that biomimicry may become a technology appended to buildings rather than an integral part of them. This risk is particularly evident when designers lack biological knowledge and fail to collaborate with biologists or ecologists in the initial design stages. Although this approach may lead to the development of innovative building technologies or materials, it may not necessarily explore methods to enhance sustainability. (Pedersen Zari, M. 2007)

II.3.7.2 Behaviour Level:

Numerous organisms confront comparable environmental conditions to those experienced by humans and encounter similar challenges. As elucidated earlier, these organisms typically function within the environmental carrying capacity of a particular area, operating within the constraints of available energy and materials. These limitations, coupled with ecological pressures that give rise to adaptations within ecological niches, imply that evolutionary processes extend beyond well-adapted individual organisms. They also encompass well-suited behaviors of organisms and the relational patterns between various organisms or species. (Reap et al., 2005)

Species possessing the capability to directly or indirectly regulate the flow of resources to other organisms and induce modifications in both biotic and abiotic (non-living) materials or systems, thereby shaping habitats, are termed ecosystem engineers. (Rosemond and Anderson, 2003)

Ecosystem engineers bring about alterations in habitat either through their intrinsic structures, exemplified by coral, or through mechanical or alternative means, as observed in the activities of beavers and woodpeckers.

Undoubtedly, humans' function as effective ecosystem engineers; however, exploring how other species alter their environments and create additional capacity for life within the system can offer valuable insights. Numerous authors present instances and elaborate on organisms modifying their habitats, fostering the presence of diverse species, enhancing nutrient cycling, and establishing mutually beneficial relationships among species. The construction behavior exhibited by various species is commonly referred to as "animal architecture" (Hansell, 2005) and can offer additional illustrations of these ecosystem engineering processes.

The well-known illustration of the North American beaver (Castor canadensis) (Fig.10) showcases its transformative impact on the landscape, leading to the creation of wetlands and an increase in nutrient retention, plant diversity, and animal diversity. This alteration contributes to enhancing the resilience of the ecosystem to disturbances. (Rosemond and Anderson, 2003).

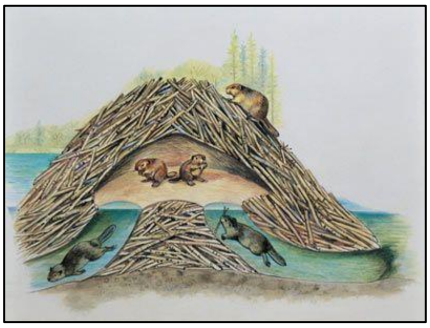


FIGURE 10 : : THE NORTH AMERICAN BEAVER.(SOURCE : FREEPIK)

In the realm of behavior-level biomimicry, the focus shifts from mimicking the organism itself to emulating its behavior. It becomes feasible to replicate the relationships between organisms or species in a similar manner. An architectural embodiment of process and function biomimicry at the behavior level is exemplified by Mick Pearce's Eastgate Building in Harare, Zimbabwe, and the CH2 Building in Melbourne, Australia (Figure 11). Both structures draw inspiration, in part, from passive ventilation and temperature regulation techniques observed in termite mounds to establish a thermally stable interior environment. The CH2 Building utilizes water extracted (and purified) from the sewers beneath, employing a mechanism akin to certain termite species that leverage aquifer water proximity for evaporative cooling mechanism (Pedersen Zari, M. 2007)

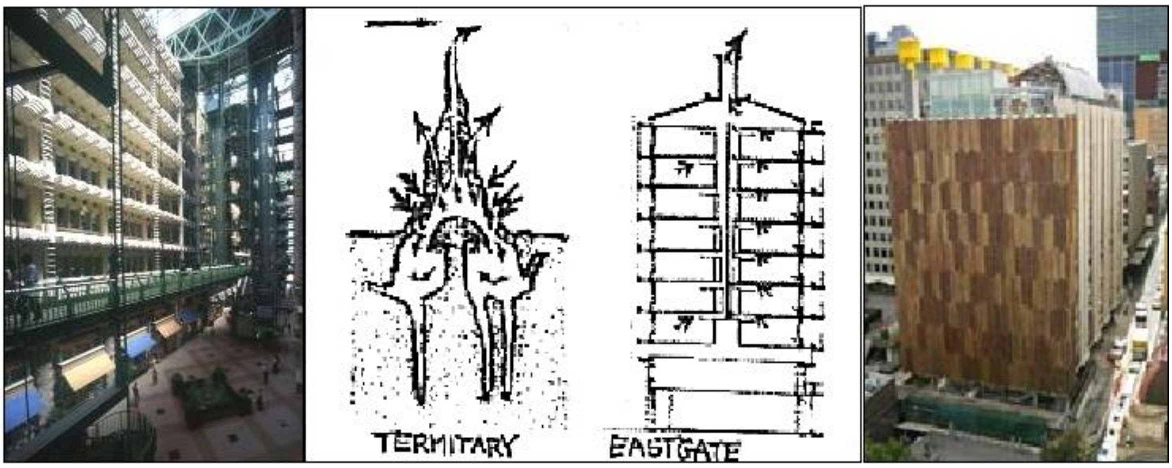


FIGURE 11 : EASTGATE BUILDING IN HARARE, ZIMBABWE AND CH2 BUILDING IN MELBOURNE, AUSTRALIA. (SOURCE: PEDERSEN ZARI, M. 2007).

Decisions of an ethical nature become imperative in the context of behavior-level mimicry, demanding careful consideration of the suitability of the behaviors being emulated within the human context. Not all behaviors exhibited by organisms are conducive for human mimicry, and there is a peril that patterns of consumption or exploitation could be rationalized based on the behaviors of other species.

For instance, while replicating the building behavior and its resultant outcomes in termites might be fitting for the development of passively regulated thermally comfortable buildings, mimicking the social structure of termite colonies would be inappropriate if universal human rights are valued. It appears more fitting to emulate specific building and survival behaviors that enhance sustainability and the regenerative capacity of human-built environments, steering clear of mimicry that could be applied to social or economic spheres without meticulous consideration. In this regard, it might be more suitable to mimic entire systems rather than individual organisms. An illustrative example is Benyus's (1997) assertion that we should "do business like a redwood forest». (Pedersen Zari, M. 2007)

II.3.7.3 Ecosystem level

Biomimicry, specifically the imitation of ecosystems, stands as a crucial aspect, elucidated by Benyus (1997) and Vincent (2007). The term "ecomimicry" has been employed to describe this practice in design contexts (Lourenci et al., 2004; Russell, 2004), with Marshall (2007) highlighting its use to represent a sustainable form of biomimicry, prioritizing the well-being of ecosystems and people over conventional motivations like 'power, prestige, or profit.' Advocates within industrial, construction, and building ecology, including Graham (2003), Kibert et al. (2002), and Korhonen (2001), advocate for the mimicking of ecosystems. Researchers emphasizing a shift to regenerative design also stress the importance of architectural design grounded in an ecological understanding. (Reed, 2006)

While comprehensive architectural examples of ecosystem-based biomimicry at the process or function level are not widely known, proposed projects, such as the Lloyd Crossing Project in Portland, Oregon, demonstrate aspects of this approach. This project utilizes estimations of the pre-development ecosystem's functioning, referred to as Pre–development Metrics™, to establish long-term ecological performance goals (Figure 12).

Designing at the ecosystem level in biomimicry offers the advantage of complementing other biomimicry levels (organism and behavior). It also allows the integration of established sustainable building methods not explicitly biomimetic, such as interfaced or bio-assisted systems, where human and non-human systems merge to mutual benefit. Examples include John and Nancy Todd's Living or Eco Machines, mimicking wastewater treatment in ecosystems and integrated with plants. (Todd, 2004) The Australian-developed Biolytix® system mimics soil-based decomposition to treat water waste and incorporates actual worms and soil microbes into the process. (Allen, 2005)

Another advantage of an ecosystem-based biomimetic design approach is its applicability to various temporal and spatial scales. (Allen, 2005) It can serve as an initial benchmark or goal for achieving truly sustainable or regenerative design for a specific place, as illustrated by the Lloyd Crossing Project (Fig. 12).

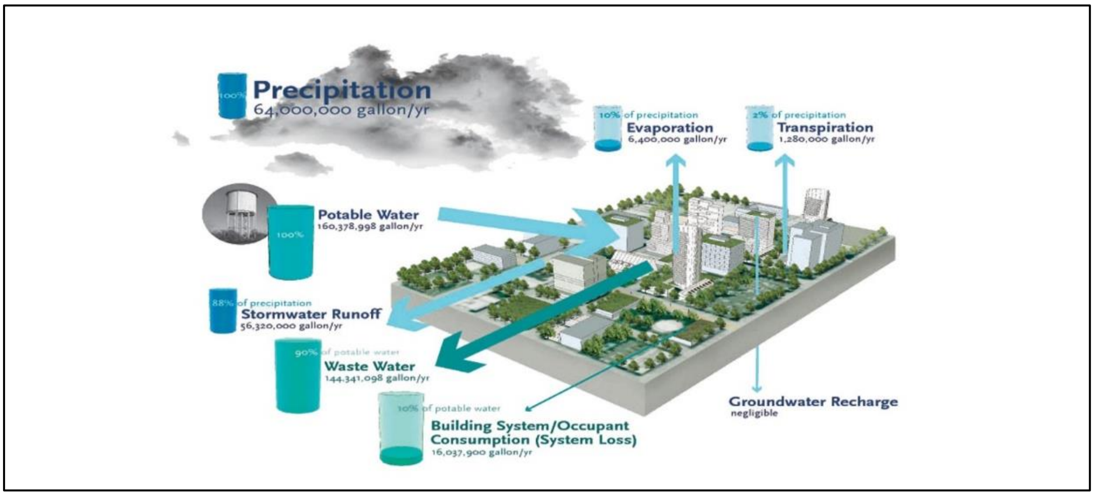


FIGURE 12 :LLOYD CROSSING PROJECT, PORTLAND, USA (SOURCE: MITHUN.COM)

However, the most significant advantage of such a biomimetic design approach might lie in its potential positive impact on overall environmental performance. Ecosystem-based biomimicry operates on both a metaphoric and a practical functional level. Metaphorically, designers with limited ecological knowledge can apply general ecosystem principles, as suggested by various authors (Benyus, 1997; McDonough and Braungart, 2002; de Groot et al., 2002). Pedersen Zari and Storey (2007) detail a set of ecosystem principles derived from interdisciplinary understandings of ecosystem functioning. Designing the built environment as a system, even metaphorically emulating an ecosystem, could potentially enhance the environmental performance of the built environment. (Korhonen, 2001)

On a functional level, ecosystem mimicry implies that a profound understanding of ecology guides the design of a built environment capable of engaging in major biogeochemical material cycles in a reinforcing, rather than damaging, manner. (Charest, 2007)

Implicit in this approach is the requirement for a deeper understanding of ecology and systems design by the design team. Moreover, increased collaboration between traditionally disparate disciplines, such as architecture, biology, and ecology, is essential. This approach challenges conventional architectural design thinking, particularly regarding the usual constraints of a building site and the time scales within which a design may operate.

While Kibert (2006) highlights similar ideas advocated by various authors, he criticizes this design approach due to the challenges in understanding and modeling ecosystems. He asserts that the "mimicking of nature in human designs is one-dimensional [and] non-complex." Although this criticism holds true in terms of realized built forms, it does not negate the notion that mimicking what is known about ecosystems remains a worthy goal for increasing sustainability. This is especially feasible considering that biological knowledge may be doubling every five years. (Benyus, 1997)

II.3.8 Biomimetic building envelope adaptation:

When applying adaptive concept into building envelopes, it means that building envelope should have the ability to deal with the exterior surroundings, in order to act as an adaptive layer capable of achieving internal thermal comfort and minimized energy consumption. This approach introduces the potential of the biomimetic concept to be used in building envelopes. A couple of general examples to plants and animals that have a diversity of ways and use a multitude of strategies to keep adapted could be mentioned in order to put some of these ideas within an architectural context is shown in the Table 1.

TABLE 1: ENVELOPE ADAPTATION IN BIOMIMETIC BUILDING (SOURCE , AUTHOR)

Means of Adaptation	Plants	Animals
Cooling	Plants loss heat through the process of the transpiration, in which the plant carries water from the soil around its root to the leaves, then evaporates water through specialized openings called stomata's (Gibson, 1996) ,(Batanouny, 2001)	The sweat glands of many mammals aid thermoregulation through evaporative cooling (BI, 2008).
Insulation skins	Thick external layers and waxy covering, which reduce heat gain (Earlham Collage, 2006).	Some animals have thick coat with dense hair, it does not only protect animals from cold winter, but it insulates them from summer heat (Shenbrot et al, 1999) ,(Costa, 1995).
	Leaves cells that can absorb moisture and store it, creating an insulation layer (Batanouny, 2001).	Coloration is an important factor in reducing of heat absorption, so lighter colored coat is more familiar in desert animals (Earlham Collage, 2006).
Avoiding heat gain	Dense small leaves, spines and hairs instead of large leaves to decrease surface exposed to direct sunlight and insulate the plants against heat gain, while allowing the fresh air to	

	pass between them (Gibson, 1996),(Springuel, 2006), (Batanouny, 2001).	
Retaining water	Shallow, radial roots, those which extended horizontally, which maximize water absorption at the surface (Springuel, 2006).	Different animals adopt different mechanisms to produce enough water such as sand lizard. It has hygroscopic skin to absorb moisture from the air

II.3.9 Biomimetic Design Strategies

II.3.9.1 Direct Biomimicry in Architectural Design

The case presented below, unlike the previous case, represents a direct collaboration between an architect and a biologist. Co-design activities involve designing forms or technological processes by transferring natural shapes or natural technological processes into the environment.

Forms or technical processes in architecture Although direct biomimicry seems to have the potential to lead to innovation, the required collaboration with biologists and the lengthy design periods pose significant challenges for its use in architecture. While the available time for designing a project is generally limited, producing new products is feasible in the industry, but much less so in architecture. However, the industry has developed tools to support the biomimetic design process.

II.3.9.2 Indirect Biomimicry in Architectural Design

In architectural design activities inspired by various living beings, architects have developed the following design methods:

- This creates completely different forms and technological processes. Things that occur in nature. These design methods generally rely on computer technology.
- These include particle systems, genetic algorithms, and multi-agent systems whose functionalities are inspired by biology. Bio-inspired computing is a research field divided into the following sub-domains:
- Connectionism, social behaviours, and emergence. Artificial intelligence or similar to artificial intelligence
- Life is linked to the domains of biology, computer science, and mathematics. In short, it means

- Creating innovative algorithms to solve known problems, such as optimization problems.
- Examples of inspiration from phenomena observed in nature

II.4 THERMAL COMFORT

II.4.1 Introduction

Current comfort standards aim to improve the thermal acceptability of interior spaces. Unfortunately, they have tended to demand energy-intensive environmental control systems and frequently exclude thermally variable solutions, such as various climate-responsive and energy-saving designs, or new mechanical strategies that allow for human control.Many researchers have concluded that office workers' productivity increases as their satisfaction with the thermal environment increases, and severe cases of thermal discomfort are associated with sick building syndrome (SBS), with occupants experiencing symptoms such as itchy eyes and runny nose, as well as skin irritation. With this importance, preserving thermal comfort for inhabitants in buildings is one of the primary tasks of building designers, including architects and HVAC engineers. so we should provide the basic principles of thermal comfort and address how this can be achieved in more sustainable ways, especially with the urgent challenges given by climate change, which results in a greater demand for cooling that must be provided by passive means or renewable energy where possible.

II.4.2 Definition

Thermal comfort is commonly defined as the desired or good state of mind that a person has in connection to how warm or chilly they feel. As a result, it is heavily influenced by the person's surroundings. Despite the name, it impacts not just comfort but also productivity, health, and well-being, thus contentment with the thermal environment is critical.

Thermal comfort is the situation in which the ambient temperature does not negatively affect the individual, providing satisfaction. This occurs because the person needs to consume less energy to adapt to the environment and feel comfortable, stabilizing the heat exchange with their internal temperature. As an architect, it is important to include the thermal comfort stage in the project, considering factors such as:

- relative air humidity;
- thermal insulation;
- natural ventilation inlets;
- the climate of the region

II.4.3 Thermal Comfort Strategies in Architecture

There are some strategies that you, as an architect, can adopt during the design process to achieve thermal comfort :

Solar orientation : The position of the sun is directly related to the structure being built and has become a fundamental issue for thermal comfort. This is because having knowledge of the orientation allows for developing strategies to take advantage of or prevent the incidence of solar rays.

In this way, reflections of heat, shadow areas, the use of glass, etc., should be considered. If solar panels are used, they should be placed in the area receiving the most sunlight

Structural openings: Among the solutions mentioned above, we can mention the design of openings in facades or roofs of the construction. They contribute to:

Capturing sunlight, ensuring natural lighting;

Allowing air to circulate freely, promoting ventilation of spaces.

For this, it is necessary to analyze wind behavior to design spaces in a way that takes advantage of natural resources. Like the direction of doors and windows, which should be thought out strategically, as winds differ in winter and summer.

This option is entirely sustainable and also influences the reduction of energy consumption in the building.

Thermal insulation : Thermal insulation can be a great alternative to maintaining the internal temperature of the environment. You can apply it using industrial materials and architectural solutions, for example:

Industrial Materials: Polyester wool, rock wool, fiberglass, etc;

Architectural solutions: the most used are Brises and Cobogós, which block heat incidence. There are also green roofs, tiles with thermal insulation, cold floors, floating floors, etc.

Another source of insulation is Drywall, a material that does not absorb external temperature. It has glass wool or rock wool in its composition, which also provides acoustic insulation to the environment

Roofing : The shape of the roof can be one of the factors influencing the thermal sensation of the environment. They end up interfering with the direction and speed of the wind, with the purpose of cooling the space.One of the solutions includes the use of green roofs, as it can provide thermal resistance to the roof. Ceramic tiles are great for ensuring the ideal temperature but will need to be placed at a certain inclination.

Bioarchitecture : The concept of bioarchitecture is linked with construction that integrates natural resources harmoniously. That is, the professional responsible for the project should consider making buildings greener.

When the climatic characteristics of each region are considered, you will be able to generate not only thermal comfort but also acoustic and luminous comfort. The consequence of this is increased energy efficiency and reduced pollutants.

II.4.4 Influencing factors

II.4.4.1 The temperature of the walls:

The temperature of the walls has a large influence on the temperature felt. Forsimply calculate the temperature felt, itmust be the average between the temperature of walls and room temperature.

II.4.4.2 Relative air humidity (humidity):

The humidity allowing good thermal comfort is between 40%-60%, a high rate causes a deregals of the thermoregulation of the organism.

II.4.4.3 Air movements:

Heat exchanges by convection its accentuated by Air movements. Taking the example of a real temperature of 0 ° C (displayed in weather), the temperature felt can be -7 ° C under the effect of the wind. Air movements are perceived by humans a speed of 0.2m/s (0.7 km/h)

II.4.4.4 Occupant:

Clothing creates a sub-vestimental microclimate, and activity determines how much heat the human body produces. An extremely intense activity could be the cause of unease.

II.4.4.5 Internal thermal gains:

Increased internal heat in a building can come from various sources such as that: the heat released by occupants who can be considered an increase passive heat, the propagation of heat through electrical equipment such asthat computers, bulbs and household appliances, etc.

II.5 ENERGY EFFICIENCY

II.5.1 Introduction

In the modern era, the challenge of energy efficiency looms large as one of the foremost imperatives of our time. Among all sectors, buildings stand out as the largest consumers of energy, wielding significant influence over our planet's climate. Yet, the current trajectory paints a concerning picture: without decisive action, the proliferation of energy-inefficient structures is set to continue unabated. Thousands of new buildings will rise without the consideration of energy efficiency, while millions of existing ones will persist in squandering resources, projecting a bleak outlook even into the year 2050.

In light of this urgency, our focus turns to the critical task at hand. This chapter is dedicated to unraveling the essential concepts that underpin the realm of energy efficiency. Furthermore, we embark on a journey to explore diverse strategies aimed at tackling this challenge head-on, with a special emphasis on the innovative principles of bioclimatic architecture. By delving into these concepts and embracing sustainable design practices, we chart a course towards a future where buildings serve as beacons of energy efficiency and sustainability, safeguarding our planet for generations to come.

II.5.2 Etymology of Energy Efficiency

The term "energy efficiency" encompasses two key components: "energy" and "efficiency." Let's break down the etymology of each:

Energy:

The word "energy" derives from the Greek word "energeia," meaning "activity" or "operation," which Aristotle used to describe the concept of actuality or the capacity for action.

In modern usage, "energy" refers to the ability or capacity of a system to perform work or to produce a change or effect. It encompasses various forms such as kinetic energy, potential energy, thermal energy, electrical energy, and more.

Efficiency:

- The term "efficiency" has Latin roots, coming from the Latin word "efficientia," meaning "accomplishment" or "performance."

- In its essence, "efficiency" refers to the ratio of output to input within a system, measuring how effectively resources are utilized to achieve a desired outcome.

- The concept of efficiency gained prominence during the Industrial Revolution as industries sought to maximize output while minimizing resource consumption and waste.

When combined, "energy efficiency" refers to the ability to achieve a desired level of energy output with the least amount of input or waste. It embodies the principles of optimizing energy use, reducing energy waste, and maximizing the productivity of energy resources. The term gained widespread usage as societies increasingly recognized the importance of conserving energy resources, reducing environmental impact, and improving economic efficiency. Today, energy efficiency is a critical concept in various fields, including engineering, environmental science, economics, and public policy, driving efforts to promote sustainable energy practices and mitigate climate change.

II.5.3 Definition of Energy Efficiency

Energy efficiency refers to the optimization of energy use to achieve a desired outcome with minimal waste. It involves utilizing energy resources in a way that maximizes output or performance while minimizing input or consumption. In essence, energy efficiency aims to accomplish tasks, processes, or activities using the least amount of energy possible without compromising quality, comfort, or functionality.

Key elements of energy efficiency include:

- Minimization of energy waste: Energy efficiency involves reducing unnecessary energy consumption and minimizing losses during energy conversion, transmission, and utilization.
- Optimization of energy systems: It entails designing, implementing, and operating energy systems, appliances, equipment, and infrastructure in a manner that enhances their energy performance and effectiveness.
- Adoption of efficient technologies: Energy efficiency often entails the utilization of energy-efficient technologies, materials, and practices that enable the achievement of desired outcomes with reduced energy input.
- Behavioral and operational improvements: Energy efficiency also involves promoting changes in behavior, habits, and operational practices to enhance energy conservation and reduce energy waste.
- Economic and environmental benefits: Improving energy efficiency can result in significant economic savings, as it reduces energy costs and enhances resource productivity. Additionally, energy efficiency plays a crucial role in mitigating environmental impacts, including reducing greenhouse gas emissions, air pollution, and resource depletion.

Efforts to enhance energy efficiency are fundamental in addressing global energy challenges, promoting sustainable development, and mitigating climate change. As such, energy efficiency initiatives are a cornerstone of energy policies, regulations, standards, and programs worldwide, aimed at fostering a more sustainable and resilient energy future.

It is defined too as the practice of using less energy to accomplish the same tasks or functions. In the context of buildings, it encompasses a wide range of strategies, technologies, and practices aimed at reducing energy consumption while maintaining or improving overall performance.

This not only reduces operational costs but also minimizes environmental impact by lowering greenhouse gas emissions. But more on that later (Benyus, 1997)

II.5.4 Role of Energy Efficiency

Energy efficiency occupies a pivotal position within environmental policy frameworks at all levels of government, playing a multifaceted role that straddles the realms of science and policy. This concept, with its robust scientific underpinnings and practical utility as a policy tool, emerges as a cornerstone in the quest for sustainable development and environmental stewardship. Its significance is particularly pronounced in the context of mitigating greenhouse gas emissions, offering a pathway towards environmental sustainability even in economies where stringent carbon reduction targets or carbon pricing mechanisms are absent.

At its core, the optimization of energy efficiency stands as one of the most critical pillars within energy and environmental policy landscapes worldwide. Its influence transcends geographical boundaries and political ideologies, resonating as a universally recognized imperative for addressing the challenges of climate change and environmental degradation. Within the intricate interplay of scientific principles and policy frameworks, energy efficiency emerges as a potent catalyst for transformative change, capable of driving tangible progress towards sustainability goals.

The versatility of energy efficiency as a mitigation strategy for greenhouse gas emissions further underscores its significance in contemporary policy discourse. In economies where comprehensive carbon reduction goals or structured carbon pricing mechanisms may be lacking, energy efficiency serves as a pragmatic and effective means of curbing emissions and fostering environmental resilience. Its ability to deliver tangible environmental benefits while simultaneously enhancing economic competitiveness renders it an attractive proposition for policymakers seeking sustainable pathways to development.

Moreover, the appeal of energy efficiency transcends mere political rhetoric, embodying a tangible and economically viable approach to addressing environmental challenges. By promoting the efficient use of energy resources, energy efficiency initiatives not only mitigate environmental impacts but also contribute to economic growth, job creation, and enhanced energy security. Its profound impact resonates not only within governmental agencies but also reverberates across industries, communities, and international platforms, underscoring its indispensable role in shaping the trajectory of global sustainability efforts.

In conclusion, energy efficiency stands as a linchpin of contemporary environmental policy, offering a pathway towards a more sustainable and resilient future. By harnessing its transformative potential and leveraging its dual capacity as a scientific principle and policy instrument, we can navigate the complex challenges of climate change and environmental sustainability with confidence and resolve

II.5.5 Energy consumption in buildings:

II.5.5.1 Internationally:

Buildings, on a global scale, assume a paramount role as the primary consumers of energy resources, constituting a staggering 30 to 40% of the total energy consumed worldwide. This revelation, as reported by esteemed researchers A. Liebard and A. De Herde, underscores the profound influence that buildings wield on our energy landscape and environmental footprint. Moreover, their contribution extends beyond energy consumption, as they are also responsible for over 40% of CO_2 emissions globally, further exacerbating the climate crisis. Delving deeper into the intricacies of energy usage within buildings, data from the Earth Trends 2005 Atlas 2006 by Liebard and De Herde elucidate that buildings account for precisely 36% of fossil energy consumption on a global scale. This breakdown reveals a nuanced picture, with residential buildings consuming 27.5% of fossil energy and commercial buildings consuming 8.7%. Such granular insights shed light on the diverse energy demands stemming from different building typologies, highlighting the need for tailored solutions to enhance energy efficiency across the board.

Beyond their substantial energy appetite, buildings also exert a significant toll on the environment across various metrics. They represent a staggering 50% of exploited natural resources, underscoring their role in resource depletion and environmental degradation. Additionally, buildings account for 45% of total energy consumption, amplifying their impact on energy demand and supply dynamics. Furthermore, they contribute to 40% of non-domestic waste production, exacerbating waste management challenges and landfill saturation.

In terms of greenhouse gas emissions, buildings are responsible for a substantial 30% of emissions globally, further intensifying the climate crisis. This statistic underscores the urgent need for transformative action to mitigate emissions from the built environment and transition towards low-carbon alternatives. Moreover, buildings account for 16% of water consumption, highlighting their role in exacerbating water scarcity issues and necessitating sustainable water management practices.

In summation, the profound impact of buildings on energy consumption and environmental sustainability cannot be overstated. Addressing the energy inefficiencies inherent in building stock and implementing sustainable design and construction practices are imperative steps towards mitigating their environmental footprint and fostering a more resilient and sustainable built environment for future generations (Liebard, De Herde, 2005)

II.5.5.2 In Algeria:

In line with the global trajectory, our nation is intricately woven into the fabric of a paradigm where buildings, encompassing both residential and commercial edifices, emerge as the predominant voracious consumers of energy. Drawing from meticulously collated data courtesy of APRUE (Agence Nationale pour la Promotion et la Rationalisation de l'Utilisation de l'Énergie) in 2007, it becomes unmistakably evident that the built environment, in its entirety, assumes a commanding stance in our energy consumption narrative. Astonishingly, buildings devoured a staggering 41.62% of the total final energy consumed during that year, a figure that towers over the allocations of other sectors. While industry claimed 19% of the energy pie, transportation commanded 32%, and agriculture secured 6.6%, it is the resounding dominance of buildings that demands our immediate attention.

These statistics not only paint a vivid portrait of our energy landscape but also serve as a clarion call for decisive action. They underscore the imperative for strategic interventions, meticulously crafted to optimize energy efficiency and nurture sustainable practices within the realm of construction and building operations. Indeed, the burgeoning energy appetite of our built environment beckons us to embark on a transformative journey towards greener, more resilient urban habitats.

As we confront the multifaceted challenges of the 21st century, tackling the energy consumption conundrum in buildings transcends mere environmental stewardship—it is an unequivocal imperative for economic vitality and national security. By embracing innovation, fostering collaboration, and reimagining the very essence of our urban landscapes, we can forge a future where energy efficiency and sustainability are not mere aspirations but indelible hallmarks of progress. (APRUE, 2005.)

II.6 EXAMPLES ANALYSIS

The analytical study involves presenting some models from nature and how they adapt to their climate and environment. It showcases buildings where the simulation of nature has been applied, using strategies inspired from the nature and their behavior in their environment.

TABLE 2 : THE FIRST EXAMPLE " THE EASTGATE CENTER " (SOURCE : AUTHOR)

<table>
<tr><td colspan="3">II.6.1 The Eastgate Center</td></tr>
<tr><td>Building type</td><td>shopping center and offices</td><td rowspan="5">
FIGURE 13 : SHADING SYSTEM IN THE BUILDING. SOURCE: LIVINSPACES.NET</td></tr>
<tr><td>situation</td><td>Harare, Zimbabwe</td></tr>
<tr><td>Regional climate</td><td>Humid subtropical climate</td></tr>
<tr><td>The Architect</td><td>Mick Pearce & Arup engineers</td></tr>
<tr><td>Mimicking approach used</td><td>Direct approach</td></tr>
<tr><td colspan="3">
FIGURE 14 : THE EASTGATE CENTER. SOURCE: LIVINSPACES.NET</td></tr>
<tr><td>Design problem</td><td colspan="2">Harare's humid subtropical climate required the purchase, installation and maintenance of a conventional air conditioning system, which has high long-term costs. The goal was to create a self-regulating ventilation system that would achieve thermal comfort inside the building.</td></tr>
<tr><td>Biological solution</td><td colspan="2">This building known by having the largest offices and shopping center in the country, it can regulate its internal temperature like a termite mound. This is achieved by mimicking the behavioral strategies of termites in the mound, creating openings for heating and cooling that constantly open and close throughout the hill during the day, with a carefully designed thermal convection system. (Ahmed.N, (2016),</td></tr>
<tr><td>The similarity between the two</td><td colspan="2">The simulation method employed in the Eastgate Center is considered one of the best examples of architectural buildings applying nature-inspired simulation principles to achieve sustainable green architecture. This medium-rise building does not incorporate mechanical air</td></tr>
</table>

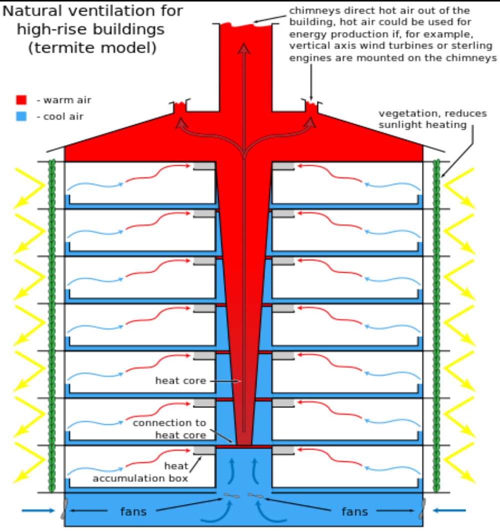
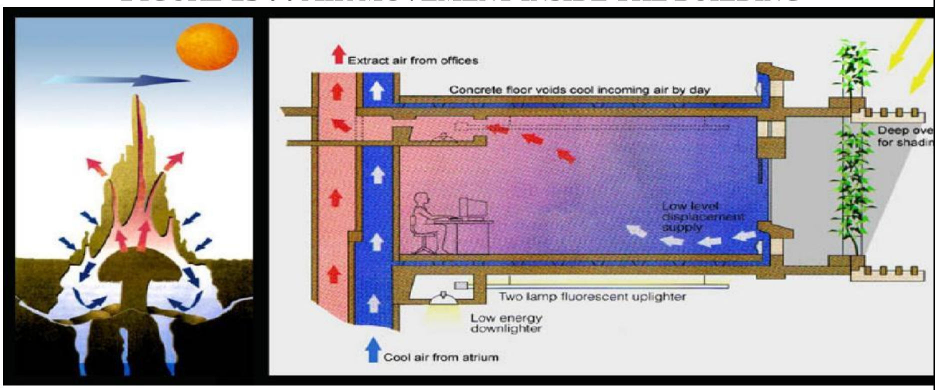
	conditioning systems, yet it achieves lower energy consumption by ensuring thermal comfort throughout the structure. It achieves this by utilizing techniques inspired by the self-cooling methods of termite mounds. The building's construction materials, particularly the concrete, possess high thermal capacity, enabling it to store or release heat throughout the day. Additionally, there are shading devices on the facades, minimizing heat gain according to a specified form. (Karabetça, A. R. (2015, March).
Mimicking method in the building	 FIGURE 15 : : AIR MOVEMENT INSIDE THE BUILDING  FIGURE 16 : VENTILATION STRATEGY. (SOURCE: MICKPEARCE)
Biomimicry level	The Eastgate Center building mimics the behavior of white ants within the mounds they inhabit, incorporating the building beneath the behavioral level of the ants.

TABLE 3 : THE SECOND EXAMPLE " THE DURIAN " (SOURCE : AUTHOR)

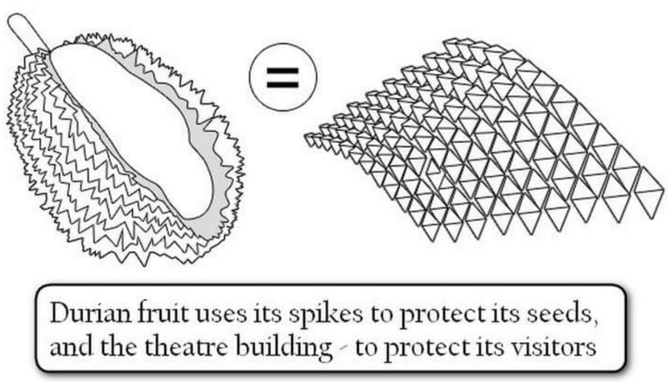
<table>
<tr><td colspan="3">II.6.2 Esplanade Theatre “The Durian”</td></tr>
<tr><td>Building type</td><td>multifaceted arts center</td><td rowspan="6">
FIGURE 17 : ESPLANADE THEATRE, SINGAPORE</td></tr>
<tr><td>Situation</td><td>Singapore</td></tr>
<tr><td>Opened</td><td>12 October 2002</td></tr>
<tr><td>Regional climate</td><td>tropical climate</td></tr>
<tr><td>The Architect</td><td>DP Architects and Michael Wilford,</td></tr>
<tr><td>Mimicking approach used</td><td>passive design strategies</td></tr>
<tr><td>Design problem</td><td colspan="2">we also needed to air-condition large interior spaces. This sound trivial but because we can't afford to have sound coming from the air-conditioners we have to deliver large volumes of air at very slow speeds.</td></tr>
<tr><td>Biological solution</td><td colspan="2">The distribution of the sunshades we designed follow slowly changing pattern. To design the exterior sunshade screen, we drew inspiration from things the properties of the structural geometry itself as well as elements from nature such as sunflowers, fish scales, the patterns of a bird's feathers etc. Such elements in nature also feature geometry that appears repetitive but changes slowly over the subject</td></tr>
<tr><td>Sustainability in design</td><td colspan="2">Beyond its aesthetic appeal, the Esplanade incorporates sustainable elements. The use of passive design strategies such as natural ventilation and shading contribute to energy efficiency. This building is a shining example of how architectural innovation can harmoniously coexist with environmental responsibility</td></tr>
<tr><td>Mimicking method in the building</td><td colspan="2">

FIGURE 18 : INSPIRATION FROM THE FRUIT DURIAN</td></tr>
</table>

	 FIGURE 19 : INSPIRATION FROM THE FRUIT DURIAN
Biomimicry level	At the heart of Esplanade's design philosophy is inspiration from nature and the incorporation of biomimicry to enhance both beauty and functionality. The shell-like structure mimics the durability and strength of organic shapes found in nature. This not only enhances the visual appeal of the building, but also serves the practical purpose of shading and ventilation. This is the organism level

TABLE 4 : THE THIRD EXAMPLE " COUNCIL HOUSE" (SOURCE : AUTHOR)

II.6.3 Council House 2 (also known as CH2)		
Building type	office building	
Situation	Melbourne central business district, Australia	
Opened	August 2006	
Regional climate	temperate oceanic climate which is characterized by summers are warm, the winters are cold and windy, and it is partly cloudy year-round	
The Architect	renowned architects at DesignInc	
Mimicking approach used	Different strategies were used as heating, ventilating, and cooling system	FIGURE 20 : COUNCIL HOUSE 2 , (SOURCE :PINTEREST)
Design problem	The main concern in the design of CH2 was indoor environmental quality , and many steps were taken to specifically optimize this : -residents may take less sick leave, have fewer headaches, and improve employee health at work. -The City of Melbourne's goal was to create a healthy, comfortable, adaptable and stimulating work environment for its employees.	
Biological solution	-Natural light permeates through the building, creating a vibrant and uplifting atmosphere -Rainwater harvesting, solar panels, and a tri-generation plant contribute to the building’s self-sufficiency in energy and water resources	
Sustainability in design	-The façade of the structure takes inspiration from the skin system i.e. the epidermis (outer skin) and dermis (inner skin) The dermis acts as an outside zone and houses stairs, ducts, lifts, etc. while the inner line defines the fire compartment -The office building was designed using strategies from a termite mound. The system used by termites to control and maintain the temperature in the mound was replicated in the building through natural convection, thermal mass, water cooling, and ventilation stacks	

<table>
<tr>
<td>Mimicking method in the building</td>
<td>

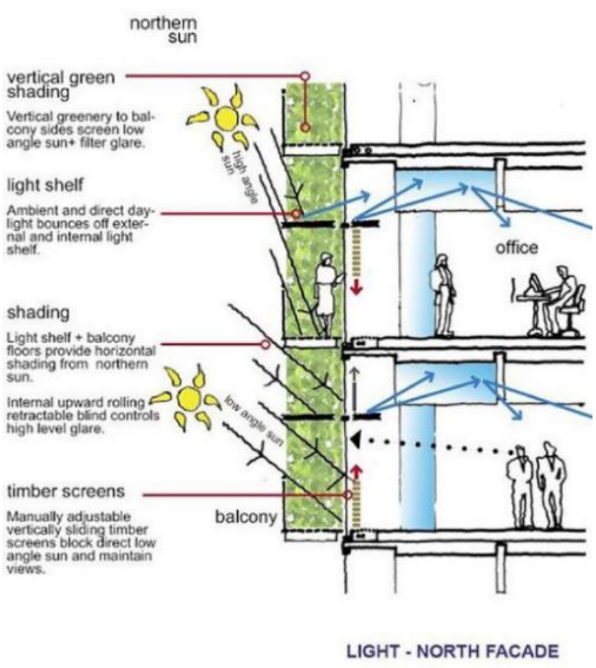


FIGURE 21 : HEATING AND COOLING STRATEGY FOR COUNCIL HOUSE 2

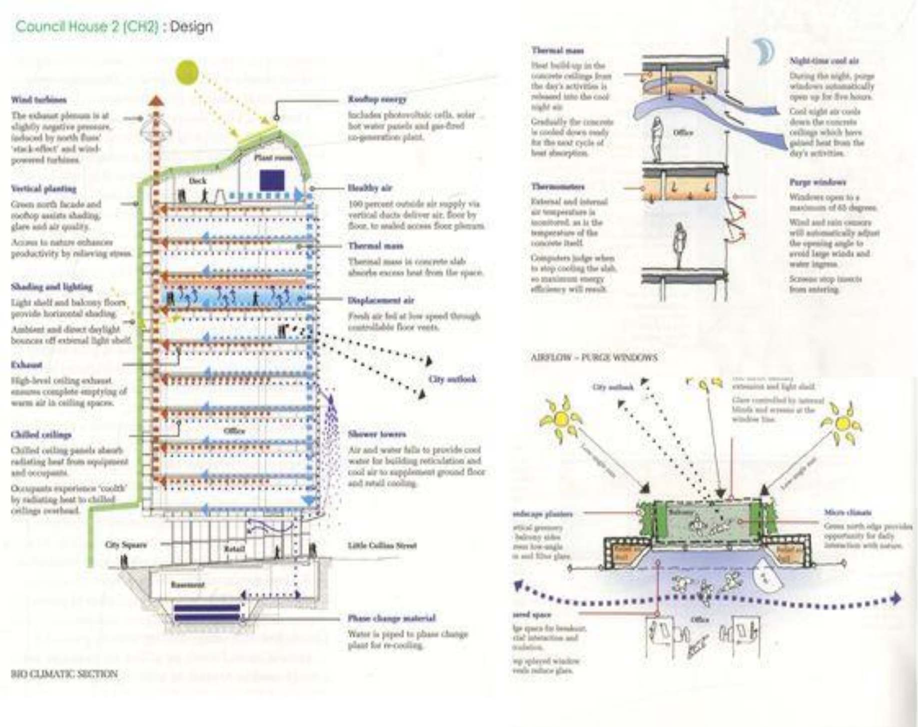


FIGURE 22 : HEATING AND COOLING STRATEGY FOR COUNCIL HOUSE 2

</td>
</tr>
</table>

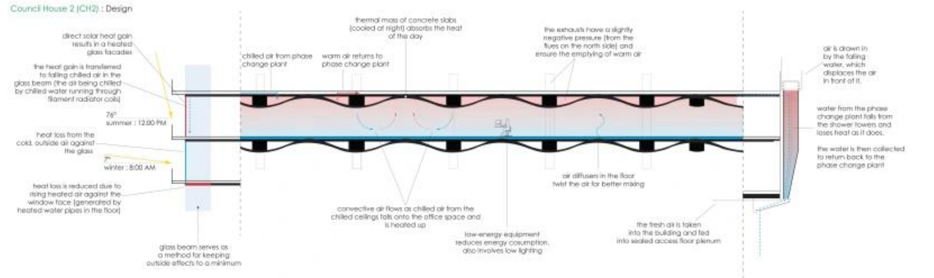
	 FIGURE 23: A SECTION THROUGH MANY OF THE SUSTAINABLE DESIGN ELEMENTS
Biomimicry level	The using of inspiration from the skin system means that’s the level is the organism level of biomimicry and the using of strategies from a termite mound and maintain the temperature in the mound was replicated in the building means that’s the second level is the behaviour level

TABLE 5 : THE FOURTH EXAMPLE "QATAR MUSEUM " (SOURCE : AUTHOR)

II.6.4 National Museum of Qatar		
Building type	national museum	 FIGURE 24 : JEAN NOUVEL’S NATIONAL MUSEUM OF QATAR
Situation	Doha, Qatar	
Opened	28 March 2019	
Regional climate	a desert climate characterized by intense dry heat.	
The Architect	Jean Nouvel	
Mimicking approach used	Indirect approach	
Design problem	‘The National Museum of Qatar is the next world-class institution that QMA is creating for our people and for our international community’ So, the main reason to build this museum is to express the traditional enclosed resting place that supported the flow of commerce, information and people across desert trade routes—and so gives concrete expression to the identity of a nation in movement.	
Biological solution	Thermal buffer zones within the disk cavities will reduce cooling loads, while the deep overhangs of the disks will create cool, shady areas for outdoor promenades and protect the interior from light and heat. Steel and concrete, the main materials of the building, will be locally sourced and/or fabricated. The landscaping will feature sparse native vegetation with low water consumption	

Sustainability in design	The building is extremely energy efficient. The disks that make up its structure are heavy and form a cushioned barrier that acts as a sunscreen. They cast long protective shadows on the built-up and on the few fenestrations it has in the setbacks, thus protecting it from the harsh sun, and enabling the visitors to explore the interior as well as the exterior in comfort. As a result, the interior spaces are efficiently air-conditioned.
Mimicking method in the building	 FIGURE 25 : DESERT ROSE  FIGURE 26 : THE DISKS AS SHADING DEVICES FOR ITS ENVELOPE AND THE SURROUNDINGS

Biomimicry level	The concept behind the design of this iconic monument is as noble as the motive of its construction. It is inspired by the Desert Rose. In the Pritzker Laurette's own words," The desert rose, a flower-like aggregate of mineral crystals occurring only in arid coastal regions, is the first architectural structure that nature itself creates, through the wind, sea spray and sand acting together over millennia. It's surprisingly complex and poetic" that's can confirm the level of biomimicry which is the ecosystem level who assure the efficient energy of the building .

TABLE 6 : THE FIFTH EXAMPLE " THE EDEN PROJECT" (SOURCE : AUTHOR)

II.6.5 The Eden Project	
situation	Cornwall, UK
Regional climate	Mild maritime climate
The Architect	Grimshaw with engineers at Arup for Eden Project Limited
Year of achievement	The doors of the Eden Project opened officially for the first time on 17 March 2001.
Mimicking approach used	Indirect approach

FIGURE 27 : THE INTERIOR OF THE DOME.

FIGURE 28 : THE EDEN PROJECT. (SOURCE: ARUP.COM)

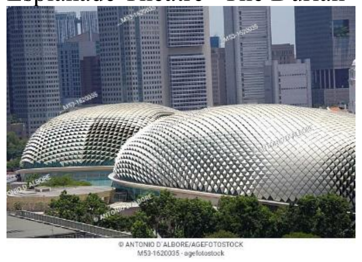
Design problem	Lack of Environmental Education Awareness:

	Problem: Limited awareness and understanding about the importance of biodiversity, environmental sustainability, and the interconnectedness of ecosystems. Threats to Biodiversity: Problem: Increasing threats to global biodiversity due to habitat loss, climate change, and other human activities. Climate Change Impact: Problem: Limited public understanding of the impact of climate change on various ecosystems and the need for sustainable practices. Environmental Impact of Construction: Problem: The environmental impact of traditional construction and architecture methods. Disconnection from Nature: Problem: Modern lifestyles often result in a disconnection from nature, leading to a lack of appreciation for the natural world.
Biological solution	In the context of the Eden Project, biomimicry is applied in several ways: Structural Design: The architecture of the biomes is inspired by natural forms and structures found in plants and organic systems. The geodesic domes, for example, draw inspiration from the structural efficiency of certain plants and their ability to support large expanses with minimal materials. Climate Control: The biomes incorporate natural ventilation and climate control systems inspired by the way that plants and ecosystems naturally regulate temperature and humidity. This helps create a sustainable and energy-efficient environment within the domes. Water Management: The Eden Project pays attention to water management, taking cues from how ecosystems naturally handle water flow and distribution. This includes efficient irrigation systems and water recycling methods. Biodiversity: The biomes aim to replicate the biodiversity found in natural ecosystems. The selection and arrangement of plant species within each biome are carefully planned to create a balanced and sustainable environment.  FIGURE 29 : A SECTION THAT SHOWS THE GENIUS OF THE BUILDING.

The similarity between the two	Bearing an enclosure resembling soap bubbles and reinforced with a naturally inspired geometry of hexagons and pentagons, the Humid Tropics Biome has earned a reputation for being lighter than the air it contains. The game changer is a high-strength polymer called Ethylene tetrafluoroethylene (ETFE) that could be made 7x larger than glass while being 1% of its weight. This meant a massive reduction in the amount of steel required and consequently, enhanced admittance of sunlight. The project, therefore, achieves next-level resource efficiency at a third of the cost of a typical glasshouse. A stellar example of biomimicry in architecture!
Mimicking method in the building	Geodesic Dome Structure at the Eden Project mimics natural geometric forms for structural efficiency. Climate control systems replicate natural temperature and humidity regulation in ecosystems through automated ventilation and heat exchange. Water management systems draw inspiration from natural hydrological processes, incorporating water recycling and efficient irrigation. Biodiversity planning involves selecting and arranging plant species to mirror the interdependence and coexistence seen in natural ecosystems.
Biomimicry level	Eden Project's biomimicry operates on three levels: 1. Organic Level (Structural Design):** Geodesic domes imitate efficient structures in plants, utilizing lightweight materials and effective load-bearing designs. 2. Behavior Level (Climate Control):** Biomimicry influences climate control systems, incorporating natural ventilation and mechanisms inspired by ecosystem behaviors for a dynamic and responsive biome environment. 3. Ecosystem Level (Biodiversity and Water Management):** Biomimicry guides the selection and arrangement of plant species to replicate natural biodiversity. Water management systems mimic efficient water use and distribution observed in natural ecosystems.

II.7 Comparative analysis

TABLE 07 : COMPARATIVE TABLES BETWEEN EXEMPLES

The exemple	Climate type	The approach	Inspiration model from the nature	The goal	Biomimicry level	SD pillar used	The result	Public friendly spaces
The Eastgate Center  FIGURE 30 :THE EASTGATE CENTER	Humid subtropical climate	Direct	 FIGURE 31 :WHITE AFRICAN TERMITS MOUNDS	Climat control	Behaviour	Environmental	Improved energy efficiency and climate control inspired by natural ventilation systems	NO
Esplanade Theatre “The Durian”  FIGURE 32 : ESPLANADE THEATRE “THE DURIAN”	Tropical climate	Direct	 FIGURE 33 : ESPLANADE THEATRE “THE DURIAN”	iconic and functional	Organisme	Environmental social	Innovative and iconic architectural design inspired by organic forms in nature.	YES
Council House 2  FIGURE 34 : COUNCIL HOUSE 2	Oceanic climate	Indirect	Termite mound  FIGURE 35 : TERMITE MOUND	High-performance	Organisme and behaviour	Environmental social	Sustainable and energy-efficient office building design influenced by natural systems.	NO
National museum of Qatar  FIGURE 36 : NATIONAL MUSEUM OF QATAR	Desert climate	Direct	The desert rose.  FIGURE 37 : THE DESERT ROSE	optimizing energy efficiency, material innovation, and cultural representation	Organisme Écosysteme	Environnement	Sustainable buliding with sustainble Landscaping. Aesthetics and iconic building with strong Cultural/local Representation	YES
The Eden Project  FIGURE 38 : THE EDEN PROJECT	Mild maritime climate	Indirect	 FIGURE 39 : SOAP BUBBLES	Environmental education and conservation through immersive biomes.	All	Environmental Economic social	Immersive biomes showcasing biodiversity, replicating natural ecosystems for environmental education and conservation	YES

II.8 CONCLUSION

This chapter has served as a comprehensive exploration, offering a nuanced framework for comprehending biomimicry and its potential applications in design. We have delved into the intricacies of biomimetic design strategies, highlighting their unique advantages and disadvantages as inherent components of distinct design methodologies. Additionally, our discussion has shed light on the diverse classifications of biomimicry, both existing and potential avenues for exploration in the future, emphasizing their conceivable sustainability outcomes.

As we progress into the subsequent section of this dissertation, our focus will shift towards a more detailed examination of the practical applications of biomimicry in architectural design. The ultimate objective is to unravel the transformative concept of living architecture specifically tailored for hot and arid regions. By homing in on this specific context, we aim to extract valuable insights that can pave the way for innovative and sustainable solutions in the realm of architectural design, contributing to a more harmonious integration of human-made structures with the natural environment.

III CHAPTER THREE: CASE OF STUDY

IV.1 INTRODUCTION

This chapter explores the many dimensions of Bechar, a city in southwest Algeria that is tucked away in the middle of the Sahara Desert. Bechar is a highly sought-after destination for scholarly research due to its rich historical background, arid terrain, and substantial economic significance in the area. Here, we carefully 57 ndeavo Bechar's urban development, looking at the complex patterns of expansion and change that have molded the city's landscape over time. We also examine the cultural composition of the city, exploring the various ethnic, linguistic, and social dynamics that shape its dynamic identity. Moreover, we address the particular issues that Bechar faces, such as socioeconomic inequality and environmental degradation, and we investigate the creative solutions used to overcome these challenges and lead the city toward a more prosperous and sustainable future. By using this analytical framework, we hope to clarify the nuances that make up Bechar and extract knowledge that is applicable to other situations around the world. Our goal as we set out on this academic adventure is to piece together the mysterious portrait of Bechar's identity and extract insights that go beyond its geographic boundaries. We explore the city's rich historical past, charting its development over many centuries of human labor and adjustment to the arid Saharan climate. In addition, we examine the current factors at work—from cultural changes to urbanization trends—and evaluate how they affect Bechar's continued development path. Our goal is to shed light on the complex interactions that shape Bechar's current reality and future prospects by placing the city within the larger discourse of urban studies and regional development. In the end, our analysis contributes to a deeper knowledge of Bechar while also providing insightful information that is applicable to other situations facing comparable challenges with urbanization, cultural diversity, and sustainable development.

IV.2 WHY BECHAR?

Bechar is a fascinating and complex subject of research for several compelling reasons. Its location in the middle of the Sahara Desert has attracted researchers fascinated by the study of arid landscapes and environments. In addition to its geographical appeal, the city has a rich historical heritage spanning the era of pre-Islamic civilization and colonial influence, making it an attractive focus for historical and cultural studies. Furthermore, the evolution of Bechar's architectural style tells a fascinating story of structural changes through different eras. Examining current socioeconomic dynamics provides an exciting context for exploring current challenges, opportunities, and urban development initiatives. Whether you study geography, history, architecture or socioeconomics, Bechar's diverse character and complex history make it an attractive and diverse area of study.

IV.3 DISCOVERING THE CITY

IV.3.1 Etymology of "Bechar":

There are two versions of the attribution of the name "Bechar" to the region:

- First of all, all the letters and mails from neighboring areas came to
Bechar Old Ksar to collect news. Therefore, the qualifier "Bechar" means "one who brings good news." It can be inferred from the history of the area that Old Ksar was an important stop for busy 58ndeavour58 or caravans bringing news.

- A second legend states that a Muslim explorer sent by the Turkish Sultan to explore the area in the 15th century took with him a goatskin flask filled with water, hence the adjective "bechar" derived from the root "58ndeavo". The explorer and the area he came from.

IV.3.2 Geographical situation

Bechar is located in southwestern Algeria. Its geographical location close to the western border serves as the north-south hub on the southern slope of the Sahara Atlas, giving it a strategic position as a southwestern commercial and military hub. Its current status as the provincial (provincial) capital makes it the main metropolitan area in the region, which includes the governorates of Bechar, Adrar and Tindouf. National Highway 6 passes through Bechar and is considered a main axis, connecting the main cities in the north and south of the country (figure 40)

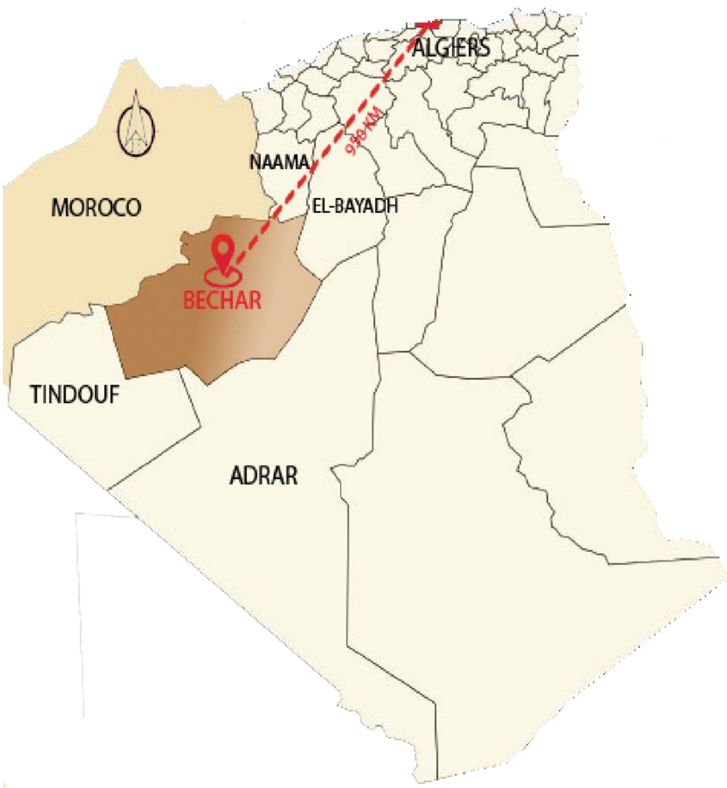


FIGURE 40 : SITUATION OF BECHAR. (ALGERIE-MONDE)

Béchar is surrounded to the north by the wilaya of Naâma, to the east by the wilaya of El Bayadh, to the west by Morocco and to the south by the wilayas of Adrar and Tindouf

IV.3.3 Bechar city situation

Béchar is located in the north of its wilaya and in the north of the Saoura territory and in the southwest of Algeria. Of which it is the capital, it is on the north-western limit of the Algerian Sahara and is part of the Saoura region. It has a single municipality of the same name, with an area exceeding 2600ha and it is located 950 kilometres southwest of Algiers the capital (figure 41).

- To the north: mougheul
- To the north-east, east and south-east by beniounif
- To the northwest by lahmar
- To the west and southwest by kenadsa
- To the southwest by abadla
- To the south by taghit

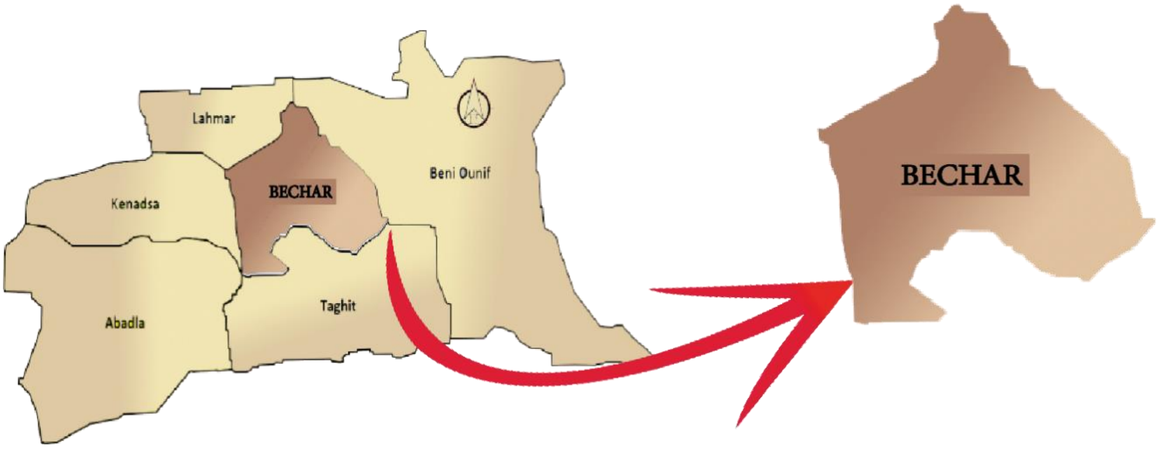


FIGURE 41 : SITUATION OF BECHAR CITY .(ALGERIE-MONDE)

IV.3.4 Bechar's Terrain and Region

The Wilaya region of Béchard occupies part of the western Algerian transition zone between the southern foothills of the Sahara Atlas and the northern edge of the Sahara Platform. Although there are some very localized mountainous and grassland areas in the north, the region is mainly dominated by the Sahara Desert and has a varied landscape. Natural boundaries of the Wilaya of Beshar:

The Bechar region is naturally bounded by the Sahara Atlas to the north, its western extension by the Moroccan Atlas, the Hamada of Draa to the west, and the Tidykert oasis to the east, and is submerged in the depths of the Atlas Tanezluft. South

IV.3.4.1 Béchar 's Geographical Mosaic

The topography of the city of Bechar consists of numerous natural elements of different shapes and textures. These are two bargas intersected by parallel ridge lines and convergence zones of these elements with linear palm groves along the direction of the wadi they encircle. This confluence zone forms two plateaus on either side of the palm forest. The first one is located to the east of the palm forest and is triangular in shape, the top of which is a confluence zone, but the sides of the palm forest and Braga form an angle of about 45 degrees, making it difficult to the depth of is expanding. , gradually heading south. His second plateau, located east of the palm grove, begins in the trust zone. It is surrounded by wadis to the south, palm groves to the west, Braga to the north, and open fields to the east. Natural element topology defines and organizes locations as follows:

58. Wadi .2. palm grove. 3. Braga 4. Merging zone 5. First board 6. Second plate. 7. The space between Braga.

IV.3.4.2 The relief

The territory of the wilaya of Béchar is made up of five (5) main reliefs: Mountains, wadis, valleys, regs (Hamada) and ergs.

-The mountains: They are bare and sometimes high. Let us mention: Jebel Antar (1953 m), Djebel Grouz (1,835 m) and Djebel Béchar (1206 m).

-The oueds: Six main oueds crisscross the wilaya. From North to South, we find: Oued Namous, Oued Zouzfana, Oued Béchar, Oued Guir, Oued Saoura and Oued Daoura.

-Valleys: These are depressions shaped by major rivers. The main ones are those of Zouzfana, Guir and Saoura

- Les Reg (Hamada): These are enormous rocky expanses. The most important are those of Guir and Daoura.

- The ergs are massive dunes that can reach up to 300 meters in height and sit on vast surfaces. The existing ergs have the names: Grand Erg Occidental, Erg Erraoui, Erg El Atchane, and the Erg

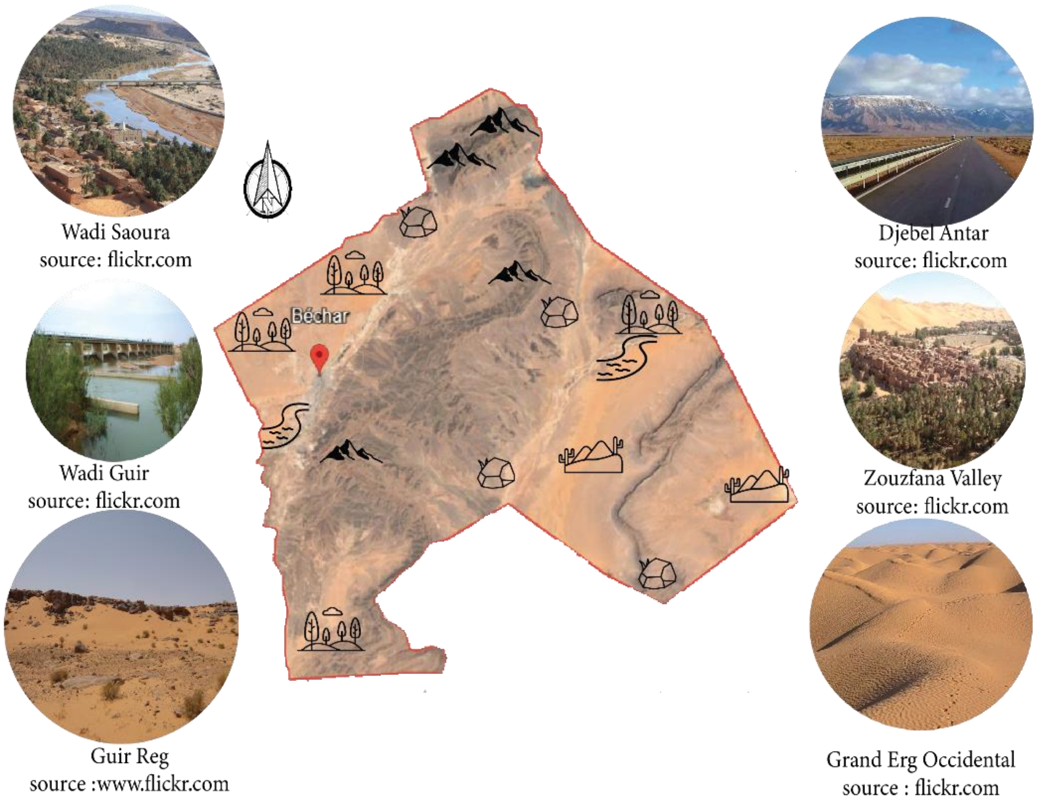


FIGURE 42 : THE RELIEF OF BECHAR (SOURCE :AUTHOR)

I.1.1 HOW TO GET TO BECHAR ?

To get to Bechar City center:

- By the national road RN6 east west, from Abadla and Taghit in the west,
- From RN41 by
- Kannadsa in the northwest.
- And from RN6 by Wekda in the east.

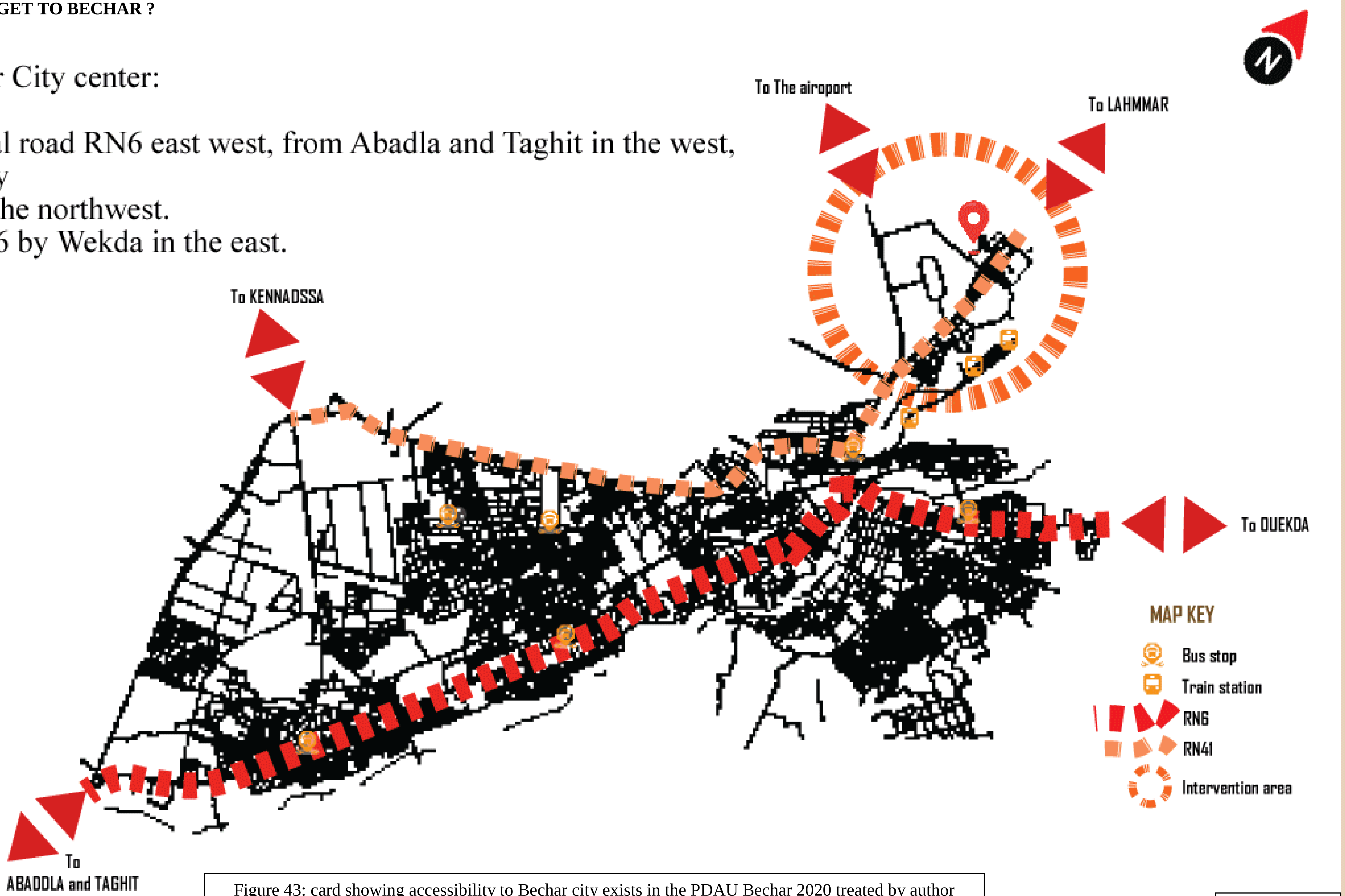


Figure 43: card showing accessibility to Bechar city exists in the PDAU Bechar 2020 treated by author

Scale :1/3800

I.1.2 Famous landmarks

The selection of these major places was based on our visit to the site and on conversations with people about the famous landmarks that define the city and that locals commonly use to orient themselves.

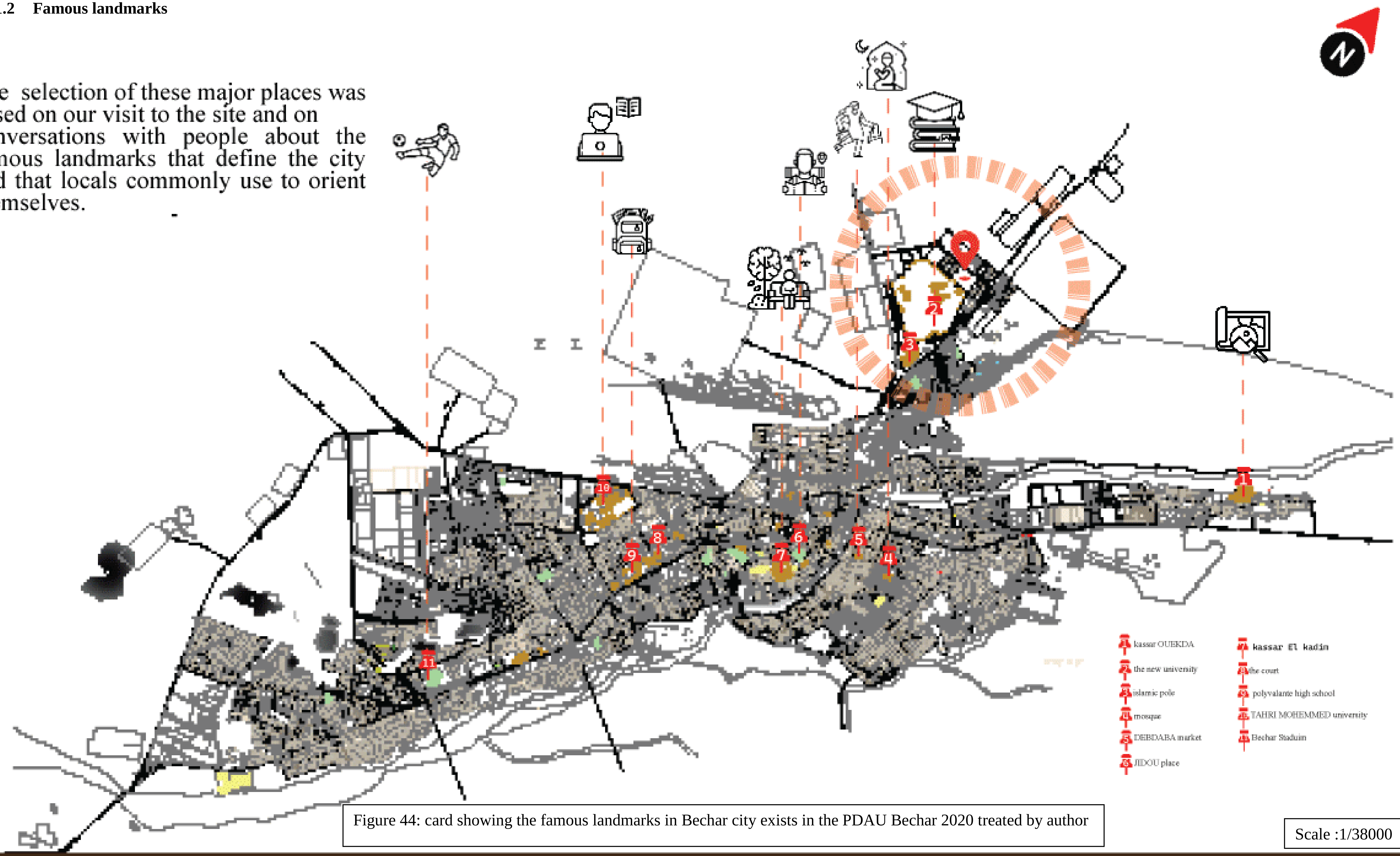


Figure 44: card showing the famous landmarks in Bechar city exists in the PDAU Bechar 2020 treated by author

Scale :1/38000

I.1.3 Zoning

- Engaging in this type of zoning helps us identify the optimal area for our project.
- to makea historical energetic link
- Highlight on the need for a shift towards more sustainable and environmentally friendly practices in response to the current environmental challenges.
- biomimicry as a new kind of harmony and sustinibility at the same time.

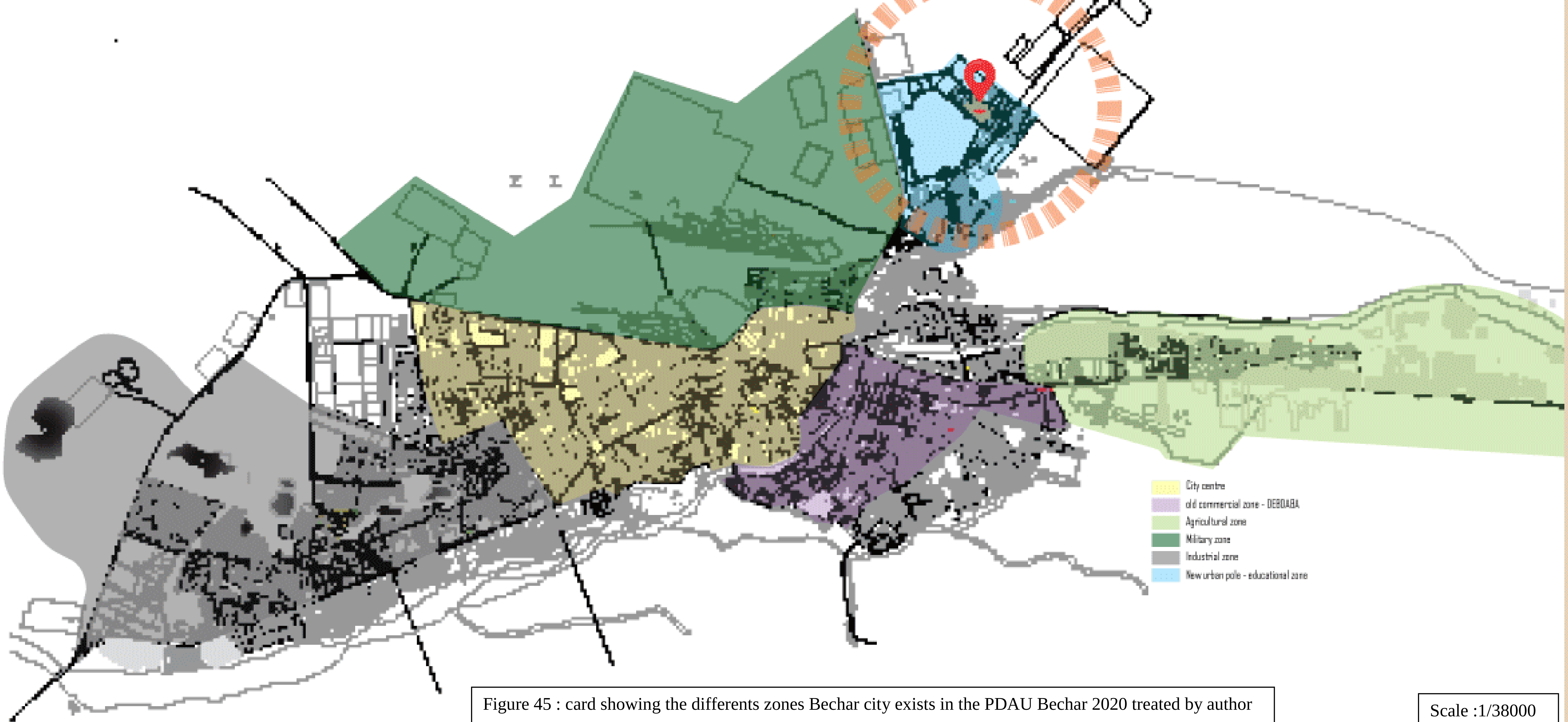


Figure 45 : card showing the differents zones Bechar city exists in the PDAU Bechar 2020 treated by author

Scale :1/38000

I.1.4 Between legacy and modernity

We easly observe a remarkable absence of local identity and a fortuitous presence of an undefined style throughout the city. There is a pressing need for change, for the establishment of a distinctidentity and harmony. Could contrast be the solution?

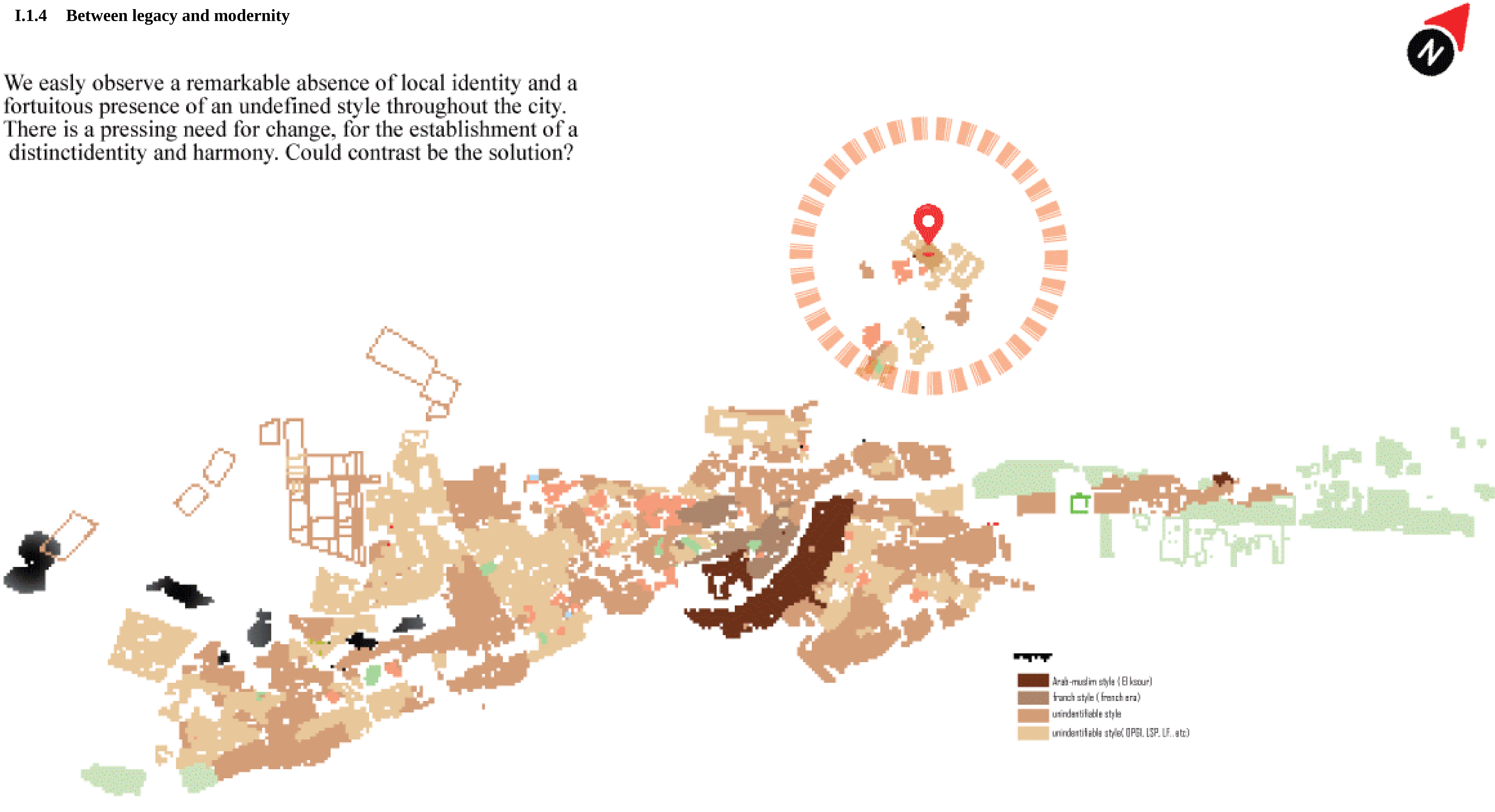


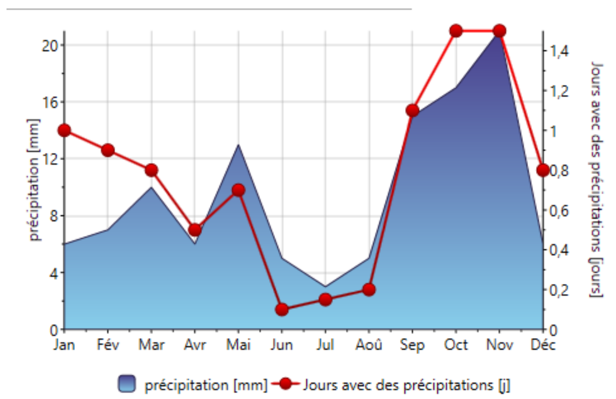
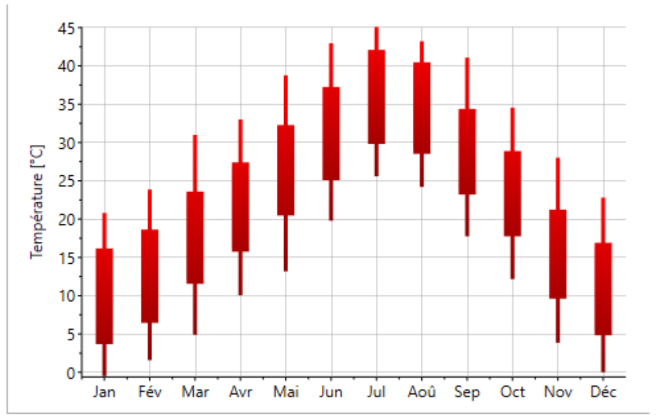
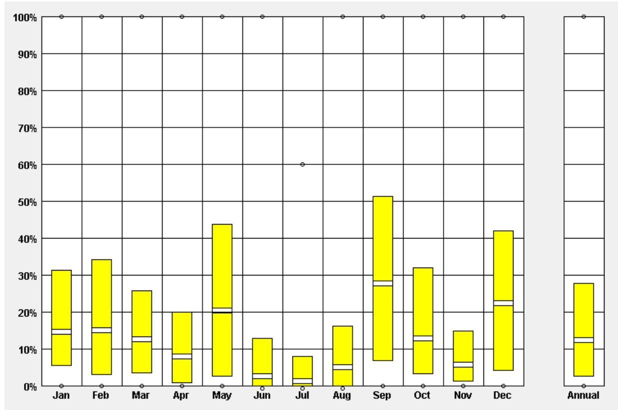
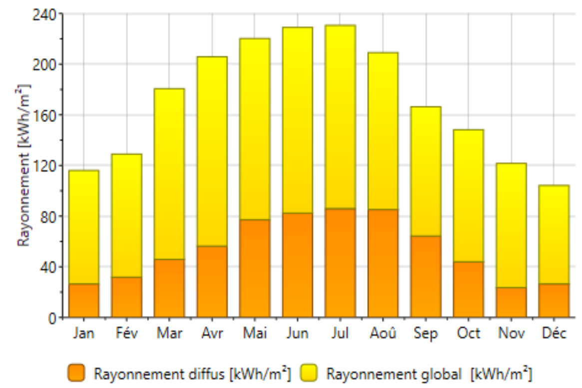
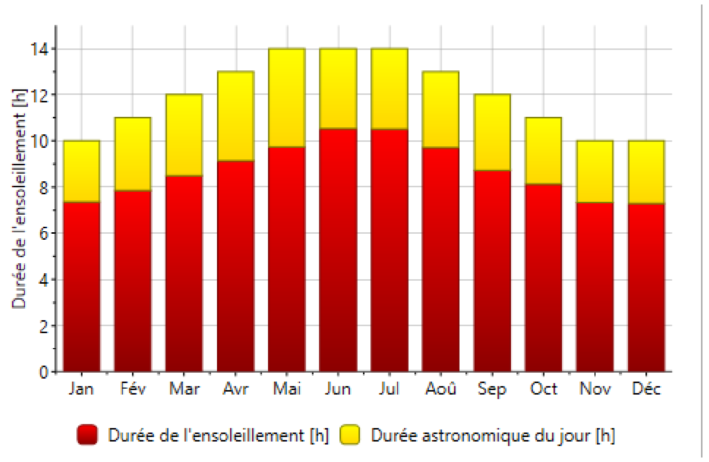
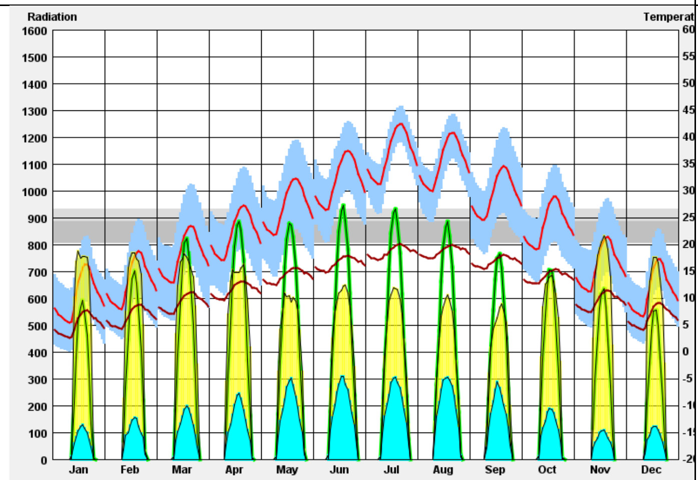
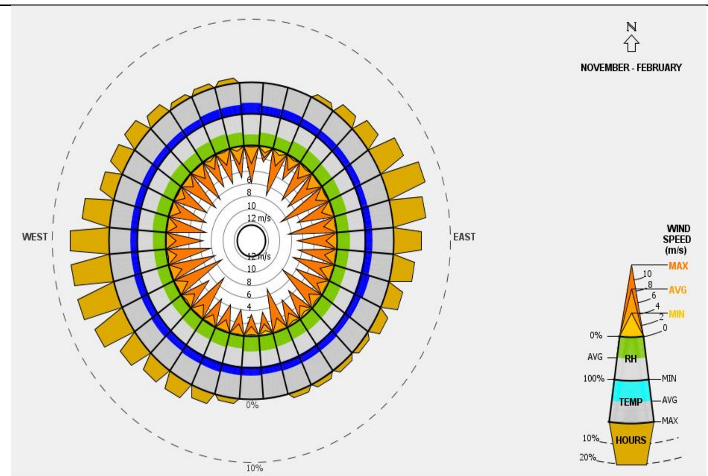
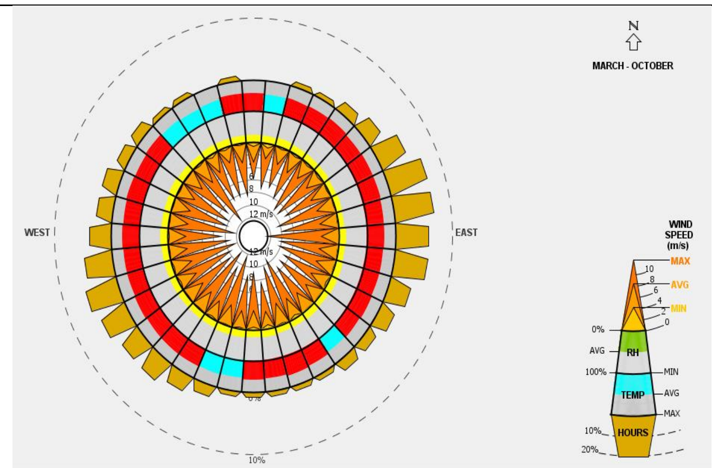
Figure46: card showing the legacy and modernity in Bechar city exists in the PDAU Bechar 2020 treated by author

Scale :1/38000

IV.3.5 It's so hot right there!

In this analysis we will develop a climatic analysis, presentation of climatic data to have an overall idea of the climatic stage of our case study through two software Meteonorm 8 and Climate Consultant V6 developed by the University of California

TABLE 7 : CLIMATIC ANALYSIS OF BECHAR CITY (SOURCE : AUTHOR)

Precipitation	Temperature	Sky cover	Radiation
 FIGURE 43 : PERCIPITQTION GRAPH , (SOURCE : METEONORM 08) The maximum amount of rainfall is 25 mm, the minimum is 3mm in July.	 FIGURE 44: TEMPERATURE GRAPH, (SOURCE: METEONORM 08) The temperature varies between Tmax: 43°C in July and Tmin: 4°C in January.	 FIGURE 45 : SKY COVER GRAPH, (SOURCE: CLIMATE CONSULTANT) - in September the cloudiest of the year overall cloudy is 37 - In July, the clearest day of the year is mostly clear is 95% cloudy.	 FIGURE 46 : RADIATION GRAPH , , (SOURCE : METEONORM 08) The length of the day in Béchar varies significantly over the course of the year. The shortest day is in December; the longest day is in July,
Sunshine	**Humidity**	**Wind whell "winter"**	**Wind whell "summer"**
 FIGURE 47 : SUNSHINE GRAPH , (SOURCE : METEONORM 08) -In the months of December, November and January the duration of sunshine is 10 hours -The sunniest months are May June and July	 FIGURE 48 : HUMIDITY GRAPH, (SOURCE: CLIMATE CONSULTANT) -The confort zone (in gray) intrects with the outdoor air 66ndeavour66e almost throught all 66ndeav of the year	 FIGURE 49 : WIND WHEEL WINTER, (SOURCE: CLIMATE CONSULTANT) During winter, the winds have a maximum speed of 9 m/s and a minimum of 0m/s. The winds direction in Bechar is mainly from the north	 FIGURE 50: WIND WHELL SUMMER, (SOURCE: CLIMATE CONSULTANT) The maximum speed in summer is 16 m/s -The winds blow in tow direction southwest and southest during summer

IV.3.5.1 Synthesis

FIGURE 51 : CLI,MATIC SYNTHESIS, AUTHOR

The climate of the wilaya of Béchar is continental desert type which is characterized by a very hot summer (+45°C) and a very cold winter (2°C to 3°C). Precipitation is low. Sand winds are very frequent and violent

IV.3.6 AFOM analysis

It is a tool combining the study of the strengths and weaknesses (internal factors) of an object of study (territory, or sector) with the opportunities and potential threats (external factors) on the environment in order to define a development strategy and contribute to the study of the relevance and coherence of future action (in the short, medium or long term). The AFOM analysis tends to guide the development strategy by maximizing the potential strengths and opportunities and minimizing the effects of weaknesses and threats.
Table below

strengths	weaknesses
-potential of renewble energy: Rich solar resources and wind -Rich land resources	-Absence of consistency between the new pole and the city center due to: -Lack of mobility and means of transportation -Undifined architectural style -Lack of vegetation -Insufficient awareness of social and environmental benifits of salar and wind energy and the low density.
opportunities	threats

-The proximity to the university and its equipements -The new islamic pole -The health pole -Empty lands for future Infrastructures -the demend for more public spaces	-The river which is in the center of the city Climate change challenges Slow execution of the project

IV.4 PRESENTATION OF THE INTERVENTION AREA

IV.4.1 Study area location

our study area “Trig lahmar” situated in the north east of Bechar city

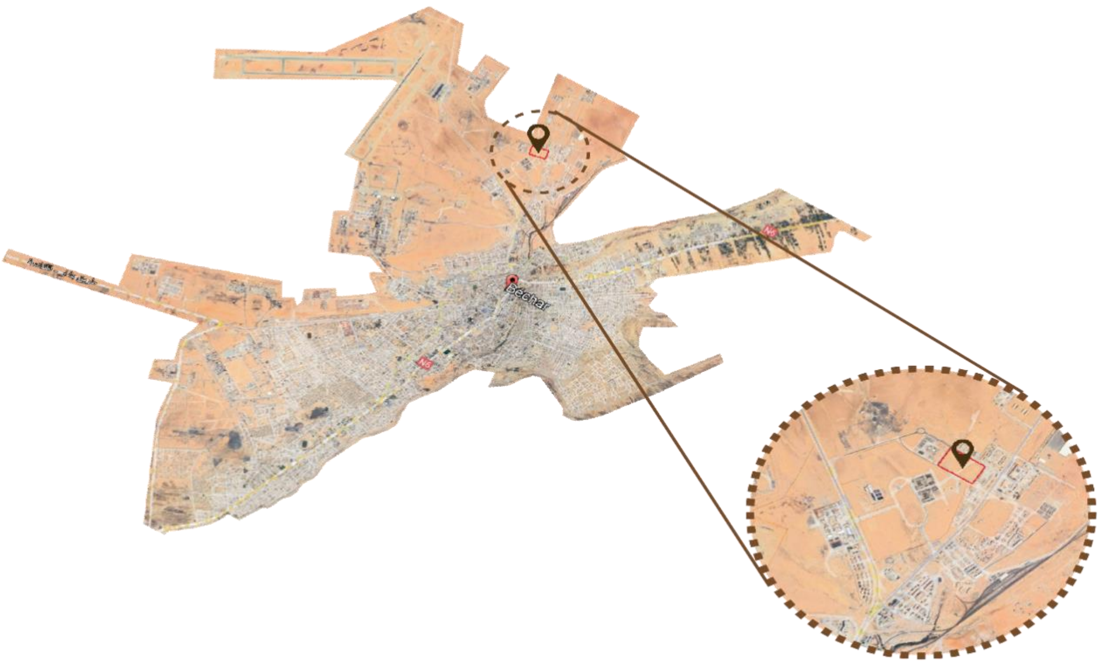


FIGURE 52 : THE STUDY AREA LOCATION IN BECHAR CITY

IV.4.2 Urban intervention

IV.4.2.1 Proposed action plan

With emphasis on the pillars of sustainable development and urban planning actions.

We have taken the following urban planning measures:

- Redevelopment: endeavour the public space. Creating a bus station pedestrian roads.

-Densification: filling the empty space around the site with projects that could have links with ours.

The pillars of sustainable development:

- Social Pillar: highlight on the importance of individuals so interduce the concept of public friendly project. To link people with our project.

- Economic Pillar: Ensuring energy efficiency through passive and active strategies

- Environmental pillar: the use of renewable energies.reduce carbon footprint by Afforesting roads edges.creating bikes line and stations.

- Local Governance: Our project was already planned in Béchar city but it wasn't ashived. So it's going to be a endeavour need.

The objective is to establish an energy campus that meets the rising demand for sustainable energy while incorporating biomimicry principles for environmental harmony. Means: create a unique building style that respects local identity, emphasizing public-friendly spaces inspired by natural ecosystems. The campus will feature green areas, water features, and interactive installations to foster community engagement and well-being. Additionally, renewable energy sources suchas solar and wind power will be integrated, aligning with nature's efficient energy conversion systems to minimize carbon footprint and transition from carbon-based to renewable resource

IV.4.2.2 Master plan concept

FIGURE 53 : DRAW THAT SHOWS CONCEPT IDEA(SOURCE : AUTHOR)

With Biomimicry, we could create a marvelous environment in a new urban space, filled with upcoming projects, addressing the lack of local identity.

Harnessing the principles of Biomimicry, we have the opportunity to craft an extraordinary urban environment within the upcoming projects, addressing the prevalent lack of local identity. By drawing inspiration from nature's design solutions, we can infuse the new urban space with organic harmony and functionality, fostering a sense of belonging and connection for its inhabitants. Biomimicry offers a transformative approach, enabling us to emulate nature's efficiency, resilience, and beauty in our architectural and urban planning endeavors.

In this envisioned urban landscape, buildings could mimic the efficiency of ecosystems, utilizing renewable energy sources and optimizing resource usage to minimize environmental impact. Streets and public spaces could echo the intricate patterns and flow found in natural systems, creating engaging and dynamic environments that invite exploration and interaction. By integrating elements inspired by the local ecosystem, such as native flora and fauna, the new urban space can cultivate a distinct sense of place, celebrating the unique identity and heritage of the region. Through Biomimicry, we have the potential to shape not just a physical environment, but also a cultural and social ecosystem that nurtures vitality and resilience for generations to come.

IV.4.2.3 Master plan steps

IV.4.2.3.1 <u>Limits and access</u>

In our pursuit of understanding and intervention, we've drawn boundaries, confining our exploration to a modest expanse of 150 hectares(figure 59). Within this delimited space lies our focal point, our site of intervention, encompassing a mere 7.10 hectares. Within these confines, we delve deep, probing, endeavour, and ultimately seeking avenues for meaningful change. Despite the limitations of our canvas, our ambitions are boundless, and within these designated borders, we strive to enact significant impact and foster positive transformation

FIGURE 54 : CARD THAT SHOW LIMITS AND ACCESS ; SCALE 1/600 (SOURCE : AUTHOR)

IV.4.2.3.2 Road rustructuration

Within this limited expanse, we embark on a transformative endeavour, reshaping the landscape by envisioning anew. Our strategy to repurpose the existing roads as the blueprint for our innovation, projecting their trajectories to forge fresh pathways. Through this calculated approach, we breathe life into dormant spaces, weaving a tapestry of connectivity and accessibility. As we reimagine the terrain, the lines of possibility extend far beyond the confines of our designated area, propelling us towards a future where ingenuity knows no bounds

FIGURE 55 : CARD THAT SHOW ROAD RUSTRUCTURATION SCALE 1/600(SOURCE : AUTHOR)

IV.4.2.3.3 Mobility & links

In our quest to bridge the gap between our study area and Bechar's bustling city center (figure 61), we embarked on a multifaceted approach aimed at bolstering connectivity and sustainability. Our first step involved the establishment of strategically placed bus and bicycle stations, serving as pivotal hubs for commuters navigating between the urban hub and our intervention site.

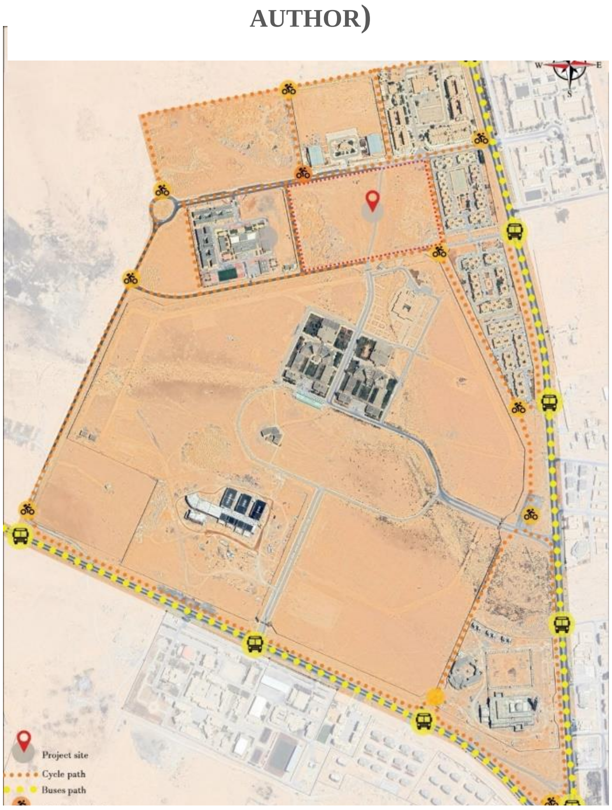


FIGURE 56 : CARD THAT SHOW MOBILITY & LINKS ; SCALE 1/600 (SOURCE : AUTHOR)

But our vision didn't stop there. Mindful of our environmental footprint, we meticulously integrated pedestrian and bicycle lanes into the urban fabric, fostering a harmonious blend of mobility and ecological consciousness. These dedicated pathways not only facilitate smoother transit but also promote healthier, more sustainable modes of transportation, aligning with our commitment to environmental stewardship. In weaving together, these elements of infrastructure and eco-conscious design, we’ve not only strengthened the physical connection between our study area and the city center but also laid the groundwork for a more vibrant, interconnected community one where movement is fluid, and the environment thrives in tandem with human activity

IV.4.2.3.4 *Availble fonctions*

Through careful observation and meticulous analysis of the existing spaces and functions within our study area (figure 62), we unveil a roadmap for evolution and enhancement. Our approach is rooted in understanding, a deep dive into the intricacies of each corner, each function, each interaction. Armed with this knowledge, we craft a proposal that seamlessly integrates with the fabric of what already exists while addressing unmet needs and aspirations.

FIGURE 57 : CARD THAT SHOW LIMITS AND ACCESS SCALE 1/600 (SOURCE : AUTHOR)

Our methodology is twofold: we identify spaces that complement the existing landscape, enriching it with new dimensions of utility and purpose. Simultaneously, we pinpoint gaps, areas where needs remain unfulfilled or opportunities lay untapped. Here, we introduce innovative solutions, sculpting spaces that serve as conduits for community engagement, cultural expression, and collective well-being.In essence, our proposal is not just about erecting new structures or repurposing old ones; it’s about sculpting experiences, shaping environments that resonate with the rhythm of life and the pulse of human interaction. By marrying careful analysis with creative vision, we strive to craft spaces that not only meet the needs of today but also anticipate the aspirations of tomorrow.

Building upon the previous map, this one illustrates future spaces to be developed in correlation with the existing

IV.4.2.3.5 Reality vs vision

Starting from the previous map, this new rendition aims to outline the prospective areas earmarked for development in tandem with the existing infrastructure(figure 63). By overlaying projections onto the existing landscape, it provides a comprehensive vision of how urban or rural spaces might evolve in the future. This forward-looking approach integrates considerations such as population growth, economic trends, and environmental factors to guide strategic planning initiatives.

The map serves as a blueprint for sustainable development, ensuring that future expansion aligns with existing resources and community needs. By identifying potential growth areas and infrastructure requirements, it facilitates proactive decision-making to support balanced and inclusive development. Moreover, it fosters collaboration among stakeholders, encouraging dialogue and coordination to realize shared goals for the enhancement of the built environment.

FIGURE 58 : CARD THAT SHOW OUR VISION ; SCALE 1/600(SOURCE : AUTHOR)

IV.4.3 master plan

FIGURE 59 : MASTER PLAN , SCALE 1/2000 SOURCE : PDAU BECHAR 2020 ,(TREATED BY THE AUTHOR)

IV.4.4 When the climate become a POWER source!

The climate data used for the simulations covers the period from 2007 to 2021 for the city of Bechar. The energy analysis is conducted using the Climate Consultant V6 psychometric diagram developed by the University of California. See the figure below.

By applying the adaptive thermal comfort model, comfort thresholds are limited

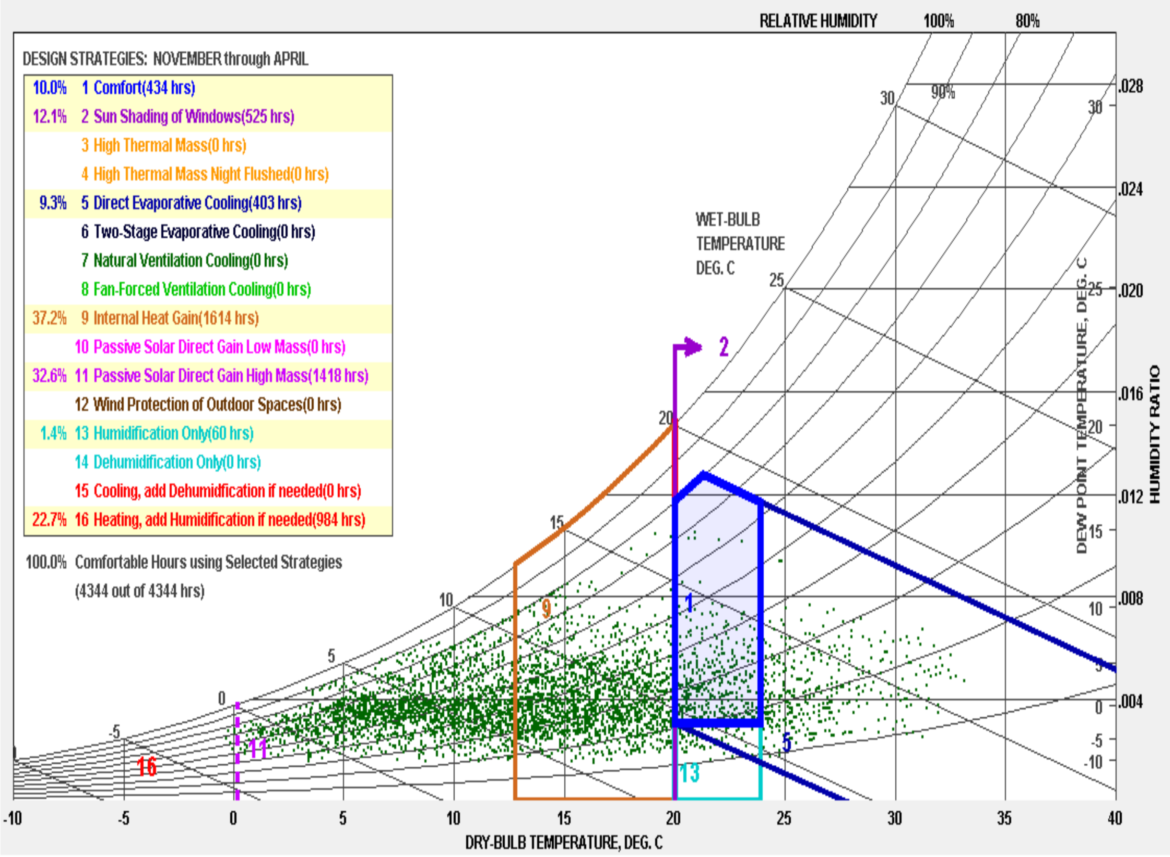


FIGURE 60 : PSYCHOMETRIC DIAGRAM OF BECHAR CITY DURING WINTER(SOURCE : CLIMATE CONSULTANT V6)

The analysis of the psychrometric chart shows us that throughout the months from January to December, the climate in Bechar is only comfortable for 10% (434 hours) due to the average temperatures ranging between 20°C and 25°C. Internal heat gains represent the least significant factor, while passive solar gains and thermal mass could further enhance comfort to 32.6 % (1418hours) and 22.7% (984 hours) respectively to heating in winter

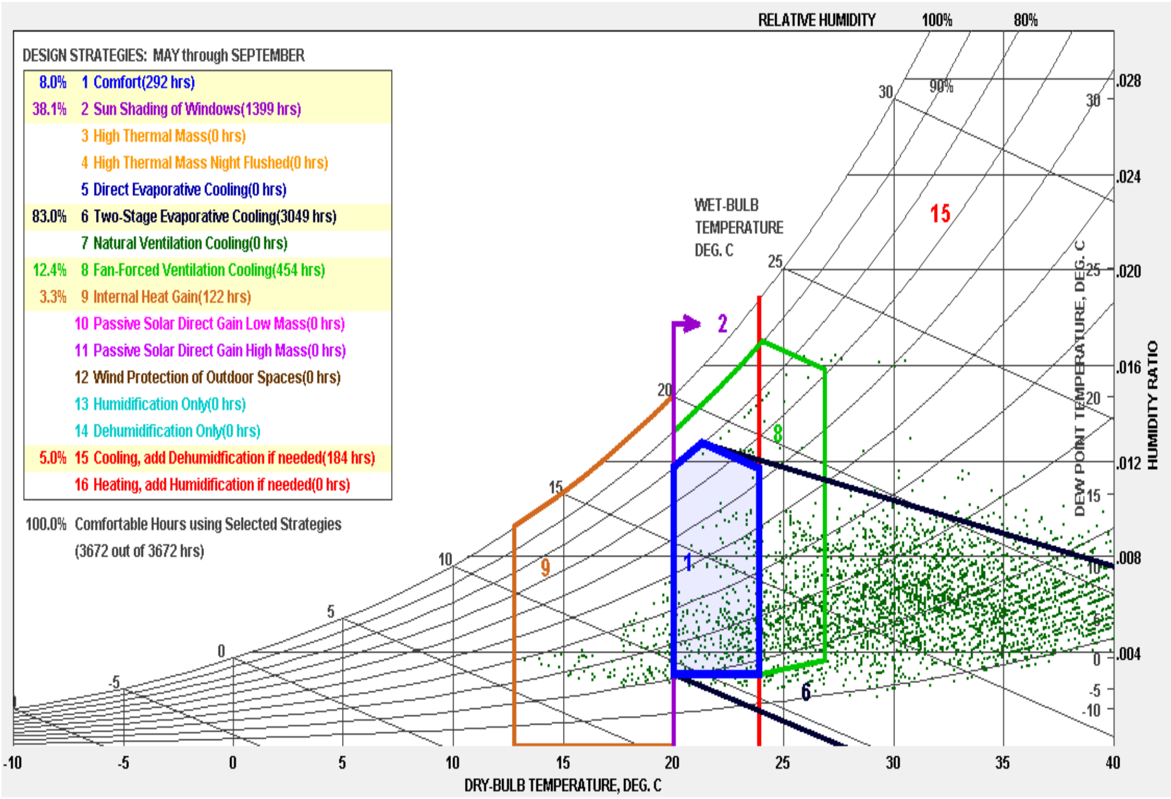


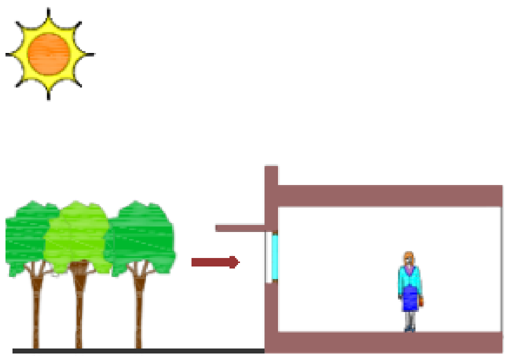
FIGURE 61 : PSYCHOMETRIC DIAGRAM OF BECHAR CITY DURING SUMMER(SOURCE : CLIMATE CONSULTANT V6)

In summer found that the cooling is 5 % (184 hours) and evaporative cooling with 83 % (3049 hours).

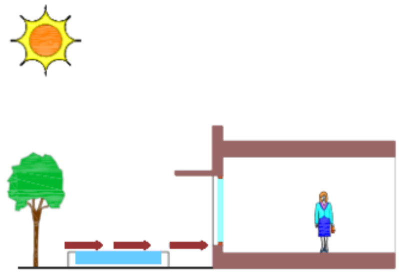
Through this analysis of the Sozoklay diagram, we have been able to derive overall recommendations on humidification , heating strategies in winter and ventilation in summer using passive solutions by solar protection , ensuring thermal comfort throughout the year in the city of Bechar.

After conducting an energy analysis, we discovered the necessity of implementing certain strategies:

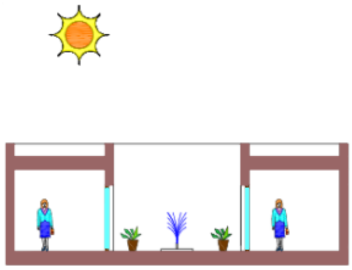
58. Humidification



An example of humidifying air by exposing it to vegetation.



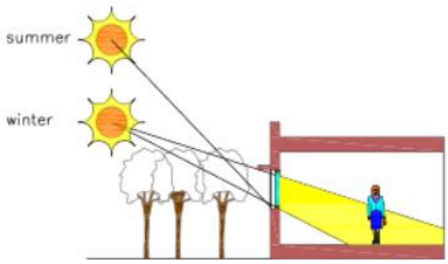
Air humidification through contact with accumulated water



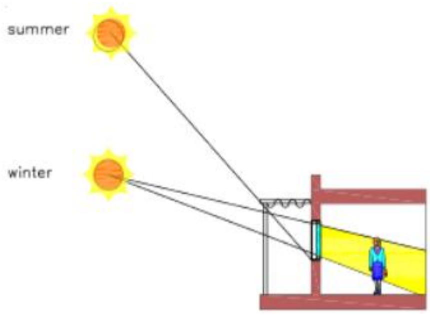
An instance of air humidification occurring through contact with vegetation within a building’s enclosed space, such as a patio

FIGURE 62: HUMIDIFICATION STRATEGIES(SOURCE : AUTHOR)

B. Solar protection



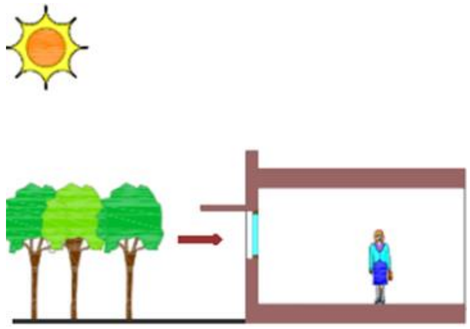
Solar protection facilitated by deciduous vegetation.



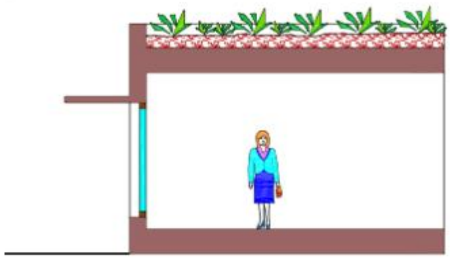
A pergola featuring a canopy of deciduous vegetation, providing solar protection

FIGURE 63: SOLAR PROTECTION STRATEGIES(SOURCE : AUTHOR)

E. Cooling systems



Utilizing exterior vegetation for evaporative cooling purposes.



roof vegetation for evaporative cooling

FIGURE 64: COOLING SYSTEM STRATEGIES(SOURCE : AUTHOR)

IV.5 Conclusion

In conclusion, this chapter delves into the multifaceted dimensions of Bechar, an intriguing city in southwest Algeria, situated amidst the vast expanse of the Sahara Desert. Through urban development, and cultural composition, we uncover the intricate patterns and dynamics that have shaped the city's unique identity. We also highlight the socioeconomic and environmental challenges Bechar faces, along with the innovative strategies implemented to address these issues, aiming for a more prosperous and sustainable future. By placing Bechar within the broader context of urban studies and regional development, our analysis not only enhances our understanding of this remarkable city but also offers valuable insights applicable to other regions grappling with similar challenges. Ultimately, this exploration of Bechar contributes to the global discourse on urbanization, cultural diversity, and sustainable development, providing a nuanced perspective on how cities adapt and thrive in challenging environments.

V CHAPTER FOUR : SIMULATION AND RESULTS

V.1 INTRODUCTION

In the pursuit of energy efficiency and sustainability, building energy simulation has emerged as a critical tool for modern architecture and engineering. This chapter delves into the intricacies of building energy simulation, also known as building performance simulation. This sophisticated process employs digital 3D models to meticulously analyze and evaluate a building's energy performance. By providing a virtual replica of a building, this technology enables stakeholders to gain profound insights into energy consumption patterns, facilitating informed design and operational decisions.

Central to building energy simulation is its capability to assess multiple factors that influence a building's overall energy consumption. These factors include heating and cooling requirements, electrical usage, water heating and consumption, thermal performance of materials, and the impact of occupancy and usage patterns. By simulating these elements, the process allows for comprehensive evaluation and optimization of energy use within a building.

The benefits of building energy simulation are extensive, ranging from increased energy efficiency and significant cost savings to enhanced sustainability through the promotion of renewable energy sources. Moreover, this technology supports regulatory compliance with energy codes and certification processes like LEED and BREEAM. By enabling scenario analysis and optimization, building energy simulation aids in identifying the most effective materials and technologies to achieve optimal energy performance.

In this chapter, we will explore the various components and applications of building energy simulation, highlighting its role in advancing sustainable building practices and its importance in modern building design and management.

V.2 What is energy simulation in building design?

Building energy simulation, or building performance simulation, is a complex process that uses digital 3D models to analyse and evaluate a building's energy performance. This advanced technology enables architects, engineers, and building managers to understand how various factors affect a building's energy consumption throughout its life cycle. By creating an accurate digital replica, the process provides detailed insights into energy usage patterns, allowing for better design and operational decisions.

The core of building energy simulation lies in its ability to evaluate multiple components and factors that influence the overall energy consumption of a building. This includes:

-Heating and Cooling: The energy required to maintain a comfortable indoor temperature, considering factors such as insulation, HVAC systems, and outside weather conditions.

-Electricity: Electrical energy consumption by lighting, appliances, equipment, and other electrical systems in a building.

-Water Usage: The energy used to heat water and overall water usage patterns within a building.

-Thermal Performance: The effectiveness of a building's insulation, affected by materials, design, and construction quality.

-Occupancy and Usage Patterns: The impact of how and when occupants use a space, including fluctuations in energy use at different times of the day or year.

Building energy modelling has a wide range of applications and offers numerous benefits. Improving and saving energy through this process can lead to increased efficiency, waste reduction, and energy optimization. These improvements lower operational costs and result in significant cost savings. Additionally, building energy simulation promotes the use of renewable energy, thereby curbing environmental impact and upholding sustainable building practices.

Moreover, building energy simulation ensures compliance with national and international energy codes, facilitating certification processes like LEED or BREEAM. Supported by scenario analysis and optimization, it allows for testing different materials and technologies to determine the best energy performance options. These aspects make building energy simulation an invaluable process in modern building design and management.

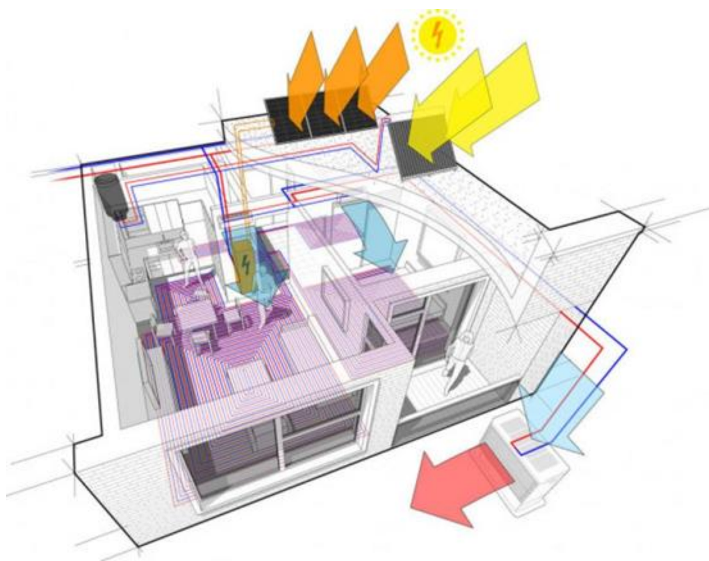


FIGURE 65 : BUILDING EFFECT ,(SOURCE , WWW.ARCH2O.COM)

V.3 What is the best energy modeling software?

The reality is that no one truly holds the solution to this imperfect query. The issue is that 'best' is subjective and open to interpretation on various levels. Some may perceive it as "the most powerful, flexible, cutting-edge software package." Yet even if it were to take five years just to grasp its usage, would it still be considered the finest? Hence, here are a handful of programs that serve the same purpose as our desired criteria

TABLE 8 : SIMULATION SOFTWARE (SOURCE , AUTHOR)

software	Description:	Strengths:	Limitations:
EnergyPlus	Developed by the U.S. Department of Energy, EnergyPlus is a powerful tool for modeling building energy consumption, lighting, ventilation, and other factors.	Highly accurate, detailed simulations, widely used in academic and professional settings.	Can be complex to use due to its detailed nature.
eQuest	eQuest is a free energy modeling tool that provides detailed simulation of building energy performance.	User-friendly with graphical interface, good for both beginners and experienced users.	Less detailed than EnergyPlus but sufficient for many applications.
IES VE (Integrated Environmental Solutions Virtual Environment)	A comprehensive tool that integrates multiple simulation capabilities including thermal, daylight, and airflow.	Highly integrated, user-friendly, strong support and documentation.	Can be expensive, steep learning curve.
TRNSYS (Transient System Simulation Tool)	TRNSYS is a flexible energy simulation tool for evaluating the performance of thermal and electrical energy systems.	Highly customizable, suitable for complex systems.	Requires more expertise to use effectively, can be costly.
OpenStudio	An open-source project providing a collection of software tools to support whole building	Free, good community support, integrated with EnergyPlus.	Interface can be challenging for beginners.

	energy modeling using EnergyPlus.		
DesignBuilder	Combines EnergyPlus with a user-friendly interface for detailed energy, carbon, lighting, and comfort analysis.	Powerful and versatile, good graphical interface	Can be expensive, requires training to use effectively.

V.4 THE SIMULATION: RESULT OF THE Thermal ASSESSMENT

V.4.1 Software choosing :

DesignBuilder is an easy-to-use modeling environment where you can work with (and play with) virtual building models. It provides a range of environmental performance data such as energy consumption, carbon emissions, comfort conditions, daylight levels, maximum summer temperatures and HVAC component dimensions

To ensure optimal thermal comfort for our building, we conducted extensive simulations using Design Builder software version 4.8. This project marks the debut of Energy Plus's fully-integrated simulation engine within a user-friendly interface, combining a graphical modeler for buildings with advanced dynamic energy simulation capabilities. This powerful tool simplifies the process of building and use case modeling, providing a swift and accurate means to analyze and enhance building performance from the early design stages.

Our primary objective was to develop a tool during the architectural design phase that would improve the effectiveness of illumination planning. To achieve this, we performed a detailed climate analysis to identify the key factors influencing the interior illumination of the museum. Accurate climatic data is crucial for this purpose, as it directly impacts natural lighting conditions and, consequently, the building's energy efficiency.

To gather this essential data, we utilized several advanced software tools. METEONORM and CLIMATCONSULTANT V6 provided comprehensive climatic information, while the DESIGN BUILDER generator was instrumental in modelling these parameters within our simulation framework. These tools enabled us to obtain precise climatic data specific to our location, allowing us to tailor our simulations to reflect real-world conditions accurately.

Moreover, this methodology supports sustainable building practices, leading to significant cost savings and a reduced environmental footprint. By leveraging cutting-edge simulation technology and comprehensive climate analysis, we are able to create buildings that are not only energy-efficient but also harmonious with their natural environment, providing a better experience for occupants and contributing positively to the community.

V.4.1.1 Why Desginbuilder

With the aid of Design Builder, we can:

- Produce an extensive array of reports and outputs to aid in evaluating the relative merits of various design options.
- Based on the client's goals, optimize the building at any point during the design process.
- Model even intricate structures in the shortest amount of time and effort.
- To help you get started with data entry, import already created CAD and BIM design data.
- Produce stunning rendered photos and videos.
- Simplify EnergyPlus thermal simulation

V.4.2 The simulation software:

DesignBuilder is a user-friendly modelling environment where you can work (and play) with virtual building models. It provides a range of environmental performance data such as: energy consumption, carbon emissions, comfort conditions, daylight illuminance, maximum summertime temperatures and HVAC component sizes

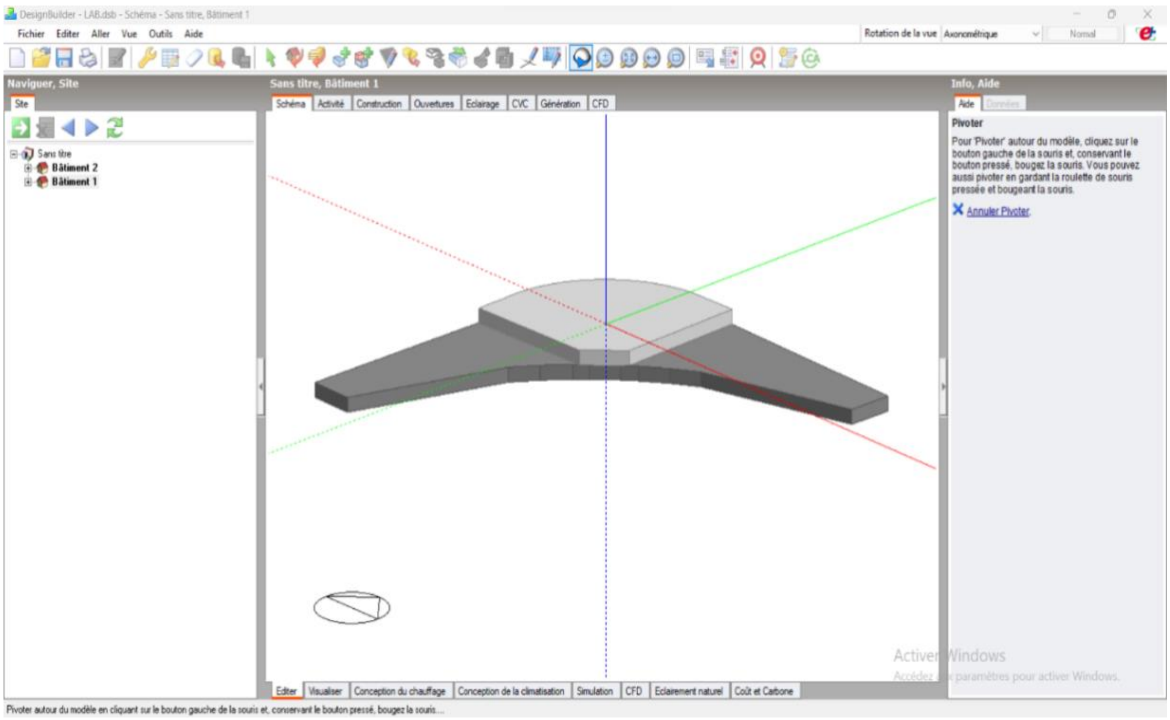


FIGURE 66 : INTERFACE OF THE SOFTWARE DESIGNBUILDER(SOURCE : DESIGNBUILDER)

It is a graph modeler with a conflictual interface for buildings; it combines fast building modeling with use scenarios to provide a dynamic energy simulation.

V.4.3 Simulation case study

We chose a lab environment to simulate our Energy Center projects to take advantage of a controlled environment, modern equipment, and collaboration with experts. This approach ensures accurate, repeatable results and handles potentially hazardous materials according to strict protocols, which improves safety. Additionally, the lab environment enables cost-effective rapid prototyping and iterative testing, accelerating development while ensuring high data quality. By simulating real-world conditions in the lab, we can thoroughly test and refine our energy systems, ensuring they are robust and efficient before being implemented in the field.

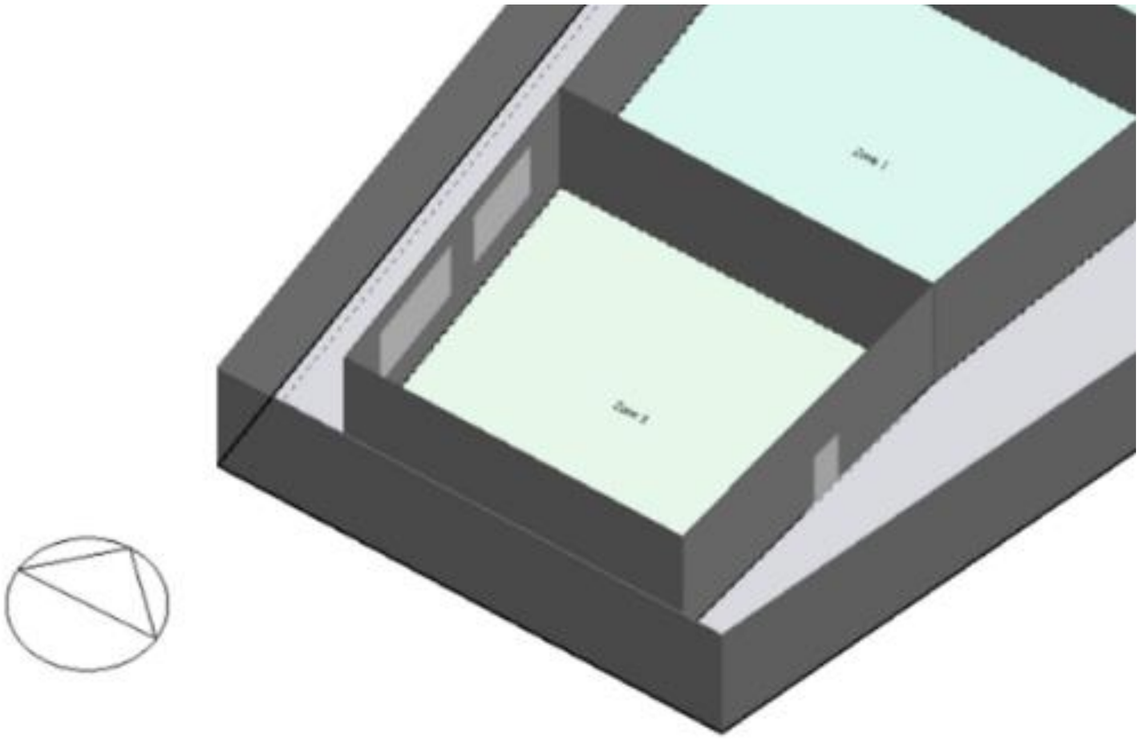


FIGURE 67: THE SPACE DESIGN LAB FROM OUR PROJECT(SOURCE : DESIGNBUILDER)

The temperature standard for research laboratories on renewable energies centers is generally between 20°C and 25°C to guarantee the accuracy of the tests and the normal operation of the equipment.

An efficient HVAC system is essential to maintaining these stable conditions shapes geometrical characteristics of our models were developed using Autocad 2D drawing, the volume was created via a 3D graphical interface integrated into the software. It displays data simulation at manual, monthly, daily and hourly intervals.

The parameters that need to be simulated are as shown in the following table:

TABLE 9 : SPACE INFORMATION (SOURCE : AUTHOR)

Space	**Orientation**	**Surface**
Laboratory	South	112 m²

V.4.4 Simulation Protocol

We conducted a simulation in the city of Béchar using the DesignBuilder software for the warmest week of the year (from July 13 to July 19) and the coldest week of the winter (from January 13 to January 19). In order to ensure annual comfort, we have also carried out a year-long simulation. (figure 68)

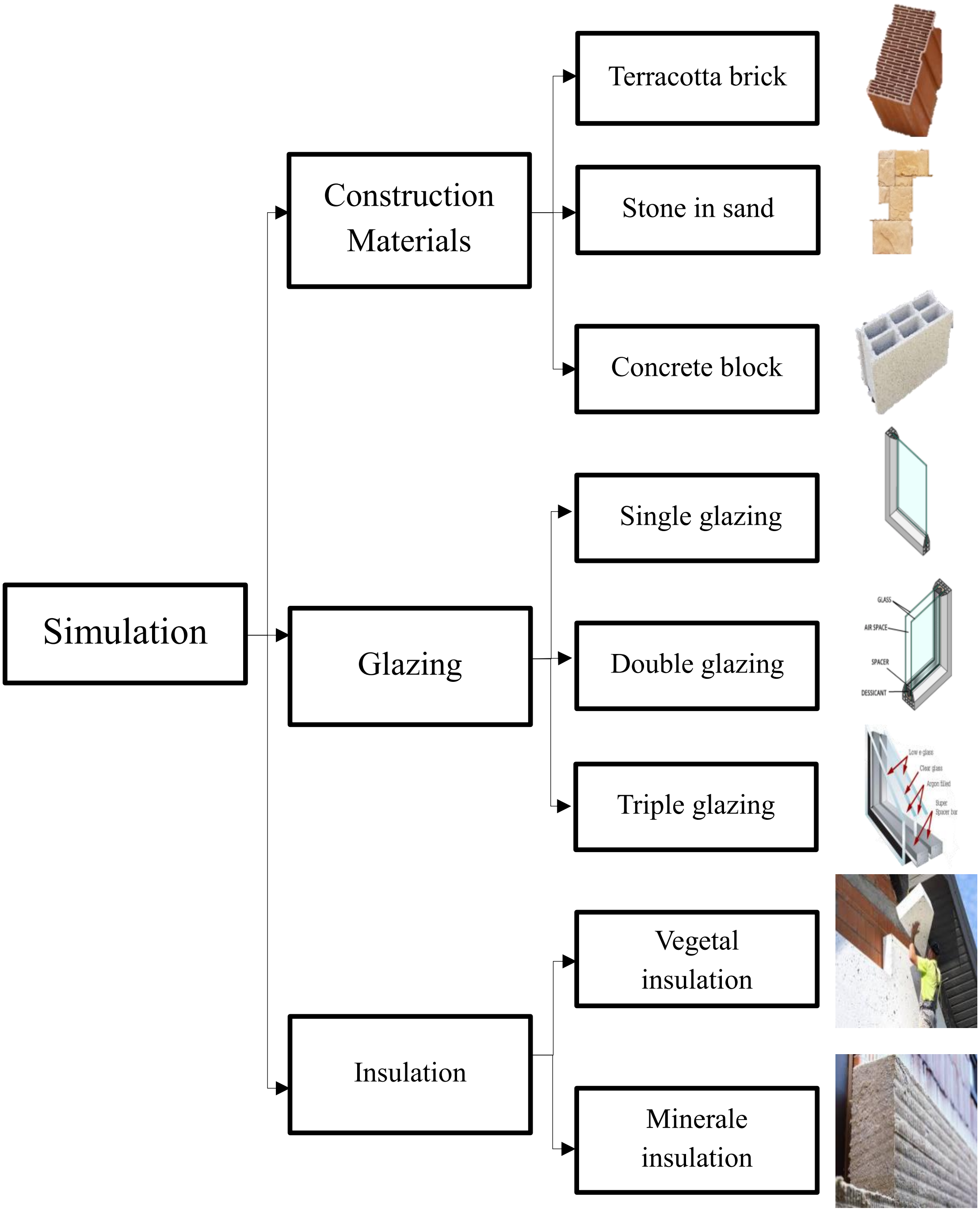
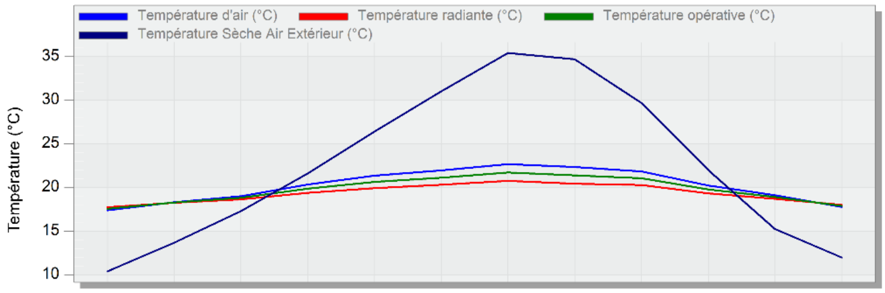


FIGURE 68:STIMULATION PROTOCOL DIAGRAM (SOURCE : AUTHOR)

V.4.4.1 Construction Materials

Terracotta brick



Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	17,39	18,29	19,00	20,33	21,36	21,95	22,67	22,35	21,83	20,22	19,12	17,77
Température radiante (°C)	17,75	18,26	18,64	19,37	19,94	20,32	20,75	20,43	20,27	19,33	18,70	18,02
Température opérative (°C)	17,57	18,28	18,82	19,85	20,65	21,13	21,71	21,39	21,05	19,77	18,91	17,90
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	32,88	27,66	26,85	32,44	27,12	32,69	34,72	35,89	41,90	41,07	30,51	32,72
Kansas Uni TSV (%)	13,76	11,28	9,17	30,90	23,80	18,27	12,87	14,85	17,34	6,49	8,74	12,26
Fanger PMV ()	-0,59	-0,48	-0,38	-1,07	-0,92	-0,76	-0,60	-0,68	-0,74	-0,13	-0,34	-0,53

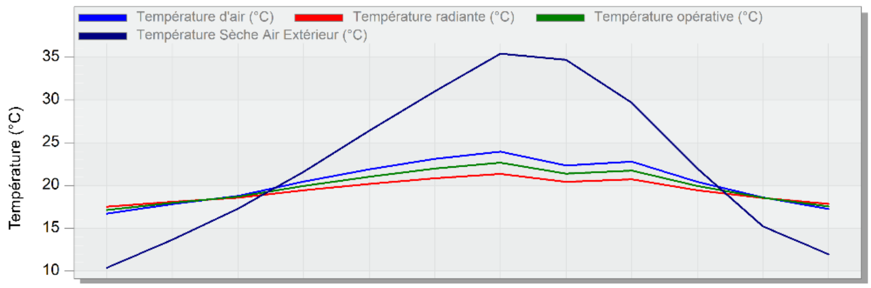
FIGURE 69 :: TABLE OF THERMAL COMFORT RESULTS AFTER USING THE TERRACOTTA BRICK (SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR.)

The following discoveries allow us to distinguish between two periods:

Periode: The temperature in May, June, July, August, and September varies from 21,71°C to 20,65°C.

Temperature swings occur in January, February, March, April, October, November, and December, ranging from 19,86°C to 17,79°C.

V.4.4.1.1 Stone in sand



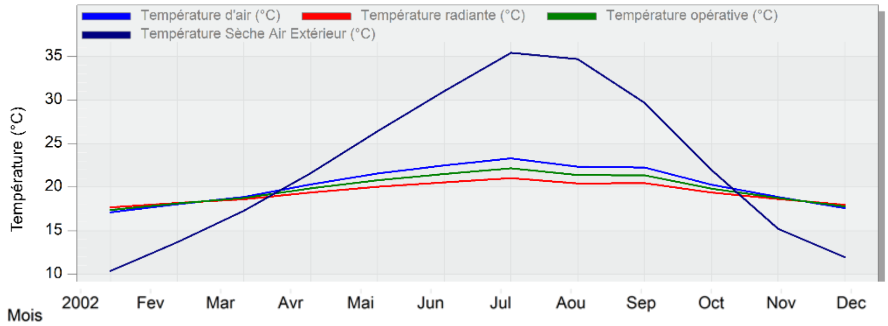
Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	16,73	17,84	18,79	20,45	21,88	23,11	23,96	22,35	22,78	20,44	18,61	17,27
Température radiante (°C)	17,53	18,11	18,58	19,45	20,19	20,85	21,37	20,43	20,72	19,45	18,54	17,85
Température opérative (°C)	17,13	17,97	18,68	19,95	21,04	21,98	22,66	21,39	21,75	19,95	18,58	17,56
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	34,09	28,41	27,18	32,38	26,57	30,90	32,39	35,89	40,14	40,79	31,26	33,66
Kansas Uni TSV (%)	15,50	12,38	9,78	31,04	22,02	15,83	11,38	14,85	15,12	7,08	9,91	13,42
Fanger PMV ()	-0,67	-0,53	-0,40	-1,04	-0,82	-0,55	-0,36	-0,68	-0,56	-0,10	-0,40	-0,59

FIGURE 70 : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE STONE IN SAND(SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR.)

Due to the obvious following discoveries, we are able to distinguish between two periods: periode: The temperature in May, June, July, August, and September varies from 22,66°C to 21,04°C.

The temperature fluctuates between 19,86°C and 17,79°C in the following months: January, February, March, April, October, November, and December.

V.4.4.1.2 Concrete block



	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	17,10	18,05	18,88	20,32	21,56	22,49	23,29	22,35	22,26	20,28	18,88	17,60
Température radiante (°C)	17,67	18,19	18,61	19,39	20,03	20,55	21,04	20,43	20,47	19,37	18,64	17,98
Température opérative (°C)	17,39	18,12	18,75	19,86	20,80	21,52	22,16	21,39	21,36	19,82	18,76	17,79
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	36,26	31,02	29,61	36,23	31,08	36,05	36,98	35,89	45,22	44,25	34,95	35,99
Kansas Uni TSV (%)	14,58	11,93	9,54	30,85	22,62	16,36	11,30	14,85	15,69	6,96	9,39	12,76
Fanger PMV ()	-0,61	-0,49	-0,38	-1,04	-0,86	-0,64	-0,46	-0,68	-0,63	-0,10	-0,35	-0,54

FIGURE 71 : : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE CONCRETE BLOCK (SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR.)

The following findings allow us to distinguish between two periods:

Level of comfort: From 22,16°C to 20,80°C is the temperature range for May, June, July, August, and September.

Sub-cooling phase: Temperature swings in January, February, March, April, October, November, and December range from 19,86°C to 17,79°C

V.4.4.1.3 Interpertation

Terracotta Brick: Offers the most stable indoor temperatures during the warmer months, which might be preferable for maintaining comfort without significant fluctuations.

Stone in Sand: Provides a warmer interior atmosphere, which may be advantageous in colder climes or unfavorable in already hot ones.

Concrete Block: Offers warmth and stability at a moderate temperature in a balanced manner

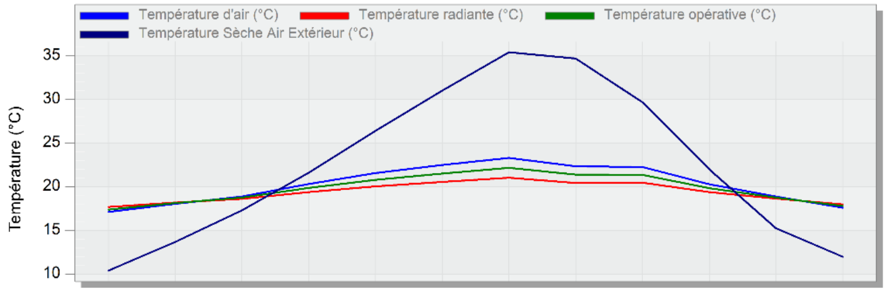
V.4.4.1.4 Results of the meterial choice

The climate of Béchar and the specific needs for thermal comfort will determine which material is best. Terracotta brick appears to be the finest choice for an interior setting that is more stable and cooler during the warmer months. If you swould rather be inside somewhere warmer, stone in sand can be a better option. Concrete blocks provide a medium ground between warmth and stability.

FIGURE 72 : THE TERRACOTTA BRICK (SOURCE : PINTEREST)

V.4.4.2 Glazing

V.4.4.2.1 Single glazing



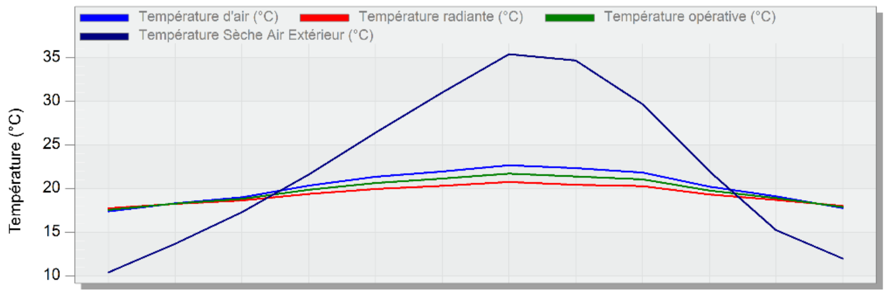
Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	17,10	18,05	18,88	20,32	21,56	22,49	23,29	22,35	22,26	20,28	18,88	17,60
Température radiante (°C)	17,67	18,19	18,61	19,39	20,03	20,55	21,04	20,43	20,47	19,37	18,64	17,98
Température opérative (°C)	17,39	18,12	18,75	19,86	20,80	21,52	22,16	21,39	21,36	19,82	18,76	17,79
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	36,26	31,02	29,61	36,23	31,08	36,05	36,98	35,89	45,22	44,25	34,95	35,99
Kansas Uni TSV (%)	14,58	11,93	9,54	30,85	22,62	16,36	11,30	14,85	15,69	6,96	9,39	12,76
Fanger PMV ()	-0,61	-0,49	-0,38	-1,04	-0,86	-0,64	-0,46	-0,68	-0,63	-0,10	-0,35	-0,54

FIGURE 73 : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE SINGLE GLAZING (SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR)

Phase 1: The temperature range is 20,80°C to 22,16°C. This period includes five months: May, June, July, August, and September.

Phase 2: The temperature range is 17.27°C to 19,86°C. This period includes seven months: January, February, March, April, October, November, and December.

V.4.4.2.2 Double glazing



Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	17,39	18,29	19,00	20,34	21,36	21,95	22,67	22,35	21,83	20,22	19,12	17,77
Température radiante (°C)	17,75	18,26	18,64	19,37	19,94	20,32	20,76	20,43	20,28	19,33	18,70	18,02
Température opérative (°C)	17,57	18,28	18,82	19,86	20,65	21,13	21,71	21,39	21,05	19,78	18,91	17,90
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	32,88	27,65	26,84	32,44	27,12	32,69	34,71	35,89	41,90	41,07	30,50	32,71
Kansas Uni TSV (%)	13,76	11,27	9,16	30,88	23,78	18,26	12,86	14,84	17,33	6,49	8,73	12,25
Fanger PMV ()	-0,59	-0,48	-0,38	-1,07	-0,92	-0,76	-0,60	-0,68	-0,74	-0,13	-0,34	-0,53

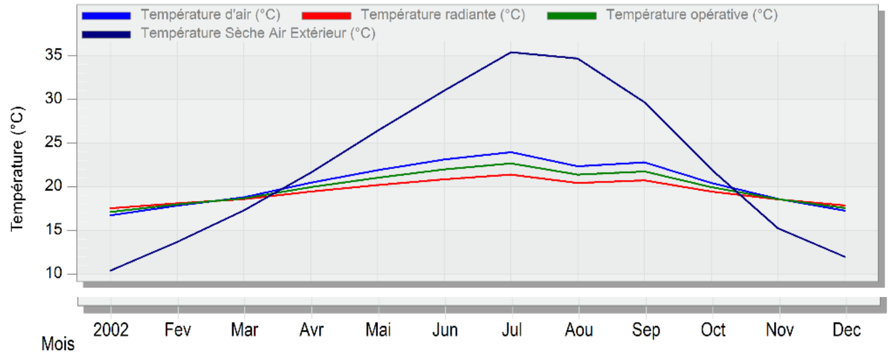
FIGURE 74 : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE DOUBLE GLAZING (SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR)

These findings allow us to distinguish two time periods:

Period 01: May to September, when the temperature ranges from 20.65°C to 21.71°C.

Period 02: January to April, October to December, when the temperature ranges from 17.57°C to 19.86°C.

V.4.4.2.3 Triple glazing



Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	16,72	17,83	18,79	20,45	21,88	23,11	23,96	22,34	22,78	20,44	18,61	17,27
Température radiante (°C)	17,52	18,10	18,57	19,45	20,19	20,85	21,37	20,42	20,72	19,45	18,54	17,85
Température opérative (°C)	17,12	17,97	18,68	19,95	21,04	21,98	22,67	21,38	21,75	19,95	18,57	17,56
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	34,10	28,42	27,19	32,38	26,57	30,90	32,38	35,90	40,14	40,80	31,27	33,66
Kansas Uni TSV (%)	15,53	12,40	9,80	31,06	22,02	15,84	11,38	14,89	15,12	7,08	9,92	13,44
Fanger PMV ()	-0,67	-0,53	-0,40	-1,04	-0,82	-0,55	-0,36	-0,68	-0,56	-0,10	-0,41	-0,59

FIGURE 75 : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE TRIPLE GLAZING(SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR)

Based on the following findings, we can distinguish two periods:

- Period: May to September, when the temperature varies between 21.04°C and 22.67°C.

- Period: January to April and October to December, when the temperature varies between 17.12°C and 19.95°C

V.4.4.2.4 Interpertiation

-Single Glazing: Provides the least amount of insulation, resulting in higher interior temperatures in warmer months and greater heat loss in colder months. Suitable for areas with milder climates or where cost is a primary consideration.

-Double Glazing: Provides better insulation, resulting in more stable and comfortable interior temperatures. It offers a good balance between cost and energy efficiency, making it a suitable choice for most climates.

-Triple Glazing: Provides the best amount of insulation, ensuring a more even interior temperature throughout the year. This option is ideal for areas with extreme temperatures and can provide significant energy savings despite the higher initial cost

V.4.4.2.5 Results of the insulation choice

Choosing the right type of glass depends on the specific climate conditions and energy efficiency goals. For Bechar, which needs to manage both hot and cold periods, double glazing offers a balanced solution due to its excellent thermal insulation properties.

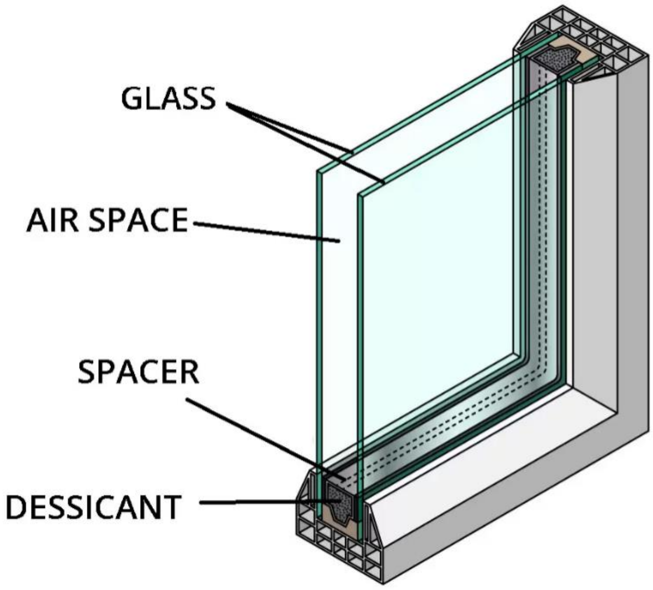
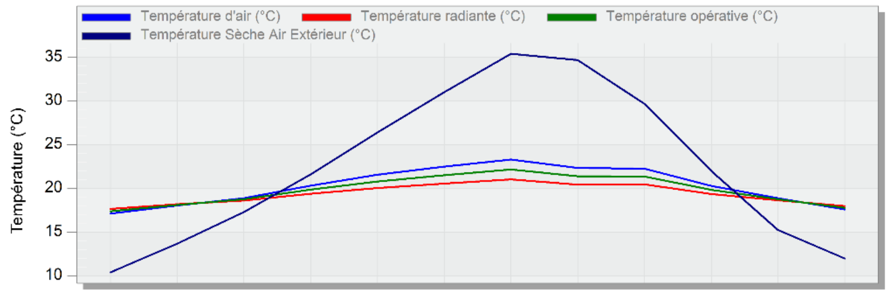


FIGURE 76 : DOUNLE GLAZING (SOURCE : PINTREST)

V.4.4.3 Insulation

V.4.4.3.1 Vegetal insulation



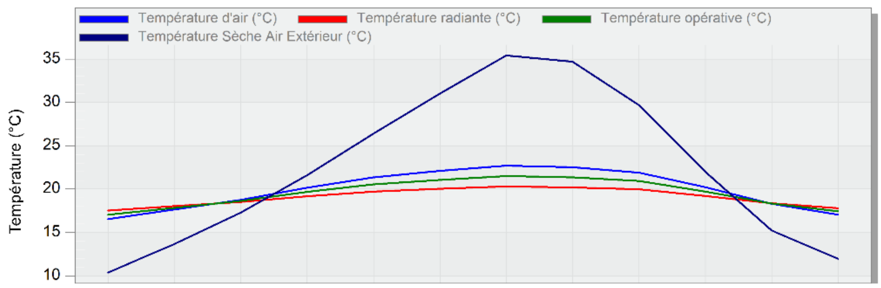
Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	17,10	18,04	18,88	20,32	21,56	22,48	23,29	22,34	22,26	20,28	18,88	17,59
Température radiante (°C)	17,66	18,18	18,61	19,39	20,03	20,55	21,03	20,42	20,47	19,37	18,64	17,97
Température opérative (°C)	17,38	18,11	18,74	19,85	20,79	21,52	22,16	21,38	21,36	19,82	18,76	17,78
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	36,27	31,02	29,61	36,24	31,08	36,05	36,98	35,90	45,23	44,26	34,95	35,99
Kansas Uni TSV (%)	14,60	11,94	9,55	30,88	22,63	16,38	11,31	14,89	15,70	6,97	9,40	12,78
Fanger PMV ()	-0,61	-0,49	-0,38	-1,05	-0,86	-0,64	-0,46	-0,68	-0,63	-0,10	-0,35	-0,54

FIGURE 77 : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE VEGETAL INSULATION(SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR)

Phase 1: The temperature range is 20,79°C to 22,16°C. This period includes five months: May, June, July, August, and September.

Phase 2: The temperature range is 17.38°C to 19,85°C. This period includes seven months: January, February, March, April, October, November, and December

V.4.4.3.2 Mineral insulation



Mois	2002	Fev	Mar	Avr	Mai	Jun	Jul	Aou	Sep	Oct	Nov	Dec
Température d'air (°C)	16,55	17,64	18,75	20,17	21,37	22,09	22,69	22,53	21,89	20,22	18,30	17,06
Température radiante (°C)	17,54	18,04	18,50	19,18	19,70	20,04	20,32	20,18	19,98	19,20	18,37	17,81
Température opérative (°C)	17,04	17,84	18,62	19,68	20,53	21,07	21,51	21,36	20,94	19,71	18,34	17,43
Température Sèche Air Extérieur (°C)	10,40	13,68	17,30	21,60	26,42	31,03	35,40	34,68	29,68	22,00	15,23	11,96
Humidité relative (%)	34,43	28,79	27,49	32,85	27,06	32,54	35,03	36,81	41,79	41,26	31,49	34,17
Kansas Uni TSV (%)	33,16	26,97	20,72	58,29	48,69	38,90	31,44	33,15	38,40	11,88	22,32	29,43
Fanger PMV ()	-1,13	-0,97	-0,80	-1,65	-1,45	-1,26	-1,11	-1,14	-1,25	-0,49	-0,85	-1,04

FIGURE 78 : TABLE OF THERMAL COMFORT RESULTS AFTER USING THE MINERAL INSULATION(SOURCE: DESIGNBUILDER PROCESSED BY AUTHOR)

Phase 1: The temperature range is 20,53°C to 21,51°C. This period includes five months: May, June, July, August, and September.

Phase 2: The temperature range is 17,04°C to 19,71°C. This period includes seven months: January, February, March, April, October, November, and December.

V.4.4.3.3 Interpretation

-Vegetale insulation: Provides good insulation but can cause interior temperatures to rise in hot months, which may require more cooling. In cold months, it provides moderate insulation and maintains a relatively comfortable interior temperature, but heating is still required.

-Mineral insulation: Provides better thermal performance than vegetable insulation, maintaining lower interior temperatures in hot months and higher temperatures in cold months. This reduces the need for cooling and heating, making them a more energy-efficient choice.

V.4.4.3.4 Results of the insulation choice

For a balanced and energy-efficient solution, mineral insulation is preferred as it provides a more stable and comfortable indoor temperature year-round and reduces overall energy consumption for heating and cooling.

In our case, Since the building is located underground, insulation may not be needed due to the natural thermal stability of the earth. Underground buildings benefit from the constant temperature of the ground, which acts as a natural insulator, ensuring a more stable and comfortable indoor climate all year round without the need for additional insulation materials.

V.4.4.4 Synthesis

By integrating appropriate material choices, glazing solutions, and insulation strategies, buildings can achieve optimal thermal comfort and energy efficiency in Béchar's climate. Whether it's leveraging the cooling properties of terracotta brick, the insulation benefits of mineral insulation, or the balance of double glazing, tailored approaches contribute to sustainable and comfortable living environments, ensuring a harmonious relationship with the surrounding climate

VI GENERAL CONCLUSION

VI.1 CONCLUSION

Throughout this academic year, we have significantly expanded our understanding of bioclimatic design and energy efficiency by drawing on prior research and studies. Our approach has been comprehensive, integrating both architectural and urban dimensions. This methodology has enabled us to explore and apply sustainable and bioclimatic design principles in innovative ways, paving the way for significant advancements in our field.

Our study focuses on issues specific to Bechar, identified in the first chapter. Bechar faces several challenges, including a discontinuity in the urban fabric between the city center and its suburbs, characterized by uncontrolled, random expansions and high energy consumption. Despite its strategic location, Bechar remains dissociated from other cities. These challenges have led us to develop and test three hypotheses:

1. Integrating Passive Strategies: We projected that integrating passive strategies inspired by biomimicry design at the project level can enhance the thermal comfort of a building in an arid climate. Passive techniques incorporate architectural components that take advantage of natural energy flows and environmental circumstances, such as natural ventilation, solar heating, and daylighting. Our findings verified this idea, revealing that buildings implementing these passive measures saved significant energy and improved environmental performance.

2. Combining Passive and Active Strategies: According to our second hypothesis, the integration of passive and low-energy active strategies, inspired by biomimetic architecture, is necessary to ensure optimal comfort in a building. Active methods include the utilization of mechanical and electrical systems such as HVAC (heating, ventilation, and air conditioning) and renewable energy sources (solar panels, wind turbines). These systems actively work to reduce a building's energy use and carbon footprint.

3. Using Local Materials: The third hypothesis suggests that local materials help improve thermal comfort in a building, despite its harsh climate. We found that using local materials enhances comfort and efficiency, contributing to a building's optimal performance at the project level.

We conclude that all three of our hypotheses are true based on our investigation. First, using passive techniques influenced by biomimicry design at the project level guarantees the energy efficiency of a building by reducing energy consumption for lighting, heating, and cooling through natural ventilation, solar heating, and daylighting. Second, active strategies—such as mechanical and electrical systems like HVAC, renewable energy sources, and energy-efficient products—effectively improve a building's energy efficiency by actively lowering energy use and carbon footprint. Thirdly, a combination strategy incorporating both passive and active methods, influenced by biomimetic design, is essential to maximize energy savings and ensure a building's energy efficiency at the project level.

We recognize that this modest work is not yet complete, as it is a prototype project that can be replicated in several Algerian cities with similar climate characteristics. However, as our work progresses, new research vistas and opportunities for enhancing energy management in urban and architectural systems arise. We are determined to continue our efforts in this direction and expand the scope of our research, as Algeria seeks to develop this field.

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VI.1.1.1.2 List of Figures

VI.1.1.1.3 *Table list*

HOW TO ARRIVE TO THE INTERVENTION AREA?

FIGURE 79 :THE ACCESSIBILITY TO THE INTERVENTION AREA (SOURCE : AUTHOR)

Road System

- Structuring axis that traverses the zone and connects it to the exit and the city center
- Structuring axis that delineates the zone on the south side and connects it to the airport
- Orthogonal connection between the roads
- Severe lack of traffic lanes.

DISCOVERING THE CONTEXT

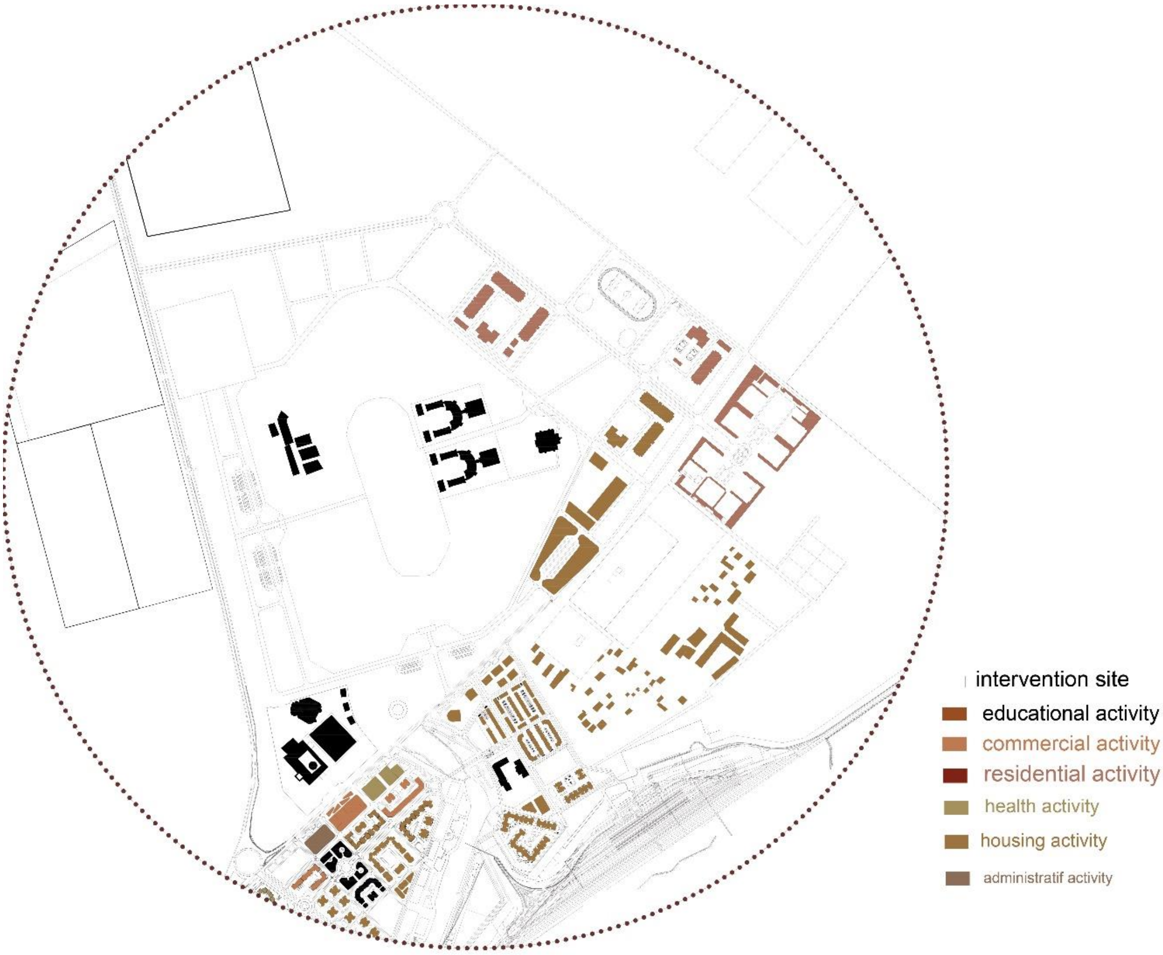


FIGURE 80: THE DIFFERENT FUNCTIONS IN THE INTERVENTION AREA (SOURCE :AUTHOR)

Regarding the intervention area, it is characterized by several functions, where the educational one is the most dominant due to the presence of the university and the Islamic pole.

Additionally, residential functions serve as subordinate equipment within the area.

QUESTIONNAIRE

Urban Spaces and Landscaping:

a. How do you evaluate the presence of public and green spaces in the city of Bashar?

(Absent, moderate, abundant)

b. How would you rate the parks and green spaces in Bechar City?

(from 1 to 5)

c. What improvements would you like to see in public spaces like parks and squares?

(chairs,green spaces, market,walking spaces)

d. How important is it for urban areas to reflect the local culture and environment in their design?

(from 1 to 5)

Local Identity:

a. What symbols or elements represent the identity of Bechar City to you?

b. Do you think architecture and public art can reflect the local identity of Bechar City?

(yes or No)

c.How?

Renewable Energy and Sustainability:

a. How familiar are you with renewable energy sources such as solar and wind power?

(from 1 to 5)

b. Do you believe Bechar City should invest more in renewable energy projects?

(yes or No)

c. How do you think renewable energy can benefit Bechar City and its residents?

d. do you think that a project related to energy could be benificial to bechar city? ?

(yes or No)

e. Are you willing to support initiatives like green building standards and waste reduction efforts in Bechar City?

f. Do you think that there are facilities in Bashar that use the principles of thermal insulation, natural ventilation and cooling?

Walkability and transportation:

a. What are the reasons that make you visit the Red Road area? (work, study, live, buy, hike)

b. Do you find it easy to walk or bike around Bechar City?

(yes, a little, no)

b. Do you find it easy to walk or bike around Bechar City?

(yes, a little, no)

c. How do you evaluate the condition of the pedestrian lanes on Lahmar Road?

(from 1 to 5)

d. How do you evaluate the presence of security and comfort facilities while walking, such as lighting and benches in the Lahmar Road area?

(Absent, moderate, abundant)

e. What improvements could be made to sidewalks and bike lanes to make them safer and more convenient?

f. Do you use public transportation for your transportation?

j.What is the most frequently used public transportation to reach Lahmar Road?

(buses, taxi, private car, bicycle, walking)

h. How important is it to reuse/revive the railway in Bechar and link it to the new city of Lahmar Road?)

(from 1 to 5)

The end

a.How old are you ?

18-15

25-35

35-45

45-60

+60

b.Are you a: men or women?

what is your profession:

student

c.Where do you live exactly in bechar?

استطلاع حول رأي مجتمع مدينة بشار حول:المساحات الحضرية، الهوية المحلية، الاستدامة، ووسائل النقل

الاستبيان يهدف إلى استطلاع آراء سكان مدينة بشار وزوارها بشأن عدة جوانب تتعلق بالبيئة الحضرية والتصميم المعماري والاستدامة ووسائل النقل. يتم طرح الأسئلة لفهم احتياجات السكان وتوقعاتهم، وذلك لتوجيه مشروع تخرجنا في مجال الهندسة المعمارية نحو تصميمات تلبي احتياجات المجتمع المحلي وتعزز جودة الحياة في المدينة.

djellidchaimaa9@gmail.com Switch account

Not shared

* Indicates required question

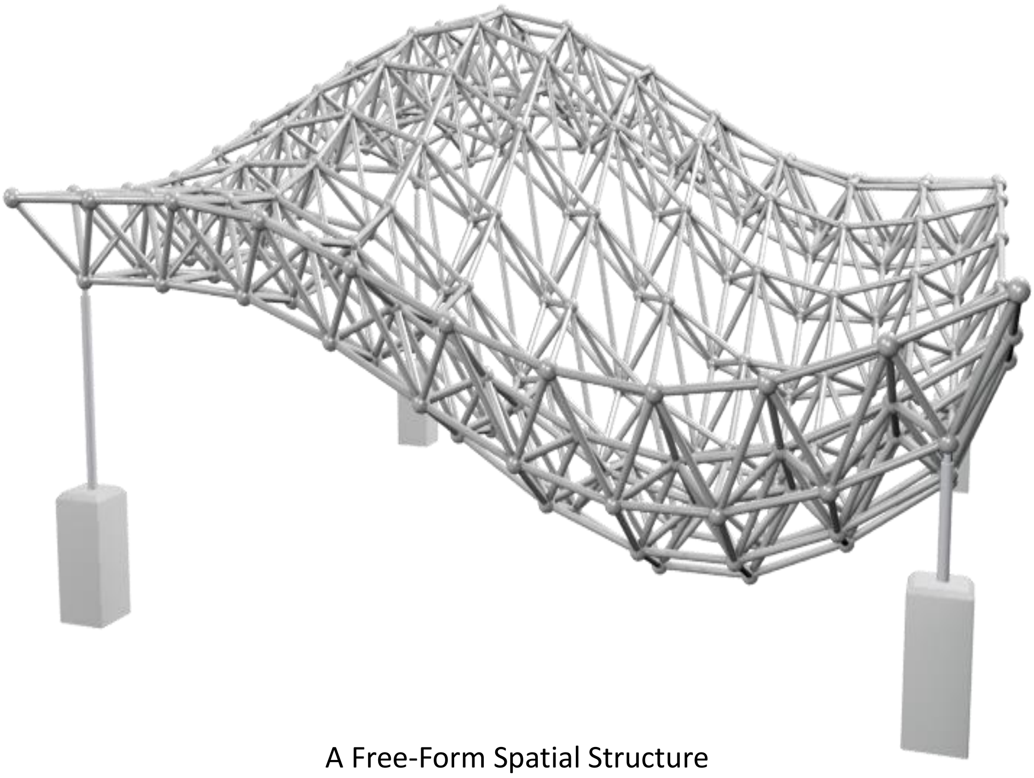
الجزء الأول: المساحات الحضرية

FIGURE 81:THE INTERFACE OF THE QUESTIONNAIRE (SOURCE :AUTHOR)

STRUCTURAL ANALYSIS

We get inspired from Hayder Aliyve culture center wich is principally comprised of two systems which work together: a concrete structure combined with a spatial structure system. With the intention of creating large-scale, free spaces of columns which allow the visitor to experiment with the fluidity of the interior, vertical structural elements are absorbed by the walls and curtain wall system. The specific geometry of the surfaces encourages unconventional structural solutions, such as the introduction of curved “starter columns” to achieve the inverse shell of the surface from the floor to the West of the building, and the “duck tail” resulting from the narrowing of the cantilevered beams which support the skin of the building on the East side.

The spatial framework system allows the construction a free-form structure and was also designed to save time throughout the construction process, while the substructure was developed to incorporate a flexible relationship between the rigid grid-work of the spatial structure and the seams of the free-form exterior cladding.

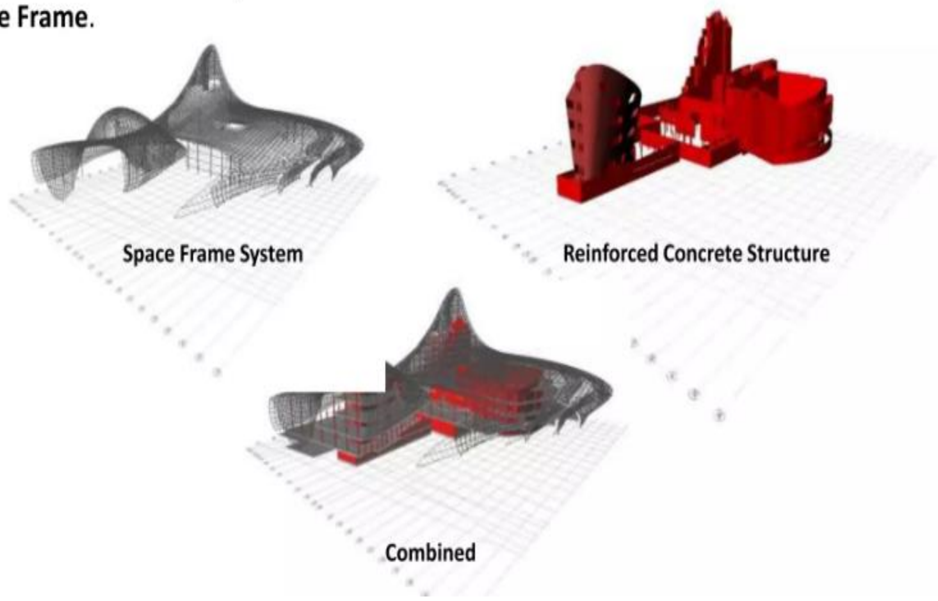


A Free-Form Spatial Structure

Source:Spatial Structures::Fundamentals::Knowledgebase::SAFAS (vt.edu)

Construction Details

The building Structural System is combined System which consists of two main systems that collaborate: **concrete structure combined** with a system of **Space Frame**.



https://en.wikiarquitectura.com/building/heydar-aliyev-cultural-center/

Heydar Aliyev Centre's fluid architecture embodies an enlightened framework.The centre's fluid exterior surfaces rise from its surroundings.Structure of this building is compose of lighter,materials that applied as irregular,non-rectilinear geometry for creating large column-free spaces. Technical design of critical areas such as the external cladding and its support structure, along with the curtain walling
The building has a single-movement joint separating concrete slabs, space frames, and other components into two sections. In addition, expansion and contraction of finishing materials, such as the external and internal skin, are unified within surrounding. The building consists of two main systems that collaborate: concrete structure combined with a system of spatial structure.

5.500 tons structural steel will carry the outer skin of 40.000 m2formed fro Fibre Reinforced Plastic (GFRP) panels, a total of almost 17.000 single p different geometry