



University of Mohammed Kheider- Biskra

Faculty of architecture, urbanism, civil engineering and hydraulic

Department of Architecture

## MASTER'S DISSERTATION

Domain: **Architecture, urbanism and city professions**

Field: **Architecture**

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**Theme: Daylight of an adaptive façade shading system integrated to hot climate.**

**Project: School of art.**

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# Acknowledgement:

Firstly and most importantly I thank the lord, my dear god almighty for granting me the will and skills to complete this marvellous piece of art and every thing in my life. So alhamdulillah.

My special thanks to the man who guided me throughout my whole life and provided regardless my beloved father and my beloved mother.

My absolute thanks and gratitude to my companion in this exciting journey, my guide, my mentor and respectfully my friend, the honourable **Mr. SAADI MOHAMED YACINE**, for his patience on my flaws and mistakes, and for sharing his rich knowledge and his vast experience and most importantly his professional kindness that ensured the best environment for guiding me till I reached here.

My thanks and deep respect for the jury members, **Dr. BESBAS YASMINA, Dr. ZINEDDINE SARA** for for acknowledging my dissertation's subject and rating it.

# Dedication:

In the name of lord, god almighty, I dedicate this masterpiece of work to the greatest man I ever knew OTHMANI MARABOUT ABDELMAJID whom I was lucky enough to be grandson of his.

I dedicate my work to my beloved parents.

I dedicate this work to my uncle TAHA a.k.a YUCEF.

Thank you all.

## ABSTRACT

This research addresses the challenge of high energy consumption and thermal discomfort in buildings located in hot and arid climates, focusing on the city of Biskra, Algeria. Traditional shading solutions, such as mashrabiya and overhangs, are no longer sufficient to manage changing solar conditions. This research proposes adaptive shading devices that respond in real-time to temperature and light, aiming to reduce reliance on mechanical cooling and improve indoor comfort.

The study is divided into three phases: a theoretical study covering art, art facilities, and smart facades; an analytical study of international case studies and the selected site in Biskra; and a practical study where an adaptive shading system was designed, prototyped, and integrated into the architectural design of a School of Art using the box-inside-box concept.

The project combines cultural sensitivity and sustainable design strategies to achieve energy efficiency and improved comfort, confirming its positive environmental performance and suitability for Biskra's climate.

### **Keywords :**

Adaptive Shading Devices, Hybrid Shading Systems, Energy Efficiency, Sustainable Architecture, Hot Arid Climate, School of Art.

## المخلص

يتناول هذا البحث تحدي ارتفاع استهلاك الطاقة والانزعاج الحراري في المباني الواقعة في المناخات الحارة والجافة، مع التركيز على مدينة بسكرة بالجزائر. لم تعد حلول التظليل التقليدية، مثل المشربية والمظلات، كافية لإدارة الظروف الشمسية المتغيرة. يقترح هذا البحث أجهزة تظليل متكيفة تستجيب أنياً لدرجة الحرارة والضوء، بهدف تقليل الاعتماد على التبريد الميكانيكي وتحسين الراحة الداخلية.

تنقسم الدراسة إلى ثلاث مراحل: دراسة نظرية تغطي الفن والمرافق الفنية والواجهات الذكية؛ ودراسة تحليلية لدراسات حالة دولية والموقع المختار في بسكرة؛ ودراسة عملية تم فيها تصميم نظام تظليل متكيف، ووضع نموذج أولي له، ودمجه في التصميم المعماري لمدرسة للفنون باستخدام مفهوم "الصندوق داخل الصندوق".

يجمع المشروع بين الحساسية الثقافية واستراتيجيات التصميم المستدام لتحقيق كفاءة الطاقة وتحسين الراحة، مما يؤكد أدائه البيئي الإيجابي وملاءمته لمناخ بسكرة.

## الكلمات المفتاحية:

أجهزة التظليل متكيفة، أنظمة التظليل الهجينة، كفاءة الطاقة، الهندسة المعمارية المستدامة، المناخ الحار والجاف، مدرسة الفنون

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# **INTRODUCTORY CHAPTER**

## **GENERAL INTRODUCTION**

The growing energy crisis and the intensifying impacts of climate change present serious environmental and economic challenges for many countries, including Algeria. In this context, architecture plays a vital role not only in reducing energy consumption but also in improving the quality of life by ensuring thermal comfort in indoor spaces. Responding to the specific needs of hot regions like Biskra has become essential, as buildings in these areas face constant exposure to high temperatures and strong solar radiation, leading to heavy dependence on energy-intensive cooling systems.

Adopting sustainable architectural solutions is now more important than ever in addressing these challenges. Among these solutions, adaptive and kinetic shading systems offer a promising path, as they can respond to changing climatic conditions in real-time. When combined with smart control strategies, such systems can optimize energy performance, reduce cooling loads, and improve indoor comfort in a more efficient and environmentally responsible way. Such innovations are particularly relevant in arid zones like Biskra, where solar exposure is persistent throughout the year.

Furthermore, cultural spaces remain a key part of urban life, especially in cities like Biskra, which are rich in heritage and artistic potential. Designing a School of Art in Biskra provides a valuable opportunity to combine advanced environmental strategies with cultural expression. By integrating dynamic shading systems within the school's design, this project aims to contribute to sustainable architectural practices while promoting cultural development. This approach aspires to offer a balanced solution that enhances user comfort, reduces energy use, and supports the broader goals of sustainable and climate-adaptive design in Algeria.

## **PROBLEMATIC**

The Algerian desert specifically the state of BISKRA is Characterized by its hot and arid climate, which means high temperature and Intense solar radiation throughout the year that leads to High cooling needs during most months .and that puts huge challenge for the thermal comfort in buildings,

Both public and residential buildings exposed to the Increased heat gain through façades and roofs, forcing the Dependency on air conditioners as a solution which rise the energy consumption to the roof and an unreasonable energy use pattern.

The traditional shadings solutions like the mashrabiya, lattices, overhangs... are barely Effective in reducing direct solar exposure and their Limited performance under changing weather conditions, because of their Static and non-adaptable function are not the best option.

That opens the chance to discover the opportunity to improve indoor comfort and reduce reliance on artificial cooling by studying the potentials of Active shading systems that adapt to local climate and respond to dynamic solar angles and user behaviour.

Based on these elements our research questions are:

- How can the design of an art school respond to Biskra's cultural identity?
- How can we improve lighting and (thermal) comfort and reduce energy consumption in hot and arid regions such as biskra?

## **HYPOTHESES:**

- Using hybrid shading solutions into building envelope to reduce indoor temperatures and cooling loads.

## **OBJECTIVES:**

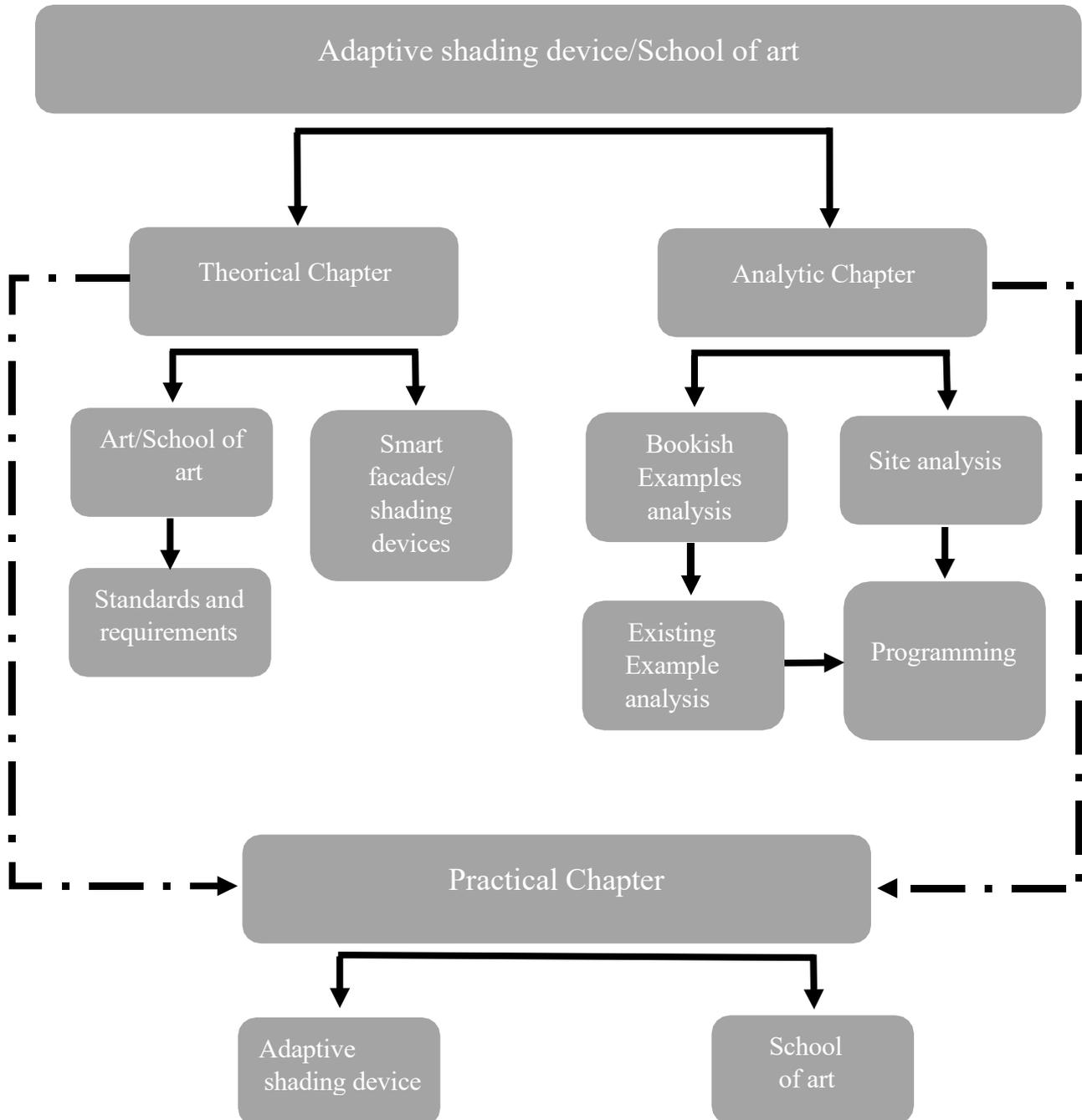
- identifying and analysing hybrid passive and active shading strategies suitable for hot-arid climates.
- To assess the energy efficiency of the adaptive shading systems in reducing indoor cooling costs.
- To integrate aesthetic considerations with technical performance in shading design.

## **METHODOLOGY:**

- Analyzing theoretical concepts related to cultural and educational fields, including cultural and educational facilities, art spaces, learning environments, and passive and active shading systems.
- Conducting an analytical study focused on case studies, project analysis, and a detailed site study.

- Designing a School of Art integrated with an adaptive shading system, developed and controlled using Arduino, light and temperature sensors, and other electronic components to create a functional, climate-responsive prototype.

**RESEARCH STRUCTURE:**



# **CHAPTER I: THEORETICAL STUDY**

## **Introduction:**

In this chapter, we will carry out a deep theoretical study covering all the essential concepts related to our project. The first part focuses on the School of Art, where we will define art itself, explore its historical evolution, and classify the different types of art facilities, including museums, galleries, cultural centers, and art schools. We will also highlight the importance and role of art schools in shaping creativity and cultural expression. In the second part, we will focus on adaptive shading devices by discussing their different types and their applications in building facades. This study will help us understand both the architectural and environmental aspects needed to build our project on a solid foundation.

## 1. Concepts of the project:

### 1.1. Art:

#### 1.1.1. Definitions

##### According to Encyclopedia Britannica:

"Art is a visual object or experience consciously created through an expression of skill or imagination. The term 'art' encompasses diverse media such as painting, sculpture, printmaking, drawing, decorative arts, photography, and installation." (Encyclopedia Britannica, n.d.)

##### According to Oxford English Dictionary:

"Art is the expression or application of human creative skill and imagination, typically in a visual form such as painting or sculpture, producing works to be appreciated primarily for their beauty or emotional power." (Oxford English Dictionary)

##### According to UNESCO:

"Art is a fundamental component of culture and an expression of human creativity, which contributes to dialogue, identity, and social cohesion." (UNESCO)

#### 1.1.2. Brief History of Art:

##### 1.1.2.1. Prehistoric Art (c. 40,000–3,000 BCE):



- Ancient art forms like cave paintings and sculptures, such as the Lascaux Cave paintings in France and the Tassili n'Ajjer rock art in Algeria. (www.bradshawfoundation.com, n.d.)



Figure 1: Lascaux Cave paintings in France

Figure 2: Tassili n'Ajjer rock art in Algeria

### 1.1.2.2. Ancient Art:

- **Mesopotamian Art (c. 3500–539 BCE):** Known for ziggurats and relief sculptures, reflecting religious themes. (H.F)



Figure 3: Sumerian inscription, detail of a diorite statue of Gudea of Lagash, 22nd century bce; in the Louvre, Paris.

- **Egyptian Art (c. 3000–30 BCE):** symbolic sculptures, with monumental architecture like the pyramids. (Gombrich)

Figure 4: Portrait of Hesire from a wooden door in his tomb.

Carved about 2700 B.C. Cairo, Museum



- **Greek and Roman Art (c. 900 BCE–476 CE):** Greek art evolved to naturalism, influencing Roman art, which emphasized realism. (Gombrich)

Figure 5: a Greek bowl. About 480 B.C. Berlin, Museum



- **Chinese Art (c. 1600 BCE–220 CE):** the painting, calligraphy, architecture, pottery, sculpture, bronzes, jade carving, and other fine or decorative art forms. (Sullivan., Michael., Silbergeld, & Jerome.)

Figure 6: Chinese sculpture from 2<sup>nd</sup> century BC



### 1.1.2.3. Medieval Art

- **Byzantine Art (c. 330–1453 CE):** embodied in architecture, paintings, and other visual arts produced all shined in the Middle Ages in the Byzantine Empire from Constantinople towards all region that came under its influence.( Byzantine art article (Encyclopedia Britannica, n.d.)



Figure 7: Empress Theodora and her retinue, mosaic, 6th century; on the south wall of the apse, church of San Vitale, Ravenna, Italy.

- **Islamic Art (c. 7th century onward):** Characterized by intricate geometric patterns, calligraphy, and architecture, such as the Alhambra in Spain and the Great Mosque of Kairouan in Tunisia.in addition to a lot of other traditional artistic figures like carpets Weaving . (Gombrich)



Figure 8: Persian Silk Prayer Carpet, enriched with metal thread made in 1500A.D Collection Mme E. Paravicini. (the story of art by E.H Gombrich)

- **African Art (c. 1st millennium CE onward):** they often emphasize abstraction and idealization over realism, masks, Textiles, Body art and others (Clarke)

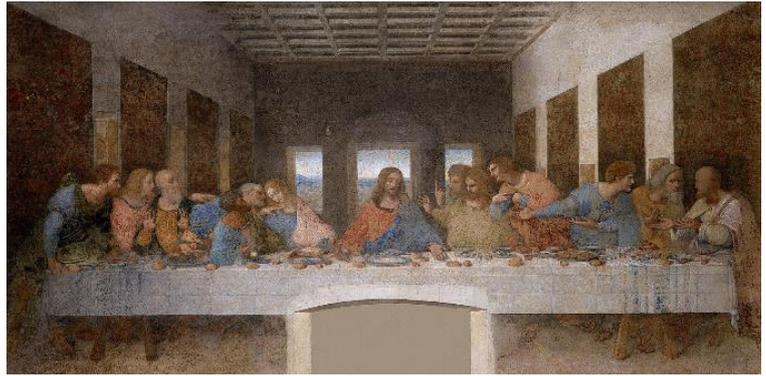


Figure 9: Seated Figure, 13th century; ca. 1235 Mali, Inland Niger Delta region (The Art of AFRICA by Christa Clarke)

### 1.1.2.4. Renaissance Art

- **Renaissance (c. 1400–1600):** a transition from the Middle Ages to modernity Embodied humanism and naturalism, with geniuses like Leonardo da Vinci and Michelangelo. (Cambridge dictionary )

Figure 10: The Last Supper by Leonardo da Vinci. 1495–1498



### 1.1.2.5. Baroque and Rococo

- **Baroque (c. 1600–1750):** a style of all of architecture, sculpture, music, painting, poetry and more arts . a link between the renaissance and the rococo later. (Encyclopedia Britannica, n.d.)

Figure 11: The Ecstasy of Saint Theresa, by Gian Lorenzo Bernini. 1647–1652 Church of Santa Maria della Vittoria, Rome



- **Rococo (c. 1730–1770):** also known as Late Baroque, it was a very dramatic and playful style of architecture, art and decoration. (Encyclopedia Britannica, n.d.)

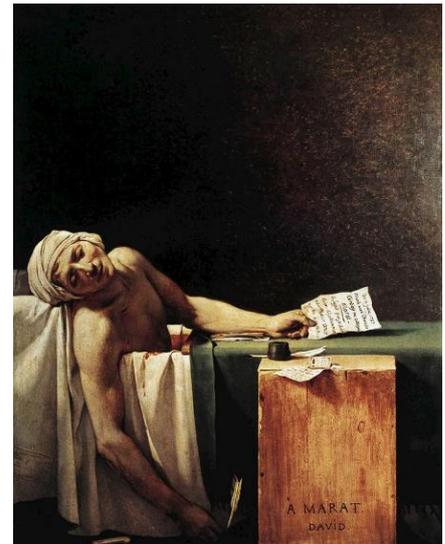
Figure 12: Capital of the Engelszell Abbey, from Austria (1754–1764)



### 1.1.2.6. Modern Art

- **Neoclassicism and Romanticism (c. 1760–1850):** Neoclassicism oriented towards classical themes and linear precision, while Romanticism embraced emotion and nature. (Klindt-Jensen)

Figure 13: The Death of Marat, oil on canvas by Jacques-Louis David, 1793; in the Royal Museums of Fine Arts of Belgium, Brussels.



- **Japanese Art (Edo Period, c. 1603–1868):** painting, architecture, pottery, sculpture and other fine or decorative visual arts produced in Japan. (Ulak)

Figure 14: The Breaking Wave off Kanagawa, woodblock colour print by Hokusai, from the series Thirty-six Views of Mount Fuji, 1826–33



### 1.1.2.7. 20th Century and Contemporary Art

- **Cubism (c. 1907–1915):** Introduced by Picasso, focused on abstract forms. (www.bradshawfoundation.com, n.d.)

Figure 15: The Café Terrace, Diego Rivera, 1915.



- **Abstract Expressionism (c. 1940s–1950s):** Emphasized spontaneous creation. (Encyclopedia Britannica, n.d.)

Figure 16: Onement 1, Barnett Newman, 1948.



- **Contemporary Art (1970s–present):** Encompasses diverse styles and media, addressing global issues. (www.bradshawfoundation.com, n.d.)

Figure 17: Making Space, Altan, Ålesund

April 25 – May 11, 2025



### **1.1.3. Classification of Art Facilities:**

#### **1.1.3.1. Museums:**

A public institutions that has a purpose of collecting and preserving artifacts, displaying cultural and scientific heritage and educating the general public. art museums, history museums and science museums are some of their different types.

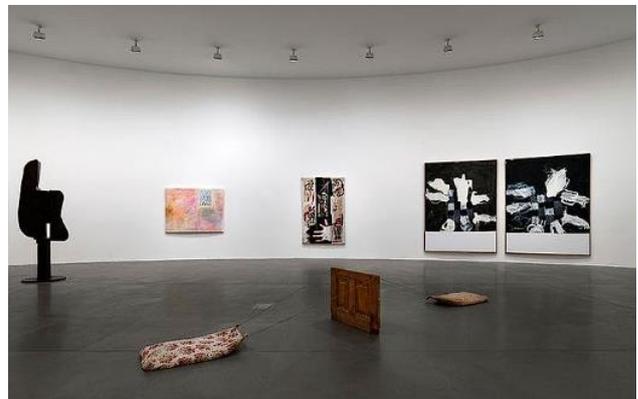
Figure 18: The Louvre in Paris is one of the most famous museums, holding art like the Mona Lisa. (Louvre.com, n.d.)



#### **1.1.3.2. Art Galleries:**

A space for exhibiting visual arts like paintings, sculptures . a place where artists can represent themselves and their artifacts and they can be privat or public.

Figure 19: The Gagosian Gallery exhibits contemporary art. (Gagosian.com, n.d.)



#### **1.1.3.3. Cultural centers:**

a space where it promotes arts, traditions and the community's cultural identity by supporting local culture and education and they serve the purpose of cultural exchange and dialogue. (Encyclopedia Britannica, n.d.)

#### **1.1.3.4. Public Art Spaces:**

Often located in an open urban area to be publicly accessible and they enhance the overall city aesthetics and its identity and offer a great platform for the direct interaction between the public and the art. (www.bradshawfoundation.com, n.d.)

Figure 20: *Cloud Gate* in Chicago



### **1.1.3.5. Art schools:**

educational institutions that focus on practicing and studying theory in visual arts and design courses, including fine art : painting, sculpture, and graphic design. They may be independent, or within a larger institution, like universities. Or associated with an art museum.

Art schools can offer elementary, secondary, post-secondary, undergraduate and even graduate programs. (Houghton, Feb. 2016)

**National Association of Schools of Art and Design (NASAD)** defines the art school as an institution that offers educational programs in visual arts and design, that exceed to standards for the academic quality. (NASAD Official Website, n.d.)

## **1.2. Role of Art Schools:**

Art schools by adopting and refining artistic intelligence, creativity, and technical skills. They offer an environment where students can learn to think like artists, developing their imagination and sensibilities, and learn the technical expertise that allows work effectively with materials.

They also function as communities of practice, where students can learn from peers, engaging in critique sessions, and developing a sense of belonging and shared purpose.

Providing a structured sequential learning, which allows students to build, upon previous knowledge and skills while preparing for the future challenges.

Art schools also contribute to the whole society's cultural and educational landscape, by encouraging the integration of arts into other disciplines. (Eisner)

## **1.3. History of Art Education:**

The concept of art schools began the 19th century, with institutions like the Royal Academy of Arts in London and the École des Beaux-Arts in Paris, and both of them encouraged academic training programs in fine arts.

In the early 20th century, iconic movements such as Bauhaus in Germany changed art education by blending both art with technology

**École des Beaux-Arts school, Paris, France** : school of fine arts founded in Paris in 1671 by Jean-Baptiste Colbert, minister of Louis XIV (École des Beaux-Arts - (Encyclopedia Britannica, n.d.)

Figure 21: École des Beaux-Arts school, Paris, France



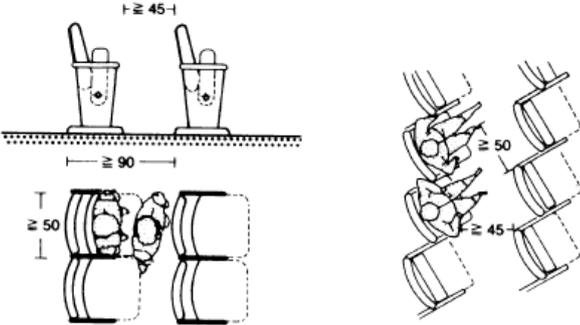
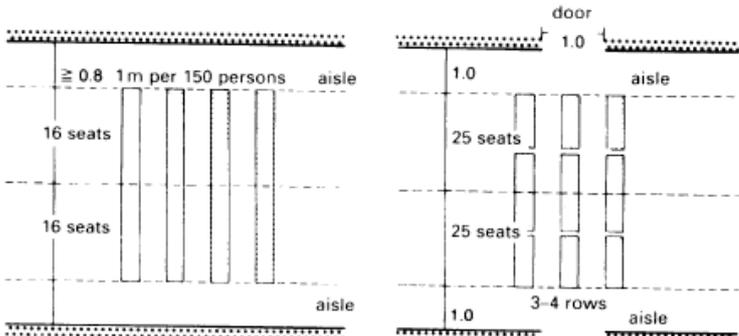
**Bauhaus:** Founded in 1919 by Walter Gropius, it integrated art, architecture, and design education into a single curriculum, emphasizing functional design and craftsmanship. (Bauhaus - (Encyclopedia Britannica, n.d.))

**Royal Academy of Arts:** Established in 1768, it played a significant role in formalizing art education through exhibitions and academies, setting standards for fine art training. (Royal Academy of Arts official site, n.d.)

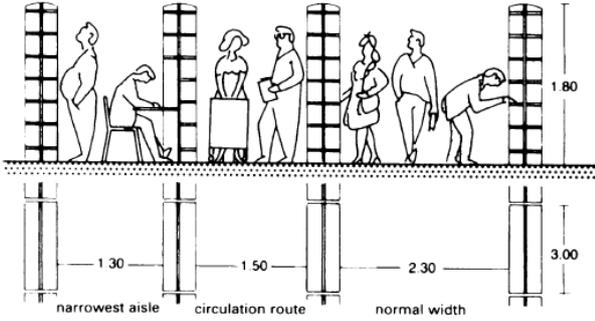
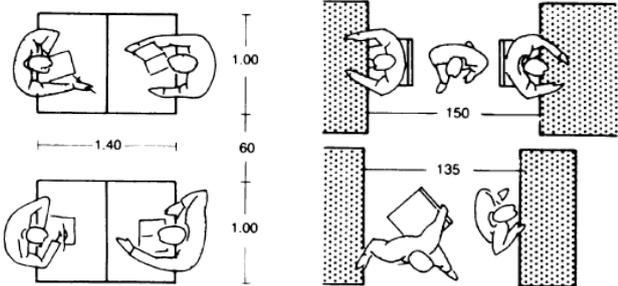
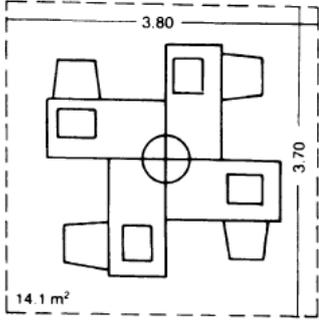
Figure 22: Royal Academy of Arts. England

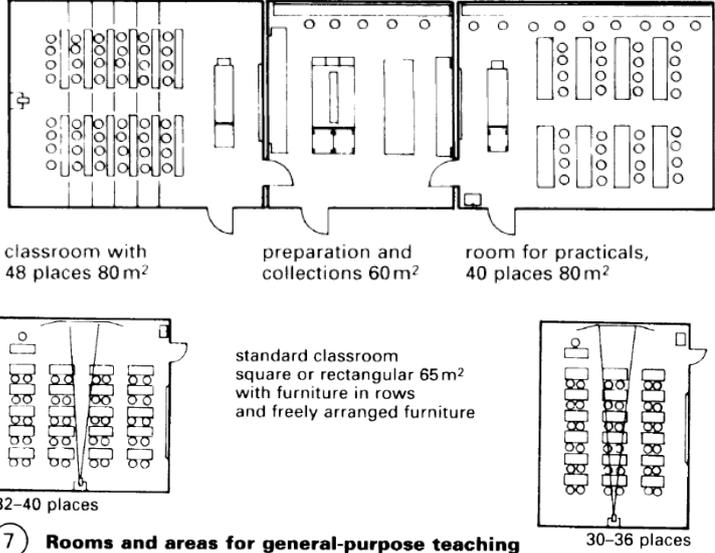
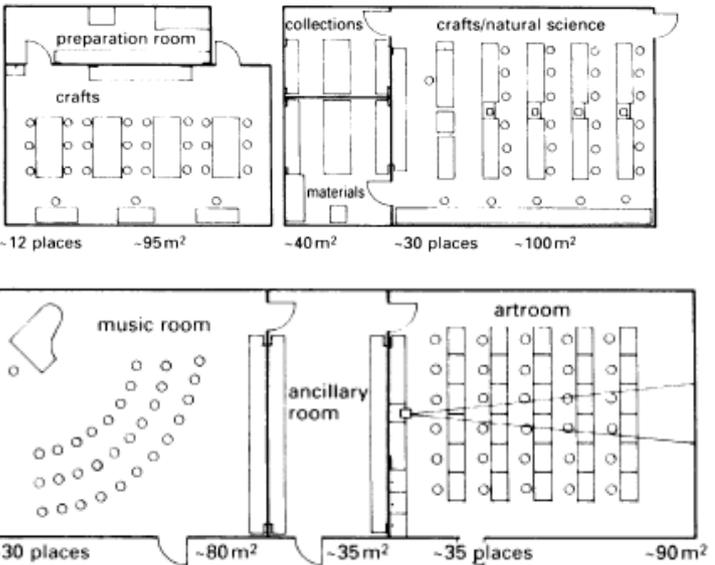


#### 1.4. Standards and requirements for Architectural design:

The space	Standards and requirements
<p><b>Theatre</b></p>	<p>Lighting, Acoustics and visibility should be taken into consideration.  Stage types:</p> <p>Little stage: Not exceeding 100 m<sup>2</sup>.  Full stage: more than 100 m<sup>2</sup>, the slab is 1m high, and a steel curtain for protection in dangerous cases.( Neufert)</p> <p>The size of the room: according to Neufert</p> <p>Number of spectators determines the total required area, with 0.5m<sup>2</sup> at least per seated spectator.</p> <div style="text-align: center;">  <p>① All seats apart from boxes must have fixed, self-operating folding seats with the above minimum dimensions</p> <p>② Offset folding seats provide elbow space</p> </div> <p>Figure 23: Theatre seating schemes.</p> <p>Length of rows: maximum of 16 seats per aisle, and 25 seat per aisle if 1m exit is provided. (Neufert)</p> <div style="text-align: center;">  <p>③ Row width: 16 seats</p> <p>④ Row width: 25 seats + necessary door</p> </div> <p>Figure 24: Theatre length of rows.</p> <p>(Neufert 3rd Edition)</p>

The space	Standards and requirements
<p><b>Theatre</b></p>	<p>Space occupancy:</p> <p>Foyer: 0.8-2.0 m<sup>2</sup> per person assuming that 1/6 of the audience goes to the foyer.</p> <p>Restrooms (W.C.): 1 for 75-100 people, with 2/5 for men and 3/5 for women. ( Neufert)</p> <p>The main entrance is located in the rear wall of the room. Theaters must have exits leading to a public thoroughfare.</p> <div data-bbox="710 631 1388 1160" data-label="Figure"> </div> <p style="text-align: center;">Figure 25: theatre plan and section.</p> <div data-bbox="686 1249 1388 1832" data-label="Figure"> <p style="text-align: center;">① Super elevation of seating (gradient)</p> <p style="text-align: center;">② Gradient curve and its modification</p> </div> <p style="text-align: center;">Figure 26: Seating slop elevation.</p> <p>(Neufert 3rd Edition)</p>

The space	Standards and requirements
<p><b>Libraries</b></p>	<p>Areas of use and reading:</p> <ul style="list-style-type: none"> <li>• Width of main circulation pathways: 1.50m to 2m,</li> <li>• Width of passages between shelves: 0.75m.</li> <li>• Storage areas are to be connected on one side to the book preparation sector and the administrative sector (Neufert)</li> </ul>  <p>③ <b>Minimum distances</b></p> <p>Figure 27: shelves dimensions</p>  <p>Figure 28: distance between tables</p>  <p>Figure 29: tables dimensions (Neufert 3rd Edition)</p>

The space	Standards and requirements
<p><b>Classrooms and studios</b></p>	 <p>classroom with 48 places 80 m<sup>2</sup>      preparation and collections 60 m<sup>2</sup>      room for practicals, 40 places 80 m<sup>2</sup></p> <p>standard classroom square or rectangular 65 m<sup>2</sup> with furniture in rows and freely arranged furniture</p> <p>32-40 places      30-36 places</p> <p>⑦ <b>Rooms and areas for general-purpose teaching</b></p>
	<p>Figure 30: classrooms layout</p>  <p>preparation room      collections      crafts/natural science</p> <p>crafts      materials</p> <p>~12 places      ~95 m<sup>2</sup>      ~40 m<sup>2</sup>      ~30 places      ~100 m<sup>2</sup></p> <p>music room      ancillary room      artroom</p> <p>~30 places      ~80 m<sup>2</sup>      ~35 m<sup>2</sup>      ~35 places      ~90 m<sup>2</sup></p> <p>Figure 31: art and music studios</p> <p>Classrooms for practical studies should be 60-80m<sup>2</sup> ideally (Neufeurt 3rd Edition)</p>
The space	Standards and requirements

## Workshops

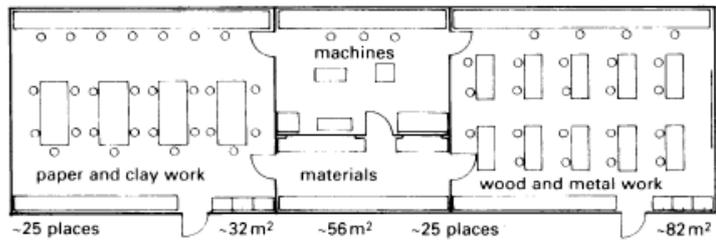


Figure 32: technical workshops

- Each space requires 3.5-4.5m<sup>2</sup>
- Natural lighting is preferable so north facing workshops is best for illumination
- Artificial light should be 500-1000lx (Neufert)

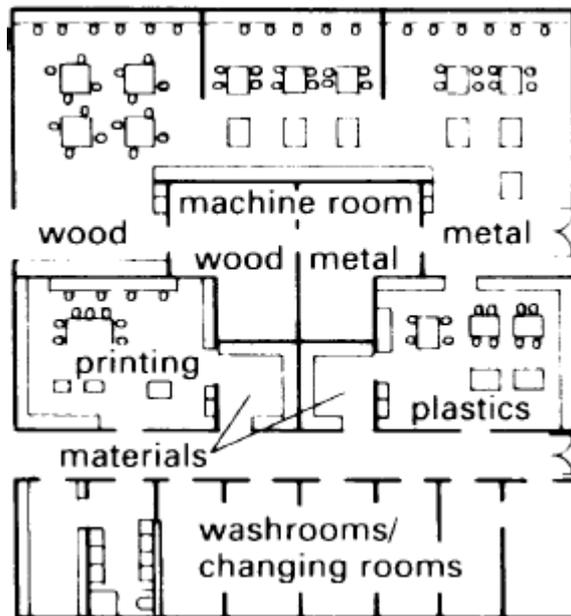
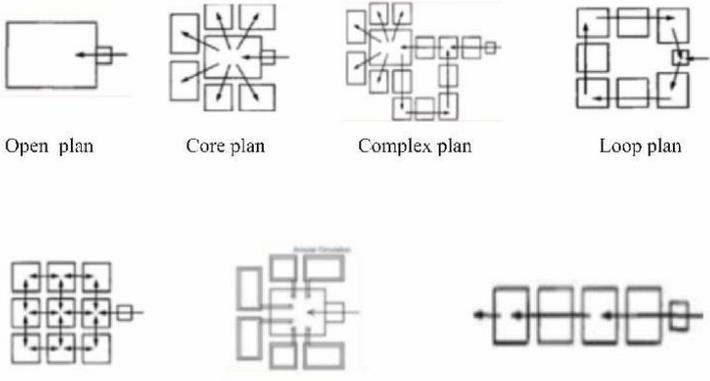
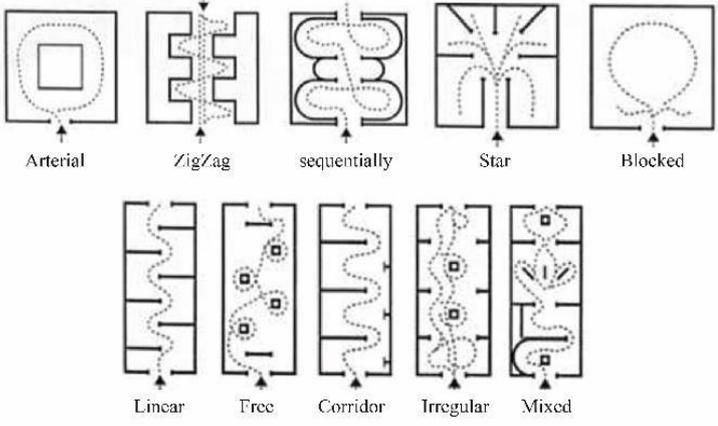
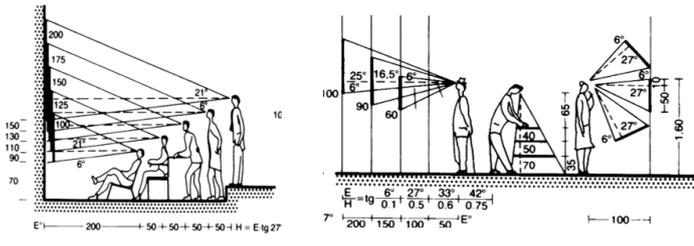


Figure 33: workshop layout.

(Neufert 3rd Edition)

The space	Standards and requirements
<p><b>Exhibits</b></p>	 <p>Open plan      Core plan      Complex plan      Loop plan</p> <p>Labyrinth plan      Annular plan      Labyrinth plan</p>
	<p style="text-align: center;">Figure 34: Exhibits spatial distribution typologies</p>  <p>Arterial      ZigZag      sequentially      Star      Blocked</p> <p>Linear      Free      Corridor      Irregular      Mixed</p>
	<p style="text-align: center;">Figure 34: Exhibits circulation types</p> 
	<p style="text-align: center;">Figure 35 : Exhibit panels normals (Neufeuert 3rd Edition)</p>

## 1.5. SMART FACADES AND SHADING DEVICES:

### 1.5.1. IMPORTANCE OF ENERGY CONSERVATION AND ITS IMPACT ON CLIMATE CHANGE:

**Energy and Climate: How to Achieve a Successful Energy Transition** by Alexandre Rojey

“as architects, we need to respond to the greatest crisis that humanity faces-climate change-through designs that reduce energy consumption.” Norman Foster.

#### 1.5.1.1. A major risk for the planet

The global demand of energy is growing significantly as a response to population expansion and the improving standard of living, leading to one of the main risks in the human future is known as the climate change caused by CO2 emissions out of fossil fuels. That’s why our health, water quality and even agricultural production are wildly effected by the consequences of the ongoing atmospheric, sea and soil pollution. The greenhouse gas emissions causing the climate change is defiantly the biggest and most immediate risk.

Although the effects on the environment of greenhouse gas emissions caused by energy consumption popped out quite recently, we shouldn’t underestimate their consequences which leads to global warming , a disaster that already has been started and is expected to accelerate in the future if we don’t take the necessary measures.  
(Rojey)

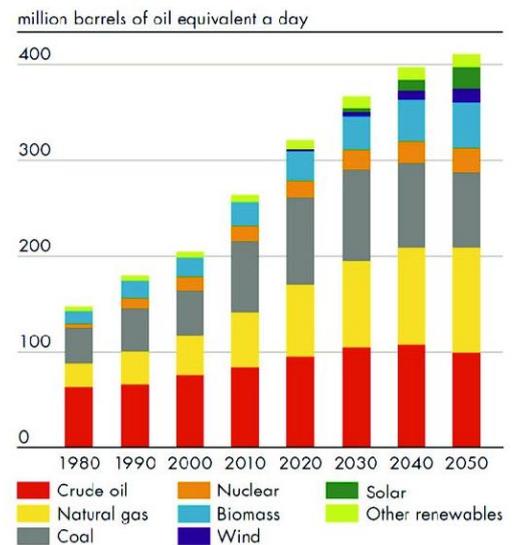


Figure 36: Global energy demand projected to 2050

(Bajracharya)

#### 1.5.1.2. Symptoms of climate change:

- Regular sea level rising.
- Multiplication of heat waves and droughts.
- Cyclones and torrential rain.
- Huge impact on the biosphere.

(Rojey)

#### 1.5.1.3. Energy alternatives:

We must therefore look towards alternative energy sources, namely nuclear and renewable. In principle, the renewable energy resources are inexhaustible on a human scale.

**Solar energy:** Solar power, or the solar electricity, is farming electricity from solar exposure, usually using photovoltaics (PV) which create electric current from light through a process called the photovoltaic. (US ENERGY DEPARTMENT)



Figure 37: solar energy panels

**Wind energy:** kinetic energy of air is converted in motion to produce electric current that's how electricity is produced from wind. using modern wind turbines, the rotor blades rotate, and that creates the rotational energy. that is transferred by a shaft which to the generator, thereby producing electrical energy. (INTERNATIONAL RENEWABLE ENERGY AGENCY)

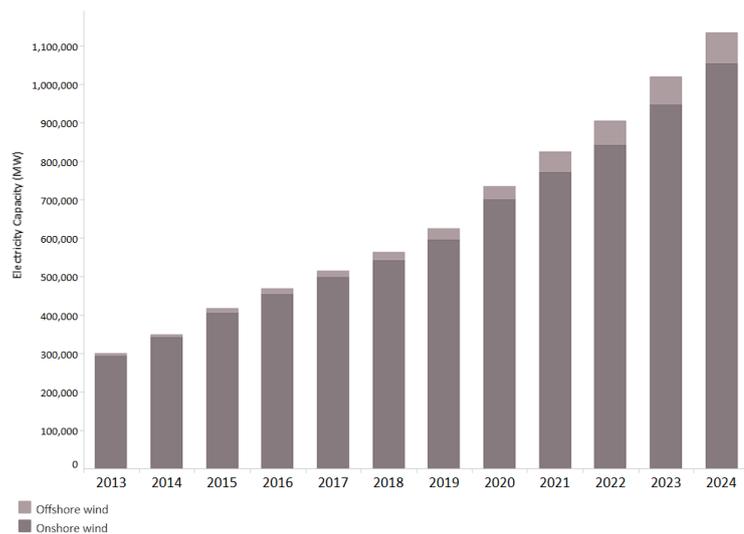


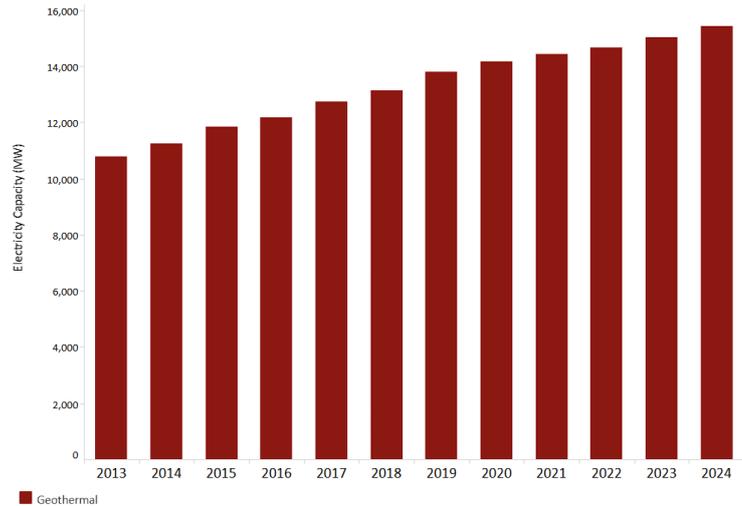
Figure 38: Electricity Capacity Trends

(INTERNATIONAL RENEWABLE ENERGY AGENCY)

**Geothermal energy:** Geothermal energy is actually capturing heat energy from the earth—geo (earth) + thermal (heat).

Geothermal resources are huge reservoirs of hot water that are natural or made by humans which have different depths and of course different temperatures. by extracting hot steam and water from various ranging wells from few meters up to kilometres of depth to the surface so it could be used in different applications. (US ENERGY DEPARTMENT)

Figure 39: Electricity Capacity Trends  
(INTERNATIONAL RENEWABLE ENERGY AGENCY)



**Biomass energy:** Bioenergy is basically the energy source we get out of the organic matter that's the plants which captures the carbon via photosynthesis . we farm this energy during the combustion of biomass which releases carbon back to the atmosphere although its low emission fuel.  
(INTERNATIONAL ENERGY AGENCY)

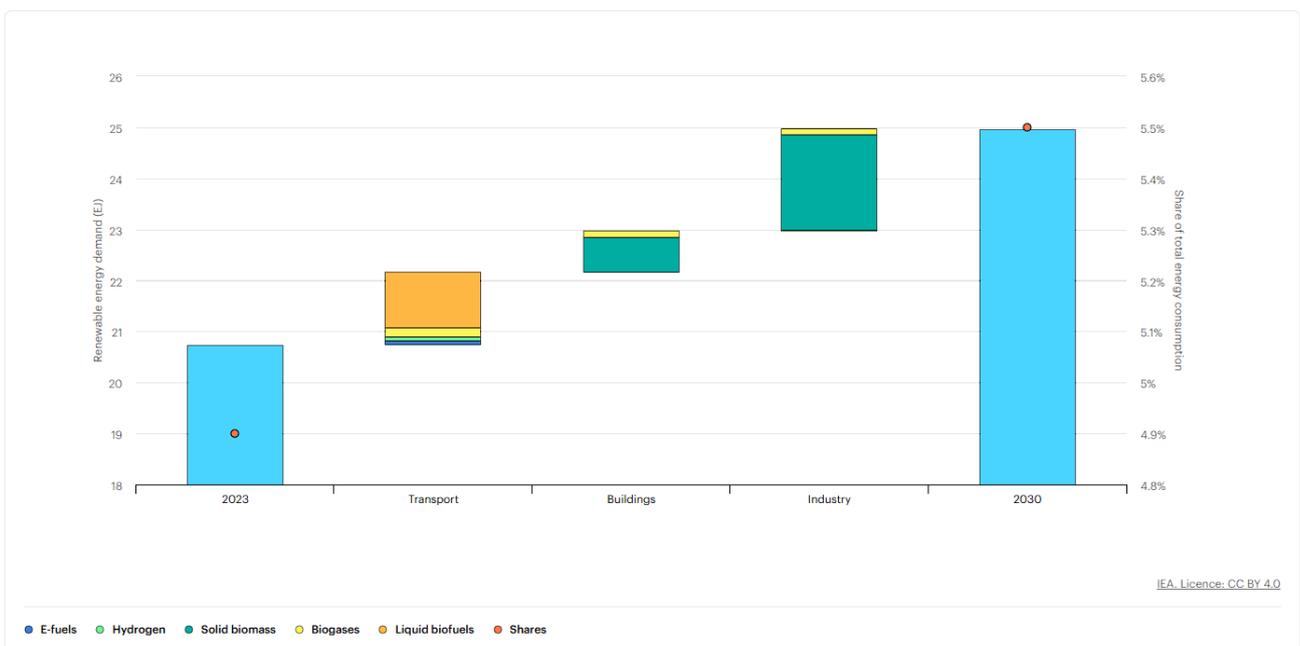


Figure 40: (INTERNATIONAL ENERGY AGENCY) (2024), *Renewable fuel growth by fuel type, main case, 2023-2030*

### 1.5.1.4. Towards the positive energy building

According to the International Energy Agency (IEA), the building sector accounts for nearly 40% of global energy use and approximately 33% of greenhouse gas emissions.

Architects must consider energy balance while designing. That to avoid energy losses and optimize solar energy inputs through the best adapted orientation.

Developing more efficient materials and building equipment is a matter of necessity now, including thermal insulation technologies, which are still advancing through the use of better performing materials and more efficient implementation. Using better performing equipment can reduce energy consumption pretty much to. In addition to what consumes 20% of the global electricity production, Lighting. (INTERNATIONAL ENERGY AGENCY)

### 1.5.2. Architectural Solutions for Minimizing Energy Consumption:

*Sustainability: "the ability to meet the needs of the present without compromising the needs of future generations."* The United Nations Conference 1987

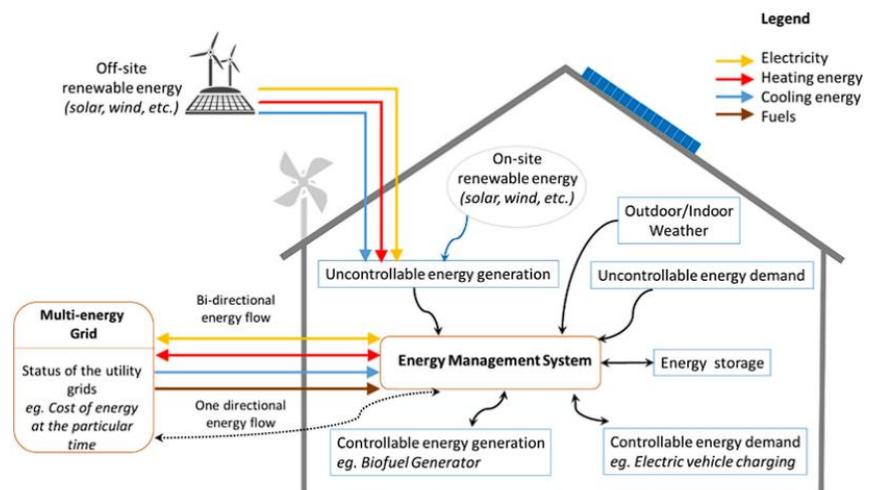
#### 1.5.2.1. Energy-Efficient Building:

Integration of many factors is the essential character of sustainable buildings.

Efficient buildings are expected to absolutely reduce the heat loss or gain, depending on the season, the region and the buildings internal metabolism. And that's only by considering siting and orientation in the first place, which affects the solar, air use, control and movement. And of course this also requires an energy-efficient construction by using good performance (Bainbridge & Haggard)

Figure 41: Smart energy management schema of PEBs.

(Bainbridge & Haggard)



Positive Energy Buildings (PEBs) represent a step forward from Net Zero Energy Buildings.

Buildings. They shall contribute by:

- Decarbonizing the built environment, including surrounding buildings, by exchanging energy among them or with the grid.
- Reducing the energy grid congestion.
- Providing a flexible energy asset that allows buildings and energy communities to act as an

integrated part of the energy system.

- Ensuring healthy and comfortable indoor environment, embracing occupants' diversities and Needs.
- Supporting users' energy-related practices and their flexibility.
- Minimizing their own carbon footprint.

(UNITED NATIONS CLIMATE CHANGE UNCC)

### 1.5.2.2. Natural Lighting

“We were born of light. The seasons are felt through light. We only know the world as it is evoked by light....To me natural light is the only light, because it has mood—it provides a ground of common agreement for man—it puts us in touch with the eternal. Natural light is the only light that makes architecture architecture.” LOUIS I. KHAN.

Natural lighting buildings is the best using of sunlight and diffuse radiation from the sky in order to light the buildings inside. In new buildings this is very essential. Natural light by adding movement, change and connection to the outdoor provides an enjoyment.

the main goal of a well natural light integration is to achieve visual comfort that is healthful, pleasant, productive, and safe for people. This is quite hard due to the complex and adaptable nature of both human eye and brain, let alone the personal subjective preferences, the visual capability, and task requirements vary very widely.

Vision can also be affected by corrective lenses, allergies, disease, and injury. But our vision is very flexible, and we can adapt to a broad range of lighting intensities and frequencies.

(Bainbridge & Haggard)

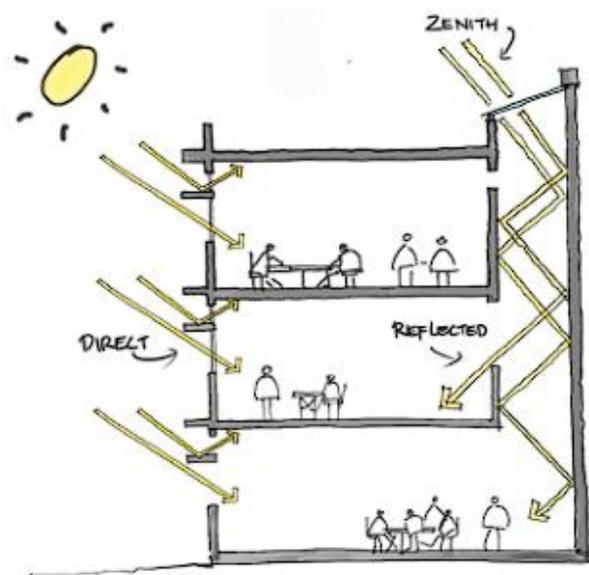


Figure 42: Natural lighting illustration.  
(Bainbridge & Haggard)

Although we can adapt to almost anything, it is good to design with the following criteria in mind:

- Visual comfort.
- Healthful levels and frequencies of light.
- Light for efficient task completion and productivity.
- Minimal glare.
- Varied light levels and patterns—connection to outdoors.
- Maximum use of daylighting.
- Integration with other building-systems goals: passive heating, cooling, and ventilation.
- Minimal life-cycle energy use and cost. p318
- Low initial cost.
- Reduced operating cost and environmental impact.
- Maximum flexibility and user control.
- Maximum desired heat gain in winter.
- Minimal undesired heat gain in summer.
- Minimal use of non-renewable energy sources.
- Well-developed educational materials and guides for use.
- Automatic control of switching to adjust to varying natural light levels. (Bainbridge & Haggard)

### **1.5.3. Smart Facades:**

“Architecture is the art of space and energy.” This shows how the built environment can manipulate daylight and climate. Jean Nouvel

Building facades have the role of a climatic moderators, that’s because they are the link between the indoor and outdoor environments, and that’s by effecting air quality, temperature, humidity, sound levels, and as a result the overall well-being.

Façade also have a direct impact to our mood through the views and a sense of time. all of materials and window placement are to be considered in order to insure fresh, airy, and daylight-filled spaces. vernacular architecture, nature and emerging technologies are great combination for our facades to become sustainable, enjoyable, and healthy for occupants.

Modern technologies and smart materials are pushing facades forward to function as complex membranes, exchanging energy, materials, and information, and integrating with building systems like sensors and actuators for efficient operation. (Herzog)

### 1.5.3.1. Smart facades types:

#### Passive Smart Facades:

These facades rely on design strategies and material properties to adapt to environmental conditions without mechanical systems or energy input. They respond to changes in temperature, sunlight, or airflow through inherent physical behavior, geometry, or material characteristics.

Examples:

- Double-skin façades
- Thermochromic glazing
- Biomimetic shading systems

(Capeluto & Ochoa, 2017)



Figure 43: Double-skin façade

#### Smart Material-Based Facades :

Facades incorporating materials that change their properties in response to external stimuli, such as heat, light, or electricity — without moving parts. These materials provide adaptive performance by altering transparency, insulation, color, or shape based on environmental triggers. (Capeluto & Ochoa, 2017)

Examples:

- Electrochromic glass.
- Phase-change materials (PCMs).
- Shape-memory alloys.



Figure 44: Electrochromic glass facade.

Figure 45: Phase-change materials (PCMs) based façade.



- Figure 46: Shape-memory alloys façade system.



### **Kinetic / Movable Facades:**

Mechanically adjustable façade elements that move in response to environmental stimuli or user input, often using motors, actuators, or hinges. These systems allow dynamic control over daylighting, ventilation, solar gain, and aesthetics. Movement can be manual or sensor-driven.

Examples:

- Rotating panels
- Folding membranes
- Automated louvers and shutters

(Moloney, 2011)

Figure 47: Rotating panels façade

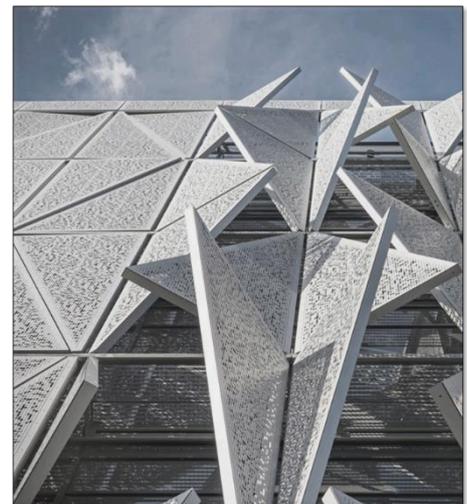


Figure 48: Folding membranes façade system.



Figure 49: Automated louvers and shutters on a façade



### **Hybrid Active-Passive Facades:**

Facades that combine both passive design principles and active control systems to achieve enhanced performance across seasons and usage scenarios. They integrate passive thermal regulation (e.g., thermal mass, cavity ventilation) with automated adjustments (e.g., operable vents, motorized shading), creating a balanced system.

Example:

- Double-skin façades with automated venting and internal blinds
- Shading systems combining fixed geometry with movable components

(Capeluto & Ochoa , 2017)

## **Conclusion:**

In this chapter, we conducted a detailed theoretical study covering all the essential concepts needed for our project. We began by defining art from different perspectives and explored its historical evolution from prehistoric times to the present. We also classified various art facilities, with a focus on the importance of art schools in supporting creativity and cultural development. In addition, we reviewed the architectural standards and spatial requirements for spaces like theaters, libraries, classrooms, workshops, and exhibition areas, which helped us understand the key design needs for our project. We also addressed the importance of energy conservation and sustainability in architecture, emphasizing the role of smart facades and shading devices in improving energy performance and user comfort. This theoretical foundation will guide us as we move to the next chapter, where we will analyze existing examples and study the chosen site to prepare for the design of our adaptive shading system and the School of Art.

# **CHAPTER II: ANALYTIC STUDY**

## **Introduction:**

In this chapter, we will analyze the three main aspects of our project to guide us in the design phase. First, we will study bookish and real-life examples of existing art schools to understand their space planning, functional distribution, and architectural strategies. This will help us extract useful references and design lessons. Then, we will conduct a detailed field analysis of the chosen site, including its location, surroundings, climate data, wind patterns, sun exposure, and accessibility. This step is essential to design a building that suits the specific environmental and urban context. Finally, based on the example analysis, official requirements, and the characteristics of the site, we will propose our final program for the School of Art.

## 1. Examples analysis:

### 1.1. Bookish examples:

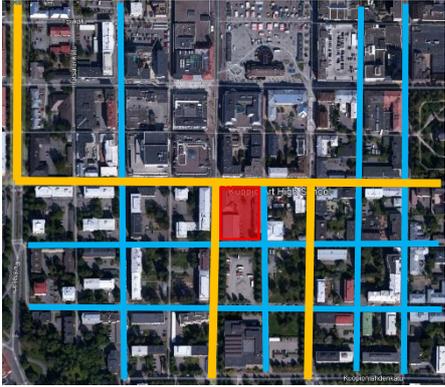
Those are our chosen examples :

- Bedales School Art and Design (United Kingdom)
- Glassell School of Art (United States)
- Lumit Art High School (Finland)

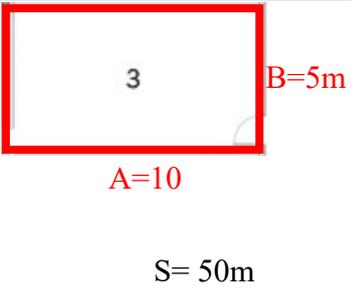
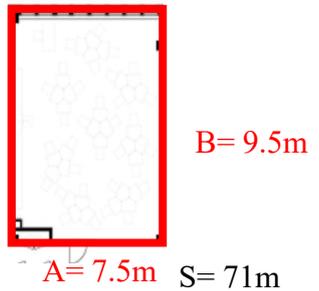
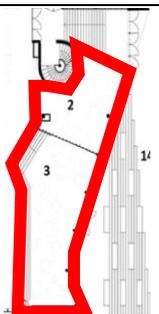
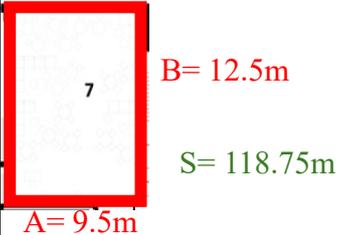


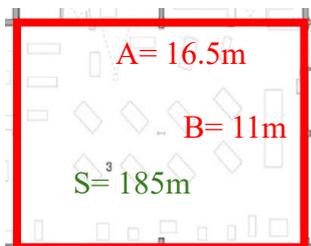
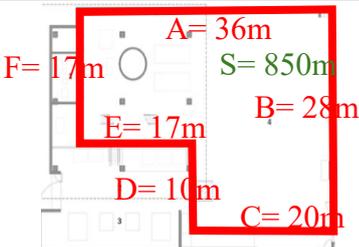
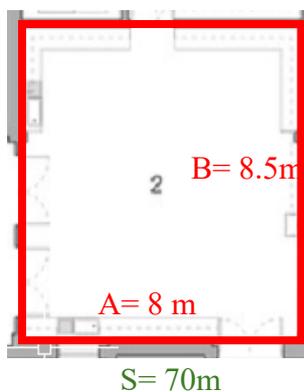
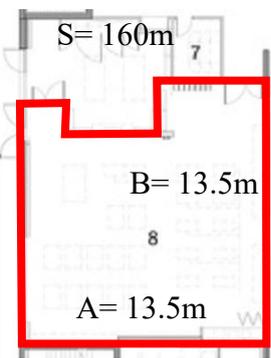
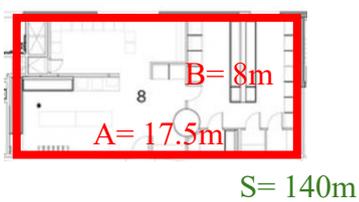
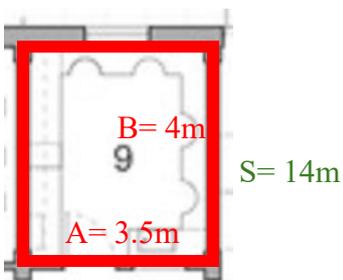
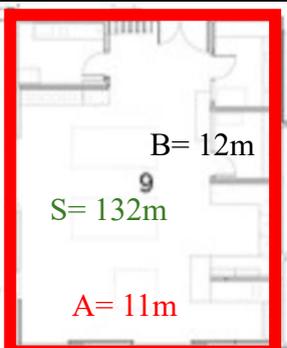
Figure50 : Chosen bookish examples to analyse

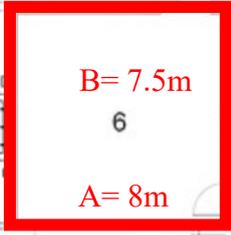
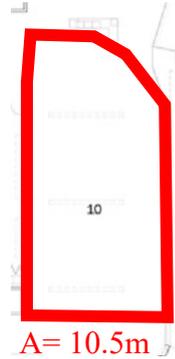
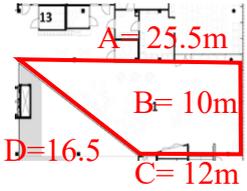
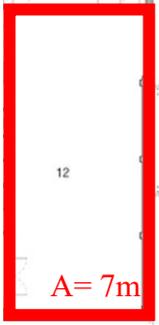
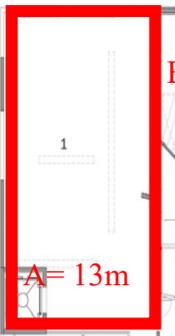
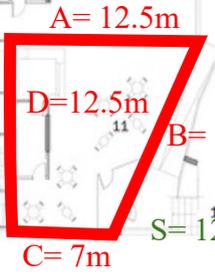
The project	Technical sheet	Location
 <p data-bbox="161 584 563 618">Bedales School Art and Design</p>	<p data-bbox="595 241 890 280"><b>Type:</b> school of art.</p> <p data-bbox="595 304 820 342"><b>Area:</b> 2100 m<sup>2</sup></p> <p data-bbox="595 367 874 405"><b>Completed:</b> 2016.</p> <p data-bbox="595 430 943 517"><b>Architect(s):</b> Feilden Clegg Bradley Studios.</p>	<p data-bbox="1029 241 1394 535">The project is located in the north of Petersfield city in England , a rural like tissue close to educational institutions (primary and middle schools).</p>
 <p data-bbox="220 1016 504 1050">Glassell School of Art</p>	<p data-bbox="595 667 890 705"><b>Type:</b> school of art.</p> <p data-bbox="595 730 820 768"><b>Area:</b> 8600 m<sup>2</sup></p> <p data-bbox="595 792 975 831"><b>Capacity:</b> 1500 students.</p> <p data-bbox="595 855 874 893"><b>Completed:</b> 2018.</p> <p data-bbox="595 918 983 1005"><b>Architect(s):</b> Steven Holl Architects.</p>	<p data-bbox="1029 667 1434 960">The project is located in Houston city in United States . an urban tissue with art and cultural milestones of many museums, including the Houston fine arts museum.</p>
 <p data-bbox="212 1420 512 1453">Lumit Art High School</p>	<p data-bbox="595 1093 890 1131"><b>Type:</b> school of art.</p> <p data-bbox="595 1155 820 1193"><b>Area:</b> 9550 m<sup>2</sup></p> <p data-bbox="595 1218 959 1256"><b>Capacity:</b> 600 students.</p> <p data-bbox="595 1281 874 1319"><b>Completed:</b> 2015.</p> <p data-bbox="595 1344 999 1431"><b>Architect(s):</b> Lukkaroinen Architects.</p>	<p data-bbox="1029 1093 1426 1350">The project is located in Kuopio city, Finland . in a residential tissue, next to educational and art institutions like museums and music school .</p>

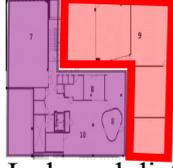
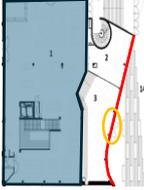
The project	Master plan study
 <p data-bbox="161 613 563 647">Bedales School Art and Design</p>	 <ul style="list-style-type: none"> <li data-bbox="1082 271 1331 304"> The project</li> <li data-bbox="1082 338 1331 371"> Main roads</li> <li data-bbox="1082 405 1398 439"> Secondary roads</li> </ul> <p data-bbox="1099 506 1382 663">The project is located in a rural-like area . with decent accessibility .</p>
 <p data-bbox="220 1205 507 1238">Glassell School of Art</p>	 <ul style="list-style-type: none"> <li data-bbox="1070 860 1319 893"> The project</li> <li data-bbox="1070 927 1319 960"> Main roads</li> <li data-bbox="1070 994 1386 1028"> Secondary roads</li> </ul> <p data-bbox="1072 1099 1378 1301">The project is located in a well-structured urban tissue . that has a very good accessibility due to various roads.</p>
 <p data-bbox="212 1753 512 1787">Lumit Art High School</p>	 <ul style="list-style-type: none"> <li data-bbox="1070 1451 1319 1485"> The project</li> <li data-bbox="1070 1518 1319 1552"> Main roads</li> <li data-bbox="1070 1585 1388 1619"> Secondary roads</li> </ul> <p data-bbox="1075 1682 1382 1883">The project is located in a well-structured urban tissue . that has a very good accessibility due to various roads.</p>

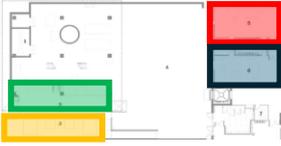
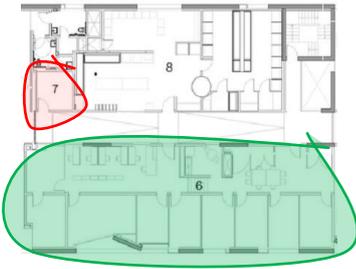
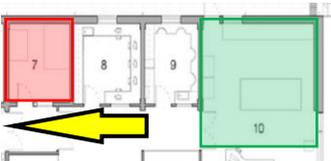
The project	Entrances
 <p data-bbox="161 613 563 647">Bedales School Art and Design</p>	 <ul style="list-style-type: none"> <li data-bbox="1090 282 1374 315"> Main entrance</li> <li data-bbox="1090 344 1323 423"> Secondary entrances</li> </ul>
 <p data-bbox="220 1205 507 1238">Glassell School of Art</p>	 <ul style="list-style-type: none"> <li data-bbox="1007 1245 1297 1279"> Main entrance</li> <li data-bbox="1007 1308 1377 1346"> Secondary entrances</li> </ul>
 <p data-bbox="212 1756 512 1789">Lumit Art High School</p>	 <ul style="list-style-type: none"> <li data-bbox="1074 1476 1358 1509"> Main entrance</li> <li data-bbox="1074 1538 1307 1617"> Secondary entrances</li> </ul>

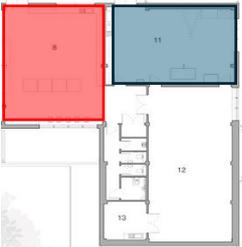
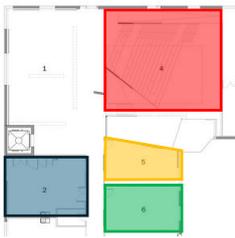
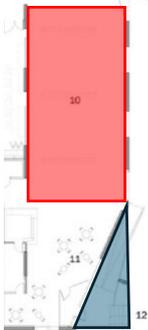
The space	Form/ dimation/surface		
	Bedales School Art and Design	Glassell School of Art	Lumit Art High School
Classrooms	/	 <p>A=10 B=5m S= 50m</p>	 <p>A= 7.5m B= 9.5m S= 71m</p>
Library	/	/	 <p>S= 150m</p>
Lecture hall	/	/	 <p>A= 9.5m B= 12.5m S= 118.75m</p>
Drawing Workshop	/	 <p>A= 13m B= 8m S= 104m</p>	/

The space	Form/ dimation/surface		
	Bedales School Art and Design	Glassell School of Art	Lumit Art High School
Sculpture Workshop	 <p>A= 16.5m B= 11m S= 185m</p>	 <p>A= 36m B= 28m C= 20m D= 10m E= 17m F= 17m S= 850m</p>	/
Ceramic Workshop	 <p>A= 8 m B= 8.5m S= 70m</p>	 <p>A= 13.5m B= 13.5m S= 160m</p>	/
Photography Workshop	/	 <p>A= 17.5m B= 8m S= 140m</p>	/
Jewellery studio	 <p>A= 3.5m B= 4m S= 14m</p>	 <p>A= 11m B= 12m S= 132m</p>	/

The space	Form/ dimation/surface		
	Bedales School Art and Design	Glassell School of Art	Lumit Art High School
Digital studio	/	 <p>B= 7.5m 6 A= 8m S= 60m</p>	/
Exhibit Hall	/	 <p>B= 21.5m 10 A= 10.5m S= 225m</p>	 <p>A= 25.5m B= 10m D=16.5 C= 12m S= 180m</p>
Gallery	 <p>S= 105m 12 B= 15m A= 7m</p>	 <p>B= 21m 1 S= 263m A= 13m</p>	/
Cafeteria	/	 <p>A= 12.5m D=12.5m B= 14m S= 125m C= 7m</p>	 <p>A= 19m S= 485m B=27m</p>

The space	Positioning/Relationships with others		
	Bedales School Art and Design	Glassell School of Art	Lumit Art High School
Classrooms	/	 <p>U shaped distribution Next to other teaching facilities: 2.meetings 7.5. digital 6.</p> <p>studios offices</p>	 <p>L shaped distribution</p> <p>Next to other teaching facilities : 7.lecture hall 8.group spaces 10.teaching lobby</p>
Library	/	/	 <p>Transparent façade</p> <p>-Have its own entrance</p> <p>-Next to restaurant lobby</p>
Lecture hall	/	/	 <p>Next to other teaching facilities : 9. classrooms 8.group spaces 10.teaching lobby</p>
Drawing Workshop	/	<p>GATHERING SPACE</p>  <p>EXTIRIOR VIEWS</p>	/

The space	Positioning/Relationships with others		
	Bedales School Art and Design	Glassell School of Art	Lumit Art High School
Sculpture Workshop	 <p>STORAGE CNC ROOM TECHNICHANS WORKSHOP</p>	 <p>WOOD WORKSHPP METAL WORKSHOP SERVICE ENTRY TRANSFORMER</p>	/
Photography Workshop	/	 <p>IT ROOM OFFICES</p>	/
Jewellery studio	 <p>CNC ROOM FASHION STUDIO MAIN WORKSHOP ENTRANCE</p>	/	/

The space	Positioning/Relationships with others		
	Bedales School Art and Design	Glassell School of Art	Lumit Art High School
Digital studio	/	 <p>DRAWING STUDIOS</p>	/
Exhibit Hall	/	 <p>FORUM CAFETERIA MAIN ENTRANCE</p>	 <p>VISUAL ART CLASSROOMS</p>
Gallery	 <p>ART STUDIO/WORKSHOP PRINTING STUDIO</p>	 <p>FORUM DIGITAL STUDIO PRINTING STUDIO DRAWING STUDIO</p>	/
Cafeteria	/	 <p>EXHIBIT HALL ENTRANCE</p>	 <p>LIBRARY GYMNASIUM KITCHEN FACILITIES</p>

## 2. Site analysis:

2.1. **Location:** Our site is located northwest of the city of BISKRA, the western extension zone.

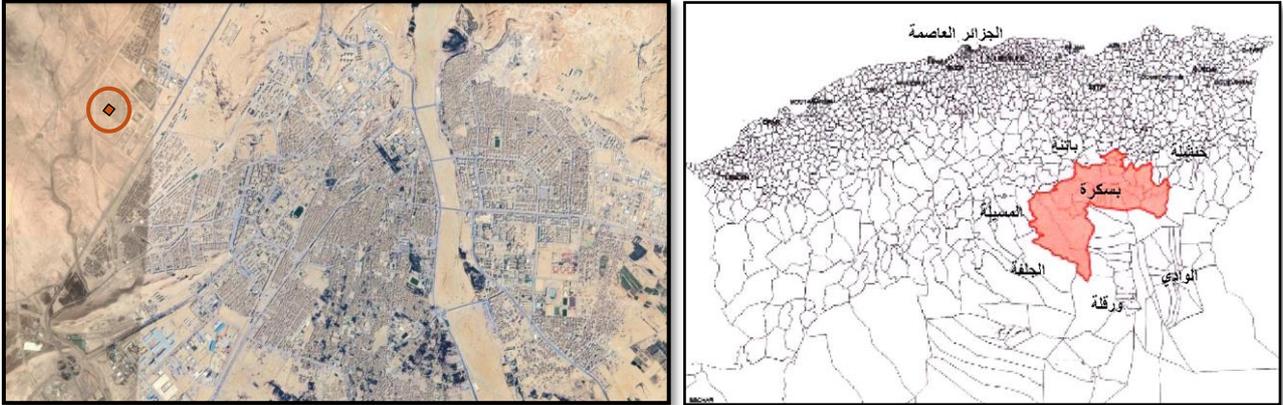


Figure 51: satellite image of city of BISKRA(google maps)

## 2.2. Neighbourhood context:

- SITE STUDIED**
- COLLECTIVE HOUSING**
- EDUCATION**
- CITY HALL**
- PUBLIC FACILITIES**
- FIRE STATION**
- POLICE STATION**

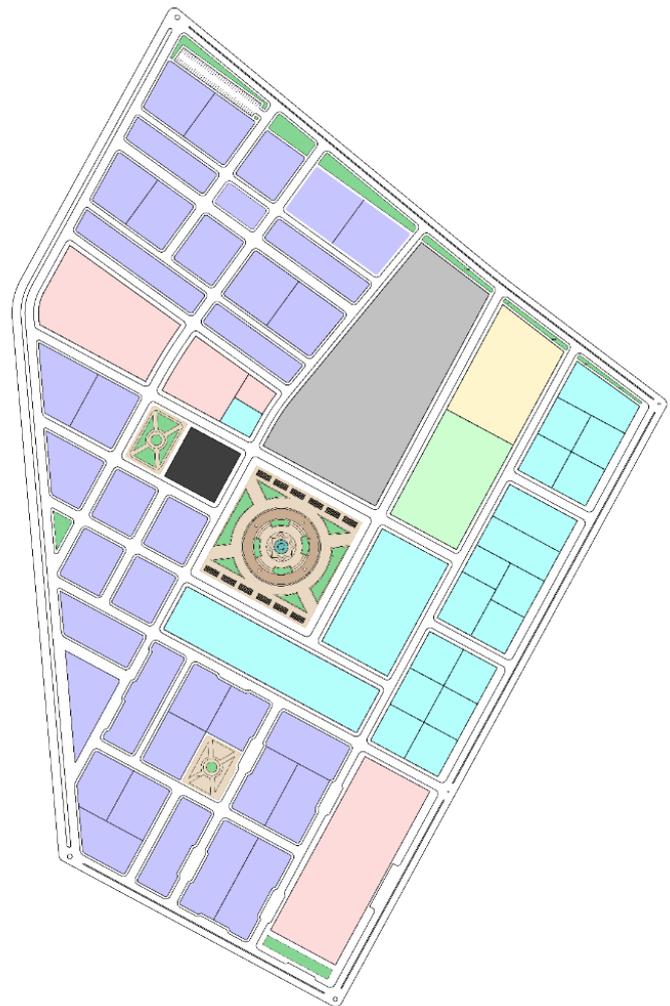
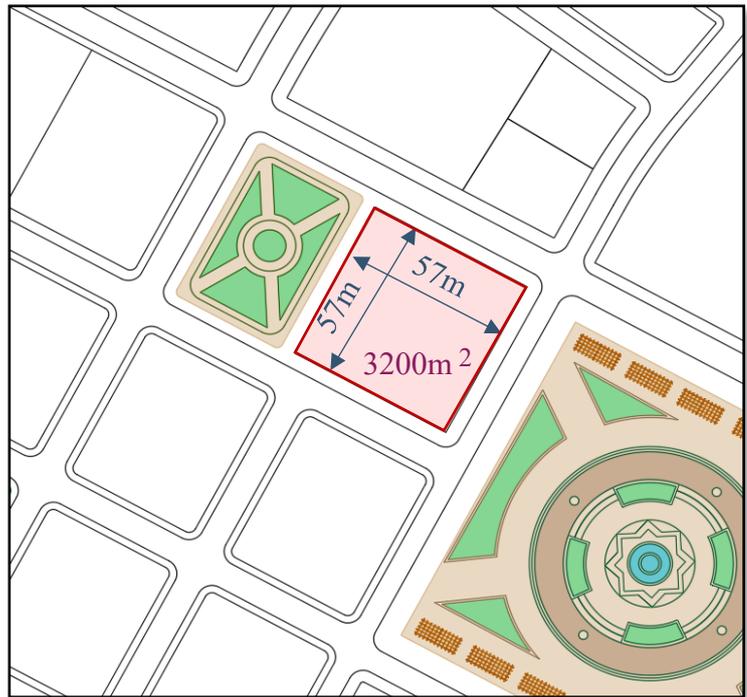


Figure 52: site plane of the chosen land.  
(P.O.S)

**2.3. DIMENTIONS:** The land is perfectly square shaped by the secondary roads and the green spaces.

Figure 53: land dimensions and Surface (P.O.S)



**2.4. Topography:** With an inferior slop of approximately 1.4%, The site is almost flat.

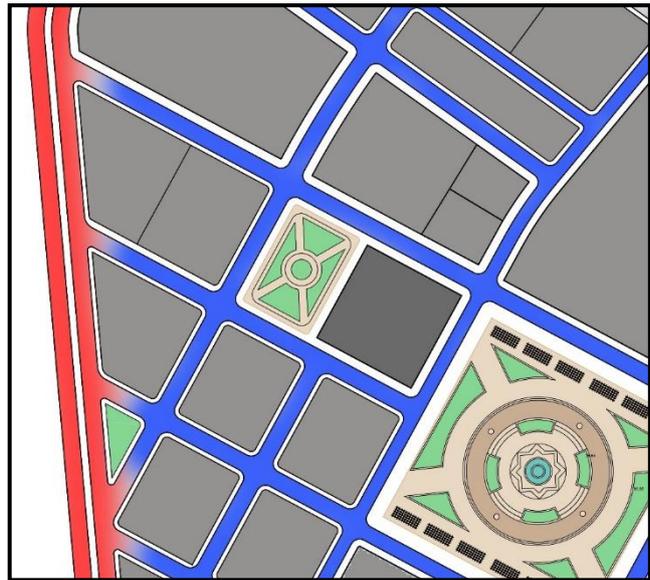
Figure 54: topographic section of the land (google earth)



## 2.5. Circulation & access:

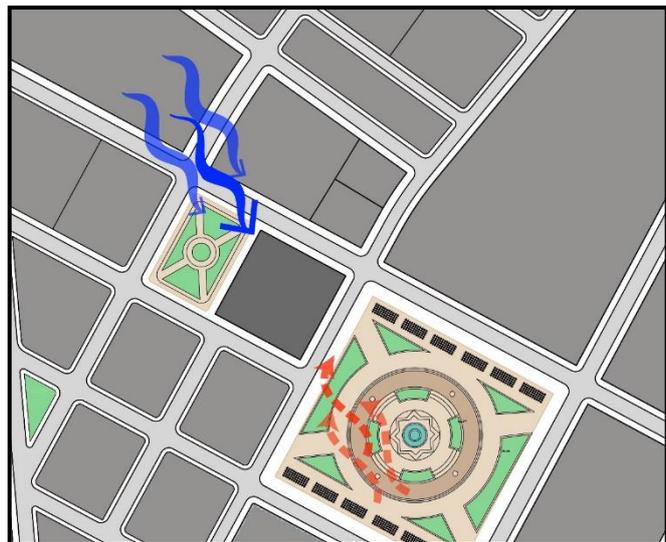
- Main roads
- Secondary roads

Figure 55: roads plan (P.O.S)



**2.6. Wind patterns:** The site is exposed to two air currents: northern and southern air currents. The most important winds to which the region is exposed are the northwestern and southeastern winds, the first blowing in winter and the second in summer. As for the Sirocco winds, they blow from the south and are active between April and October.

Figure 56: wind pattern plan  
(P.O.S)

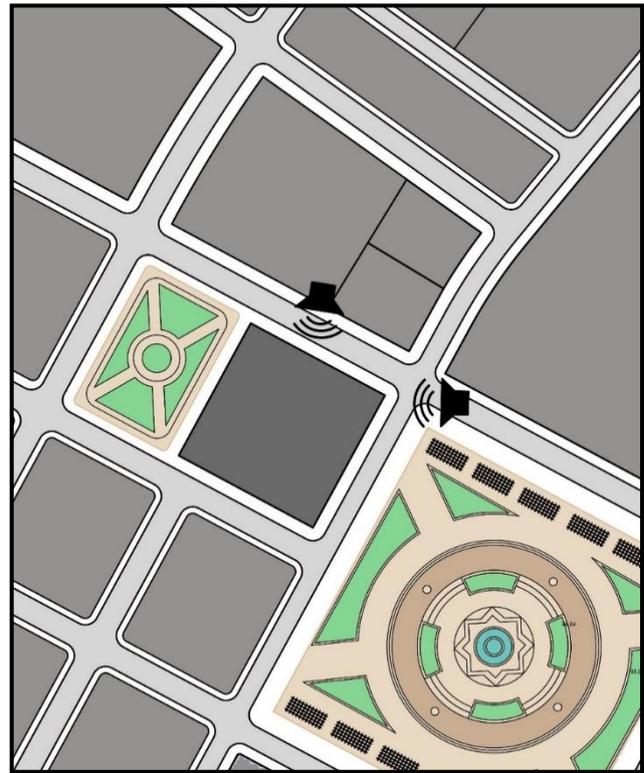


## 2.7. Noise sources:

🔊 Noise sources

Green spaces

Figure 57: noise sources plan  
(P.O.S)



## 2.8. STRENGTHS AND WEAKNESSES

STRENGTHS	WEAKNESSES
<ul style="list-style-type: none"> <li>• being the site is proposed for a cultural centre.</li> <li>• Green spaces north and south of the site.</li> <li>• Strong mechanical accessibility.</li> <li>• Site located in an administrative area.</li> <li>• Nearby housings.</li> <li>• Suitable topography that's almost flat.</li> <li>• Huge area allowing good exterior management and green spaces.</li> </ul>	<ul style="list-style-type: none"> <li>• Totally exposed to sun rays almost all the daytime.</li> <li>• Considerable noise sources surrounding the site.</li> </ul>

### 3. Programming:

	<b>Bedales School Art and Design</b>	<b>Glassell School of Art</b>	<b>Lumit Art High School</b>	<b>official programme</b>
Director's Office	/	/	/	<b>25</b>
Secretariat	/	/	/	<b>15</b>
Education Service	/	/	/	<b>30</b>
Teachers' room	/	/	<b>100</b>	<b>50</b>
Classrooms	/	<b>8x45</b>	<b>2x200</b>	<b>40</b>
Library	<b>37</b>	/	<b>150</b>	<b>270</b>
Lecture hall	/	/	<b>120</b>	/
Exhibit Hall	<b>100</b>	<b>2x180</b>	<b>180</b>	<b>150</b>
Cafeteria	/	<b>180</b>	<b>420</b>	<b>80</b>
Black box theatre	/	/	<b>330</b>	/
Cloakroom	/	/	<b>35</b>	/
Sculpture Workshop	<b>180</b>	<b>850</b>	/	<b>70</b>
Metal-workshop	<b>15</b>	<b>125</b>	/	/
Wood-workshop		<b>125</b>	/	/
Printing studio	<b>75</b>	<b>65</b>	/	/
Ceramic Workshop	<b>70</b>	<b>180</b>	/	<b>70</b>
Kiln room	<b>6.5</b>	<b>20</b>	/	/
Photography Workshop	/	<b>140</b>	/	<b>70</b>
Digital studio	/	<b>75</b>	/	/
Jewellery studio	<b>13</b>	<b>140</b>	/	/
Interior Decor Workshop	/		/	<b>70</b>
Drawing Workshop	/	<b>7x100</b>	/	<b>4x70</b>
Technician's workshop	<b>90</b>	/	<b>100</b>	/
Plant rooms	<b>2x25</b>	/		/

#### 4. Proposed programme:

<b>FUNCTION</b>	<b>SPACE</b>	<b>AREA</b>	<b>NUMBER</b>	<b>TOTAL AREA</b>
<b>ADMINISTRATION</b>	Director's Office	25	1	25
	Secretariat's Office	15	1	15
	Education Service	50	1	50
	Meeting room	65	1	65
	<b>TOTAL</b>			<b>155</b>
<b>THEORETICAL EDUCATION</b>	Library	240	1	240
	Lecture hall	160	1	160
	Classrooms	50	6	300
	<b>TOTAL</b>			<b>600</b>
<b>PERFORMING SPACES</b>	Exhibit	250	1	250
	Theatre	235	1	235
	<b>TOTAL</b>			<b>485</b>
<b>PRACTICAL EDUCATION</b>	Metal-workshop	120	1	120
	Wood-workshop	120	1	120
	Ceramic/Sculpture Workshop	120	2	240
	Music Workshop	120	1	120
	Photography-workshop	120	1	120
	Drawing studio	62	6	372
	Interior Decor	62	2	124
	Jewellery studio	62	2	124
	Digital studio	62	2	124
<b>TOTAL</b>			<b>744</b>	
<b>ANNEXES</b>	Cafeteria	265	1	265
	Restrooms	40	4	160
	<b>TOTAL</b>			<b>425</b>
	Circulation			<b>1500</b>
<b>Slabbed Area</b>				<b>3909</b>
<b>Parking lots (10)</b>				

## **Conclusion:**

In this chapter, we have covered a detailed analytical study that focused on three main aspects of our project. We started by analyzing selected examples of art schools from different countries, which helped us understand the functional organization, spatial relationships, and key design strategies applied in each case. We then carried out a deep study of the chosen site in our city of Biskra, examining its location, access, wind patterns, sun exposure, topography, surrounding context, and noise sources. Through this site analysis, we were able to clearly identify both the strengths and weaknesses of the land, which helped us shape our design decisions to suit the local conditions. Finally, we proposed a detailed program for the School of Art based on the lessons learned from the analyzed examples, the official requirements from the Algerian Ministry of Culture, and the characteristics of the site. This analytical phase has set the ground for the practical design stage, which will be presented in the next chapter.

# **CHAPTER III: PRACTICAL STUDY**

## **Introduction:**

After completing the theoretical and analytical studies in the previous chapters, this chapter focuses on the practical application of our work. Here, we will design and develop our adaptive shading system, which aims to regulate temperature and light levels in buildings while maintaining a strong architectural identity. The shading system will not only address the technical performance but will also contribute to the aesthetic quality of the project. Once the shading system is finalized, we will integrate it into the architectural design of the School of Art, applying our chosen design concepts and energy strategies to achieve an environmentally responsive and culturally rich building.

## **1. The shading devices:**

In this work we are going to create a shading device that is a three-dimensional that is controlled by the input of temperature and light levels for the purpose of minimizing the heat gain and insuring a visual comfort with decent light levels.

The shading device will be mechanically change its state answering to the weather data in real-time.

### **1.1. The shading devices mechanism:**

The shading devices will be closed or opened analogically depending on the temperature and light levels that are captured , and that need several part to deliver this precise function :

#### **1.1.1. The pannels:**

A two dimensional Pannel that will be the major moving part .could be made of different materials such as aluminum, wood, resin...

#### **1.1.2. The frame:**

A metallic structure that holds all the different parts in place, must be regide and well calculated.

#### **1.1.3. Actuator:**

Electric motor that allows to control the movement of the shading device.

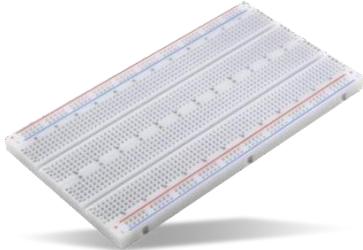
#### **1.1.4. Control System :**

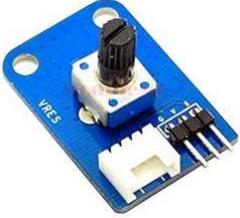
Includes switches, remote controls, sensors (for light, temperature),and microprocessors to automate the adjustment of louvers.

### **1.2.The shading devices programme:**

In order to create a program that automates the movable shading device, a hardware and a software are needed such as sensors, actuators and a control system such as a microcontroller (Arduino uno in our case), to adjust the shading device based on the environmental conditions.

This is the used hardware :

Component	Function	Image
Arduino Uno	It is the intelligence of the product, it receives data read by sensors and analyze it, to operate the shading device and achieve comfort.	
Breadboard	Used by designers to build temporary circuits.	
Servo motor	It is a motor that has a built-in driver, it receives the signal from the Arduino to operate the shading device mechanism	
Light dependent resistor (LDR)	A type of resistors that resists light intensity and indicate it.	

<p>Digital Temperature and Humidity Sensor (DHT 22)</p>	<p>It measures the temperature and humidity of the surrounding air (in our case we will measure only temperature).</p>	
<p>Potentiometer</p>	<p>A variable resistor that works as voltage divider, it allows to operate the shading device manually.</p>	
<p>Push buttons</p>	<p>They are used to change between 3 modes in the shading device (Lighting, Temperature, Manual operation)</p>	
<p>Light emitting diode (LED)</p>	<p>Help indicate which mode the shading device is in.</p>	

<p>Jumper wires</p>	<p>They Connect two points to each other without soldering, to transfer both power and data.</p>	
<p>Lithium battery</p>	<p>It is used as a power supply for the product.</p>	

### 1.3.Uploading the code :

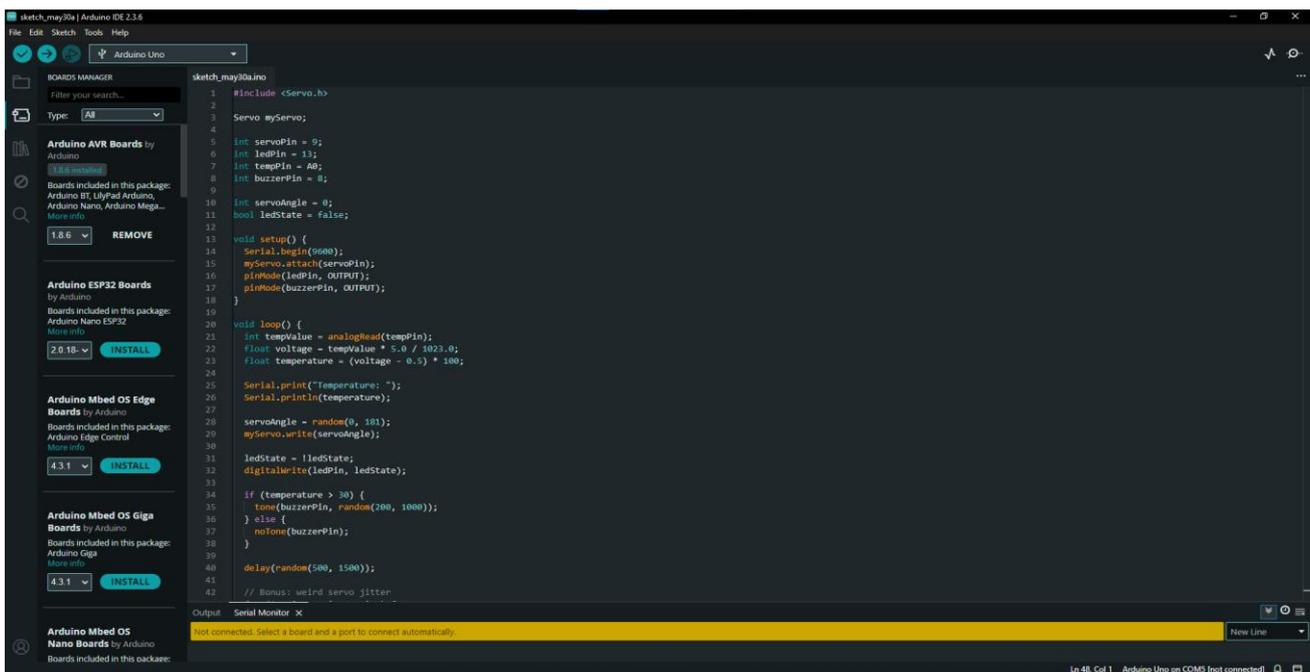
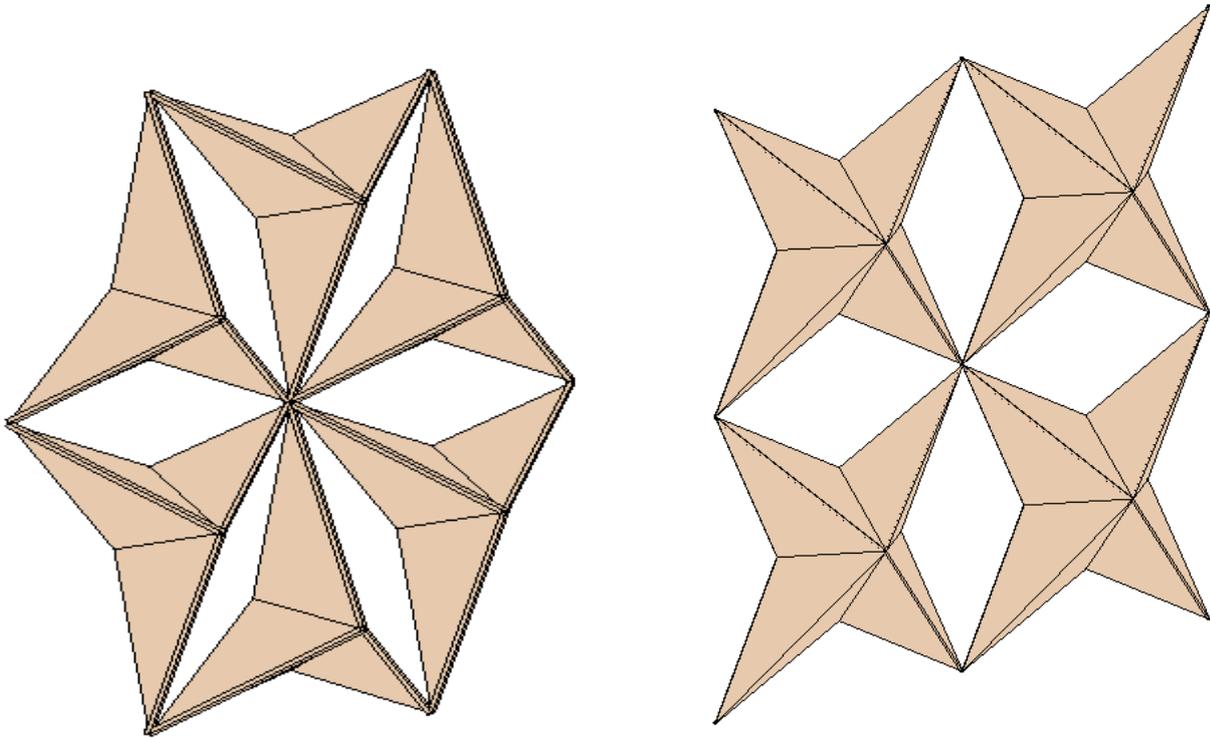


Figure 58: Arduino code uploading. (Arduino ide)

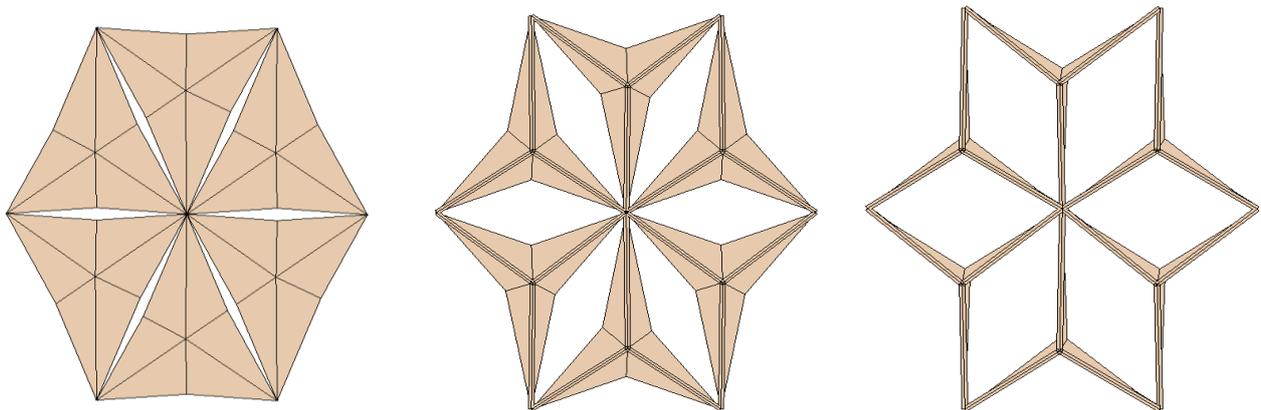
#### 1.4.The different shading devices options and their states:



**Triangle based**

**Square based**

Figure 59: Shading devices current options . (The Author)

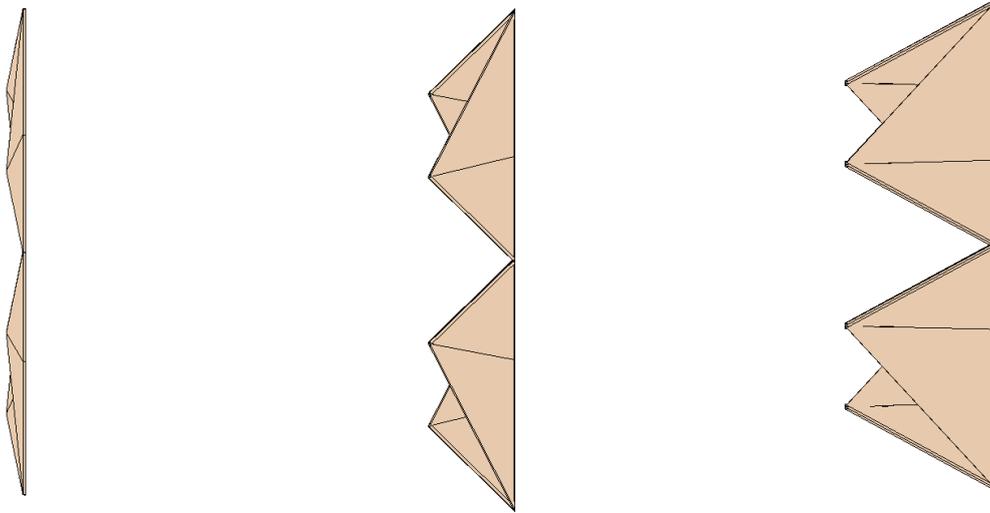


0% Opened

50% Opened

100% Opened

Figure 60: Triangle based shading devices open state elevation view. (The Author)

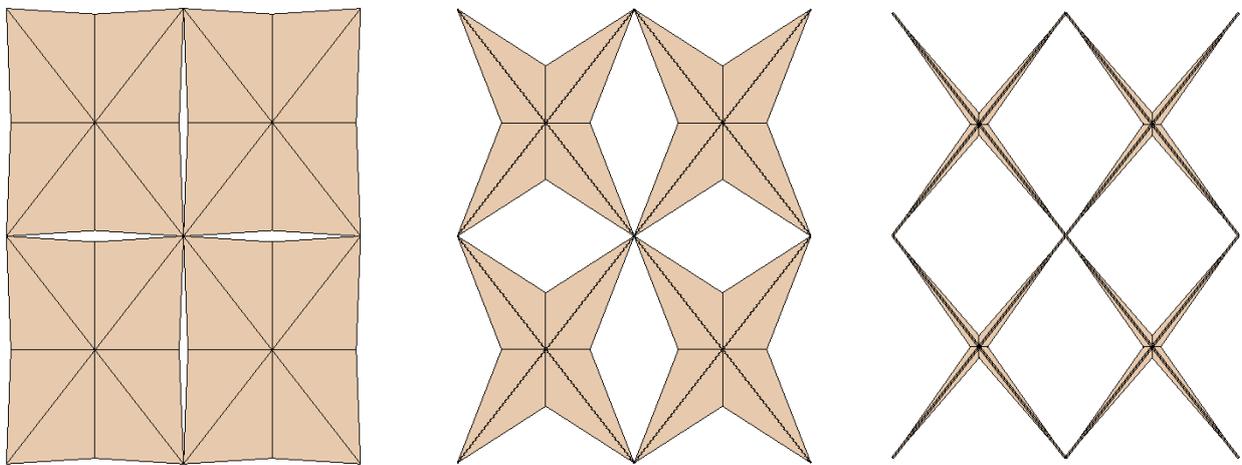


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Figure 61: Triangle based shading devices open state section view. (The Author)

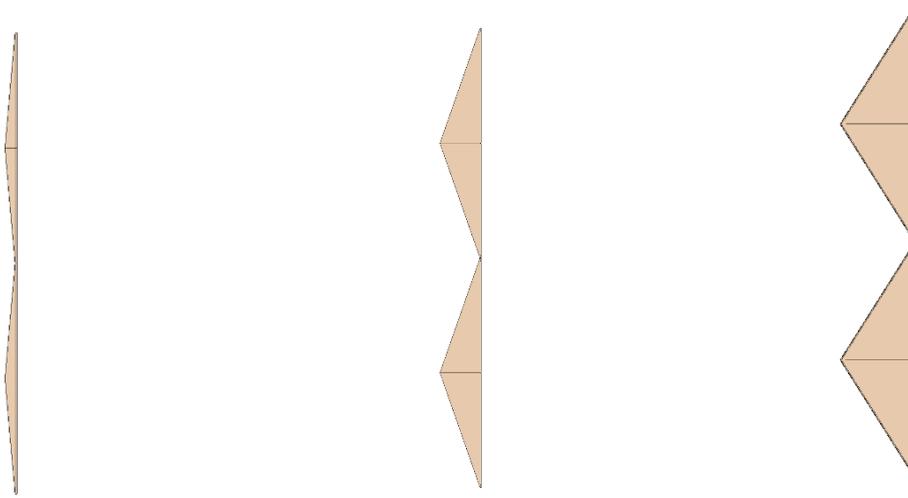


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Figure 62: Square based shading devices open state elevation view. (The Author)



0% Opened

50% Opened

100% Opened

Figure 63: Square based shading devices open state section view. (The Author)

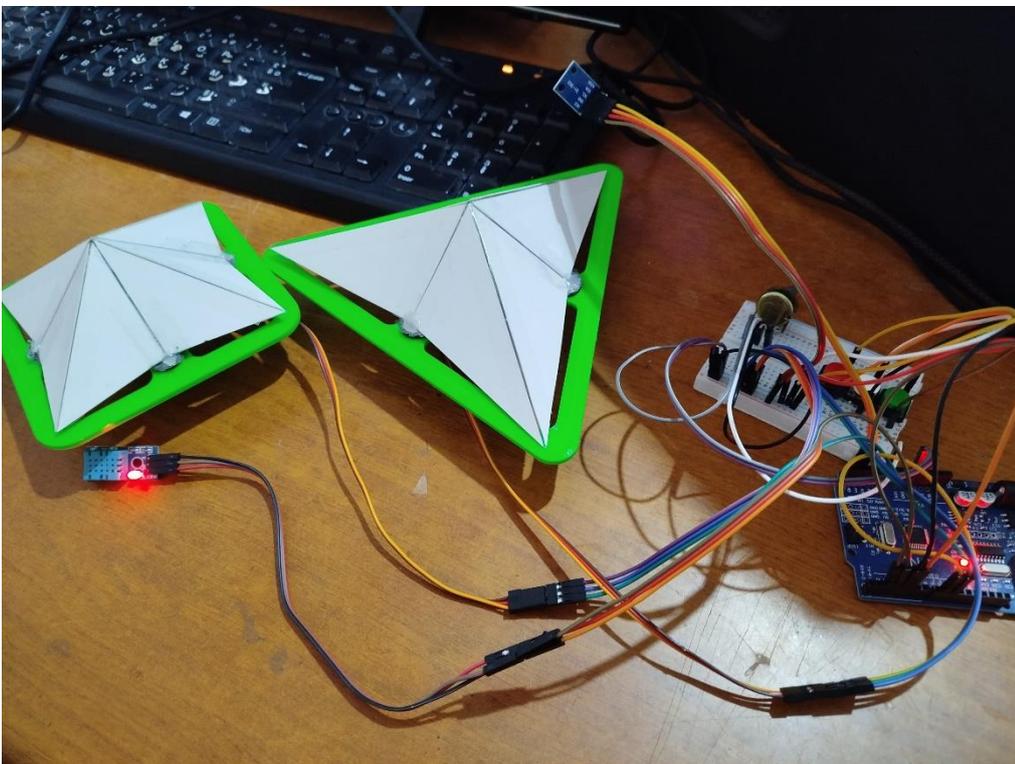


Figure 64: The prototype preview.(The Author)

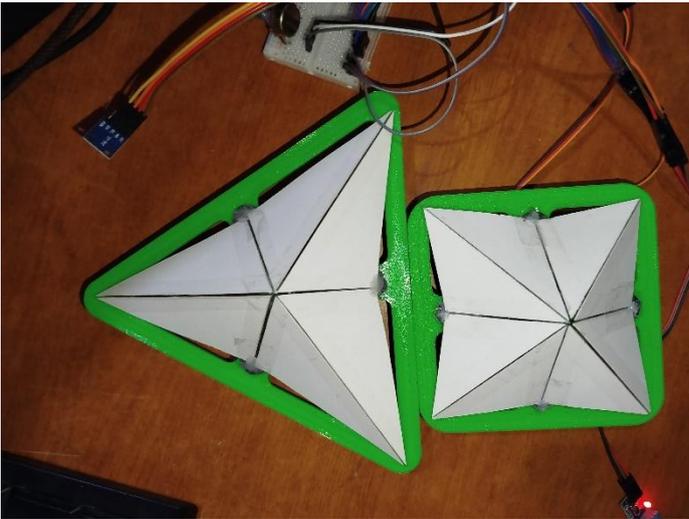


figure 65: closed shading devices (The Author)



figure 66: opened shading devices(The

Author)

## 2. THE ART SCHOOL PROJECT :

### 2.1.The conceptual idea:

#### 2.1.1. BOX INSIDE BOX CONCEPT

The "box inside box" concept involves enclosing one architectural form within another. These nested volumes may differ in materiality, scale, function, or orientation. It aligns with ideas like:

- Spatial hierarchy
- Thresholds and transitions
- Symbolic containment

Christopher Alexander notes that nested spaces enhance psychological comfort and spatial clarity. (Alexander, 1977)

## **2.1.2. Architectural Functions and Intentions**

### **2.1.2.1. Functional Purposes**

- Climate control (insulation through outer shell)
- Privacy (inner sanctum vs. public space)
- Acoustics (isolated performance halls)

### **2.1.2.2. Aesthetic Purposes**

- Visual contrast between materials and textures
- Play of light and shadow

### **2.1.2.3. Symbolic and Cultural Purposes**

- Sacredness (like temples and shrines).
- Philosophical representation of containment.

## **2.1.3. Examples of use:**

### **Fondation Louis Vuitton by Frank Gehry in Paris, France**

Glass "icebergs" (inner boxes) are protected by a transparent sail-like outer shell.

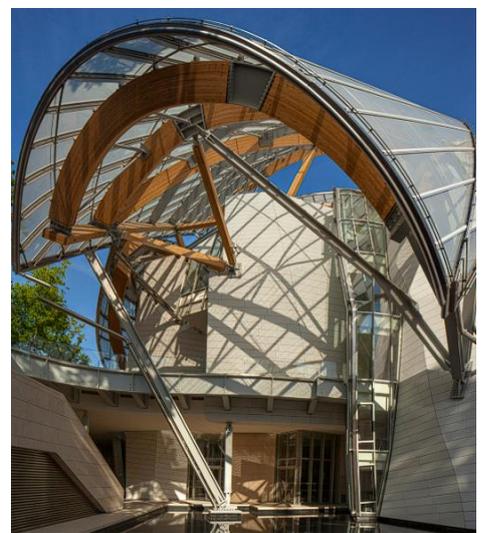


Figure 67: Fondation Louis Vuitton project.

### **Philharmonie de Paris by Jean Nouvel in France**

The performance hall is acoustically isolated by being placed within another outer building structure.



Figure 68: Philharmonie de Paris

### School of Architecture by Bernard Tschumi Architects in New York, USA

Tschumi applied a **box-in-a-box logic** in a very **modern, didactic, and functional** way to the renovation and expansion of this architecture school. The design demonstrates transparency, flexibility, and spatial layering.

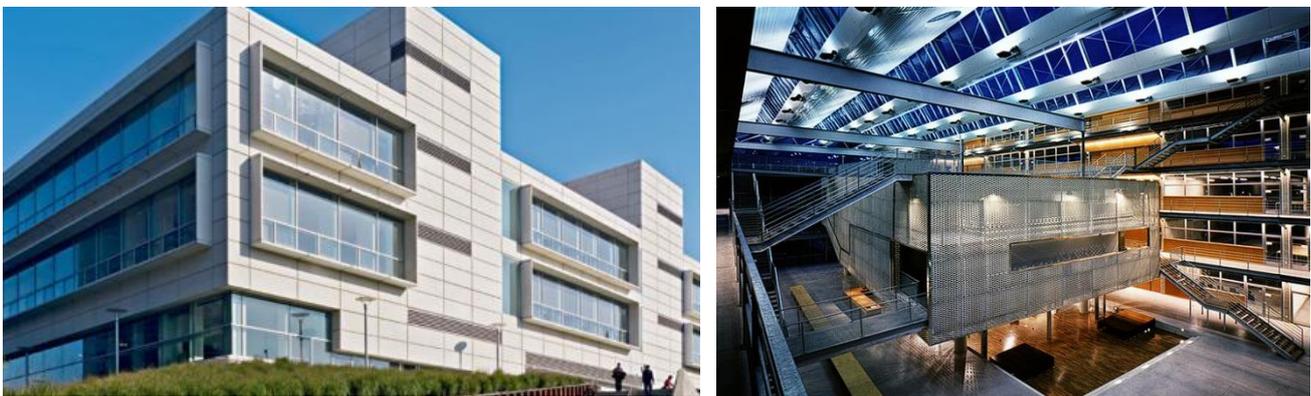


Figure 69: School of Architecture by Bernard Tschumi, New York, USA

#### 2.1.4. Advantages :

- Thermal and acoustic efficiency
- Strong symbolic meaning
- Flexible spatial zoning

(Roth, 2013)

### 2.1.5. Our use case:

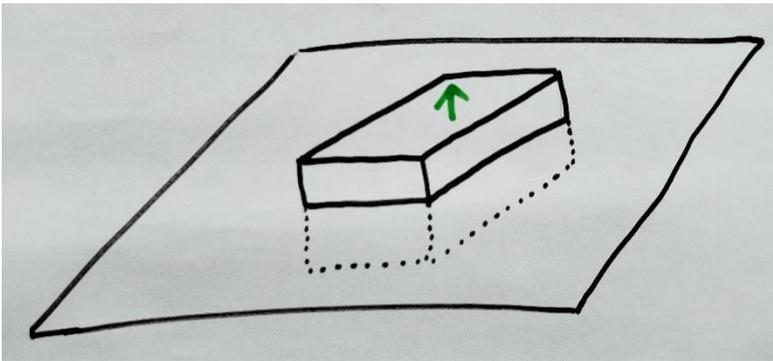


Figure 70: idea progress 1

1. Cutting a volume from the ground (The Author)

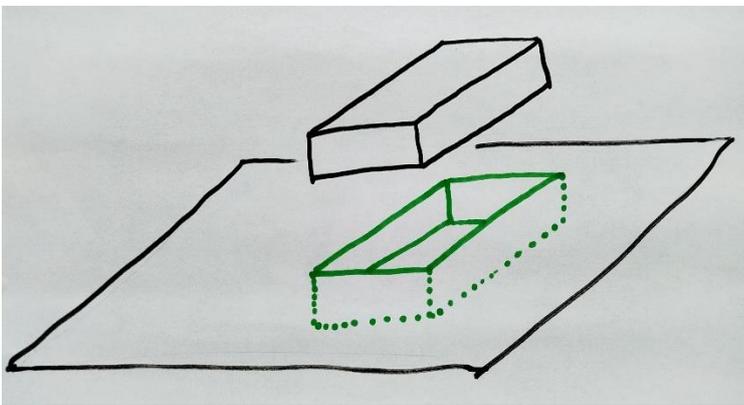


Figure 71: idea progress 2

2. elevating the volume , creating an initial gap underneath . and a floating effect. (The Author)

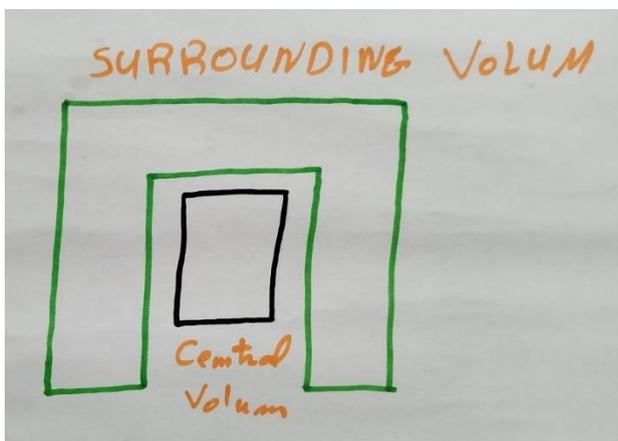


Figure 72: idea progress 3

3. Creating a surrounding volume . (The Author)

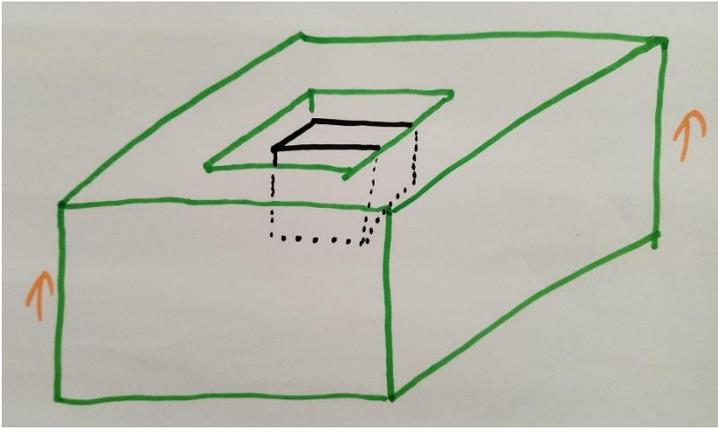


Figure 73: idea progress 4

4. wrapping the outer volume around the core volume. (The Author)

## 2.2. Key Transition Elements (Eléments de passage)

The conceptual process that led to the development of the School of Art project is grounded in a series of architectural, environmental, and cultural reflections. These transition elements represent the guiding principles that shaped the project's main design decisions and architectural expression:

### 2.2.1. Box-in-a-Box Concept: Thermal Protection and Climate Response

The adoption of the "box in box" architectural strategy was a deliberate response to the local climatic challenges, particularly the intense heat and high solar exposure typical of the region. This design approach creates an additional thermal envelope that enhances insulation and reduces direct heat transfer from the exterior. It serves as both a passive thermal protection system and an architectural solution to mitigate harsh environmental conditions, providing a more comfortable interior microclimate.

### 2.2.2. Orientation and Spatial Distribution

The project's spatial layout was carefully studied in relation to solar orientation. Classrooms and workshops were intentionally positioned towards the north and northeast to take advantage of stable, diffused natural lighting while minimizing exposure to direct sunlight, especially from the south and west. This strategic orientation not only optimizes visual comfort but also contributes to passive cooling and energy efficiency throughout the building.

### 2.2.3. Façade Treatment: Cultural and Contextual Integration

The façade design draws its inspiration from local cultural elements and natural surroundings. The form is reminiscent of palm tree trunks, a symbolic and dominant feature in the Algerian desert landscape. This approach gives the building a distinct regional identity and reinforces its connection to the local context. Beyond its visual narrative, the façade system is designed to project dynamic shadow patterns inside the building, emulating the filtered, intersecting shadows typically experienced beneath palm tree leaves. This creates a poetic, soothing interior atmosphere while effectively managing solar gains.

### 3. SHADING DEVICES APPLICATION IN THE SCHOOL OF ART

#### 3.1.SHADING DEVICES IN THE FAÇADE TREATMENT:



Figure 74: shading devices in the façade treatment (The Author)

### 3.2.SHADING DEVICES IN THE ROOF TRETMENT:

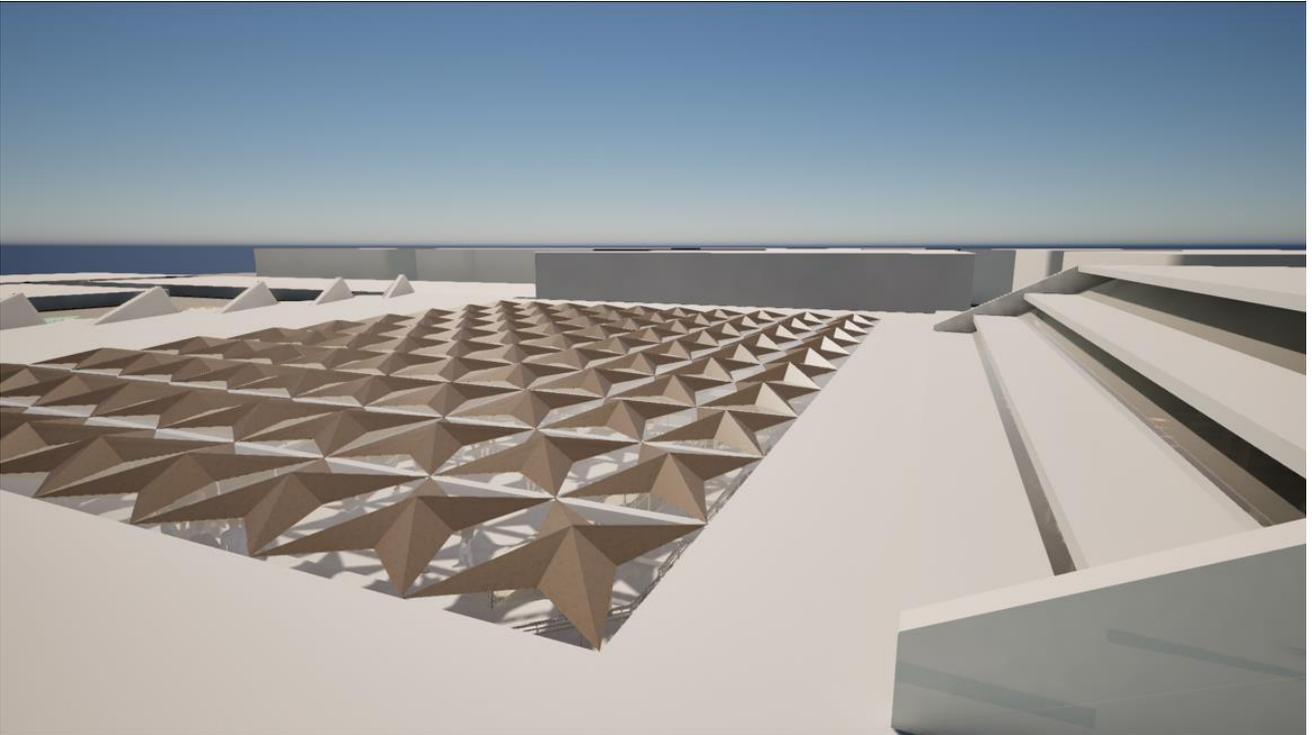


Figure 75: shading devices in the roof treatment (The Author)

## **Conclusion**

In this chapter, we applied the practical side of our work based on the theoretical and analytical studies completed earlier. We focused first on creating the adaptive shading devices by developing both their mechanical system and control program, which respond in real-time to temperature and light levels to optimize indoor comfort. We carefully selected and connected the necessary hardware components such as sensors, actuators, and an Arduino microcontroller to ensure smooth, automated operation of the shading system. After finalizing the shading system, we integrated it into the architectural design of the School of Art using the "box inside box" concept, which provided thermal protection, aesthetic richness, and flexible spatial organization. The project also combined other passive and active design strategies to enhance energy efficiency and climate responsiveness. And we can say that this practical chapter successfully connected all the research phases into a functional architectural solution.

## **OVERALL CONCLUSION:**

This research aimed to develop an architectural solution that responds to the environmental challenges of climate change, particularly the high energy consumption caused by the growing dependence on mechanical cooling in buildings. This issue is especially critical in hot and arid regions such as the city of Biskra, Algeria, where extreme solar radiation and high temperatures dominate most of the year.

Throughout this work, we focused on providing a sustainable alternative by integrating adaptive and hybrid shading devices that dynamically respond to changing environmental conditions. The architectural dimension of this project was equally essential, as it addressed not only the technical performance but also the cultural importance of the built environment. In this context, we chose to design a School of Art in Biskra, a facility that contributes to the promotion of the local cultural and educational landscape while incorporating energy-efficient strategies.

The first chapter presented the theoretical foundation, covering both the cultural and architectural significance of art schools, and the development of smart and adaptive shading systems. This provided the essential knowledge required to align the technical, aesthetic, and cultural aspects of the project.

In the second chapter, we analyzed several examples of art schools from different contexts, in addition to conducting a detailed study of the selected site in Biskra. This helped shape our design choices to suit the local climate, social context, and functional needs.

The practical chapter focused on the architectural design of the School of Art, where we integrated the adaptive shading systems into the building's façade

At the end of this research, we were able to propose a functional architectural project that respects the cultural identity of Biskra, integrates intelligent shading devices, and offers an energy-conscious solution adapted to the climatic realities of the region. Through this work, we confirmed that integrating adaptive shading devices can significantly contribute to improving indoor comfort and reducing energy consumption, while enriching the architectural experience.

This project responds to the research questions, meets the proposed objectives, and offers a practical contribution to sustainable design in hot and arid zones like Biskra.

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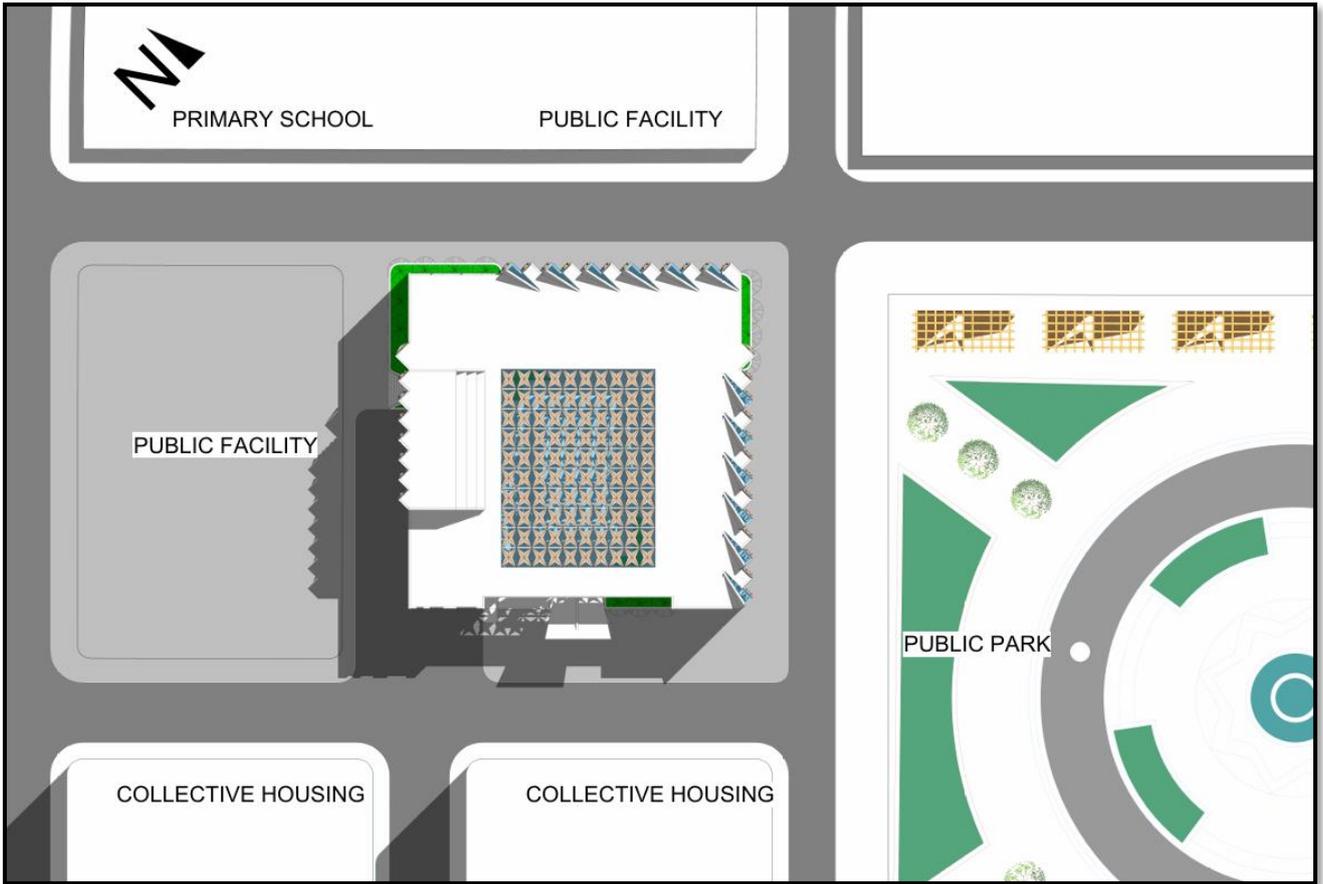
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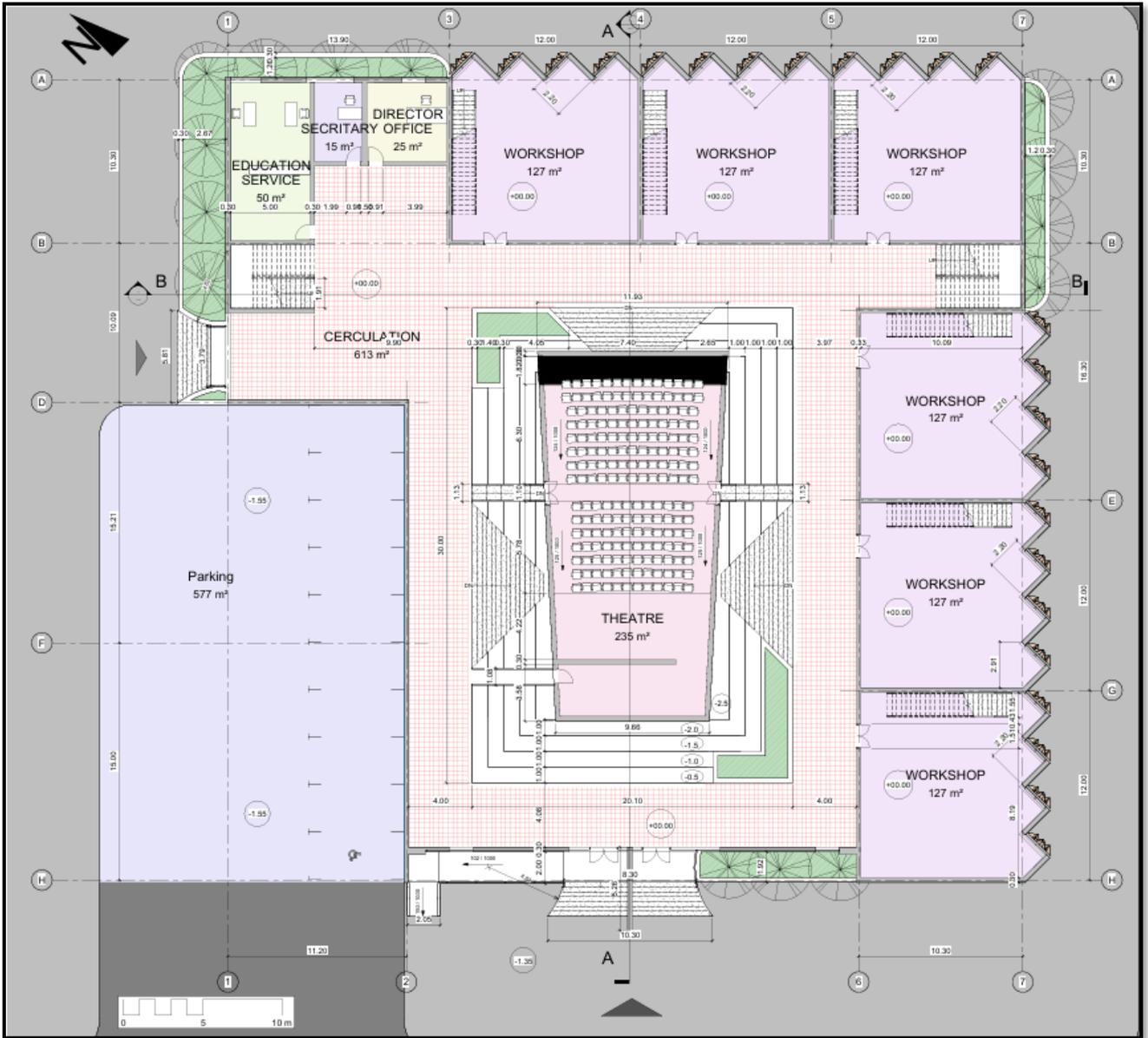
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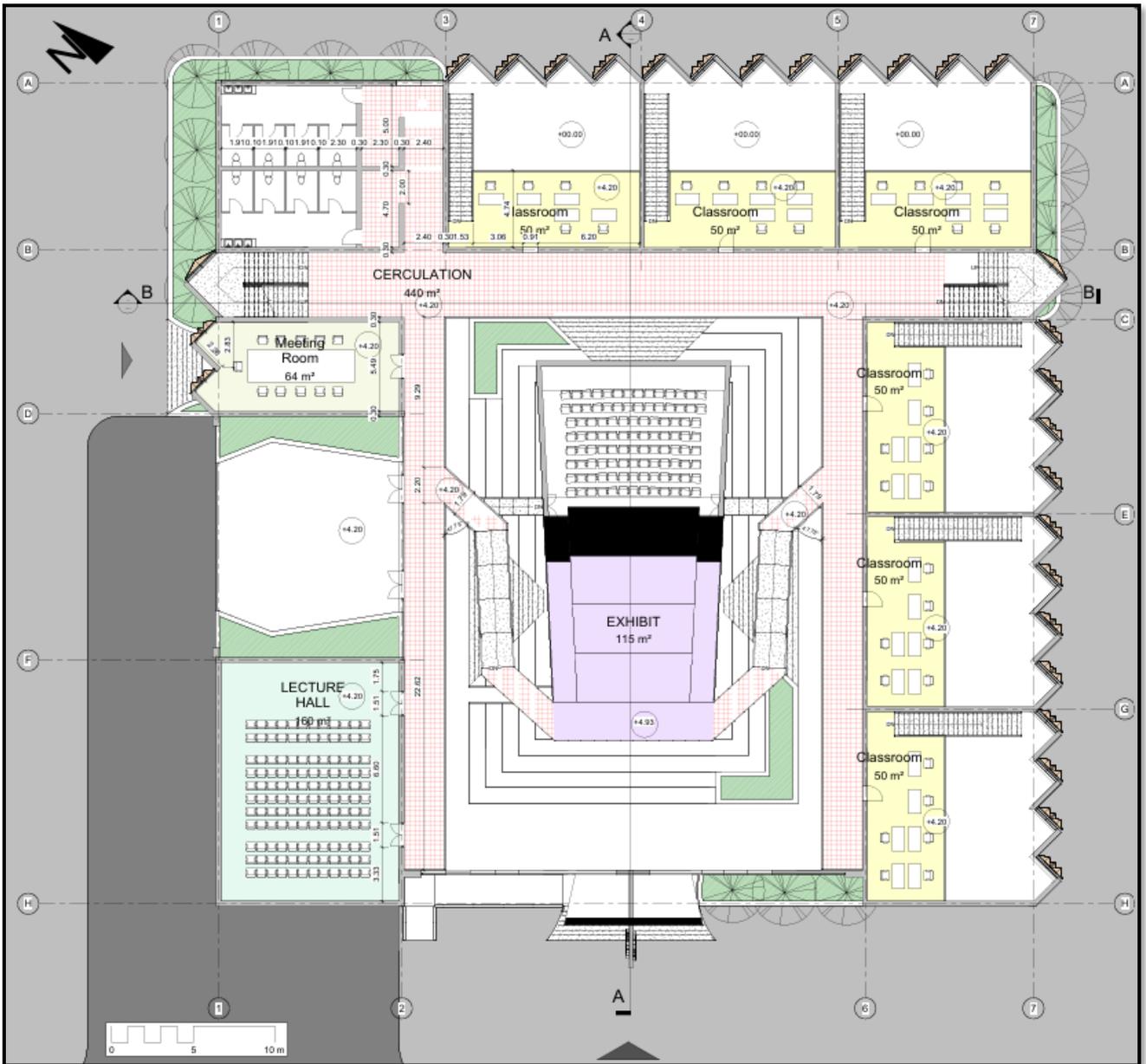
# ANNEXES



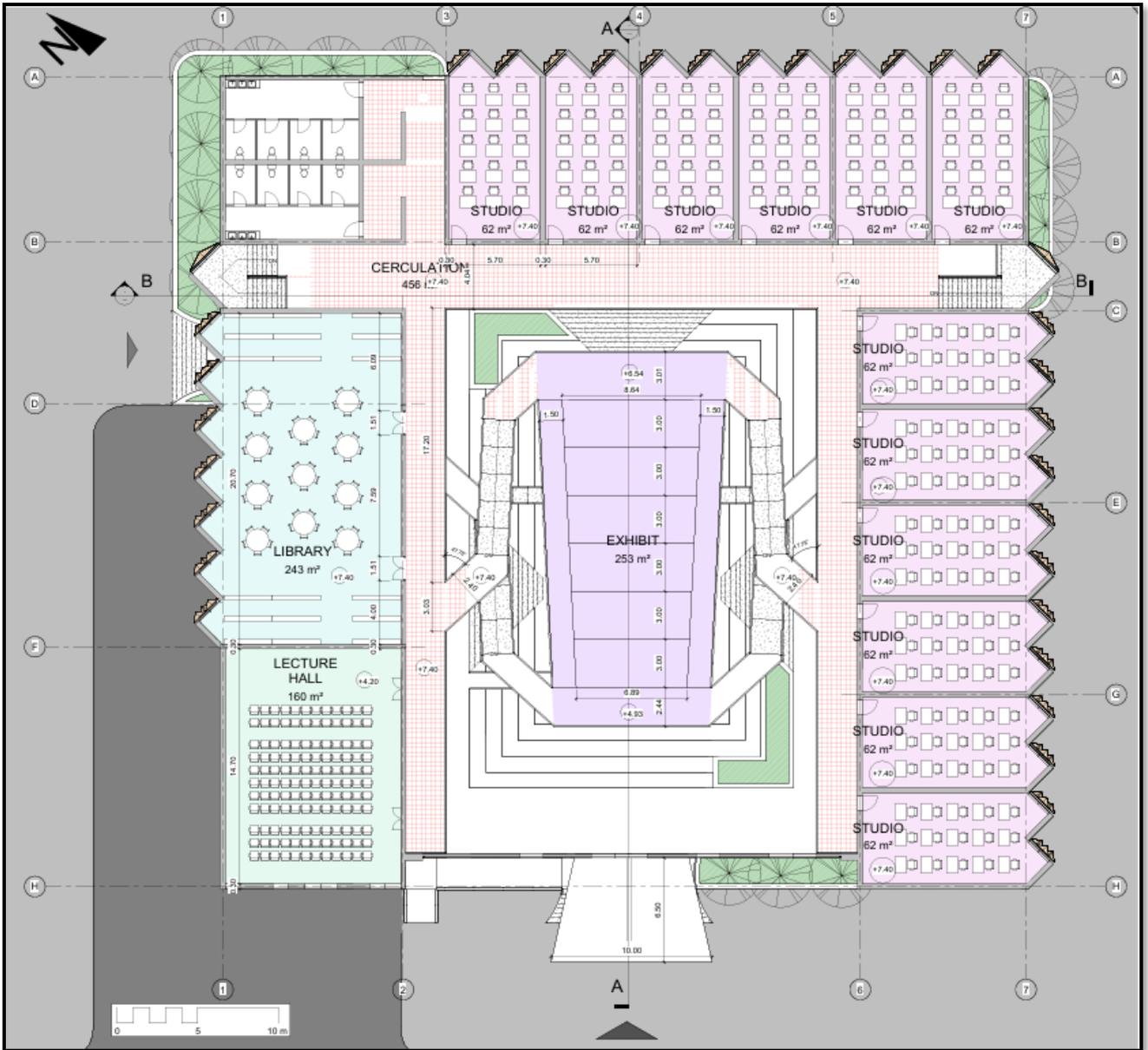
**MASTER PLAN**



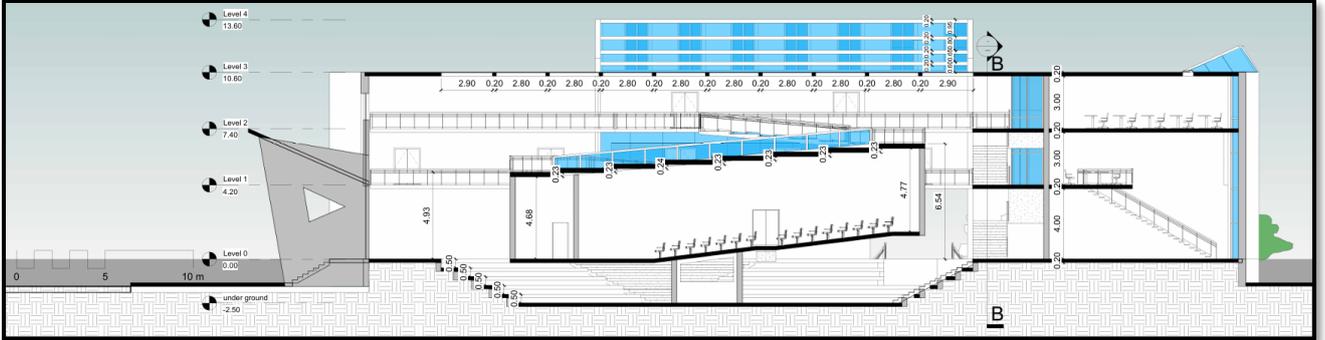
**GROUND FLOOR PLAN**



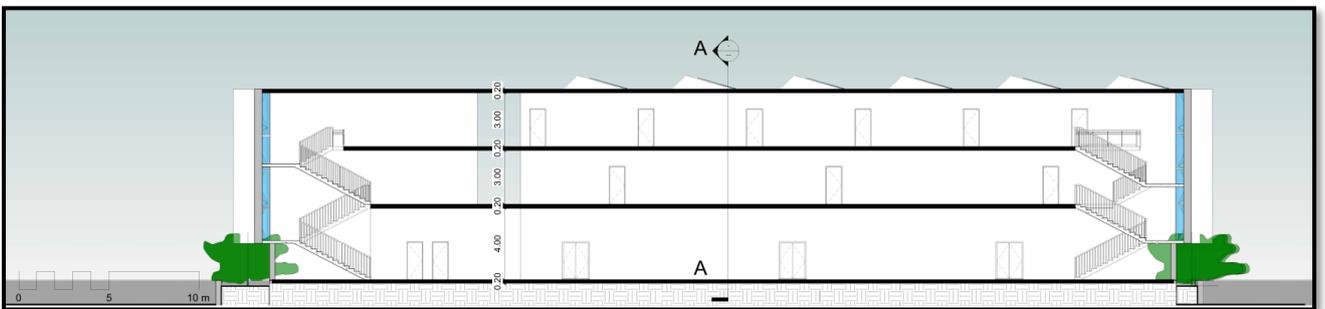
**1<sup>ST</sup> FLOOR PLAN**



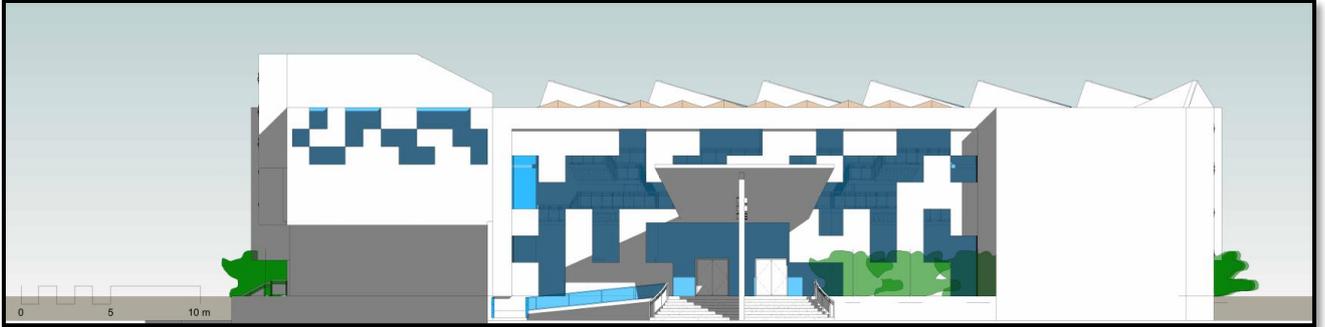
**2<sup>ND</sup> FLOOR PLAN**



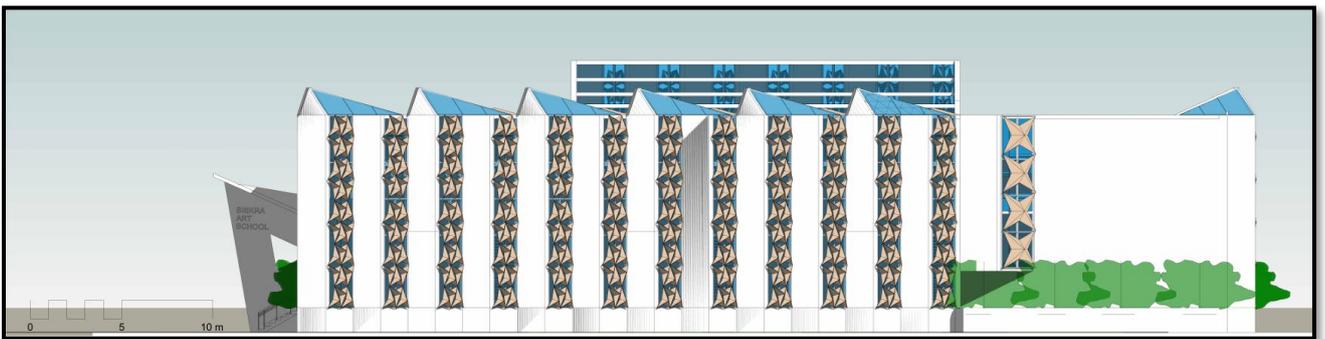
**SECTION A-A**



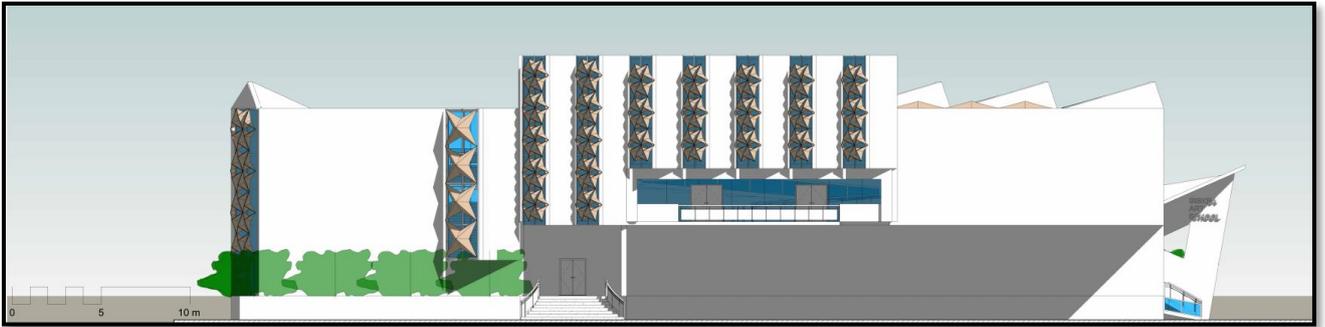
**SECTION B-B**



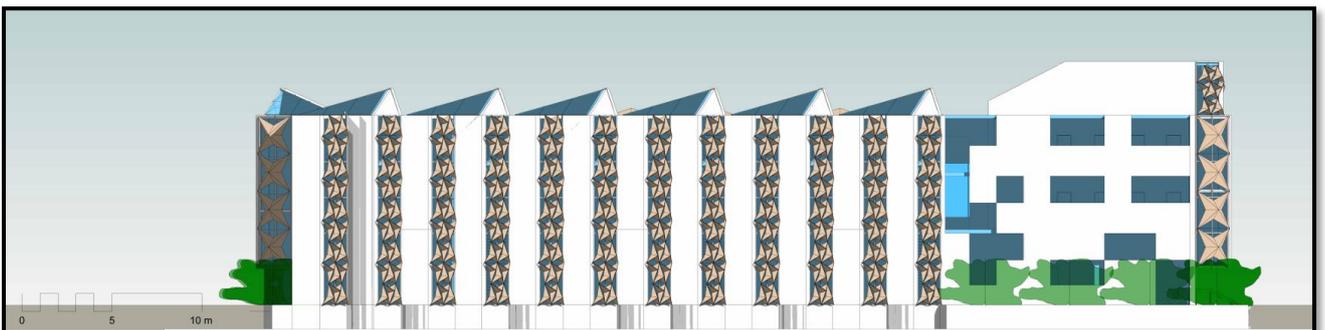
**SOUTH-WEST ELEVATION (MAIN)**



**SOUTH-EAST ELEVATION**



**NOTH-WEST ELEVATION**



**NORTH-EAST ELEVATION**

## INTERIOR VIEWS



















## EXTERIOR VIEWS



