الجمـــهوريـــة الجـــزائريـــة الديـمقراطيـــــــة الشــعبيـــــــة
THE PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
وزارة التعـليـم الـعـالــي و الـبـحـث الـعلـمي
THE MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH
جـامـعـة عمّـــار ثـلـيــجــي بالأغـــواط
AMAR TELIDJI UNIVERSITY OF LAGHOUAT

كـلـيــــة الـتكنولوجيا
FACULTY OF TECHNOLOGY

قسم الالكتروتقني

DEPARTMENT OF ELECTROTECHNIC

Master's dissertation

Domain : Science and Technology
Field : Automatic
Option : Automatic and systems

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THEME

Energy Management of a Bioclimatic Building Based on Heat Balance Study and Optimal Stand-Alone PV Systems Sizing Using IoT

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Abstract

Due to the high energy demand of buildings, countries are required to build energy efficient buildings, especially in areas that suffer from electricity shortages. The aim of this work is to develop an ideal energy management model for a smart bioclimatic building, located in Laghouat (Algeria). The dissertation involves sizing a bioclimatic building based on an estimate of heat balance, to understand heat exchange processes in buildings. In the second phase, the study integrates internet of things (IoT) technology to develop an intelligent energy management system for the building. In addition to size stand-alone PV systems, taking into account factors such as; energy demand and solar radiation. The results contribute to the development of sustainable and energy-efficient building practices, paving the way for a greener future in the built environment.

Key-words: bioclimatic, heat balance, internet of things, sizing, PV systems.

ملخص

نظرًا لارتفاع الطلب على الطاقة في المباني، يتعين على الدول بناء مباني ذات كفاءة في استخدام الطاقة، خاصة في المناطق التي تعاني من نقص الكهرباء. الهدف من هذا العمل هو تطوير نموذج مثالي لإدارة الطاقة لمبنى مناخيبيولوجي ذكي، يقع في الأغواط (الجزائر). تتضمن الأطروحة تحديد حجم مبنى مناخي حيوي بناءً على تقدير توازن الحرارة لفهم عمليات التبادل الحراري في المباني. في المرحلة الثانية، تدمج الدراسة تقنية إنترنت الأشياء لتطوير نظام ذكي لإدارة الطاقة للمبنى. بالإضافة إلى تحجيم الأنظمة الكهروضوئية المستقلة، مع مراعاة عوامل مثل؛ الطلب على الطاقة والإشعاع الشمسي.تساهم النتائج في تطوير ممارسات البناء المستدامة والموفرة للطاقة، مما يمهد الطريق لمستقبل أكثر اخضرارًا في البيئة المبنية.

الكلمات المفتاحية: مناخي بيولوجي, ، توازن الحرارة، إنترنت الأشياء، تحجيم الأنظمة الكهروضوئية المستقلة.

Résumé

En raison de la forte demande énergétique dans les bâtiments, les pays doivent construire des bâtiments économes en énergie, en particulier dans les zones qui souffrent de pénuries d'électricité. L'objectif de ce travail est de développer un modèle de gestion énergétique idéal pour un bâtiment bioclimatique intelligent, situé à Laghouat (Algérie). La thèse consiste à dimensionner un bâtiment bioclimatique à partir d'une estimation du bilan thermique, pour comprendre les processus d'échanges thermiques dans les bâtiments. Dans la deuxième phase, l'étude intègre la technologie Internet des objets pour développer un système intelligent de gestion de l'énergie pour le bâtiment. En plus de dimensionner les systèmes PV autonomes, en tenant compte de facteurs tels que ; Demande d'énergie et rayonnement solaire. Les résultats contribuent au développement de pratiques de construction durables et économes en énergie, ouvrant la voie à un avenir plus vert dans l'environnement bâti.

Mots-clés : bioclimatique, bilan thermique, Internet des objets, dimensionner les systèmes PV autonomes.

Acknowledgments

First and foremost, we are very grateful to **ALLAH S.W.T** for giving us the key and opportunity to accomplish our master dissertation.

We would like to express our sincere gratitude to our supervisor, **Dr. BENMOUIZA Khalil** for his invaluable guidance and support and providing helpful feedbacks and suggestions, throughout our master's program. Also for his expertise and encouragement helped us to complete this research and write this thesis. Thank you sir.

We want to thank our co-supervisor, **Dr. OUBBATI Yousef**, for his constant support, availability, which were determinant for the accomplish of the work presented in this dissertation.

We would like to thank the architects who helped us in this work **M^{me}. BEHTITA Safia Khadija** and **Mr. TAIBI Mohamed Amine.**

Thank you for your help we really appreciate that.

We also thank the members of the jury who will do the honor of judging my work, Providing their scientific thoughts and suggestions.

We would like to thank all the professors in the University of Laghouat for their acceptance to examine this dissertation.

Finally, we want to thank all of professors, staff and technicians in our department of electro-technicalin **Amar Telidji**University of Laghouat for their cooperation, indirect or directly contribution in finishing our master dissertation.

BENMOUIZA Zineb **CHEBHA Safia**

Dedication

Thanks to the almighty **ALLAH**, who gives me the strength, faith and patience to complete this work.

My dear parents; **Messaoud**, **CHEBHA Oum Elkheir** who represent my life, my happiness, thank you for your support, love, patience, guidance and encouragement. Thank you for everything. May God protect you.

My brothers and sisters; **Mohamed, Amel, Aya, Mostapha** and **Anes**, Thank you for your unconditional love.

To all my CHEBHA family.

I dedicate this work to my best friend and sister **BENMOUIZA Zineb**, I am lucky to have you as my friend. Thank you for always being by my side. I love you so much that words can never express the actual depth of my feelings.

To my friend **BENAMAR Mariam**, I ask God to heal you.

I also thank the members of the jury who will do the honor of judging my work, Providing their scientific thoughts and suggestions.

I express my deepest gratitude to everyone who contributed to my success in my studies.

❖ CHEBHA Safia

Dedication

Thanks to **ALLAH S.W.T** who gives me strength and faith

I dedicate my dissertation work to my family and all of my friends.

A special feeling of gratitude to my loving parents: **Belhout** and **BENAROUS Asma**, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve. I am very fortunate and grateful. May **ALLAH** bless you.

My sisters: **Ikram, Rosa**. And my brothers: **Mohammed, Ahmed**, thank you for always supporting me. I love you all

To all of my **BENMOUIZA** and **BENAROUS** family.

I give a special thanks to my best friend and my partner: **CHEBHA Safia**, thank you for your excellent work. Thank you for being with me during this journey.

And thank you for always being by my side. I love you.

I would like to thank my cousin **BEHITITA Safia Khadija** for her support and help in my life and in this work because she's the architect of this work. Thank you so much for being here.

I would like to say to my friend **BENAMAR Mariam** that I believe in you. You can move this distress. May **ALLAH** heal you and bless you.

And a special thanks to my girls; Zineb BENRAHAL, Bouchra AISSAOUI, Meriam BENAMAR, and Amani BOUFATAH. Thank you for being here during this journey.

I would like to thank all the professors at the University of Laghouat, especially in our department for their acceptance to examine this dissertation.

❖ BENMOUIZA Zineb

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C	Conductance of a wall ($W/m^2.°C$)
λ	Thermal conductivity ($W/m.°C$)
R	Material Resistance ($m^2.°C/W$)
K	The heat transfer coefficient ($W/m^2.°C$)
$\mathbf{d_A}$	Loss through transmission ($W/°C$)
A	Crawlspace slab area (m^2)
$\mathbf{d_L}$	Losses through peripheral slab ($W/°C$)
L	The perimeter (outside) of the slab (m)
F	Global depredations coefficient($Wh/day.m^2.°C$)
$\mathbf{S_{pl}}$	Floor area (m^2)
I	Solar gain of glazing (Wh/day)
$\mathbf{t_e}$	Average daily outdoor temperature ($°C$)
S	Monthly coefficient
$\mathbf{I_{dc}}$	Intensity required per day (Ah/day)
$\mathbf{N_p}$	Number of PV panels
$\mathbf{E_{ff}}$	Battery efficiency (Ah/day)
$\mathbf{F_{safe}}$	Factor of safety

List of acronyms

AC	Alternating Current
BIPVS	Building Integrated Photovoltaic Systems
DC	Direct Current
DOD	Depth Of Discharge
E – Mobility	Electric Mobility
Eq	Equations
IDE	Integrated Development Environment
IFTTT	IF This Than That
iOS	iPhone Operating System
IoT	Internet of Things
LDR	Light Dependent Resistor
LED	Light Emitting Diode
MEGA	Michigan Economic Growth Authority
MPPT	Maximum Power Point Tracking
PV	Photovoltaic
RDC	Repair Design Certificate
RN	National Route
UNO	United Nations Organization

General introduction

Buildings are one of the major sources of electricity in the world, and Home systems and appliances are among the most energy-intensive components; Which leads to mismanagement of energy, With the appearance of new trends in electricity production and consumption, the shortage of electricity distribution networks has saddening become a reality.

Solar power is the fastest growing source of electricity. Technology has provided a number of ways to use this abundant resource. Where solar photovoltaic energy is used that provides consumers with the ability to generate electricity in a clean, quiet and reliable way.

Given high energy demands of buildings, electricity use of buildings is highly uncertain due to the high prices and the cost, and this requires designing for low energy houses, seeking coherence between construction and energy efficiency, always taking into account the maximum comfort of the people who live there.

In light of these challenges, the bioclimatic design concept is one of the best alternatives to weave this harmony between the building and its environment.

Bioclimatic architecture (or sustainable) is defined as the buildings' designing by alternative way that are energy-efficient, comfortable, and environmentally friendly. According which the researcher is taking into account a series of parameters, aiming the make efficient use of energy, building materials and other resources [1]. A lot of consideration will be given to the building's orientation, the selection of the site, and the construction itself.

However, to assess the effectiveness of bioclimatic design strategies and to ensure optimal thermal comfort within a building, the concept of heat balance plays an important role. It refers to the analysis and calculation of heat transfer within a system using simple methods that can be done manually.

This dissertation evaluates existing research on bioclimatic design with the goal of identifying the key themes of earlier studies and outlining potential future research avenues that will help increase building energy efficiency.

On the other hand, it appears to be crucial to enhance people's living circumstances at home. This is accomplished by incorporating Internet of Things technology, in which smart homes employ natural interfaces to control the lighting, temperature, or various electronic gadgets. Internet of things as the name suggests, is the connectivity of everyday devices with each other. The majority of smart home systems are managed by smart phones and microcontrollers, to provide comfort, intelligence, safety and improving quality of life [2].

Additionally, the integration of standalone PV systems further enhances the sustainability of bioclimatic buildings. These systems consist of solar panels that convert sunlight into electricity, which can be used to power various building systems and appliances.

However, to ensure reliability of the system, optimal performance and cost-effectiveness, it is crucial to accurately size the PV system according to the building's energy requirements [3].

The main objectives of this dissertation are to design a building in a region in Laghouat, Algeria, that adapts to the local climate using passive strategies to achieve a favorable indoor environmental quality with the lowest possible energy consumption and integrate Internet of Things (IoT) technology, in addition to the ability to generate electricity in a clean and reliable way to be decisive. In improving living conditions at home.

This dissertation is organized in three chapters:

The **first chapter** has two main points the first point will be a general discussion on the climate approach to urban development. This part aims specifically at the general concept of bioclimatic buildings, with a focus on thermal concepts that affect thermal comfort inside the building. To achieve environmental quality with the lowest possible energy consumption.

The second point will describe home automation and the IoT from home automation standards to an analysis of the basics of smart building and the IoT. Down to some of the different sensors and devices used in some smart building systems.

The **second chapter** explains how to calculate the thermal balance inside the building. This chapter also describes stand-alone photovoltaic systems and the method for determining the exact size of the photovoltaic system according to the energy requirements of the building.

The **third chapter** is devoted to results, discussion, circuit diagram and final project. It consists of creating a prototype of the Laghouat site using bioclimatic design techniques, then implementing the thermal balance improvement of the building, optimizing the sizing of the standalone photovoltaic system plus an economical (cost) optimization, and finally the circuit diagram and the final project.

Finally, a general conclusion with future works were made to conclude our work.

Chapter I

Bioclimatic buildings

I.1 Introduction

Bioclimatic architecture is a way of designing buildings based on the local climate, intending to ensure thermal comfort using environmental resources Freebies - sun, wind, rain, etc. to reduce a building's environmental impact. Another key aspect is energy efficiency, a crucial weapon for fighting climate. Bioclimatic buildings prioritize sustainability, efficiency, and occupant comfort and health.

Smart buildings, on the other hand, utilize advanced technology and automation systems to optimize building performance and enhance the occupant experience and reduce the environmental impact of urban areas.

The aim of this chapter is to discuss the idea of bioclimatic architecture, and passive design and study the thermal comfort in a building, in search of smart and inventive bioclimatic applications.

I.2 Bioclimatic architecture

Bioclimatic architecture or bioclimatic design is a frequently used but not uniformly defined term. Various definitions with foci on local climate, improvement of energy efficiency and thermal comfort exist. For this study, bioclimatic architecture is the design of a building adapted to the local climate using passive strategies to achieve a favourable indoor environmental quality at the lowest possible energy consumption [4].

Key goals of bioclimatic architecture include ensuring healthy living spaces, protecting the environment, reducing pollution, promoting biodiversity, and efficiently using energy, water, and building materials.

I.2.1 Bioclimatic strategies in architecture

Bioclimatic buildings are based on design and daily use strategies that contribute to reducing their energy costs. These are the most common [5]:

- Bioclimatic, efficient design: Designing buildings that adapt to the local climate to minimise energy expenditure and resources used, avoiding leaks and wastage.
- Control and smart use of space: Buildings and their rooms should be of a suitable size as to optimise energy use.
- Sustainable materials: Like wood, stone, natural fibre and recycled materials minimise the impact of the building.

- Use of renewable energies: Bioclimatic buildings use different types of renewable energies solar, geothermal, wind and hydraulic to reduce their consumption.
- Use of smart materials: For example; window panes that automatically darken, tiles that store the heat of the sun and smart materials that repair themselves to lengthen their useful life.

I.2.2 Elements of bioclimatic design

Bioclimatic buildings require the use of a series of elements and building techniques that help to reduce their energy consumption and environmental impact [5]:

- The orientation, size, height, layout, and even the colour of these houses are planned before they are built to make the best use of energy.
- The buildings are kept compact to reduce their surface area, with the main windows face to make the most of passive solar energy.
- The materials surrounding the outside of the house (walls, doors, roofs, etc.) must be properly insulated to avoid heat loss through transference.
- Ventilation systems ensure that the heat in the air that is removed from the building istransferred to the fresh air that is brought in through heat exchangers to avoid thermal losses.
- Water and plants are also important in hotter climes, using trees, climbing plans, vertical gardens, green roofs and other techniques to create cool areas that protect from the heat of the sun.
- Thermal accumulators such as heat exchangers and pumps make it possible to capture and store the heat generated by the heating system or the sun and avoid losses.
- The air tightness of the building is essential. Leaks through gaps should be minimal with respect to the total volume of the house.
- Thermal bridges must be avoided. Edges, corners and joints must be created carefully to avoid heat loss through these bridges.
- Hygro thermal comfort can be achieved by efficiently controlling air currents, evaporation caused by the sun or by reducing condensation, particularly in warm climates.

I.3 Passive design

Passive design refers to the d esign of buildings or spaces to optimize their performance and reduce their reliance on mechanical heating, cooling, and lighting systems. It involves using natural resources such as sunlight, shade, and wind to create a buildings or spaces that are comfortable, healthy, and energy-efficient.

Passive design principles include factors such as building orientation, insulation, ventilation, and thermal mass, which are used to maximize the benefits of natural resources, while reducing the impact on the environment.

I.3.1 Passive solar design basics

Passive solar design refers to the use of the sun’s energy for the heating and cooling of living spaces by exposure to the sun. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in a home as shown in **Fig.I.1** [6].

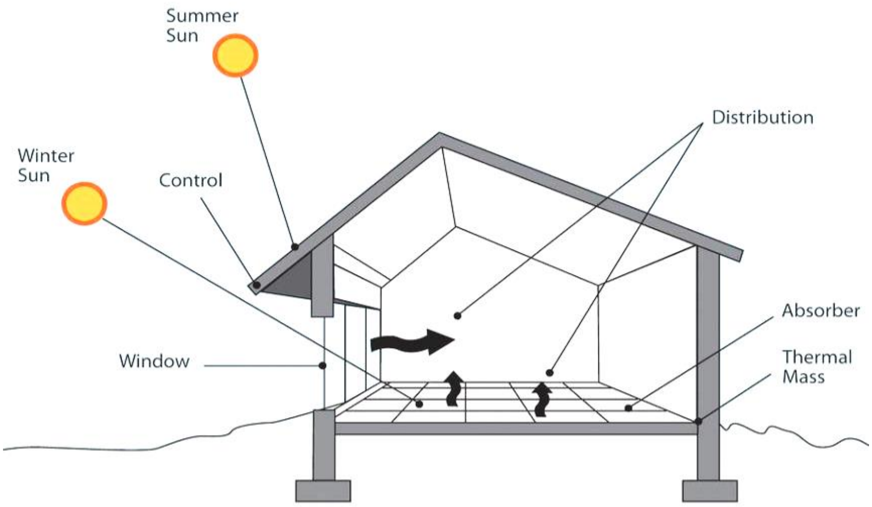


Fig.I.1 Elements of a passive solar system [6].

A complete passive solar design has five elements [6]:

- **Aperture/Collector**

The large glass area through which sunlight enters the building. The aperture (s) should face within 30 degrees of truesouth and should not be shaded by other buildings or trees from 9a.m. to 3p.m. daily during the heating season.

- **Absorber**

The hard, darkened surface of the storage element. The surface, which could be a masonry wall, floor, or water container, sits in the direct path of sunlight. Sunlight hitting the surface is absorbed as heat.

- **Thermal mass**

Materials that retain or store the heat produced by sunlight. While the absorber is an exposed surface, the thermal mass is the material below and behind this surface.

- **Distribution**

Method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes- conduction, convection and radiation- exclusively. In some applications, fans, ducts and blowers maybe used to distribute the heat through the house.

- **Control**

Roof overhangs can be used to shade the aperture area during summer months. Other elements that control under and/or over heating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.

a) Passive solar heating

The goal of passive solar heating systems is to capture the sun's heat within the building's elements and to release that heat during periods when the sun is absent, while also maintaining a comfortable room temperature. The two primary elements of passive solar heating are south facing glass and thermal mass to absorb, store, and distribute heat. There are several different approaches to implementing those elements as shown in **Fig.I.2** [6].

Passive solar heating systems can be categorized into three types [6]:

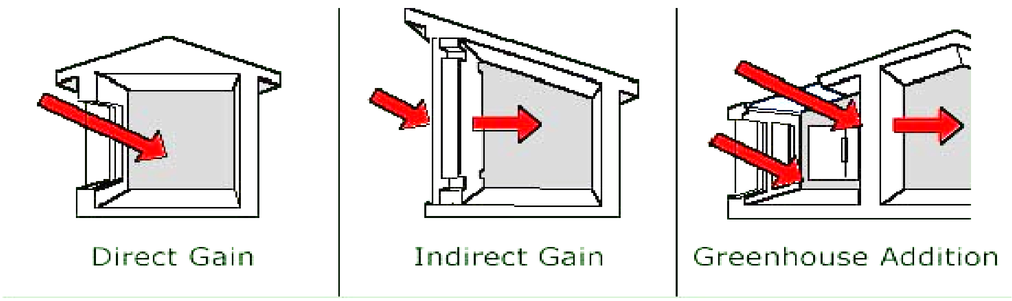


Fig.I.2 Types of passive solar heating [7].

- **Direct gain**

South facing glass admits solar energy into the house where it strikes masonry floors and walls, which absorb and store the solar heat, which is radiated back out into the room at night. These thermal mass materials are typically dark in color in order to absorb as much heat as possible. The direct gain system utilizes 60-75% of the sun's energy striking the windows. For a direct gain system to work well**.**

- **Indirect gain**

Allows the solar radiation to heat a wall and then the energy is slowly delivered into the interior of the house.

The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will use 30-45% of the sun's energy striking the glass adjoining the thermal mass.

The most common indirect gain system is a Trombe wall a 6-18-inch-thick masonry wall, is located immediately behind south facing glass. Solar heat is absorbed by the wall'dark-colored outside surface and stored in the walls mass, where i radiates into the living space. Solar heat migrates through the wall, reaching its rear surface in the late. When the indoor temperature falls, be low that of the wall's surface, heat is radiated into the room**.**

- **Greenhouse addition**

An attached sunspace and/or solar greenhouse heated by the solar energy - where some of the energy is used to grow the plants and some of it is used to heat the interior of the house [7].

b) Passive solar cooling

Passive solar cooling systems work by reducing unwanted heat gain during the day, producing non-mechanical ventilation, exchanging warm interior air for cooler exterior air when possible, and storing the coolness of the night to moderate warm daytime temperatures [6].

Passive solar cooling systems can be categorized into three types as shown in **Fig.I.3** [6]:

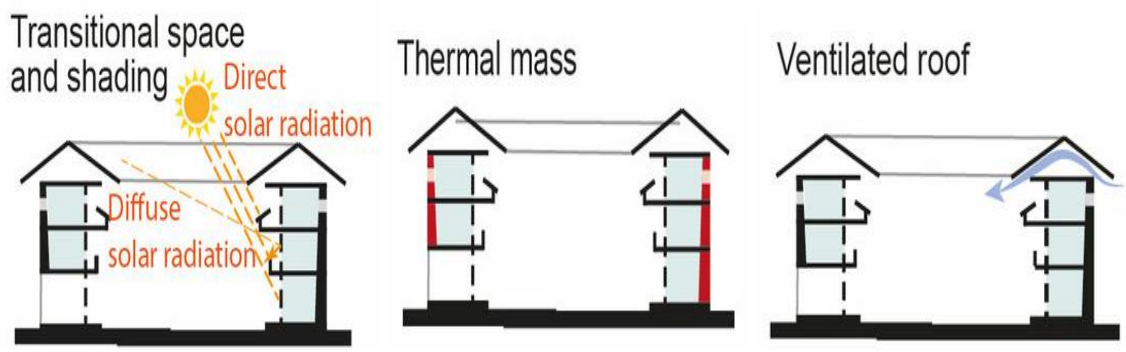


Fig.I.3 Types of passive cooling heating [8].

- **Shading**

To reduce unwanted heat, gain in the summer, all windows should be shaded by an overhang or other devices such as awnings, shutters and trellises. If an awning on a south facing window protrudes to half of a window'sheight, the sun's rays will be blocked during the summer, yetwill still penetrate into the house during the winter. The sun is low on the horizon during sunrise and sunset, so overhangs on east and west facing windows are not as effective. Try to minimize the number of east and west facing windows if cooling is a major concern. Vegetation can be used to shade such windows. Landscaping in general can be used to reduce unwanted heat gain during the summer.

- **Thermal mass**

Thermal mass is used in a passive cooling design to absorbs heat and moderate internal temperature increases on hot days. During the night, thermal mass can be cooled using ventilation, allowing it to be ready the next day to absorb heat again. It is possible to use the same thermal mass for cooling during the hot season and heating during the cold season.

- **Ventilation**

Natural ventilation maintains an in door temperature that is close to the out door temperature, soit'sonly an effective cooling technique when the indoor temperature is equal to or higher than the outdoor one. The climate determines the best natural ventilation strategy.

I.4 Concept of comfort

Comfort is defined as a complex sensation produced by a physical, physiological and psychological factor, leading the individual to express the well-being of his condition There are many types of rest, including the following [9]:

I.4.1 Thermal comfort

Thermal comfort is defined as a state of satisfaction with the thermal environment. It is determined by the dynamic equilibrium established by exchange thermal between the body and environmental factors such as; (Temperature, Airflow, Humidity, and Sunlight)**.**

I.4.2 Winter comfort

- **Capture**: capture is ensured by glass surfaces.
- **Storage**: depend of thermal inertia of materials exposed to solar radiation.
- **Distribute**: use convection and radiation to restore stored heat.
- **Conserve:** this is done by insulating the walls to accumulate heat in the air**.**

I.4.3 Summer comfort

- **Catch:** avoid the direct penetration of solar radiation by installing various shading techniques (projecting roof, deciduous planting).
- **Avoid:** bypass the transfer of heat to the interior of the materials by the insulation of the walls, the presence of plants on the exterior walls and roofs vegetated.
- **Dissipate:** ventilate the stored heat inside the building.
- **Cooling:** by the use of planswater for cooling the air entering**.**

I.4.4 Visual comfort

The visual environment must allow see objects clearly and without fatigue in pleasant colorful atmosphere. visual comfort is:

- A visual relationship with the outside.
- Optimal natural lighting in terms of comfort and energy cost.
- Satisfactory artificial lighting in addition to natural lighting**.**

I.5 Passive house

Passive house is a building standard that aims to create highly energy-efficient buildings that require little to no energy for heating or cooling. The passive house standard requires buildings to meet specific criteria, including airtightness, high levels of insulation, thermal bridge-free construction, and high-performance windows and doors.

Passive House is considered the most rigorous voluntary energy-based standard in the design and construction industry today. Consuming up to 90% less heating and cooling energy than conventional buildings, the Passive House high-performance building standard is the only internationally recognized. Fundamental to the energy efficiency of these buildings, the following five the basic features of a passive house [10]:

I.5.1 The basic features of a passive house

The five principles of passive house design [10]:

- Super insulated envelopes
- Airtight construction
- High-performance glazing
- Thermal-bridge-free detailing
- Heat recovery ventilation.

I.6 Smart Building

Smart buildings use a variety of sensors, automation systems, and data analytics to monitor and control various building systems. It is a step towards what is referred to as the internet of things.

The Internet of Things is an emerging technology across the world that has been recently incorporated into our daily living to provide comfort, intelligence, safety and improving quality of life. IoT can also improve occupant health and well-being by reducing human intervention in everyday tasks.

In this part, we present some definitions of the basic concepts. In the next section; we provide some examples of hardware, applications, and software used in smart building automation.

I.6.1 Home Automation

Home automation is building mechanization for a home, called a smart home [11]. Home automation constitutes a branch of ubiquitous computing that involves incorporating smartness into dwellings for comfort, safety, security, and energy conservation. Remote monitoring systems are common components of smart homes, which use telecommunication and web tecnologies to provide remote home control. Home automation offers a better quality of life by introducing automated appliance control [12].

Home automation refers to the ability to program and schedule different home appliances, and to integrate multiple technologies into a single system. The home automation system enables the benefit of many high-tech functions and makes life very simple.

I.6.2 Internet of things IoT

Internet of Things (IoT; also known as Internet of Objects) refers to the networked interconnection of everyday objects, which are often equipped with ubiquitous intelligence. They refer to the rapidly growing network of connected objects that are able to collect and exchange data using embedded sensors [13].

IoT technology is most synonymous with physical things (electronic device, microchip, and sensor) all these things can collect information and exchanging data and share it with each other. On the other hand, we can enable the Internet of Things to control all home devices connected to the Internet, such interconnection allows people to monitor, control, and improve their overall environment.

I.7 Used materials in the project

I.7.1 The hardware

a) Arduino

It is an open source, computer hardware and software. Arduino used for construction and interactive objects that can sense and control objects in the real world. The microcontrollers are programmed using the programming languages C and C++ [14].

Arduino is designed to make electronics simple to a large extent and accessible to hobbyists, beginners, and makers to design devices and their own versions.

- **Different types of arduino boards**

There are in various shapes, sizes and colors for Arduino; with extended features and upgraded versions. Among the important types of Arduino, we have the two most used cards: Arduino; (UNO and MEGA).

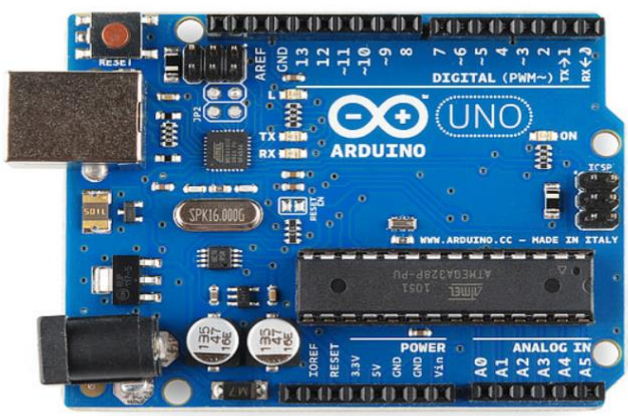


Fig.I.4 Arduino UNO card [15].

The features of different types of Arduino boards are listed in the tabular form. We have chosen to quote the two most used cards (UNO, MEGA)

Table I.1: Features of some types of arduino [15].

Arduino Board	Processor	Memory	Digital I/O	Analogue I/O
Arduino UNO	16Mhz ATmega328	2KB SRAM, 32KB flash	14	6 Input, 0 Output
Arduino MEGA	16Mhz ATmega2560	8KB SRAM, 256KB flash	54	16 Input, 0 Output

b) NodeMCU

The NodeMCU is an open source IoT hardware development board. It contains the Wi-Fimodule (ESP8266) which is used to connect the devices with the network. ESP8266 is a cost-effective Wi-Fi chip; hence NodeMCU is an inexpensive firmware which is suitable for theconstruction of home automation systems [16].

NodeMCU Pinout

The NodeMCU board has several pins that can be used for various purposes such as digital input/output (I/O), analog input, power supply, etc. Here is a typical pinout diagram for the NodeMCU board (See appendice A).

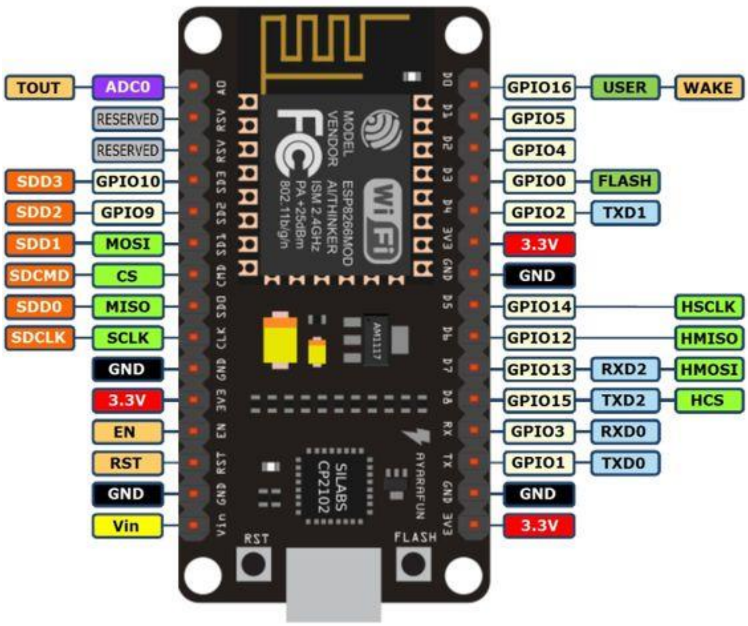


Fig.I.5 Node MCU pinout [17].

I.7.2 The sensors

a) MQ7 sensor

MQ7 sensor is a highly sensitive sensor; it is used to detect carbon monoxide and measure CO concentration between 20 to 2000 ppm. It carries detection on the basis of cycle high and low temperature and detects CO when temperature is low [18].

It works by measuring changes in electrical conductivity when CO gas comes into contact with its sensitive material. This sensor is used in many applications. However, it can only detect CO and may not be suitable for detecting other harmful gases.

Fig.I.6 MQ7 gas sensor module [18].

Technical characteristics of the MQ7 sensor [19]

- Voltage: 5 V.
- Current: 150 mA.
- Temperature: -10 to +50 ° C.
- High sensitivity to Combustible gas in wide.
- Stable performance, long life, low cost.

Table I.2: Pinout of MQ7 sensor.

Pin Number	Pin Name	Description
1	**Vcc**	The [in is there to power the module, requires 5V.
2	**Ground**	To connect the module to the system's common ground.
3	**Digital Out**	Digital output pin, the Threshold value can be set by using the potentiometer.
4	**Analog Out**	Analog output pin. Analog voltage based on the concentration of the gas.

b) LDR sensor Light Dependent Resistor

The LDR 10mm (Light Dependant Resistor) is a variable resistor type electronic component, ie it is a resistor whose resistance varies according to the intensity of the light it receives and can be used as a light sensor. In practice, it converts brightness to resistance, the higher the brightness the lower the resistance, and the lower the brightness the higher the resistance. Extremely functional, LDR can be found in a wide range of consumer goods, such as cameras, security alarms, home lighting, or even street lighting [20].

Fig.I.7 LDR sensor light dependent resistor module [20].

Technical characteristics of the LRD sensor [20]

- LDR 10mm Lightness Sensor.
- Light Dependent Resistor – LDR.
- Variable resistor.
- Photocell LDR.
- Resistance varies with light intensity.
- Lower brightness higher resistance.
- Higher brightness lower resistance.

Table I.3: Pinout of LDR sensor.

Pin Number	Pin Name	Description
1	**Vcc**	Sensor’s power supply 5V
2	**Out**	Analog output

c) HC-SR04 Ultrasonic Sensor

Ultrasonic sensors are electronic devices that calculate the target's distance by emission of ultrasonic sound waves and convert those waves into electrical signals. The speed of emitted ultrasonic waves traveling speed is faster than the audible sound [21].

The Ultrasonic Sensor module is a compact and versatile device that can function as both a transmitter and receiver.

The distance between the sensor and an object is determined using time-of-flight measurement, which involves transmitting an inaudible sound pulse and measuring the time it takes for the pulse to travel to an object and return to the sensor. This time interval is calculated based on the speed of sound, which is approximately 343 meters per second in air. By applying the formula that relates the speed of sound, distance, and time, the distance between the sensor and the object can be accurately calculated. The formulary related to speed of sound, distance and time is:

$$\mathbf{Distance} = \mathbf{Speed} \times \mathbf{Time}$$

Fig.I.8 HC-SR04 ultrasonic sensor module [21].

Technical characteristics of the HC-SR04 Ultrasonic Sensor [21]

- Power Supply: +5V DC.
- Quiescent Current: <2mA.
- Working current: 15mA.
- The sensing range: 40 cm to 300 cm.
- The response time: 50 ms to 200 ms.
- The Beam angle is around 50.
- Preciseness is ±5%.
- The frequency of the ultrasound wave is 120 kHz.
- The ultrasonic sensor weight 150 g.
- Temperature is -250C to +700C.
- The target dimensions 5 cm × 5 cm.

Table I.4: Ultrasonic Sensor pins.

Pin Number	Pin Name	Description
1	Vcc	5V Power supply
2	Trigger	Trigger Input pin
3	Echo	Receiver Output pin
4	Ground	Power ground pin

I.7.3 Modules

a) Buzzer sound module

A buzzer is an electronic device that generates an audible sound or beep in response to an electrical signal. Buzzers can be broadly categorized into two types: magnetic and piezoelectric. The focus is on the piezoelectric buzzer.

A piezoelectric buzzer is an electronic device that uses the piezoelectric effect to generate sound. The piezoelectric effect is a phenomenon in which a material generates an electrical charge in response to applied mechanical stress. Piezoelectric buzzers are commonly used in a variety of applications, including alarms, timers, toys, and electronic devices [22].

Fig.I.9 Buzzer sound module [22].

Technical characteristics of buzzer [23].

- Operation Voltage: 3-5V DC.
- Current: <25mA.
- Frequency: 2,300 Hz.
- Operating Temperature: - 20° to +65°C.
- Weight: 2.4 g.
- Size: 1.2cm diameter x 1cm tall (0.47" x 0.39").

Table I.5: Buzzer sound pins.

Pin Number	Pin Name	Description
1	**Positive**	Identified by (+) symbol or longer terminal lead.
2	**Negative**	Short terminal lead. Generally connected to the earth of the circuit.

b) Servo motor

The Micro Servo Motor SG90 is a small and compact motor with a high output power. It is a type of servo motor that can rotate up to 180 degrees (90 degrees in each direction), providing precise and accurate control over motion. It is often used in small-scale applications, such as in robotics, and other electronic devices.

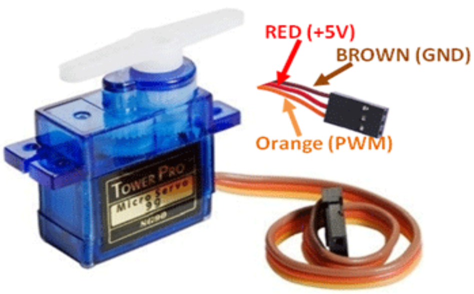


Fig.I.10 Servo Motor SG90 module [24].

Technical characteristics of Servo motor [25]

- Weight : 9 g.
- Dimension : 22.2 x 11.5 x 27 mm.
- Operating speed : 0.1 s/60°.
- Operating voltage : 4.8 V (~5V).

A servo motor consists of three wires;

Table I.6: Servo motor wires.

Wires Color	Pin Name	Description
Red	**Vcc**	Red wire connected to the power supply (+5V)
Brown	**Ground**	Ground wire (Brown wire) connected to the ground
Orange	**Output**	A orange wire connected to the control unit

I.7.4 Other electronic components

a) LEDs

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. When current passes through an LED, the electrons recombine with holes emitting light in the process. LED allows the current to flow in the forward direction and blocks the current in the reverse direction [23].

Fig.I.11 LED light-emitting diode [26].

LEDs have 2 pins:

- Positive: big leg (Anod).
- Negative: small leg (Cathode).

b) Resistances

Electrical Resistance (also known as ohmic resistance) is the opposition that an electrical device has to the flow of electrical current; the unit of resistance is Ohm.

When an electrical device is directly connected to a power source, it attempts to dissipate as much energy as possible. To prevent this, it is essential to limit the intensity of the current. To achieve this, resistors with specific values are employed to control the current and prevent excessive flow of electrons, thereby protecting the circuit components from damage.

Fig.I.12 Electrical resistance [27].

I.7.5 The software

a) The IDE software

Arduino Integrated Development Environment is an open-source software thatuses Java as its programming language mainly used for writing and compiling code intoArduino module. This also supports C, C++ programming languages. The code written by userconsists of two functions, setup () and loop () which are compiled, linked with main () function [16].

Arduino software is a tool to develope and creates new electronic projects; it is very simple and easy to use for beginners and users.

Fig.I.13 The IDE software.

b) IFTTT

IFTTT - a service where a user can program a response to event using simple conditionalstatements. Simply, it is a website where if-else statements generally known as applets arecreated. IFTTT facilitate us to define the commands to be given from the Google Assistant to switch ON or OFF the appliance. Whenever the command is given from Google Assistant, then IFTTT application will trigger Adafruit IO which will pass the command to NodeMCU through Wi-Fito switch ON or OFF the respective appliance [16].

Fig.I.14 IFTTT platform.

c) Google Assistant

Google Assistant or Google's voice assistant is software which is used to give voice commands. It is Virtual assistant software based on Artificial Intelligence which allows the user to controlthe applications in their device. In general, the keyword "Ok Google" is used to start the communication with the Google Assistant. Assistant is able to schedule alarms, search theInternet, adjust hardware settings and show this data in their Google account. This feature is available in almost all kinds of android mobile phones. The users can give the voice commandsthrough Google Assistant to access smart devices and applications [16].

Fig.I.15 Google assistant app.

d) Adafruit IO

Adafruit IO is basically a cloud service. User can store and visualize the data multiple times. User can connect over the internet anywhere and view the dashboards. This application allows user to create chart, graph etc… to display the data. The data is kept private and secured for us. This data can be accessed through a web-browser; hence it provides the ideal hub for operatingvarious IoT applications [16].

Fig.I.16 Adafruit platform.

I.8 Conclusion

The study described the idea of bioclimatic architecture. The bioclimatic design strategies - passive design - can substantially enhance the thermal comfort of the inhabitants. In addition, the climate has a noticeable impact on building design and planning. Should Good use of natural and environmental materials (such as solar radiation and wind, etc...) it is a part of the design features.

Smart Buildings leverage advanced technologies such as the Internet of Things (IoT), automation, to achieve sustainability in construction, optimize building operations, improve energy efficiency, enhance occupant comfort and safety, and reduce operational costs.

Chapter II

Buildings energy performance

II.1 Introduction

Heat balance and performance of buildings refer to the study of the thermal behavior of buildings and their energy consumption. It involves understanding how heat is transferred through the building envelope, including walls, windows, and roofs, as well as the impact of external factors.

Photovoltaic systems, on the other hand, are a type of renewable energy technology that converts sunlight into electricity. They are commonly used to offset their electricity consumption. Photovoltaic systems consist of solar panels, inverters, and electrical components that work together to generate clean energy.

By analyzing a building's heat balance and understanding the performance characteristics of photovoltaic systems, can optimize its energy performance and reduce its environmental impact.

II.2 Heat balance and performance of buildings

Estimating thermal balance and energy management and improving its efficiency and utilization can be very troublesome, some of the techniques used may be easy and simple and provide information on the average load or temperature; others are complex and require more detailed input information. However, the latter performs accurate heat balance calculation and quantitative energy efficiency analysis and provides more accurate results. In this chapter we will present a simple method for calculating heat balance and analysing energy efficiency. The principle of this method is the following structure:

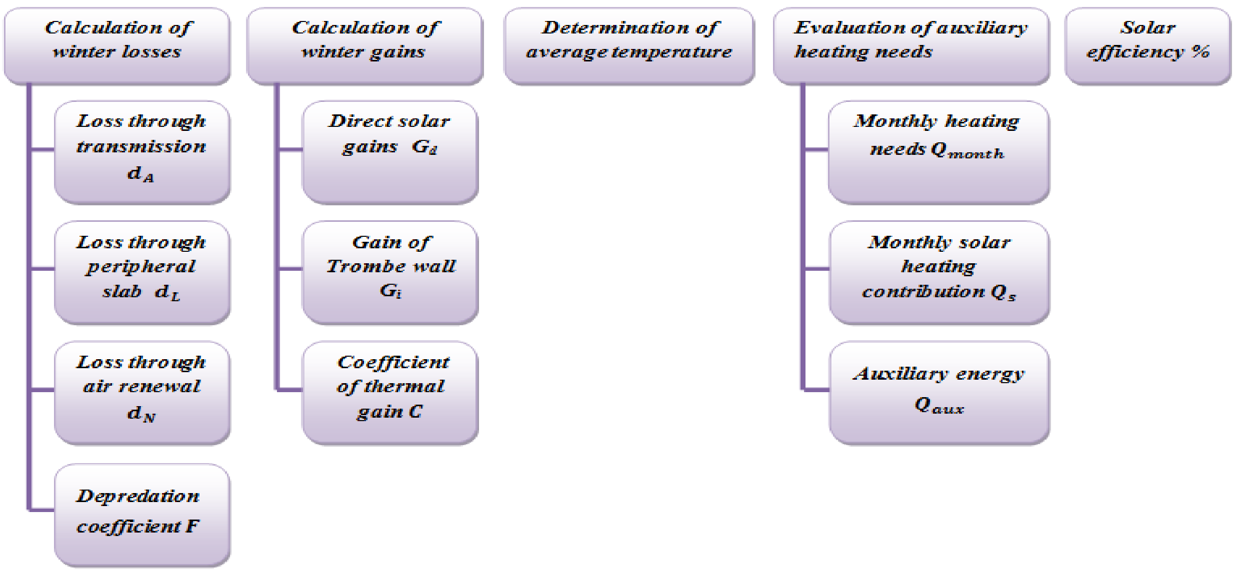


Fig.II.1 Structure of the heat balance.

II.2.1 Material Resistance

The thermal conductivity is a measure of the capacity of a material to conduct heat through its thickness λ. Can be expressed in $(W/m.°C)$ (Watts per meter per degree). The thermal conductivity is defined as the heat hourly flux per m^2 of wall for a temperature deference of $1°C$ between its two faces, in this case the wall thickness which is considered and not the length unit, like for conductibility.

The conductance of a wall is expressed by $(W/m^2.°C)$. Is obtained by devising the conductance λ by the wall thickness [28].

$$C = \frac{\lambda}{e} \qquad (W/m^2.°C) \qquad (II.1)$$

The inverse of the conductance is the resistance or the material ability to slow down the heat flux. Is expressed by $(m^2.°C/W)$. Material insulation properties are proportional to its resistance value [28].

$$R = \frac{1}{C} \ or \ \frac{e}{\lambda} \qquad (m^2.°C/W) \qquad (II.2)$$

II.2.2 Surface resistance

In the case of heated building, a temperature difference is observed between the exterior and external face of the facade and thus between the internal air and the internal face of the same wall. These differences are due to the presence of thin air film immobility to the wall surface. The heat flux passing $m^2$of wall, from the wall into the adjacent air surface, is called transmission rate or the surface exchange coefficient; and is written h_i (for internal face) and h_e (for external face). The inverse of this coefficient exchange is the resistance R to superficial exchanges as expressed in E_q below [28]:

$$R = \frac{1}{h_i} \ or \ \frac{1}{h_e} \qquad (m^2.°C/W) \qquad (II.3)$$

The Table II.1 indicates the values of h and $R(1/h\ )$for vertical wall. For different wind speeds, from 0 (natural convection), to 48 $Km/$ h. In the calculation of winter heat loss, the value of R corresponding to a wind speed of $24Km/$ h. is used, unless the building has good protection against winter winds [28].

Table II.1: Coefficient of superficial exchanges for vertical wall [28].

Wind Speeds (Km/h)	**Coefficient of superficial exchanges $h_e (W/m^2.°C)$**	**Resistance to superficial exchanges $1/h_e$ $(m^2.°C/W)$**
0 (Natural convection)	8.28	0.120
8	18.14	0.054
12	22.68	0.044
16	26.08	0.039
24	34.02	0.030
32	41.39	0.025
40	48.76	0.021
48	56.75	0.018

II.2.3 Global heat transfer coefficient

The heat transfer coefficient K of a composite wall (composed of one or more layers of materials) is the inverse of the total resistance and is expressed in $(W/m^2.°C)$. Between the two environments that separates this wall, is expressed in E_q below [28]:

$$K = \frac{1}{R_{totale}} \qquad (W/m^2.°C) \qquad \text{(II.4)}$$

Where;

$$R_{totale} = R_{cwall} + \frac{1}{h_i} + \frac{1}{h_e} \qquad (m^2.°C/W) \qquad \text{(II.5)}$$

II.3 Calculation Steps of heat balance

Step1: Calculation of winter losses

- **Loss through transmission d_A**

The value of K is multiplied by the corresponding surface (facade, roof, or window) for finding the transmitted stream;

$$d_A = \sum K \times A \quad (W/°C) \qquad \text{(II.6)}$$

Where;

A: The wall, door, window, roof or crawlspace slab area (m^2);

K: Transmission coefficient $(W/m^2.°C)$.

- **Losses through peripheral slab d_L**

The heat does not cross perpendicularly a slab -on-ground to be lost in the depths of the earth.

$$d_L = k \times L \ \ (W/°C) \tag{II.7}$$

Where;

L: The perimeter (outside) of the slab (m);

k: The linear heat loss coefficient $(W/m.°C)$Table II. 2 shows its different values.

Table II.2: The linear heat loss coefficient [28].

Thermal resistance of insulation panels $(m^2.°C/W)$	Height of the perimeter insulation		
	30cm	45cm	60cm
1.76	0.35	0.31	0.29
1.18	0.55	0.48	0.47
0.88	0.74	0.67	0.64
0.70	1	0.86	0.83
0.58	1.21	1.07	1.02
0.44	1.73	1.52	1.46

- **Calculation of losses through air renewal d_N**

The air renewal losses are given by the following formula:

$$d_N = 0.34 \times N \times V \ \ (W/°C) \tag{II.8}$$

Where;

0.34: Heat capacity $(Wh/m^3.°C)$;

N: Air exchange rate en $(1/h)$. Table II.3 shows deferent values of N;

V: Volume of outside air (m^3).

Table II.3: Air exchange rate for deferent premises [28].

Building Local	Air exchange rate N
Local without doors or windows	0.5
Local with outside door or window on one side.	1
Local with external doors or windows on two sides.	1.5
Local with external doors or window on three sides.	2
Entrance hall.	2

- **Global depredations coefficient F**

$$F = \frac{d_{tot}}{S_{pl}} \times 24 \ \ (Wh/day.m^2.°C) \tag{II.9}$$

$$d_{tot} = d_A + d_L + d_N \ \ (W/°C) \tag{II.10}$$

Where;

S_{pl} : Floor area in (m^2).

Values of F which seem reasonable to expect from $34 - 68(Wh/day.m^2.°C)$ for a well-insulated house and $113 - 227(Wh/day.m^2.°C)$ for greenhouse [28].

Step 2: Calculation of winter gains

- **Direct solar gains G_d**

$$G_d = A \times I \ \ (W/day) \tag{II.11}$$

Where;

A: Unshaded glazing surfaces (m^2);

I: Solar gain (Wh/day).

Table II.4: Direct solar gains of each face [28].

Glazed surface	*A*	*I*
South	A_1	5357.2
SE, SW	A_2	3910 ,61
East, West	A_3	2854,745
NE, NW	A_4	2083
North	A_5	1520,59

- **Gain of Trombe wall or roof or an attached greenhouse Gi**

$$Gi = A \times I \times p \ \ (W/day) \tag{II.12}$$

Where;

A: The surface (m^2);

I: Solar gain per m^2 of glazing, in (Wh/day);

p: Percentage of the incident energy.

- **Coefficient of thermal gain C in m^2**

$$C = \frac{G_d}{S_{pl}} + \frac{Gi}{S_{pl}} \ \ (Wh/day.m^2) \tag{II.13}$$

Where;

S_{pl} : Floor area in (m^2).

Step3: Determination of the average temperature

$$t_i = \frac{C}{F} + t_e \ \ (°C) \qquad \text{(II.14)}$$

Where;

C: Thermal gain coefficient $(Wh/day.m^2)$;

F: The global coefficient of heat losses $(Wh/day.m^2.°C)$;

t_e: Average daily outdoor temperature $(°C)$.

Step 4: Evaluation of auxiliary heating needs

- **The need for auxiliary energy Q_{aux}**

$$Q_{aux}=Q_{month} - Q_s \ \ (kWh) \qquad \text{(II.15)}$$

Where;

Q_s : Monthly contribution of solar heating (kWh);

Q_{month} : Monthly heating needs (kWh).

- **Monthly heating needs Q_{month}**

Given by E_q: (II.16)

$$Q_{month} = F \times S_{pl} \times D_{dmonth} \ \ (kWh) \qquad \text{(II.16)}$$

Where;

F : Global loss coefficient $(Wh/day.m^2.°C)$;

S_{pl} : Floor area (m^2);

D_{dmonth}: The Degree-day of the month the number of degree-days per day is the difference between $18°C$ and the mean outside temperature. The number of degree -days for a period of several days is then the sum of degree days for each day of that period [28].

- **Monthly solar heating contribution Q_s**

Takes three successive calculations to determine the monthly solar heating contribution:

- **Monthly coefficient s**

It is a dimensionless number calculated for each month according to the following formula [28];

$$s = \frac{solar\ energy\ absorbed\ in\ the\ month}{Q_{month}} \qquad (II.17)$$

We get the amount of solar energy absorbed by the product of four factors: the tapping surface (A), solar energy transmitted through each m^2 of glazing (I), the percentage of energy absorbed within the building (the absorption coefficient) and the number of days of the month in question [28].

$$Solarenergy\ absorbed\ in\ the\ month = A \times I \times absorption\ coefficient \times the\ number\ of days\ of\ the\ month \qquad (II.18)$$

Where;

A: Unshaded glazing surfaces in (m^2);

I: Average daily solar gain through an m^2 of glazing, (KWh/day).

Absorption coefficient: is the percentage of solar energy absorbed inside the building (in the case of a direct contribution building must be taken 0.95 for a dark or deep within local and 0.90 for a bright interior or local shallow) [28].

- **Portion of the monthly heating needs met by solar energy f**

The Fig. II.2 shows a simple graphical method to determine the portion of the monthly heating needs satisfied in a passive realization.

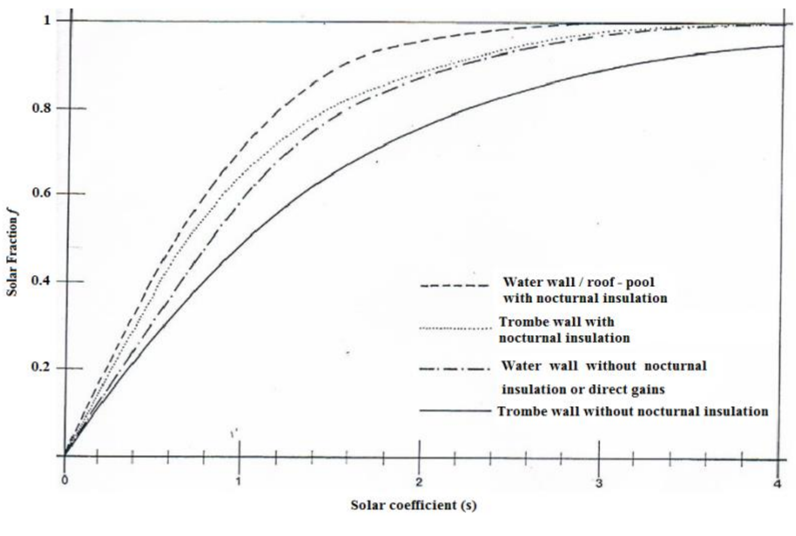


Fig.II.2 Fraction of the monthly heating demand met by solar energy [28].

- **The monthly solar contribution**

Calculate the monthly share of solar heating on every month;

$$Q_s = Q_{month} * f \quad (kWh) \qquad \text{(II.19)}$$

Step 5: Solar efficiency

The annual solar share of total consumption in heating a building with direct contribution is the ratio of monthly sum Q_s by all annual needs.

$$solar_{annual}\% = \frac{100(Q_{s1} + Q_{s2} + Q_{s3} + \cdots)}{Q_1 + Q_2 + Q_3 + \cdots} \qquad \text{(II.20)}$$

II.4 Photovoltaic systems

Growing concerns for the depletion of the world's natural resources has increased the development and the use of renewable energy sources.

When people think about alternative or renewable energy, the first image that comes to mind is often solar panels. Solar power is currently the fastest growing source of electricity. Solar techniques include the use of photovoltaic systems. Technology has provided a number of ways to utilize this abundant resource, especially in areas where there is no practical source of electrical power but there is abundant sunshine. Below, we provide a brief on photovoltaic systems, how they work, and what the future might hold for solar energy.

II.4.1 Stand alone PV systems

A standalone PV system is made up of four primary components; solar panels, an inverter, batteries, and a load. The solar panels capture sunlight and convert it into DC power, which the inverter transforms into AC power for household use. The batteries store excess energy produced during sunny periods for later use. A controller monitors the electrical input from the solar panels, regulating the amount going into the inverter and the amount used for charging and discharging the battery bank. In what follows, we will describe all sections of a standalone PV system.

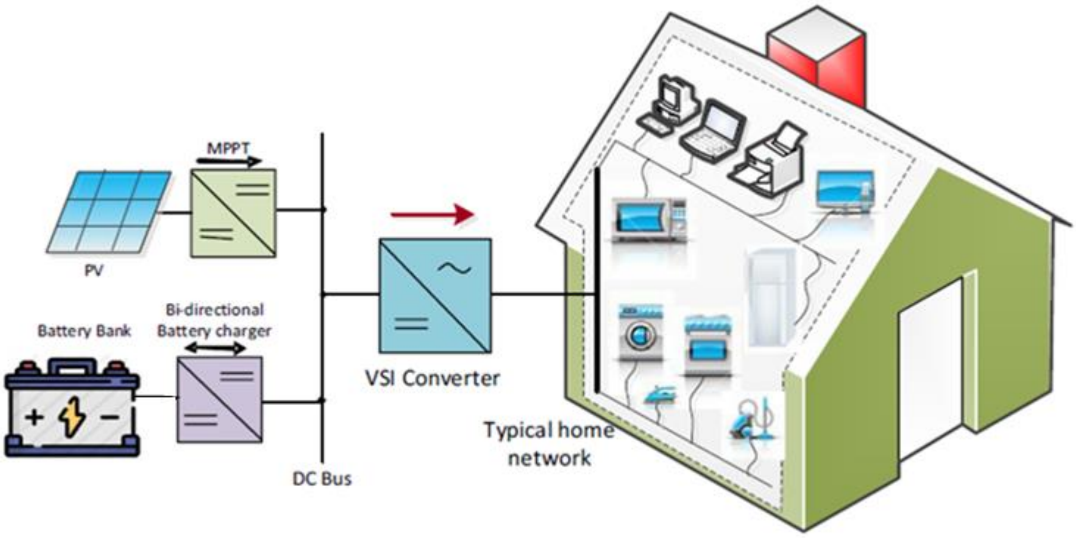


Fig.II.3 Stand alone PV system.

II.4.2 Photovoltaic components

Photovoltaic (PV) systems consist of several components that work together to generate electricity from sunlight. Here are the main components of a PV system [29]:

a) Photovoltaic generator

A photovoltaic generator is a set of interconnected photovoltaic panels. It is made up of a set of PV solar array interconnected in parallel or/and in series to provide the direct current (DC) as well as the voltage desired.

b) Batteries

It stores electric energy for providing to electrical devices when there is a need. There might be periods when there is no daylight. Night times, evenings and shady days are cases of such circumstances outside our ability to control.

Normally a battery bank consists of number of batteries which are wired in series or parallel according to needed battery bank by the solar PV system.

c) DC/AC inverter

Is an exceptional kind of power inverter that transforms direct current (DC) into alternating current (AC) and sustains it into an existing electric grid in grid-connected solar PV systems and to the AC electric appliances.

d) Solar panels

Solar panels are the entire electric power creating unit. It comprises of any number of PV modules. The most crucial segment of any solar PV system is the PV module, which are made out of various interconnected solar cells.

Fig.II.4 Solar panel.

e) MPPT control

Charge Controller Directs the voltage and current originating from the PV panels going to the battery and prevents battery overcharging and prolongs the battery life span. A charge controller decides how much current ought to be injected into the batteries for its most ideal electric performance. As it decides the efficiency of the whole solar PV system, it affects the operating life of the batteries and it is considered to be a vital segment in the solar PV system.

f) Load

Load it is the electrical appliances that connected to the solar PV system such as (lights, TV, PC's, etc…).

II.4.3 Building integrated photovoltaic systems (BIPVS)

The integration of photovoltaic (PV) systems in buildings has gained significant momentum in recent years, offering a sustainable and efficient approach to harness solar energy for various applications. Building-integrated photovoltaic (BIPV) not only generate clean, renewable electricity but also serve as functional and aesthetic components of a building's design. BIPV can be integrated into facades, rooftops, and even windows, replacing traditional building materials with PV modules.

BIPV offers numerous benefits, including reduced energy consumption, decreased reliance on fossil fuels, and lower greenhouse gas emissions. By generating clean, renewable energy on-site, buildings become more energy-independent and contribute to a greener environment.

As awareness of the importance of sustainability and renewable energy grows, the demand for BIPV systems is expected to increase. This will encourage advancements in PV technology, making it more efficient and affordable while promoting the widespread adoption of clean energy solutions in the construction industry [30].

II.4.4 Application for building-integrated photovoltaic

There are many applications for building integrated photovoltaic (BIPV), including the following [30]:

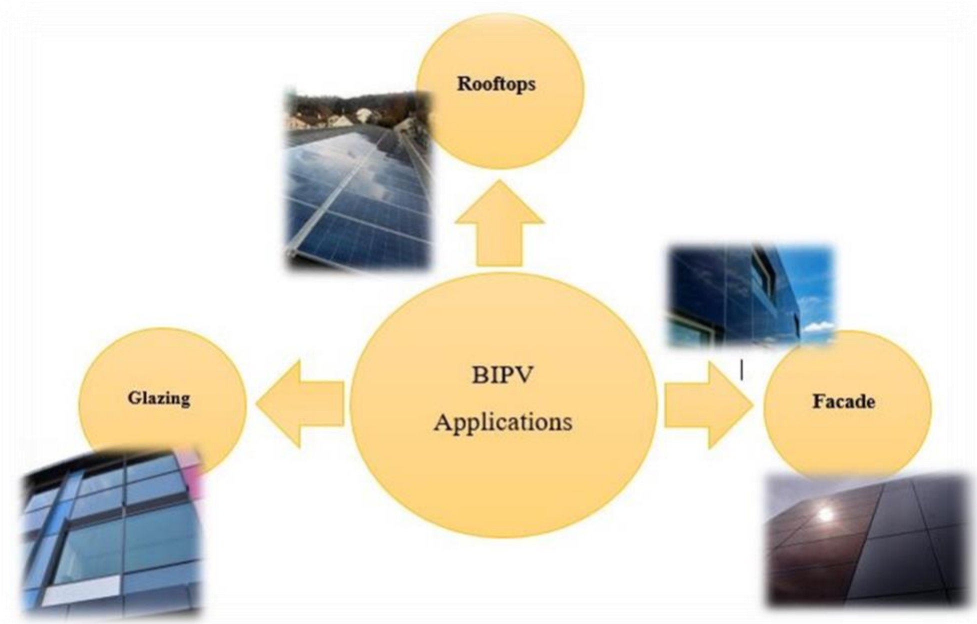


Fig.II.5 BIPV applications.

a) Facade

PV can be integrated into the sides of buildings, replacing traditional glass windows with semi-transparent thin-film or crystalline solar panels. These surfaces have less access to direct sunlight than rooftop systems, but typically offer a larger available area. In retrofit applications, PV panels can also be used to camouflage unattractive or degraded building exteriors.

b) Rooftops

In these applications, PV material replaces roofing material or, in some cases, the roof itself. Some companies offer an integrated, single-piece solar rooftop made with laminated glass; others offer solar “shingles” which can be mounted in place of regular roof shingles.

c) Glazing

Ultra-thin solar cells may be used to create semi-transparent surfaces, which allow daylight to penetrate while simultaneously generating electricity. These are often used to create PV skylights or greenhouses.

II.4.5 Smart homes and photovoltaic integration

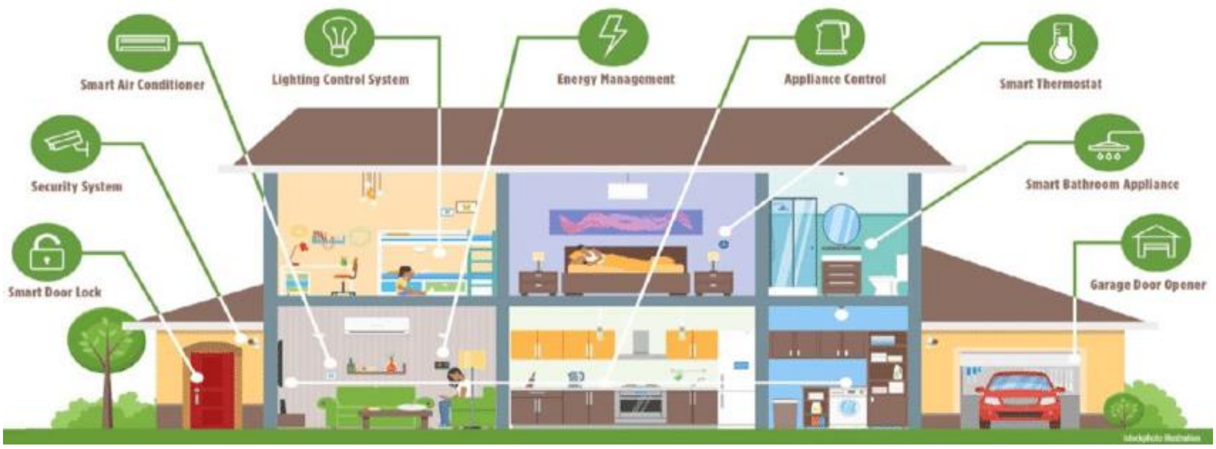


Fig.II.6 A graphical representation of a smart home [31].

The world experiences continual revolutions, going from energy sustainability to innovation of smart household devices that can provide high quality lives. It is not news that the concept of a solar-powered smart home is an enticing one, delivering the idea of an energy efficient home where appliances can be monitored and power obtained from sustainable sources, then stored for later use. Indeed, the world is working towards a future in which one has absolute control over energy consumption. Installing a solar PV system will have an immense contribution for that, especially in North Africa where sunlight is plentiful.

In Africa, smart home technology is not widely spread but as the continent moves into the future, smart homes will begin to find expression in different parts of Africa because of its many advantages and overall energy consumption reduction capacity. However, energy availability and accessibility remain a significant challenge in many parts of Africa, posing a challenge to powering these smart homes. Without a reliable and constant supply of electricity for monitoring and controlling these homes, the whole concept becomes futile. Therefore, incorporating solar PV technology into smart homes is a significant advantage, as it provides a reliable and sustainable energy source for powering these homes [31].

The advantages of having a solar smart home far much exceed their constraints. Here are yet a couple of the benefits of incorporating solar PV into smart homes [31]:

- Negating Extra Energy Costs.
- Environmentally Friendly.
- Use Your Smart Tech When You Need It.
- Saves You Money.
- Save on Energy Consumption.
- E – Mobility.

II.5 A stand-alone photovoltaic system design and sizing

Designing a stand-alone PV system involves evaluating factors such as location, load size, daily power consumption, and sunlight availability to ensure the correct size so that it can generate enough electricity to meet load power requirements while maintaining an appropriate balance between solar array and battery size.

Step1: Determine power consumption demands

- **Calculating total watt-hours per day for each appliance used.**

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system by adding the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances [32].

- **Calculate total watt-hours per day needed from the PV modules**

The total power and energy consumption of all loads of the house is then divided by the systems efficiency factor (Considering the efficiency of the systems) [32].

- **Intensity required per day**

Intensity required per day can be calculated by dividing The Total power that needs to be supplied by the Solar Panels by the DC-voltage of the system. By system voltage we mean; the mechanism that connects batteries and solar panels [32].

$$I_{\mathrm{dc}} = \frac{Total\ daily\ energy\ consumption}{System\ DC\ voltage}\ (Ah/day) \qquad (\mathrm{II}.21)$$

Step2: Size the PV modules

- **Calculate the total watt-peak rating needed for PV modules**

To calculate the size needed to meet our predicted energy consumption, divide the daily energy consumption by the average daily peak sun hours [32].

$$\text{peak power} = \frac{\text{Total daily energy consumption}}{Peak\ sun\ \text{hours}} \quad (w) \qquad (\text{II}.22)$$

- **Calculate the number of PV panels for the system**

The number of parallel modules, which equals peak power divided by power of one panel [32].

$$N_\text{p} = \frac{Peak\ \text{power}}{Power\ of\ one\ panel} = \frac{P_\text{P}}{P_\text{o}} \qquad (\text{II}.23)$$

Step3: Battery sizing (Calculate the number of batteries required)

The battery type recommended for using in solar PV system is deep cycle battery. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days [32].

- **Daily consumption**

The amount of rough energy storage required is equal to the multiplication of the total power demand and the number of autonomy days. The term days of autonomy means the number of days a battery bank can provide the appliances you have connected to the system without a recharged by the solar panels [32], and is expressed by (Ah/day).

$$E_{rough} = \text{Intensity required per day} \times \text{No of autonomy days} = I_\text{dc} \times \text{D} \qquad (\text{II}.24)$$

- **Depth of discharge (DOD)**

For safety, the result obtained is divided by the maximum allowable level of discharge $(MDOD)$, and is expressed by (Ah/day). In E_q below:

$$E_\text{Safe} = \frac{\text{Rough } energy \text{ storage required}}{Max\ dept\text{h of discharge}} = \frac{E_\text{rough}}{MDOD} \quad (Ah/day) \qquad (\text{II}.25)$$

- **Battery efficiency E_ff**

The efficiency is obtained by dividing E_Safe by the efficiency of the battery. and is expressed by (Ah/day). In E_q below:

$$E_\text{ff} = \frac{E_\text{Safe}}{\text{efficiency of the battery}} \quad (Ah/day) \qquad (\text{II}.26)$$

- **Determine the number of batteries**

The number of parallel paths (N_{p}) is obtained by E_{q} below :

$$N_{\mathrm{p}} = \frac{E_{\mathrm{ff}}}{\text{Battery capacity}} \qquad (\mathrm{II.27})$$

The number of batteries in series (N_{s}) equals the DC voltage of the system divided by the voltage rating of one of the batteries selected :

$$N_{\mathrm{s}} = \frac{System\ DC\ voltage}{Battery\ voltage} = \frac{V_{\mathrm{DC}}}{V_{\mathrm{b}}} \qquad (\mathrm{II.28})$$

Step4: Inverter sizing (Calculate the required inverter size)

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts that will be using at one time. The inverter size should be 25-30% bigger than total Watts of appliances [32].

Step5: Solar charge controller sizing (Calculate the size of the freight regulator)

Sizing of the voltage regulator can be obtained by multiplying the short circuit current of the modules connected in parallel by a safety factor E_{Safe}. The result gives the rated current of the voltage regulator, and is expressed by (A) [32].

$$\mathrm{I} = N_{\mathrm{P}} \times I_{\mathrm{sc}} \times F_{\mathrm{safe}} \qquad (A) \qquad (\mathrm{II.29})$$

The factor of safety is employed to make sure that the regulator handles maximum current produced by the array that could exceed the tabulated value. In other words, this safety factor allows the system to expand slightly [32].

II.6 Conclusion

This chapter firstly, discussed the study of the performance and heat balance of a building using an easy method that to understand and amenable to hand calculation.

The second point in this chapter gives out the principal components of stand-alone PV systems and their integration in the buildings especially smart ones. It is used in isolated areas and also in bioclimatic smart houses. Energy efficiency is an important aspect, and photovoltaic systems are an exciting opportunity to improve our way of life by reducing total energy consumption in smart and bio-climate homes.

The next chapter studies and calculates the sizing method for the heat balance and explains how to calculate the energy cost (PV installation sizing) for a typical house.

Chapter III

Results and discussions

III.1 Introduction

Bioclimatic building is based on much more advanced systems, both passive and active. The goal of this part is to achieve the optimal sizing of a bioclimatic house using passive and active sizing, we have implemented it in order to use energy at a low cost and how we automate the house. Also the suitability of these measures for future building design is discussed. To do this, we propose a method based on six steps as expressed in the flowchart of **Fig III.1.**

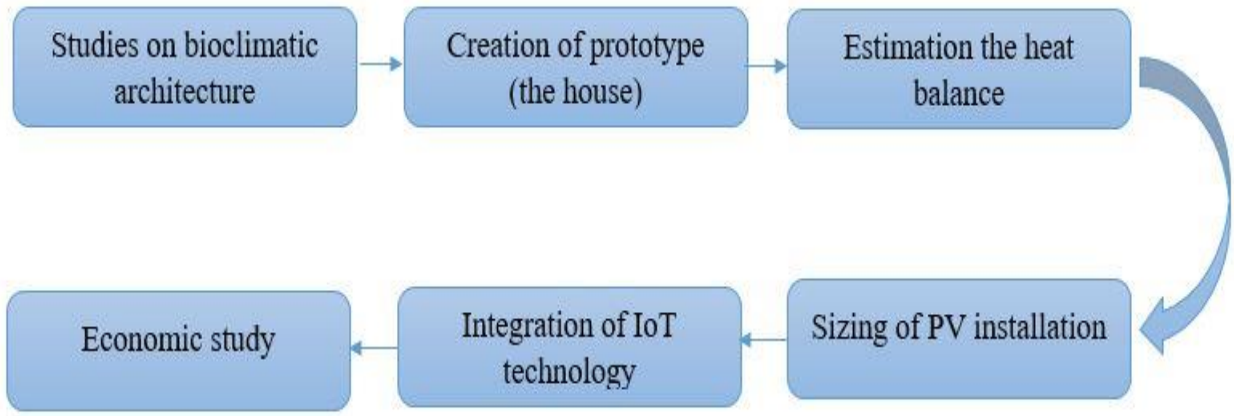


Fig.III.1 Flowchart of the proposed method.

The methodology is based on six essential parts:

- Based on studies on bioclimatic architecture;
- Determine the prototype of the house (plan);
- Estimate the heat balance of the house;
- the optimal size of PV systems;
- Integration of IoT technology in homes and how to implement home automation;
- Economic study to know how much the system costs.

III.2 Creation of prototype

The contextual analysis is an essential step in the development of any project; it makes it possible to know the various urban, architectural and climatic constraints which must be taken into consideration upstream of the design phase of the project.

The information gathered during this approach, such as (the location, the climate, the built environment and landscape etc...), will be used to adapt various facets. We choose our prototype in the Laghouat city it is created with taking into consideration the preceding conditions.

III.2.1 A contextual analysis of Laghouat

a) Geographical and administrative situation

The state of Laghouat is an Algerian state; its capital is the city of Laghouat. It is one of the fifty-eight Algerian states bearing the number (03) within the administrative division of the country. It is characterized by two regions: The Saharan Atlas region, the high plateaus.

It is bordered to the north by the wilaya of Tiaret, to the west by the wilaya of El Bayadh, to the south by the wilaya of Ghardaia and to the east by the wilaya of Djelfa.

It is considered the gateway to the desert regions. The wilaya of Laghouat is located in the heart of the country, 410 km from the capital, Algiers, at an altitude of 830 m to the west and 790 m to the north. It has latitudes of 33° and 46° and longitude of 2° and 56°. It covers an area of 25,052 square kilometers. It is connected to the national road RN°23 and National Road RN°01.

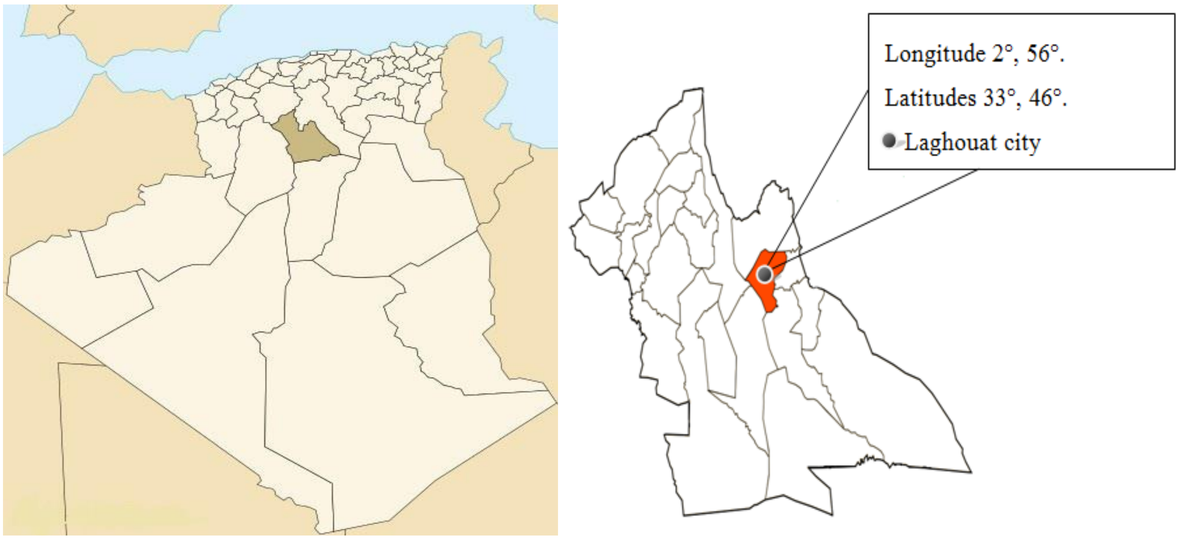


Fig.III.2 Geographical situations of Laghouat.

b) The climatic characteristics of the city of Laghouat

Laghouat is characterized by the diversity of its geographical regions: mountains, plateaus and deserts, which give it a climatic diversity.

- **Temperature**

The climate of Laghouat is continental and dry with an average temperature of -5 degrees Celsius in the cold season. This season is characterized by white frosts. In the hot season, the temperature exceeds 40 ° C. The summer is characterized by intense heat accompanied by sand storms.

➢ **The rainfall**

Precipitation ranges in the Saharan Atlas region, the continental climate ranges from 300 to 400 mm, with snow, while the dry desert climate ranges between 150 mm in the center and 50 mm in the south.

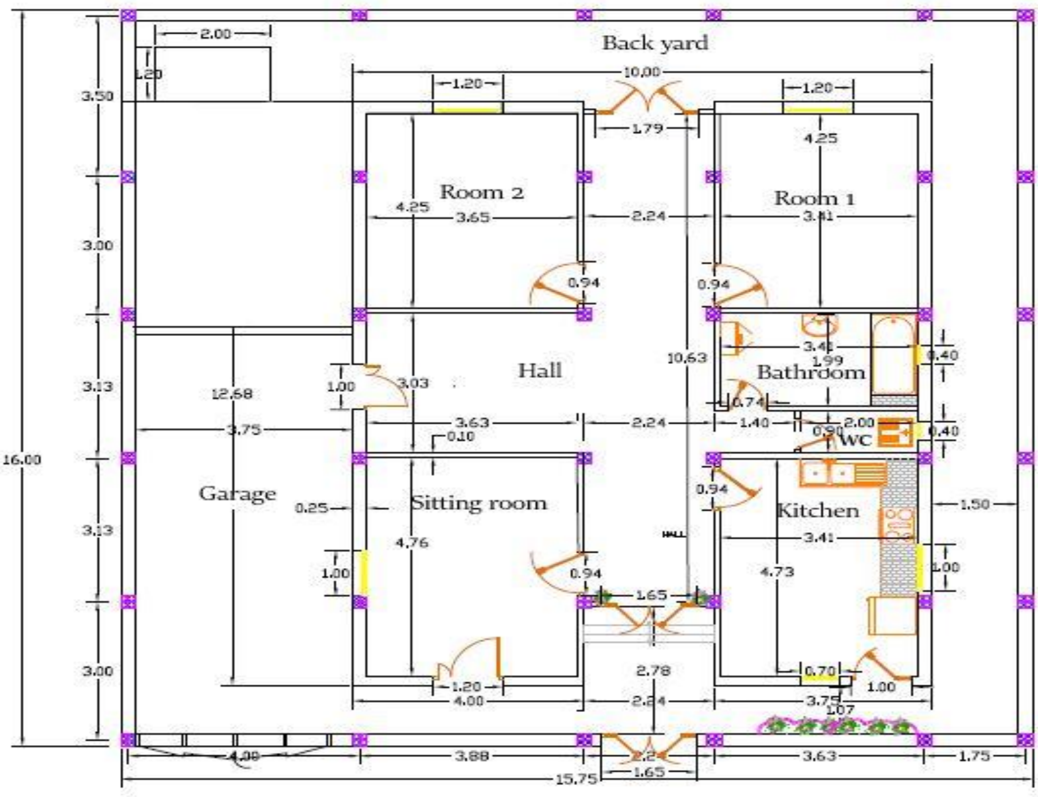
➢ **The wind**

The presence of winds is monthly between a maximum value of 180 km/h and a value not less than 58 km/h.

III.2.2 The created prototype

The house plan is for one floor of 120 (m^2) **on a plot of 252**(m^2).

- Windows are square.
- The height of all doors is 2.1 (m).



RDC PLAN

Fig.III.3 The house plan.

- **3D home design**

Fig.III.4 The 3D house plan.

- **Description of the house**

The construction of the house is based on the following characteristics:

- The house is localized in the North West of the chosen area.
- For internal distribution the maximum of living rooms was located in the south of the building.
- The maximum of the glazing facing south were used, using French doors instead of single doors to make the best solar gain in winter.
- As building materials, materials that combine thermal inertia and insulation were utilised. Among the materials being used in our region is the brick. It was used in double walls for the outer walls with a total thickness of 30 cm and one for the inner walls with a thickness of 15 cm.
- For insulation an air layer was leaved with a 10 cm of thickness between two walls of the external wall. Also; 13 mm of coat and 2.5cm of plaster (the external wall insulation).
- The material construction of the slab is concrete with 15 cm of thickness, and for its insulation the polystyrene was used with 10cm of thickness.

Note: Wall thickness is intended to store heat to reduce energy consumption.

Table III.1: Thermal conductivity materials of used construction [28].

Material	Brick	Air	Concrete	Polystyrene	coat
Thermal conductivity (W/m. °C)	0.5	0.024	0.156	0.03	0.83

III.3 Heat balance

According to the equations explained in chapter II, the heat balance of the house is calculated in the next points:

Step1: Calculation of winter losses

- **Loss through transmission d_A**

According to E_q (II. 6);

$$d_A = 155.94 \quad (W/°C)$$

Where;

$K_{wall} = 0.1233\ (W/m^2.°C)$;

$A_{Wall} = 158.69\ (m^2)$.

We use these parameters: $\begin{cases} \textbf{Brick 30cm} \\ \textbf{air 10cm} \\ \textbf{polysterne 10cm} \\ \textbf{coat 13mm} \end{cases}$ to calculate "K" of wall.

$K_{roof} = 0.1138\ (W/m^2.°C)$;

$A_{roof} = 120.3\ (m^2)$.

We use these parameters: $\begin{cases} \textbf{Brick 15cm} \\ \textbf{concrete 15cm} \\ \textbf{air 10cm} \\ \textbf{polysterne 10cm} \\ \textbf{plaster 2.5cm} \end{cases}$ to calculate "K" of roof.

$K_{glazing} = 6.25\ (W/m^2.°C)$;

$A_{glazing} = 9.63\ (m^2)$.

Our coefficient of glazing was chosen depending on winter conditions $K_{glazing} = 6.25\ (W/m^2.°C)$, Simple glazing [28].

- **Losses through peripheral slab d_L**

According to E_q (II. 7);

$$d_L = 22.225 \quad (W/°C)$$

Where;

$L = 63.5\ (m)$; (Peripheral of all house)

$K = 0.35\ (W/m^2.°C)$ (Table II. 2).

- **Calculation of losses through air renewal d_N**

According to E_q (II. 8);

$$d_N = 154.496 \quad (W/°C)$$

We have:

Room1: $V = 43.47m^3 N = 1$(table II. 3)
Room2: $V = 46.53m^3$, $N = 1$(table II. 3)
Kitchen:$V = 48.38m^3 N = 1.5$(table II. 3)
Hall: $V = 104.48m^3$, $N = 2$(table II. 3)
Sitting room: $V = 57.12m^3$, $N = 1$(table II. 3)
Bathroom:$V = 20.35m^3$, $N = 1$(table II. 3)
Toilet : $V = 5.4m^3$, $N = 1$(table II. 3)

- **Global depredations coefficient F**

We have ;

Total losses: d_{tot}= 332.656 $(W/°C)$;

Floor surface: $S_{pl} = 120.3\ (m^2)$.

According to E_q (II. 9)

$$F = 66.3652(Wh/day.m^2.°C). \text{ (Well-insulated house)}$$

Values of F which seem reasonable to expect from [34 68] $(Wh/day.m^2.°C)$ for a well-insulated house and [113 227] $(Wh/day.m^2.°C)$ for greenhouse [28].

Step 2 : Calculation of winter gains

- **Direct solar gains G_d**

Total south glazing surface $A = 8.57$ (m^2).

Table III.2: Direct solar gains of each face [28].

Glazed surface	$A(m^2)$	I	$G_d = A \times I$
South	8.57	5357.2	$4.6*10^4$
East, West	4.42	2854,745	$1.2*10^4$
North	6.63	1520,59	$1.008*10^4$
			$6.8*10^4$ (W/day)

$$G_d = 6.8 * 10^4 \ (W/day)$$

- **Gain of Trombe wall or roof or an attached greenhouse Gi**

According to E_q (II.12) $\quad Gi = 0 \ (W/day)$

Note: For a well-insulated house, it is difficult to predict the percentage of energy transmitted crosses the wall because of the many variables intervening in the heat exchanges. We can only give a very rough estimate in this case.

- **Coefficient of thermal gain C in m^2**

According to E_q (II.13)

$$C = 5.65 \times 10^2 \ (Wh/day.m^2)$$

Step3: Determination of the average temperature

According to E_q (II.14), monthly average external and internal temperature is given in table below;

Table III.3: The average external and internal temperature of months considered.

Month	November	December	January	February	March
$t_e(°C)$	12.57	7.63	9.38	14.63	18.15
$t_i(°C)$	21.08	16.14	17.89	23.14	26.66

Step 4: Evaluation of auxiliary heating needs

- **Monthly heating needs Q_{month}**

According to E_q (II. 16), monthly heating needs is given in table below;

Table III.4: Monthly heating needs.

Month	November	December	January	February	March
Q_{month} (kWh)	$3.3292*10^6$	$3.0897*10^6$	$3.0897*10^6$	$3.3292*10^6$	$4.0477*10^6$

- **Contribution of solar heating Q_s**

- **Monthly coefficient s**

According to E_q(II. 17);

$$s = 0.54$$

According to E_q(II. 18), solar energy absorbed in each month is given in table below;

Table III.5: Solar energy absorbed in each month.

Month	November	December	January	February	Marsh
Energy absorbed	$3.4 *10^6$	$3.5133 *10^6$	$3.5133*10^6$	$3.1733*10^6$	$3.5133*10^6$

- **Portion of the monthly heating needs met by solar energy f**

According to Fig (II. 2); $f = 0.25$

- **The monthly solar contribution**

According to E_q (II. 19), solar contribution is given in table below;

Table III.6: Solar contribution.

Month	November	December	January	February	March
Q_s (kWh)	$9.975*10^5$	$8.323*10^5$	$7.7242*10^5$	$7.7242*10^5$	$8.323*10^5$

- **The need for auxiliary energy Q_{aux}**

According to E_q (II. 15), auxiliary energy needs is given in table below;

Table III.7: Auxiliary energy needs.

Month	November	December	January	February	March
Q_{aux} (kWh)	3.0502*10^6	2.4969*10^6	2.3172*10^6	2.3172*10^6	2.4969*10^6

Step 5: Solar efficiency

According to E_q(II. 20); $solar_{annual}\% = 25\%$

The value of the global depredations coefficient found is about $66.36\ (Wh/day.m^2.°C)$ indicating that the house is well insulated. The average monthly internal temperatures were calculated using the average monthly temperature of Laghouat.

III.4 Sizing of PV installation

In this part we have designed an integrated solar energy system that is sufficient to power a home.

Step 1 : Determine power consumption demands

- **Calculating total watt-hours per day for each appliance used**

As expressed in Table below;

Table III.8: House Energy Consumption.

Equipment	Power (Watt)	Number	Operating time (hour /day)	Daily consumption (Wh/day)
refrigerator	150	1	24	3600
Television	20	1	5	100
microwave	1000	1	2	2000
Washing machine	2000	1	0.4	800
Laptop	15	1	5	75
LED lamp	12	7	10	840
Total consumption	/	/	/	7415

- **Calculate total watt-hours per day needed from the PV modules**

Considering the efficiency of the batteries (85%) and the inverter (90%), 20% must be added to compensate for the energy lost in the system.

The Total power that needs to be supplied by the Solar Panels:

$$7415 \times 1.2 = 8135 \ \ (wh/day)$$

- **System voltage selection**

By system voltage we mean; the mechanism that connects batteries and solar panels.

$48\ V$ Large installations $> 2400\ W$; So the system voltage is $48\ V$.

- **Intensity required per day(Ah/day)**

According to $\mathrm{E_q}$ (II. 21),

$$I_{\mathrm{dc}} = \frac{8135}{48} = 169.47 \ \ (Ah/day)$$

Step 2 : Size the PV modules

- **Calculate the total watt-peak rating needed for PV modules (Panels energy required)**

According to $\mathrm{E_q}$ (II. 22) Panels energy required;

$$\text{peak power} = \frac{8135}{5\mathrm{h}} = 1627 \ \ (w)\ ; \quad 1.627 \ \ (Kw)$$

Where;

- The daily consumption 8135 (Wh/day);

- Sunshine hours $5(h)$ (Peak Sun Hour) [33].

- **Calculate the number of PV panels for the system**

We choose Mitsubishi Electric PV-MF180UD4 panel with the follow specifications [34]:

- **Panels specification**
  - Maximum power (Pmax) $180(W)$;
  - Voltage at Maximum Power (Vmax) $24(V)$;
  - Current at Maximum Power (Cmax) $7.45(A)$;
  - Open Circuit Voltage (Voc) $30.4(V)$;
  - Short Circuit Current (lsc) $8.03(A)$.

According to E_q (II. 23), the number of PV panels for the system:

$$Np = \frac{1627}{180} = 9.03 \approx 10\ panels$$

- This system requires 2 series of 10 panels to be connected in series. To connect the panels, the voltage of the panels must be greater than the system voltage.

The voltage of the panels 60.8 V > system voltage 24 V

Note: Result of the calculation is the minimum number of PV panels. If more PV modules are installed, the system will perform better and battery life will be improved. If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened.

Step 3: Battery sizing (Calculate the number of batteries required)

- **Daily consumption**

We have the intensity required per day: $169.47(Ah/day)$

- Suppose; the number of days of absence of the sun (the number of days that you need the system to operate when there is no power produced by PV panels): $2\ (day)$.

According to E_q (II. 24), $E_{rough} = 169.47 \times 2 = 338.94\ (Ah/day)$

- **Depth of discharge (DOD) :**

We choose Lithium-Ion Battery with the follow specifications [35]:

Battery specification

- Battery capacity: $150(Ah)$;
- Nominal voltage: $12(V)$;
- Depth of Discharge (DOD) 80%;
- energy efficiency (Eff) 98%.

According to E_q (II. 25), $E_{\text{Safe}} = \frac{338.94}{0.8} = 423.67\ \ (Ah/day)$

- **Battery efficiency (Eff)**

According to E_q (II. 26), $E_{\text{ff}} = \frac{423.67}{0.98} = 432.32\ \ (Ah/day)$

- **Determine the number of batteries**

- Number of battery series: $N_{\text{p}} = \frac{432.32}{150} = 2.88\ \approx 3$

- The number of batteries within each series: $N_{\text{s}} = \frac{48}{12} = 4$

So the total number of batteries is: $4 \times 3 = 12$ (batteries)

This system requires three series of 12 batteries to be connected in series.

Step 4: Inverter sizing (Calculate the required inverter size)

Table III.9: The total power to determine the required inverter size.

Equipment	Power (Watt)	Number	Multiplier value (for device boot)	Total power (Watt)
refrigerator	150	1	3	450
Television	20	1	1.3	26
microwave	1000	1	1.3	1300
Washing machine	2000	1	3	6000
Laptop	15	1	1.3	19.5
LED lamp	12	7	1.3	109.2
Total consumption	/	/	/	7904.7

- **Inverter specification WZRELB [36]**

- Rated Power 8000W
- Rated Voltage 48V

For safety, the inverter should be considered 25% , 30% bigger size. It is better to choose an inverter whose energy value is higher than the required total energy value.

Step 5: Solar charge controller sizing (Calculate the size of the freight regulator).

- **Freight account, which enters the freight regulator**

Depending on the current produced by the panels $I_{sc} = 8.03(A)$ and number of series $N_s = 2$ and safety coefficient $F_{safe} = 1.25$.

According to E_q (II. 29), $\mathrm{I} = 8.03 \times 2 \times 1.25 = 20.07\ (A)$

So, the solar charge controller should be rated 20 A or greater. For example: MPPT Solar Charge Controller Xantrex C Series-C35, C40 & C60 Charge Controllers 48V/60A [37].

III.5 Circuit diagram

Circuits are designed using a combination of devices, boards, and sensors, including some modules. Circuit diagrams implemented for home automation are added in (Appendice C).

III.6 Final project

This project contains five subsystems: (Smart door, gas detection, sun detection, water level, smart lights).

Smart door

- After loading the program on the Arduino Uno, the system needs a few seconds to start up.
- The sensor works in several positions, horizontal, vertical and inclined.
- When the person approaches the designated distance (the door), the door will be opened.

Note: this project can be developed (adding face cam lock or voice lock or code pin)

Sun detection

- After uploading the program to the Arduino Uno, the system needs a few seconds to start up.
- The sensor is attached to detect the sun. If there is no sun the LED lights up and if there is sunlight the LED will turn off.

Gas detection

- After uploading the program to the Arduino Uno, the system needs a few seconds to start up.
- A gas sensor is connected to the control unit to detect leakage at any time.
- The control unit receives signals from the sensor and processes the data to determine gas levels. If there is smell of gas, incense, smoke the buzzer will indicate.

Note: Alarms can also be integrated with other safety systems, such as emergency shutdown systems or building automation systems.

Smart lights

- After loading the program on the microcontroller (Nodemcu), the system needs a few seconds to start up.
- Smart lights systems use energy-efficient LED bulbs or fixtures that have built-in communication capabilities.
- Smart lights communicate wirelessly using Wi-Fi technology,
- This enables connectivity with smart phones and voice assistants, allowing users to control the lights remotely through voice commands.

Water level

- After uploading the program to the Arduino Uno, the system needs a few seconds to start up.
- The ultrasonic sensor detects the water level and sends the signal to the Arduino.
- Based on the water level readings, the Arduino determines if the water level is within the required range or if it exceeds a preset threshold.
- If the water level is within the abnormal range, the LED is programmed to flash to draw attention to the water level.
- If the water level exceeds the minimum limit, the Arduino triggers the buzzer to sound an alarm.

III.6.1 Final prototype

This prototype of Smart Home is designed to reduce the needfor human intervention and energy efficiency.

In this project, some projects are designed for the smart home prototype such as; (Smart door, gas detection, sun detection, water level, smart lights). Smart home prototype as shown in **Fig.III.5** ;

Fig.III.5 The Final prototype.

III.7 Economic study

It is the estimated average construction price of a bioclimatic house in Algeria-Laghouat- achieved using different building materials (concrete and brick) and different technologies (form, function, equipment, living space, quality of life, etc...).

The economic study contains calculation of the following posts costs: the cost of the insulation (external wall and the polystyrene used in the slab...etc.) building plus the PV system installation cost and equipment of IoT technology in homes.

Insulation bioclimatic cost

- The brick wall cost: one-meter square of brick walls in Algeria costs 2.66$(360DZD), a 158.69 m^2 costs;

The brick wall cost = 422.83 $ (57128.4DZD)

- Polystyrene wall cost: one-meter square of polystyrene costs Algeria 1.85$ (250DZD),

a 120.3m^2 of slab it costs;

Polystyrene wall = 222.55 $ (30075DZD).

- The coating wall cost: one bucket of coating wall in Algeria costs18.46$ (2500 DZD) can do 60-metersquare, we have 158.69m^2 of walls, so we need 3 buckets costs;

The coating wall cost = 55.38 $ (7500DZD)

- The insulation bioclimatic cost ;

$$422.83 + 222.55 + 55.38 \approx 701\$ \ (94901.00 \text{ DZD})$$

PV installation cost

- Inverter cost : 380$(51736,24DZD)
- Battery costs : 220 $(29952,56DZD)
- Panel costs : 184$(25000DZD)

It contains the cost of 12batteries (2640$) and 10 panels (1840 $); it was calculated in the previous steps that is about 1898$ plus the inverter cost (we have chosen an 8000 Watt inverterthat costs380$).

PV system cost = 4860$ (661679,28 DZD)

- Equipment of IoT technology cost

Table III.10: Used equipment pricing

Equipment	Price $
Nodemcu	44
Arduino mega	35
LED	6
Jumping wires	7
Bread board	11
Servo motor	14
Gas detector	28
Buzzer	8
Ultrasonic sensor	8
LDR sensor	5
Resistors	9
Total consumption	**166**

IoT installation cost = Total consumption = 166 **$ (22447.02 DZD)**

- **The final cost of the system**

It includes the cost of insulation systems, photovoltaic systems, and IoT equipment cost;

The final cost of the system=
insulation cost **+** Equipment of IoT technology cost+PV installation cost

The final cost of the system =166+701+4860 ($),

The final cost of the system = 5727 $ (779719DZD)

The total cost of installing photovoltaic panels and IoT equipment in a building can be high, with 85% of the total cost being attributed to the cost of photovoltaic panels and batteries. However, it is important to note that this cost can be reduced over time due to the decreasing prices of these technologies.

Moreover, the bioclimatic architecture involves also a way of life. Therefore, the way of thinking about life must be changed, to be enthusiastic about choosing bioclimatic architecture as a step forward towards sustainable development.

III.8 Conclusion

In this study, the results of the prototype have been in Laghouat demonstrated its success in harnessing solar potential and reducing energy needs. The heat balance study provides valuable insights into the energy requirements and thermal behavior of the building. Furthermore, the sizing of standalone PV systems allows for efficient use of solar energy, ensuring that the generated energy meets the building's demand without oversizing or undersizing the system. Alsothe integration of IoT technology further enhances the energy management capabilities of the bioclimatic building.

Despite the higher the total cost of installing photovoltaic panels and IoT equipment in a building, it is important to note that this cost can be reduced over time due to the decreasing prices of these technologies.

General conclusion

General conclusion

While there are many regions in the world that have inherited traditional construction method, there are requirements to move towards more energy efficiency in the construction and to ensure a high level of thermal comfort and provide intelligence, comfort, to improve the way one lives and works.

The study described in the first chapter the idea of bioclimatic architecture. Bioclimatic analysis indicates that some passive design interventions can significantly enhance the thermal comfort of residents and achieving sustainability in construction, which is reflected in improving energy efficiency standards.

In addition, the second part of this chapter describes the design and modeling of a smart home automation system and the Internet of Things. Smart homes equipped with IoT devices can improve energy efficiency, enhance security, and provide personalized experiences for residents with the ability to remotely monitor and control various aspects. As IoT technology continues to advance, smart homes will become increasingly integrated and intelligent, transforming the way we live and interact with our living spaces.

The second chapter; presents principal of sizing method. Where, takes the heat requirement sizing based on some materials. By analyzing the heat exchange processes, thermal losses, and gains, it helps identify areas of improvement for energy efficiency and optimal thermal comfort.

In the other hand, Bioclimatic architecture approaches and smart homes can be complemented by effective solar energy retention measures through stand-alone photovoltaic (PV) systems; they provide a reliable and sustainable electricity generation solution in remote locations or areas with limited access to the grid. These systems harness solar energy to produce clean electricity, reducing reliance on traditional energy sources.

In the last chapter, the study is limited to hot spots in Laghouat Province (Algeria), that are faced the challenges of energy transition. We created a highly-effective and low-cost a bioclimatic house especially. The bioclimatic design strategies were addressed to make a building that contributes to minimum impact on the environment, the bioclimatic home approach was complemented by effective measures to save electricity through stand-alone photovoltaic systems.

An overall bioclimatic analysis of the rural coastal settings suggests that some passive design interventions can substantially enhance the thermal comfort of the inhabitants. The study is limited to the region of Laghouat (Algeria). The overall thermal comfort of the building in all scenarios yielded better results in both winter and summer.

The results of the study indicate that using the optimal configuration for building electrification in Laghouat is beneficial and suitable for long-term investments, especially if the initial prices of photovoltaic energy systems decrease and their efficiency increases.

In addition, the Internet of Things has played an important role in creating intelligent and interconnected environments, through the deployment of sensors, actuators, and IoT devices. Physical objects can be integrated with intelligence and connected to the Internet, to provide many services and improve the quality of life.

Finally, future work can focus on the practical implementation of this method in real-life scenarios. Exploring alternative materials and finding the optimal balance between load feeding, IoT development and cost reduction will further enhance the practicality of bioclimatic buildings. By promoting collaboration and knowledge sharing, adoption of this approach can be accelerated, leading to a more sustainable and energy efficient built environment.

Appendices

Table A: NodeMCU Development Board Pinout Configuration [16].

Pin Category	Name	Description
Power	**Micro-USB** **3.3V** **GND** **Vin**	NodeMCU can be powered through the USB port. Regulated 3.3V can be supplied to this pin to power the board. **GND:** Ground pins. **Vin:** External Power Supply.
Control Pins	**EN, RST**	The pin and the button resets the microcontroller.
Analog Pin	**A0**	Used to measure analog voltage in the range of 0-3.3V.
GPIO Pins	**GPIO1 to GPIO16**	NodeMCU has 16 general purpose input-output pins on its board.
SPI Pins	**SD1, CMD, SD0, CLK**	NodeMCU has four pins available for SPI communication.
UART Pins	**TXD0, RXD0, TXD2, RXD2**	NodeMCU has two UART interfaces, UART0 (RXD0 & TXD0) and UART1 (RXD1 & TXD1). UART1 isused to upload the firmware/program.

1. Smart door

```
#include<Servo.h>
#definetrigPin 12
#defineechoPin 11
Servoservo;
int sound = 250;
voidsetup () {
Serial.begin (9600);
pinMode(trigPin,OUTPUT);
pinMode(echoPin,INPUT);
servo.attach(9);
}
voidloop () {
long duration, distance;
digitalWrite(trigPin,LOW);
delayMicroseconds(2);
digitalWrite(trigPin,HIGH);
delayMicroseconds(10);
digitalWrite(trigPin,LOW);
duration =pulseIn(echoPin,HIGH);
distance = (duration/2) / 29.1;
if (distance < 10) {
Serial.println("the distance is less than 5");
servo.write(90);
delay (1500);
}
else {
servo.write(0);
}
if (distance > 60 || distance <= 0) {
Serial.println("The distance is more than 60");
}
else {
Serial.print(distance);
Serial.println(" cm");
}
delay (500);
}
```

2. Sun detection

```
//set pin numbers
//const won't change
constint ledPin1 =6;    //the number of the LED pin
constint ledPin2 = 7;    //the number of the LED pin


constintldrPin= A0;   //the number of the LDR pin


voidsetup() {

  Serial.begin(9600);
  pinMode(ledPin1,OUTPUT);
  pinMode(ledPin2,OUTPUT);//initialize the LED pin as an output
  pinMode(ldrPin,INPUT);   //initialize the LDR pin as an input
}

voidloop() {

  intldrStatus=analogRead(ldrPin);    //read the status of the LDR value

  //check if the LDR status is <= 300
  //if it is, the LED is HIGH

   if (ldrStatus<=300) {

    digitalWrite(ledPin1,HIGH);              //turn LED on
    digitalWrite(ledPin2,HIGH);

    Serial.println("LDR is DARK, LED is ON");

   }
  else {

    digitalWrite(ledPin1, LOW);        //turn LED off
    digitalWrite(ledPin2, LOW);

    Serial.println("---------------");
  }
}
```

3. Gas detection

```
int smokeA0 = A0;
int buzzer = 11;
floatsensorValue;

voidsetup ()
{
  pinMode (buzzer,OUTPUT);
    pinMode (smokeA0,INPUT);
    Serial.begin(9600);
        Serial.begin("Gas sensor warning up!");
delay (2000);
noTone(buzzer);

}

voidloop ()
{
  sensorValue=analogRead(smokeA0);
  Serial.begin("sensorValue:");
  Serial.begin(sensorValue);
  if (sensorValue> 300)
  {
    Serial.begin(" Smoke detected?");
    tone(buzzer,1000,200);
  }
  else {
    noTone(buzzer);
  }
  Serial.begin("");
delay (200);
}
```

4. Smart lights

```
#include<ESP8266WiFi.h>
#include"Adafruit_MQTT.h"
#include"Adafruit_MQTT_Client.h"

#define led1            D1
#define led2            D2

#define WLAN_SSID        ""              // Your SSID
#define WLAN_PASS        ""          // Your password

//************************* Adafruit.io Setup

#define AIO_SERVER       "io.adafruit.com"//Adafruit Server
#define AIO_SERVERPORT   1883
#define AIO_USERNAME     ""             // Username
#define AIO_KEY          ""    // Auth Key

//WIFI CLIENT
WiFiClientclient;

Adafruit_MQTT_Clientmqtt(&client,       AIO_SERVER,       AIO_SERVERPORT,
AIO_USERNAME, AIO_KEY);

Adafruit_MQTT_Subscribe      Light1      =Adafruit_MQTT_Subscribe(&mqtt,
AIO_USERNAME"/feeds/led01"); // Feeds name should be same everywhere
Adafruit_MQTT_Subscribe      Light2      =Adafruit_MQTT_Subscribe(&mqtt,
AIO_USERNAME "/feeds/led02");

voidMQTT_connect ();

voidsetup () {
  Serial.begin(115200);
  pinMode(led1,OUTPUT);
  pinMode(led2,OUTPUT);

  // Connect to WiFi access point.
  Serial.println(); Serial.println();
  Serial.print("Connecting to ");
  Serial.println(WLAN_SSID);
  WiFi.begin(WLAN_SSID, WLAN_PASS);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println();

  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());

  mqtt.subscribe(&Light1);
  mqtt.subscribe(&Light2);
```

```
}

voidloop() {

  MQTT_connect();


  Adafruit_MQTT_Subscribe*subscription;
  while ((subscription =mqtt.readSubscription(20000))) {
    if (subscription ==&Light1) {
      Serial.print(F("Got: "));
      Serial.println((char*)Light1.lastread);
      int Light1_State =atoi((char*)Light1.lastread);
      digitalWrite(led1, Light1_State);

    }
    if (subscription ==&Light2) {
      Serial.print(F("Got: "));
      Serial.println((char*)Light2.lastread);
      int Light2_State =atoi((char*)Light2.lastread);
      digitalWrite(led2, Light2_State);
    }
  }


}

voidMQTT_connect() {
  int8_t ret;

  if (mqtt.connected()) {
    return;
  }

  Serial.print("Connecting to MQTT... ");

  uint8_t retries = 3;

  while ((ret =mqtt.connect()) != 0) {
    Serial.println(mqtt.connectErrorString(ret));
    Serial.println("Retrying MQTT connection in 5 seconds...");
    mqtt.disconnect();
    delay(5000);
    retries--;
    if (retries == 0) {
      while (1);
    }
  }
  Serial.println("MQTT Connected!");

}
```

5. Water level

```
// C++ code
//
Int ultrason= 0;

long readUltrasonicDistance(int triggerPin,int echoPin)
{
  pinMode(triggerPin,OUTPUT);  // Clear the trigger
  digitalWrite(triggerPin,LOW);
  delayMicroseconds(2);

  // Sets the trigger pin to HIGH state for 10 microseconds
  digitalWrite(triggerPin,HIGH);
  delayMicroseconds(10);
  digitalWrite(triggerPin,LOW);
  pinMode(echoPin,INPUT);
  // Reads the echo pin, and returns the sound wave travel time in
microseconds
  Return pulseIn(echoPin,HIGH);
}

voidsetup()
{
  Serial.begin(9600);
  pinMode(9,OUTPUT);
  pinMode(10,OUTPUT);
  pinMode(10,OUTPUT);
}

voidloop()
{
  ultrason= 0.01723 *readUltrasonicDistance(7, 6);
  Serial.println(ultrason);
  if (ultrason<= 5 ) {
    digitalWrite(9,HIGH);
  }
  else {
    digitalWrite(9,LOW);
  }
if (ultrason>=10 ) {
 digitalWrite(9, HIGH);
 }
else {
digitalWrite(9, LOW);
}
    if (ultrason<= 10) {
    tone(10, 92, 100); // play tone 30 (F#2 = 92 Hz)
  } else {
    digitalWrite(10,LOW);
  }
  delay(10); // Delay a little bit to improve simulation performance
}
```

In order to test and analysis our circuit before any experimentation that can be harmful and destroy the components, a simulation phase is needed. Hence, we have used the tinker-cadsoftware. It is virtual simulation software that can simulate the behavior of the Arduino Uno and NodeMCU as well as the used components. The following figures describe the used simulation schematics for our work.

1. Smart door

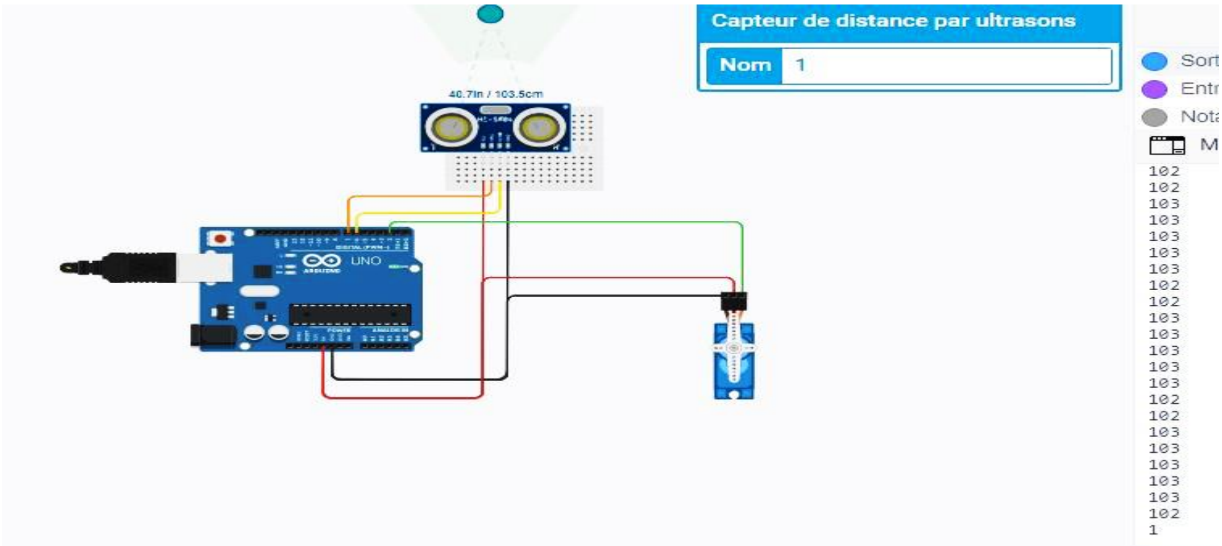


Fig.C1 Smart door system (closed door).

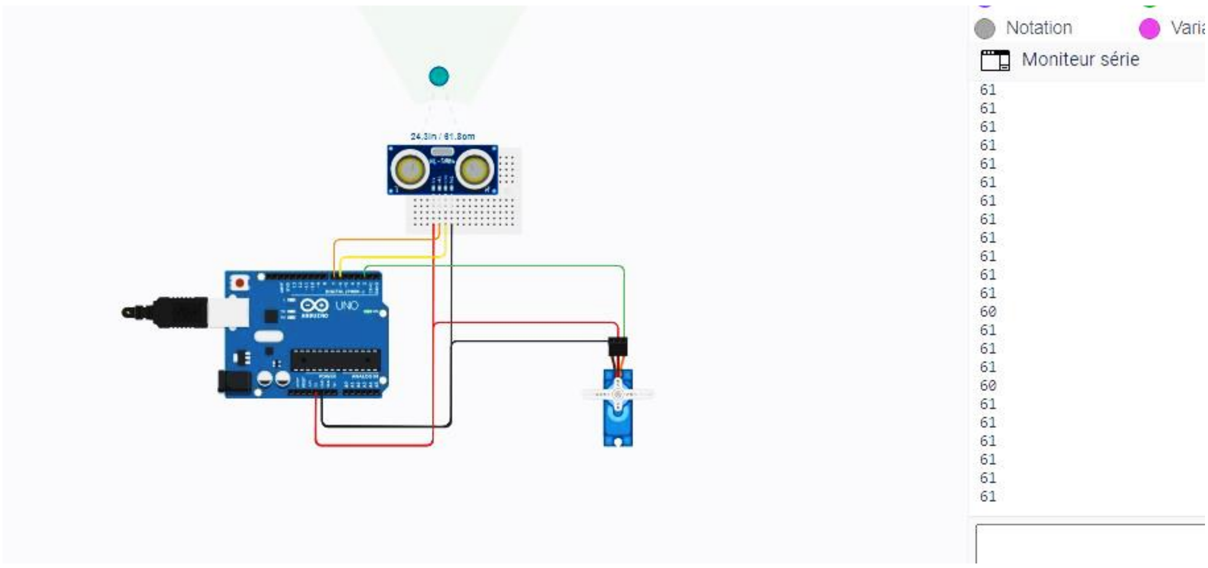


Fig.C2 Smart door system (opened door).

2. Sun detection

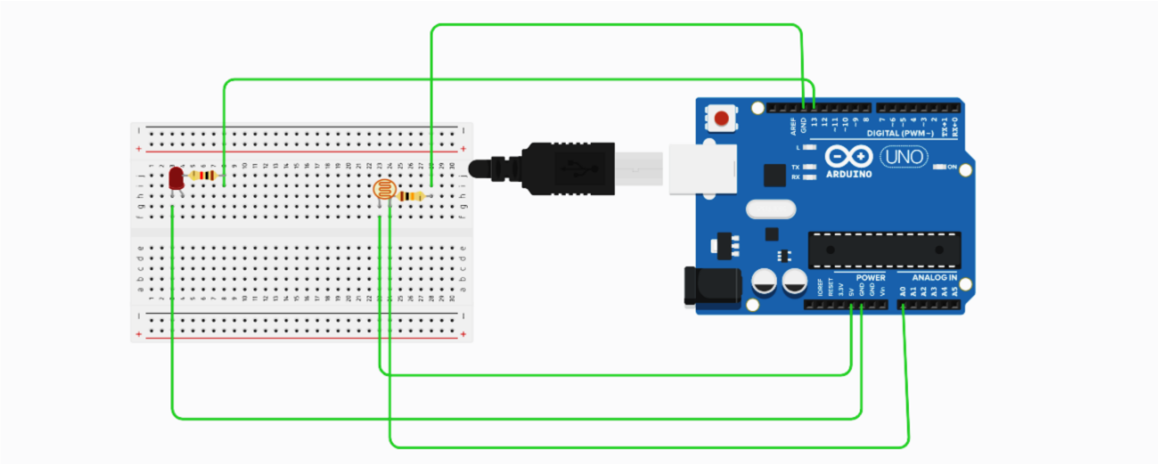


Fig.C3 The circuit diagram of the sun detection system.

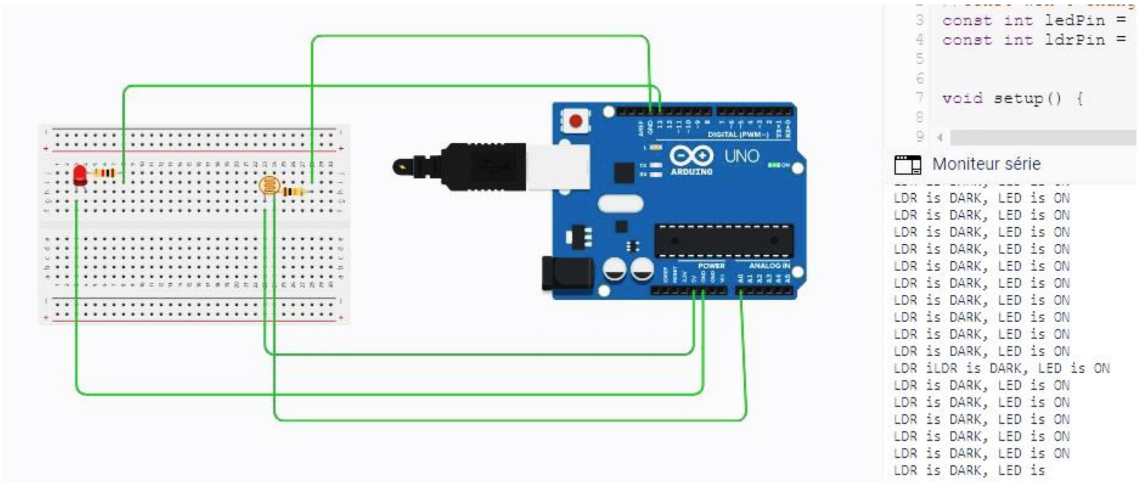


Fig.C4 The circuit diagram of the sun detection system (simulation).

3. Gas detection

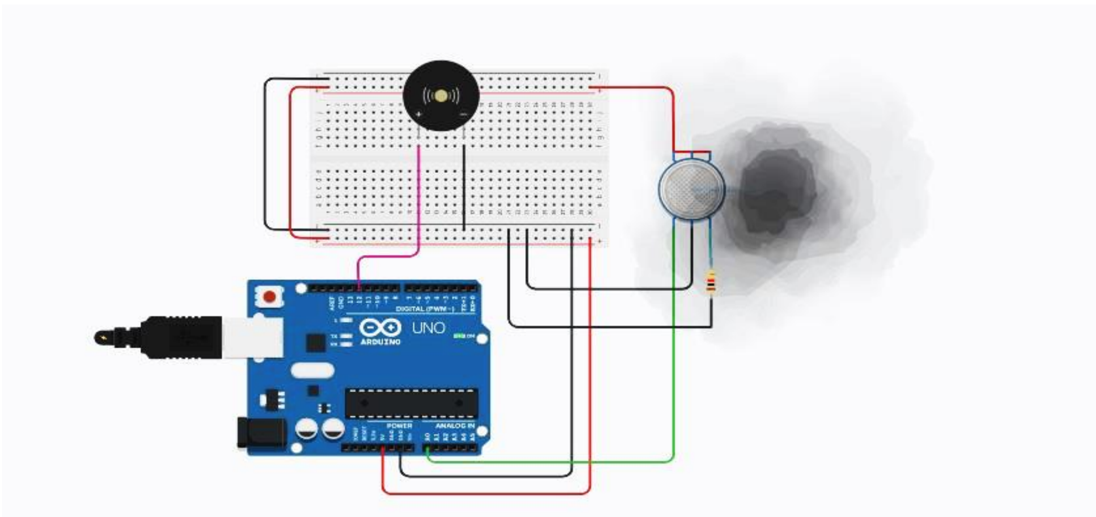


Fig.C5 The circuit diagram of gas detection system (simulation).

4. Smart lights

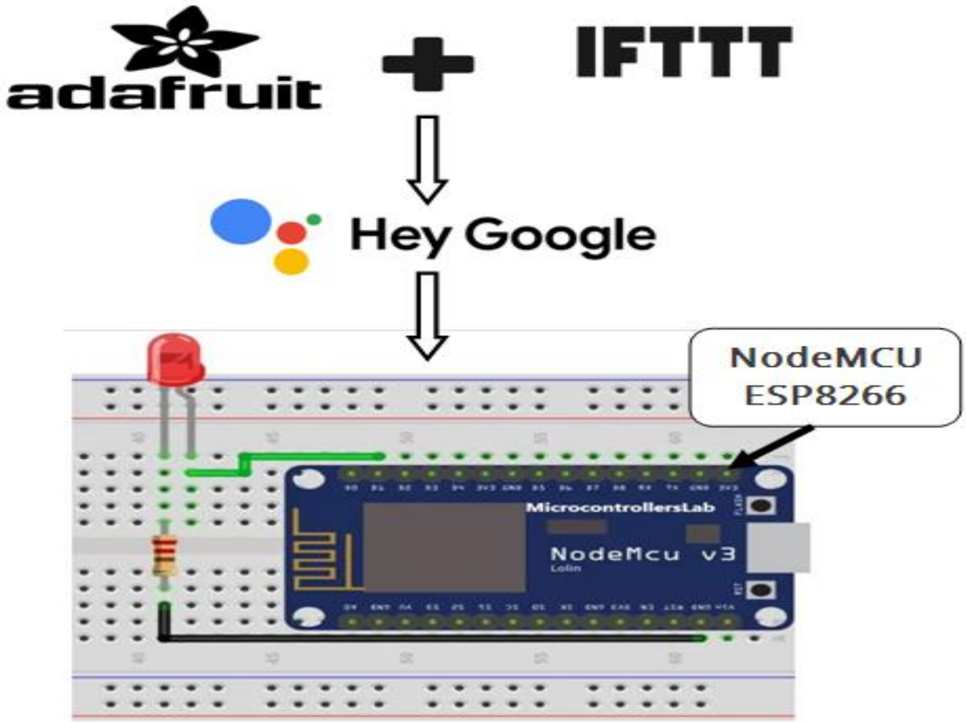


Fig.C6 The circuit diagram of smart light system.

5. Water level

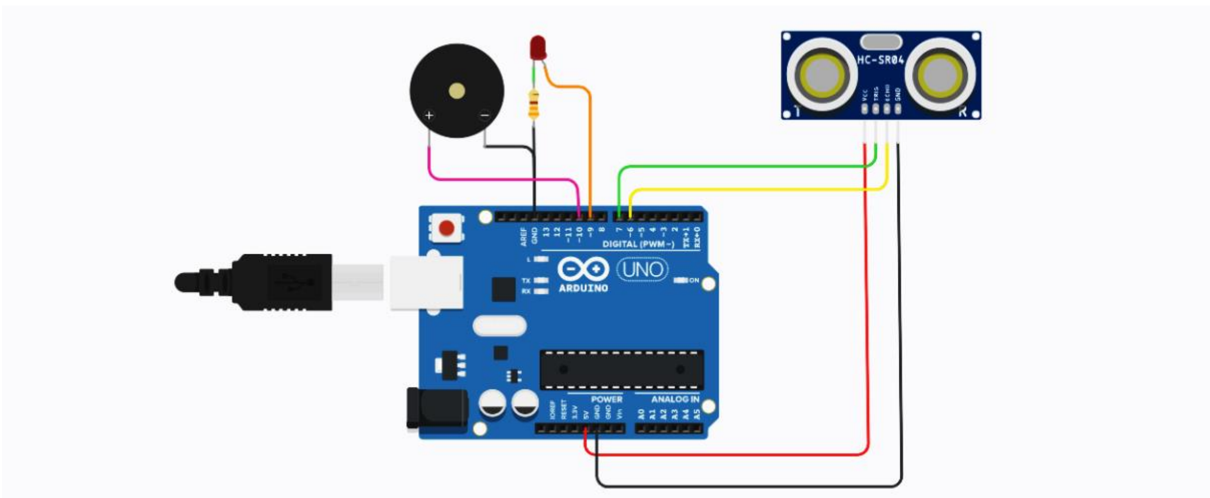


Fig.C7 The circuit diagram of water level system.

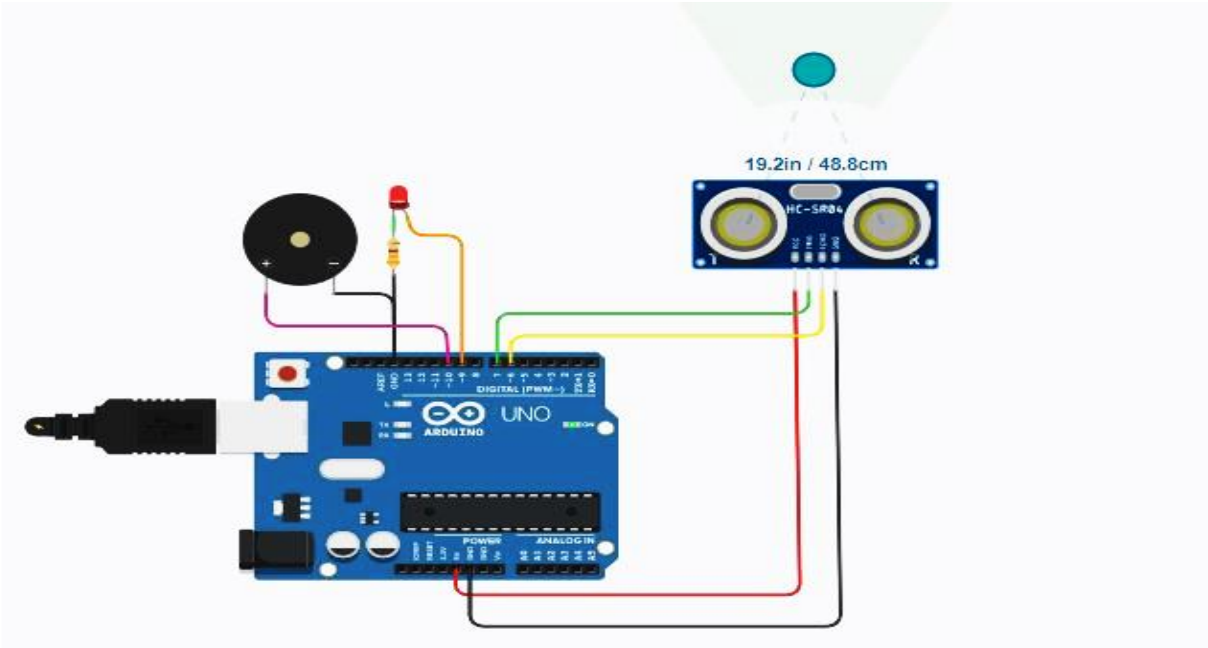


Fig.C8 The simulation of water level system.

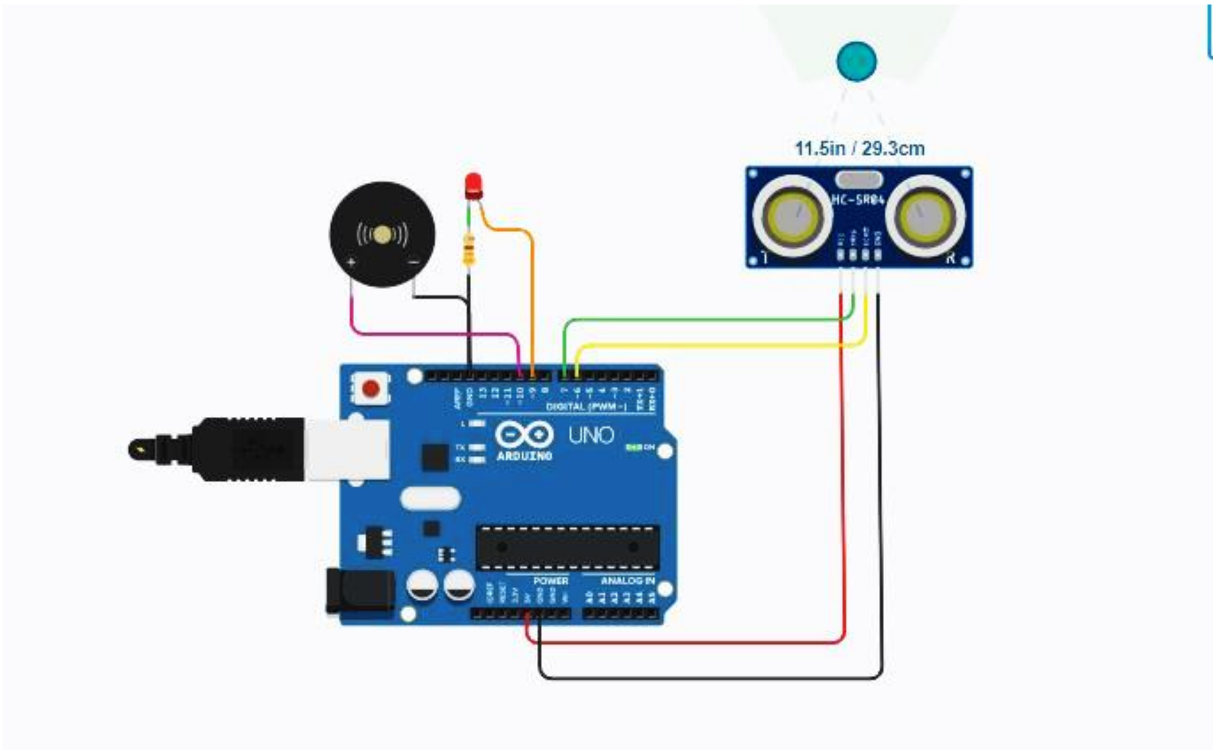


Fig.C9 The simulation of water level system (full tank).

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