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*Présenté par:*

Senigra Belgacem

Sighi Khaled

Ben Ali Oussama

## **Thème**

*Design, feasibility and realization of an air-ground  
exchanger in the arid zone integrated into the building*

Devant le jury composé de

Mr. MANSOURI Khaled	MAA	Président	UEHL El-Oued
Mr. BOUKHARI Ali	MCA	Examineur	UEHL El-Oued
Mr. ATIA Abdelmalek	MCA	Encadreur	UEHL El-Oued
Mr. Kaddour Abdelmajid	MRA	Co-Encadreur	URAER Ghardaïa

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Mémoire préparé au sein du Laboratoire d'Exploitation et de Valorisation des **Ressources**  
Energétiques Sahariennes



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FACULTY OF: TECHNOLOGY



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**Submitted by:**

Senigra Belgacem

Sighi Khaled

Ben Ali Oussama

### Theme

**Design, feasibility and realization of an air-ground exchanger in the arid zone integrated into the building**

President	Mr .MANSOURI Khaled	M.A.A	El-Oued University
Examiner	Mr .BOUKHARI Ali	M.A.A	El-Oued University
Supervisor	Mr. ATIA Abdelmalek	M.C.A	El-Oued University
Co supervisor	Mr. Kaddour Abdelmajid	M.R.A	URAER Ghardaïa

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Mémoire préparé au sein du Laboratoire d'Exploitation et de Valorisation des Ressources  
Énergétiques Sahariennes

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Belgacem Senigra , Khaled Sighi and Oussama Ben Ali

## Table of Contents

Acknowledgments.....	i
Dedication .....	ii
Table of Contents.....	iii
List of Figures .....	v
List of Tables .....	vii
Nomenclature.....	viii
Abbreviations.....	ix
General Introduction.....	1
Generalities.....	3
I. Overview .....	4
II. State of the art .....	5
III. Gap in the literature .....	6
IV. Objective .....	7
Material and method .....	9
I. TRNYS Definition .....	10
II. Two different files from TRNBUILD .....	10
III. Description of the building studied.....	10
IV. Popular mathematical description of the thermal version .....	12
IV.1. Thermal Zone .....	12
IV.2. Convective Heat Flux to the Air Node .....	12
V. Integration of Walls and Windows.....	13
VI. Modeling of the air-ground heat exchanger.....	15
VII. How the simulation works .....	15
VII.1. The first step .....	15
VII.2. The second step .....	16
VII.3. Third step .....	18
VII.4. The last step .....	19
VIII. Simulation tools.....	20
IX. Energy gain assessment brought by the exchanger .....	20
IX.1. Thermal resistances .....	21

IX.2. Air temperature at the exit of the exchanger .....	21
IX.3. Definition of the heat exchanger efficiency .....	21
Results and discussion.....	22
I. ANSYS Simulation Building .....	23
II. Validation of simulations .....	23
II.1. Ambient temperatures .....	23
II.2. Humidity relative .....	24
II.3. Evolution of the air temperature .....	26
II.4. Outlet air temperature of the exchanger .....	27
II.5. Indoor air flow .....	28
II.6. Heat exchanger efficiency .....	29
III. Ambient temperature and relative humidity in the El-Oued .....	30
IV. Cooling and Heating.....	31
V. Coupling Trnsys-Fluent.....	32
General Conclusion .....	36
References.....	37
ABSTRACT .....	

# ***List of Figures***

## **Chapter II**

<i>Figure II.1: Studied building</i> .....	11
<i>Figure II.2: Ambient temperature for El-Oued region</i> .....	11
<i>Figure II.3: Heat balance on the zone air node</i> .....	12
<i>Figure II.4: Surface Heat Fluxes and Temperatures</i> .....	14
<i>Figure II.5 : Conceptual view of (a) cooling and (b) heating mode, air / floor heat exchanger</i> .....	15
<i>Figure II.6: Entering climate data</i> .....	16
<i>Figure II.7: The zone window</i> .....	17
<i>Figure II.8: The new wall type window</i> .....	17
<i>Figure II.9: The new layer window</i> .....	18
<i>Figure II.10: Planned trnsys building</i> .....	19
<i>Figure II.11: Temperature ambient and humidity relative for El-Oued region</i> .....	19

## **Chapter III**

<i>Figure III.1: Ambient temperatures in the regions of El-Oued, Oran, and Beshar, in the month of August</i> .....	24
<i>Figure III.2: humidity relative in the El-Oued, Oran, and Bechar - July 2020</i> .....	25
<i>Figure III.3 : Air temperature changes at the exchanger outlet during August 2020</i> .....	26
<i>Figure III.4: The evolution of the air temperature at the outlet of the exchanger in the month of August 2020</i> .....	27
<i>Figure III.5: Simulation of outlet air temperature of the exchanger</i> .....	28
<i>Figure III.6: Indoor air flow changes during July month</i> .....	29

<i>Figure III.7: Heat exchanger efficiency changes during July 2020.....</i>	<i>30</i>
<i>Figure III.8: Evolution of ambient temperature and relative humidity for the month of July 2020 .....</i>	<i>31</i>
<i>Figure III.9: Cooling and heating needs for a building for a year .....</i>	<i>31</i>
<i>Figure III.10: Air blowing location: (a) blowing air from above and (b) blowing air from below .....</i>	<i>32</i>
<i>Figure III.11: blowing air from above .....</i>	<i>33</i>
<i>Figure III.12: blowing air from below .....</i>	<i>33</i>
<i>Figure III.13: Internal temperature changes over time .....</i>	<i>34</i>
<i>Figure III.14: The evolution of indoor air temperature throughout the building .....</i>	<i>34</i>

# *List of tables*

## *Chapter II*

<i>Table II.1: Study building</i> .....	<i>16</i>
<i>Table II.2: Material properties</i> .....	<i>18</i>
<i>Table II.3: Simulation software applications</i> .....	<i>20</i>

## *Chapter III*

<i>Table III.1: Boundary conditions</i> .....	<i>23</i>
<i>Tables III.2: Heat exchanger properties values</i> .....	<i>25</i>

## ***Nomenclature***

$T_{in}$ :	<i>Temperature of the fluid at the inlet of the conduit [<math>^{\circ}</math> C].</i>
$T_{out}$ :	<i>Temperature of the fluid at the outlet of the duct [<math>^{\circ}</math> C].</i>
$\phi$ :	<i>Heat Flux [kW].</i>
$m_{air}$ :	<i>Mass air flow [kg / s].</i>
$Cp_{air}$ :	<i>Heat capacity of air [J / (kg .K)].</i>
$\Delta T$ :	<i>Temperature difference [<math>^{\circ}</math> C].</i>
$r_1$ :	<i>Outer radius of the tube [m].</i>
$r_2$ :	<i>Inner radius of the tube [m].</i>
$r'_1$ :	<i>Radius outside the ground [m].</i>
$r'_2$ :	<i>Inner radius of the ground [m].</i>
$R_G$ :	<i>Overall thermal resistance [m K / W].</i>
$R_{conv}$ :	<i>Linear thermal resistance corresponding to the convective exchange between the air and the wall of the tube [m K / W].</i>
$R_{tube}$ :	<i>Thermal resistance of the buried tube [m<sup>2</sup> K / W].</i>
$R_{sol}$ :	<i>Thermal resistance between the tube and the cylindrical adiabatic surface [m K / W].</i>
$h_{conv}$ :	<i>Convective heat exchange coefficient [W / m<sup>2</sup> K].</i>
$\lambda_{tube}$ :	<i>Thermal conductivity of the wall of the buried tube [W / m K].</i>
$\lambda_{sol}$ :	<i>Thermal conductivity of the soil [W / m K].</i>
$V_{air}$ :	<i>Air velocity [m / s].</i>
$\varepsilon$ :	<i>Energy efficiency of the exchanger [%].</i>
$h_c$ :	<i>Convective heat exchange coefficient [W / m<sup>2</sup>.K].</i>
$T_s$ :	<i>Average ground surface temperature [<math>^{\circ}</math> C].</i>

## *Abbreviations*

**EAHE:** Earth-air heat exchanger

**FEM:** Finite element method

**PVC:** Polyvinyl Chloride

**HVAC:** Heating, ventilation and air-conditioning

**CFD:** Computational fluid dynamics

## GENERAL INTRODUCTION

It is well known that energy is the lifeblood of all human activities. From a large perspective, energy acts as a primary catalyst in wealth era for a country via gambling an essential function in growing the technological, business, financial, and social sectors inside a society. Currently, it seems that the size of energy consumption exceeds the normal demand and this must be cautiously addressed via the software of energy conservation and power management techniques. Indeed, it's far important and urgent to locate opportunity for electricity sources (easy energy) to update conventional fuels which have an impact on the environment.

In developing international locations, the electricity sector is seen as a very crucial area, with greater consumer demand as compared to its manufacturing. Indoor thermal comfort results from heating, air flow, and air conditioning (HVAC) systems, which devour a number of energy and make a contribution strongly to making the development area chargeable for about 40% of world power intake [1], and this superb intake of energy in creation does now not boom the electricity disaster not most effective. However, it is additionally poses a big challenge to the surroundings. Similarly, the call for electricity in the industrial zones has been increased considerably in recent years due to the growth in population, monetary boom, and standard of residing. Approximately 32-33% of the overall power consumed via the construction zone is used for space heating/cooling [2].

The main purpose of this thesis is the design, feasibility, and evaluation of an air-to-earth heat exchanger for cooling and heating. To reduce heating/cooling power consumption in buildings and decrease extent, or even castoff traditional HVAC systems, geothermal energy appears to be the appropriate energy for this purpose. It is a sort of the heat energy that is generated inside the earth, and it may be used at once for heating and cooling or for generating electricity... etc. It can be found everywhere in the continent. The deployment of geothermal electricity also has additional benefits that make a contribution to reducing the outcomes of world warming and public fitness dangers because of using conventional energy resources. Furthermore, the spread of geothermal electricity allows to reduce the dependence on fossil fuels.

Geothermal power uses a tunnel-air warmness alternate tool and a warmness tunnel inside the ground as a heat source or sinks and air as a working fluid. Outdoor air is drawn into the floor ductwork prior to supplying the building with air conditioning, rather than

entering immediately into the heat exchanger. As air passes through the ducts, the heat is transmitted from the soil to the air. Due to the late thermal response of the sub-soil, the ground temperature at enough depth is decrease than the ambient temperature in summer season. As a result, the air is pre-cooled by way of the soil in summer and pre-heated in winter.

Underground ductwork may be used directly for indoor heating/cooling packages and like any geothermal machine, it exploits the inertia of the soil. This is because of the truth that the soil temperature remains steady after a certain depth: from 2 to 5 m [5]. This kind of formation has been round for lots of years (3000 bc), however, the first research started out to appear within the mid-twentieth century. After the 1979 oil surprise, studies on air-to-surface warmness exchangers have growth specifically during the last 3 years [4]. Numerous researchers have modeled horizontal and vertical air-ground geothermal exchangers for one-of-a-kind geometries of the exchanger, exceptional varieties of soil, and for one of a kind climatic zone. However, in this article the layout, the feasibility, and the conclusion of an air-ground exchanger intended for the cooling and heating of a building has been conducted. The present thesis consists of three chapters:

Chapter One: Previous studies conducted around the world.

Chapter Two: Materials and Simulation Method.

The third chapter: Presenting the results and discussion, and finality general conclusion and perspectives.

Chapter I

Generalities

## I. Overview

Energy is undoubtedly the lifeblood of the progress of human development (in various sectors, including technological, industrial, economic and social) and if it worsened, the main obstacle to that was, the production of energy by fossil fuels led to many negatives, including the abundance of carbon dioxide in the atmosphere, which led to global warming.

In recent times, the volume of energy consumption has increased as it has exceeded the normal demand and the current scenario indicates that the issue of energy consumption in buildings has increased great concern all over the world, this is due to climate changes, the increasing temperature in the summer and the sharp decrease in the winter season. There is a concept called thermal comfort, which is known as the human feeling of thermal equilibrium in a building.

As buildings consume nearly 40% of the global energy [5], especially in developing countries. It is expected that the population of the world will increase with the passage of years, which will increase the consumption of energy. Therefore, we have to search for alternative energy that is sufficient to meet the requirements of society and is without carbon emissions.

At the present time, non-conventional energy sources (renewable energy) are the best choice for clean and sustainable energy as they play an important role in covering demand, the most famous of which is solar and geothermal energy. The latter has promising application potentials and is present in all parts of the world. In residential buildings, livestock homes and offices, as well as in agriculture and industry, to achieve comfort conditions.

One of the applications of geothermal energy on buildings is the use of the geothermal heat exchanger to air (EAHE) of increasing interest due to it being environmentally friendly, energy saving and inexpensive, in general (EAHE) consists of 3 meters deep underground mesh tubes and a blower, its working mechanism combined with a relatively stable temperature Underground where this EAHE system is commonly used in low energy buildings to reduce the heating and cooling load of air handling units.

Algeria is considered one of the oil-producing countries. This does not mean that it will be satisfied with that, but it also has great potential for renewable energy, including solar energy and geothermal energy. Algeria has hot regions, so achieving internal thermal comfort in buildings is a challenge that is not difficult.

The state of El-Oued (Reguiba) is classified from dry desert areas with extreme heat in summer and very cold in winter, the subject of our study of the building of rabbit breeding and the provision of thermal comfort to them throughout the year by the geothermal heat exchanger to the air (EAHE).

## II. State of the art

Jacovides et al. [6] studied several statistical characteristics of the soil temperatures at the surface and at various depths and for both bare and short-grass-covered areas. A study of single pipe carrying warm fluid buried in medium wet sand for pipe diameter, initial soil moisture concentration, temperature and fluid-tube interface temperature using FEM [7]. Bojic et al. evaluated the technical and economic performance of an earth air tunnel heat exchanger which consists of pipes buried in soil coupled to the system for heating or cooling of a building that uses 100% fresh air as cooling or heating medium during summer and winter respectively, using mathematical modeling [8]. According to Manz [9], the temperature of the blinds in a traditional double glass window can be heated to 60C by absorbing solar radiation. The greater temperature difference should benefit a more efficient utilization of shallow geothermal energy. Shukla et al. developed a thermal model for green houses using earth-air tube systems for heating [10].

Chardome and Feldheim [11] studied the heat transfer and condensation phenomena of an EAHE made of 50 m of pipes and buried at 1.25 m under-ground level. They found that the air quality at the outlet of the EAHE can be greatly affected by the condensation phenomena inside the tube. Congedo et al. [12] inspected the efficiency of an earth-to-air heat exchanger in four different cities with various climatic conditions: Turin (North of Italy), Brindisi (South of Italy), Tromsø (Norway) characterized by hot climates, and Béchar (Algeria) classified as a hot-arid region with 45 different configurations. Akhtari et al. [13,14] proposed a hybrid model coupling an EAHE with other renewable resources energy like sun, wind, etc. They assumed that this combination can enhance the performance of the new system by 8%. They also reported that greenhouse gas emissions and fossil fuel consumption can also be reduced by almost 48%.

Cuny et al. [15] investigated numerically the effect of some parameters like the tube radius, tube length, air velocity, burial depth, and soil nature on the thermal performance of an EAHE in the French climate. They found that a simple earth-to-air heat exchanger with large tube length, an intermediate burial depth, and low radius and air velocity

can achieve an excellent thermal performance. A new EAHE buried at low depth was studied experimentally by Pakari and Ghani [16], by using the advantage of the green cover in Doha, Qatar. They found that a near surface EAHE (with a length of 21.5 m and a diameter of 0.15 m) buried at 0.4 m with short grass ground cover and 9 m/s airflow velocity could reduce the air temperature at the outlet by 6.5 °C on a typical summer day. Rosti et al. [17] declared that EAHE technique could reduce the building insulation requirements in comparison with the same building using conventional air conditioning systems. Rosa et al. [18] investigated the effects of spaces between pipes, pipes diameter, and flowing air velocity. They found that the pipe diameter and air velocity are the main parameters affecting the EAHE performance and the distance between two pipes can be reduced to 0.5 m.

Darius et al. [19] Reported that the main parameters affecting the efficiency of an EAHE may be resumed in four parameters: the pipe dimension, pipe material, depth and soil properties, and air velocity inside the tubes. Hatraf et al. [22] highlighted in their study that the soil nature, depth, pipe diameter, and induced airflow have direct effects on the thermal performance of an EAHE. Neemrana (India) for ventilation of a hostel and academic block. Total fourteen earth air tunnels were employed to maintain the building's inside temperature around 28 °C. Additionally, an air handling unit was also used for recooling and dehumidifying the air in each tunnel thus slashing the energy cost about 60-70 % while the capital cost remains the same as that of air conditioning unit [21]. Regarding a residential building in the hot and arid climate region, Benhammou et al. [22] Investigated the cooling performance of an EAHE system. Their results showed that when the insulated building was equipped with an EAHE, the indoor air maximal temperature could be reduced by 11°C.

In the Maghreb climatic context, Menhoudj et al. [23] studied the energy performance of an EAHE system to investigate the feasibility of the EAHE in buildings. The results showed that about 58% of cooling load could be provided by the EAHE. Krarti et al. developed a simple model to predict the air temperature variation along the earth-air tube [24]. Thiers and Peuportier [25] obtained a technical solution for an earth-to-air heat exchanger to reduce energy consumption while providing a satisfactory thermal comfort level in buildings.

### **III. Gap in the literature**

The results presented in the previous studies mentioned above are clearly having a shortage regarding the influence of flow rate and temperature on the performance of the air-

ground heat exchanger and Coefficient of performance of EAHE COP as a function of temperature for different air flow rates.

The main reason for designing EAHEs is to understand the sub-soil temperature distribution to achieve (heating and cooling). During the summer and winter periods, the researchers studied the influence of internal and external factors on the performance of EAHEs.

All the basic modeling techniques used in measuring EAHE performance have not been found, so we have to understand the strengths and limitations of the modeling techniques used in the EAHE system.

#### **IV. Objective**

The main goal of this study is to present the concerns relating to the design, the feasibility and the realization of an air-ground exchanger intended for the cooling and heating of a building. The sizing of an air-ground exchanger is quite important because of the number of parameters to be optimized: length, diameter and number of tubes, burial depth, and ventilation rate. The purpose of the sizing instructions presented here is to propose objective criteria for the choice of these different characteristics.

In the first part of this study, we will look at the design and study of an arid region air-to-ground exchanger (Reguiba) integrated into a rabbit breeding building. We will model and simulate the air-to-ground heat exchanger via ANSYS Fluent:

- ✓ Influence of flow rate and temperature on the performance of the air-ground heat exchanger
- ✓ Validation with the literature concerning the performance of air-ground heat exchangers
- ✓ The efficiency as a function of the inlet air flow
- ✓ The heat transfer coefficient as a function of temperature for different air flow rates.

In the second part, we will present the realization and economic feasibility of an air-ground exchanger:

- ✓ Primary monthly consumption of a building without an exchange.
- ✓ Primary monthly consumption of a building with exchanger.
- ✓ Recovery of the energy consumed by the building with exchanger.

- ✓ Cost Saving: payback period: installation prices, maintenances: Annual economic gain.
- ✓ Optimum utilization of cooling loads and heating loads for the studied rabbit breeding building in the valley El-oued (Reguiba).
- ✓ Realization and experimental study of the heat exchanger system coupled to the building under climatic condition.
- ✓ Validation of simulation model of our experimental air-ground exchanger.

Chapter II

Mathematical  
Modeling and Method

## I. TRNYS Definition

TRNSYS is dynamic simulation software developed by the solar energy laboratory at the University of WISCONSIN Madison, USA. It is used to calculate the energy performance of single or multi-zone buildings under dynamic conditions. TRNSYS can be easily connected to many other applications and TRNSYS includes:

- Solar systems (solar thermal and PV)
- Low energy buildings and HVAC systems with advanced design features (heating/cooling, etc.)
- Renewable energy systems
- Anything that requires dynamic simulation

Components are identified by their types and unit numbers. The types most used for simulation in the building are:

- ✓ Type 9: Standard data reader.
- ✓ Type 54: Meteorological data generator.
- ✓ Type 33: Reading from the psychometric diagram.
- ✓ Type 16: Processor or solar generator.
- ✓ Type 25: Data printing.
- ✓ Type 65: Display of results.
- ✓ Type 56: Multi -zone building (simulate the thermal behavior of the building) using TRNBUILD [26].

## II. Two different files from TRNBUILD

- The first is a building data file (.BUI) which contains all the information about building materials, orientation and envelope materials.
- The second folder (info) contains the information concerning type 56 inputs and outputs to be provided for the simulation [27].

## III. Description of the studied building

The study was conducted on a building for raising rabbits in the state of El Oued, Al Rugaiba, with an area of 99.2 m<sup>2</sup> its internal dimensions are 12.4 m long, 8 m wide and 2.35 m high. The walls of the building are made of polyester material with a thickness of 6 cm, and the ceiling is an arch, as shown in the figure I.1.

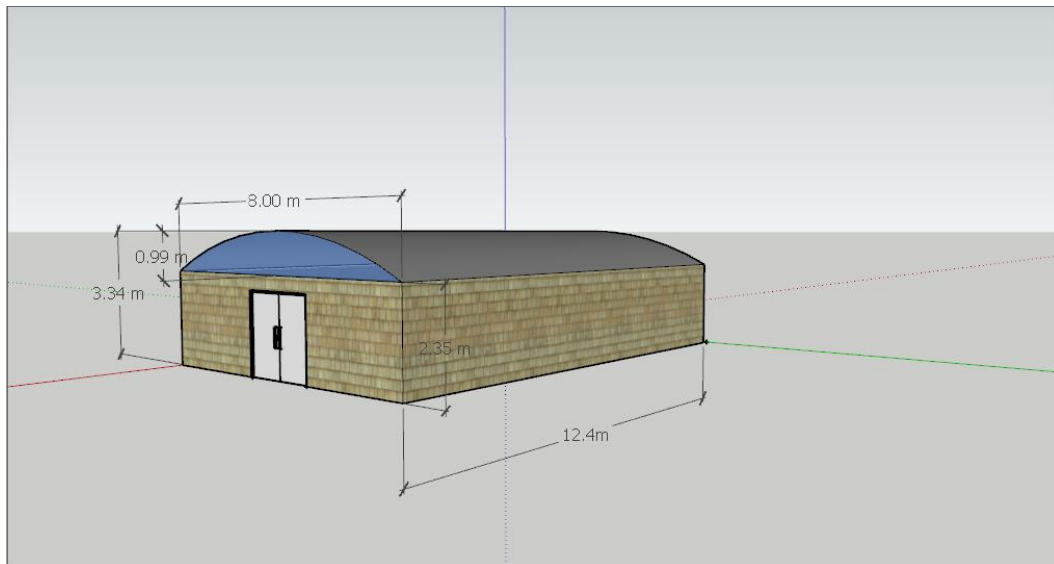


Figure II.1: Studied building.

Figure II.2 presents the maximum and minimum temperature of the el-oued region.

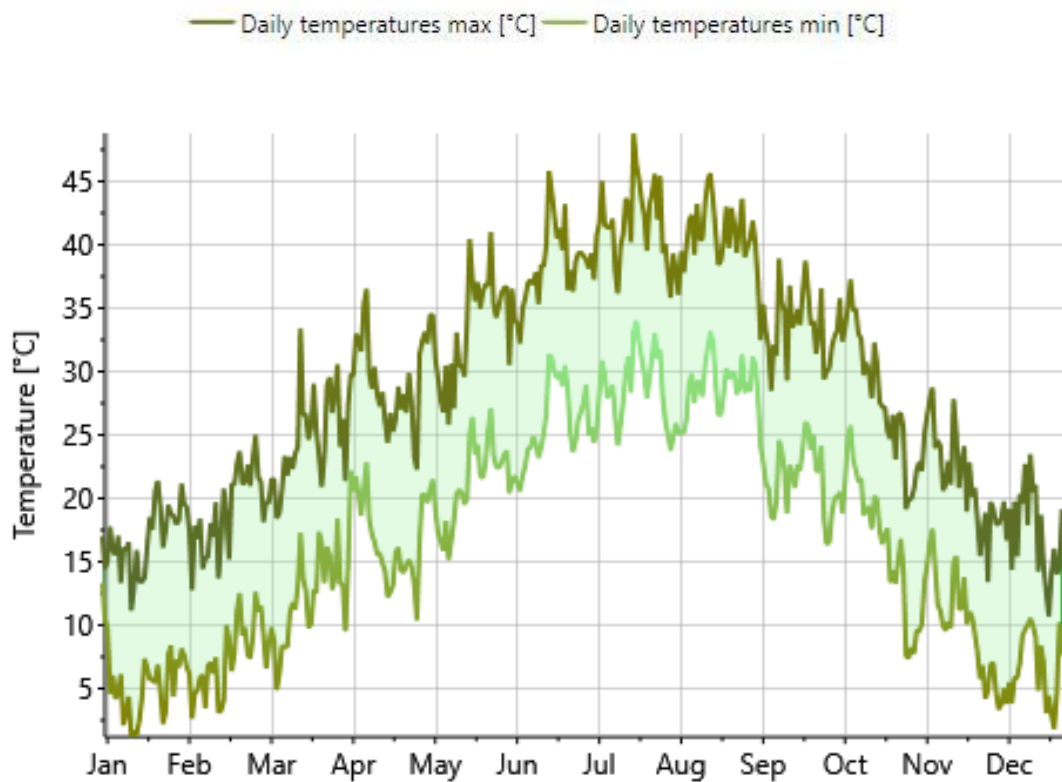


Figure II.2 : Ambient temperature for El-oued region [Source: METEONORM]

## IV. Popular mathematical description of the thermal version

The general case, which does not encompass the simplified version of the heating and cooling system, is provided first. If separate device additives are used, they can be coupled to the zones as both internal convective profits and airflow gains. Following this, the simplified method of presenting heating and cooling gadget in the type 56 factor is defined. Every other phase will cover using a simulation time step that is not the same as the time base on which the wall switch feature relationships are based. Subsequently, descriptions of the optical and thermal window model, the way in which sun and internal radiation are allotted within each zone, the moisture balance calculations, and the incorporated model for thermo-energetic partitions are given.

### IV.1. Thermal Zone

The building model in TYPE 56 is a non-geometrical balance model with one air node per zone, representing the thermal capacity of the zone air volume and capacities which are closely connected with the air node (furniture, for example). Thus the node capacity is a separate input in addition to the zone volume [28].

### IV.2. Convective Heat Flux to the Air Node

In this part, evolution of heat transfer by TRNSYS has been carried out. The convective exchanges are taken into account as follows in equation 1 given by [29]:

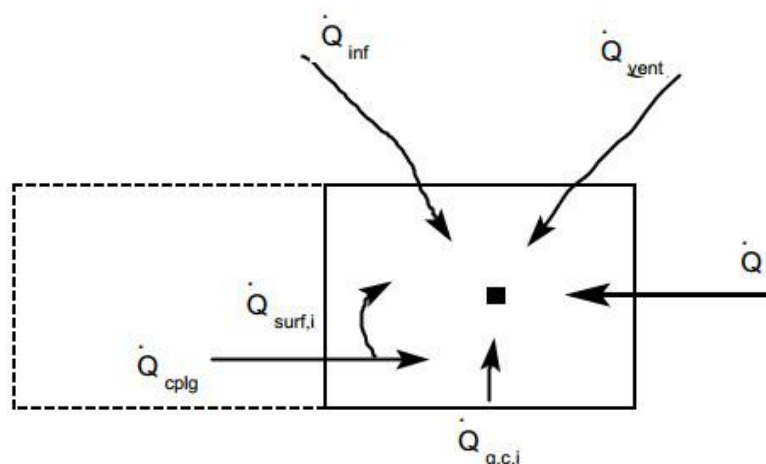


Figure II.3: Heat balance on the zone air node.

$$\dot{Q}_i = \dot{Q}_{surf,i} + \dot{Q}_{inf,i} + \dot{Q}_{vent} + \dot{Q}_{g,c,i} + \dot{Q}_{cplg,i} \quad (1)$$

Where

$\dot{Q}_{surf,i}$  : Convective heat flow from all inside surfaces

$$\dot{Q}_{surf,i} = U_{w,i} \cdot A_{w,i} \cdot (T_{wall,i} - T_{air}) \quad (2)$$

$\dot{Q}_{inf,i}$  : Infiltration gains (air flow from outside only)

$$\dot{Q}_{inf,i} = \dot{V} \cdot \rho \cdot c_p \cdot (T_{outside} - T_{air}) \quad (3)$$

$\dot{Q}_{vent,i}$  : Ventilation gains (air flow from a user defined source, like a HVAC system)

$$\dot{Q}_{vent,i} = \dot{V} \cdot \rho \cdot c_p \cdot (T_{ventilation,i} - T_{air}) \quad (4)$$

$\dot{Q}_{g,c,i}$  : Internal convective gains (by people, equipment, illumination, radiators, etc.)

$$\dot{Q}_{g,c,i} = \left[ \frac{KJ}{h} \right]$$

$\dot{Q}_{cplg,i}$  : Gains due to (connective) air flow from zone i or boundary condition [25]

$$\dot{Q}_{cplg,i} = \dot{V} \cdot \rho \cdot c_p \cdot (T_{zone,i} - T_{air}) \quad (5)$$

## V. Integration of Walls and Windows

Figure II.4 shows the heat fluxes and temperatures that characterize the thermal behavior of any wall or window. The nomenclature used in Figure II.4 is defined as follows:

$S_{s,i}$  : Radiation heat flux absorbed at the inside surface (solar and radiative gains)

$S_{s,o}$  : Radiation heat flux absorbed at the outside surface (solar gains)

$\dot{q}_{r,s,i}$  : Net radiative heat transfer with all other surfaces within the zone

$\dot{q}_{r,s,o}$  : Net radiative heat transfer with all surfaces in view of the outside surface

$\dot{q}_{w,g,i}$  : User defined heat flux to the wall or window surface

$\dot{q}_{s,i}$  : Conduction heat flux from the wall at the inside surface

$\dot{q}_{s,o}$  : Conduction heat flux into the wall at the outside surface

$\dot{q}_{c,s,i}$  : Convection heat flux from the inside surface to the zone air

$\dot{q}_{c,s,o}$  : Convection heat flux to the outside surface from the boundary / ambient

$T_{s,i}$  : Inside surface temperature

$T_{s,o}$  : Outside surface temperature

$T_i$  : Temperature of zone i (air node)

$T_{a,s}$  : Temperature of ambient air at the outer boundary of surface.

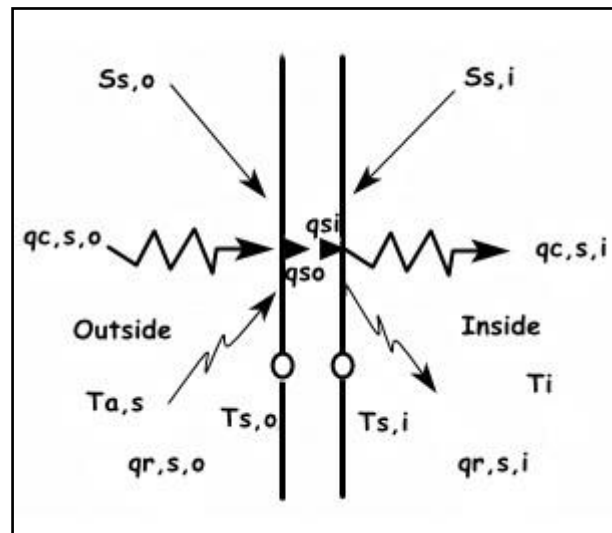


Figure II.4: Surface Heat Fluxes and Temperatures

The walls are modelled according to the transfer function relationships of Mitalas and Arseneault [30] defined from surface to surface. For any wall, the heat conduction at the surfaces is:

$$q_{s,o} = \sum_{k=0}^{na} a_s^k \cdot T_{s,o}^k - \sum_{k=0}^{nb} b_s^k \cdot T_{s,i}^k - \sum_{k=0}^{nd} d_s^k \cdot q_{s,o}^k \quad (6)$$

And

$$q_{s,o} = \sum_{k=0}^{nb} b_s^k \cdot T_{s,o}^k - \sum_{k=0}^{nc} b_s^k \cdot T_{s,i}^k - \sum_{k=0}^{nd} d_s^k \cdot q_{s,o}^k \quad (7)$$

These time series equations in terms of surface temperatures and heat fluxes are evaluated at equal time intervals. The superscript k refers to the term in the time series. The current time is k=0, the previous time is for k=1, etc. The time base on which these

calculations are based is specified by the user within the TRNBUILD description. The coefficients of the time series  $a^k, b^k, c^k$  and  $d^k$  are determined within the TRNBUILD program using the z-transfer function routines of [31].

## VI. Modeling of the air-ground heat exchanger

Modeling a ground-air heat exchanger for heat exchange to provide thermal comfort to a building for raising rabbits by burying the exchanger at a specific depth of 2 meters or more in order to cool or heat the air inside the building through heat exchange between the ground and air. Figure II.5.a represents the heating process for a building for breeding Rabbits in the winter and Figure II.5.b Cooling a building for keeping rabbits in the summer.

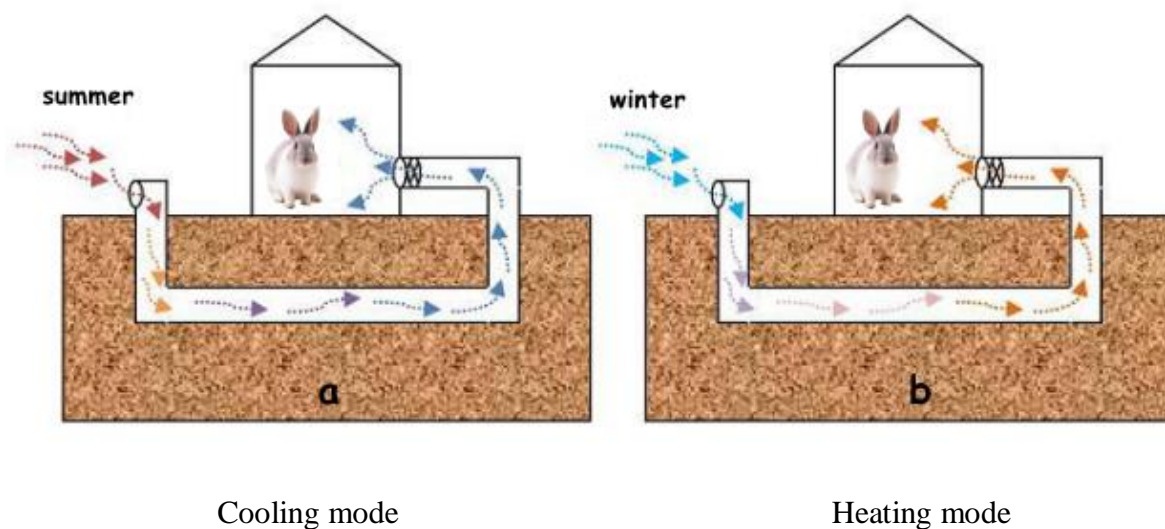


Figure II.5: Conceptual view of (a) cooling and (b) heating mode, air/floor heat exchanger [32].

## VII. How the simulation works

The simulation with the TRNSYS.16 software is carried out in three important stages.

### VII.1. First step:

Covers the introduction of climatic data for the El-Oued region using Weather data type:

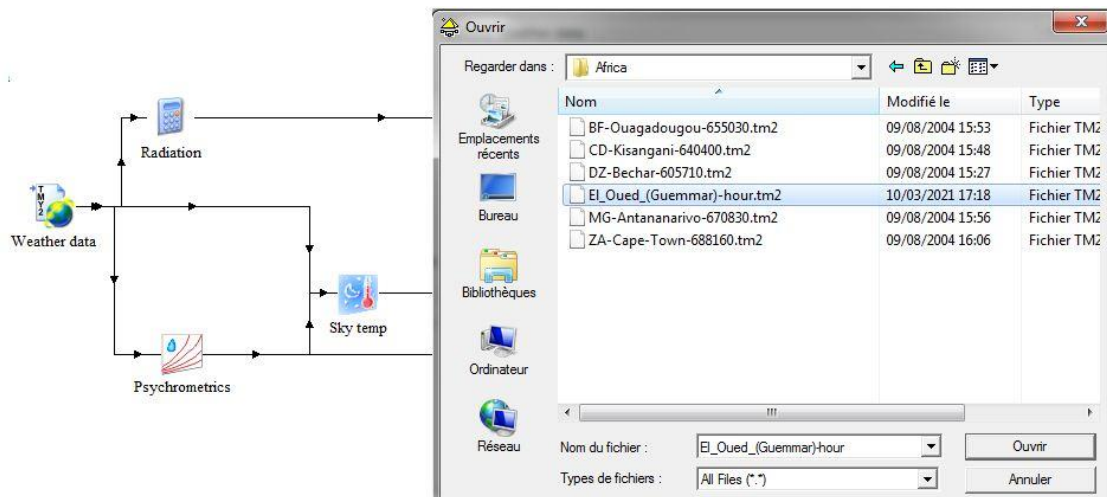


Figure II.6: Entering climate data.

## VII.2. Second step:

Dealing with the detailed description of the building in the TRNBUILD files taking into account the thickness, the conductivity, the thermal capacity of the material and the orientation. The construction of the test cell was made to be considered as an isolated construction, the vertical walls and the top and bottom floor are shown in the following tables.

Table II.1: Study building settings

	Material	Thickness[cm]
Walls	Polystyrene insulator	6
Downstairs	Sol	10
Upstairs	Polystyrene insulator	6

The zone window contains all the information describing the thermal zone of the building as shown in Figure II.7.

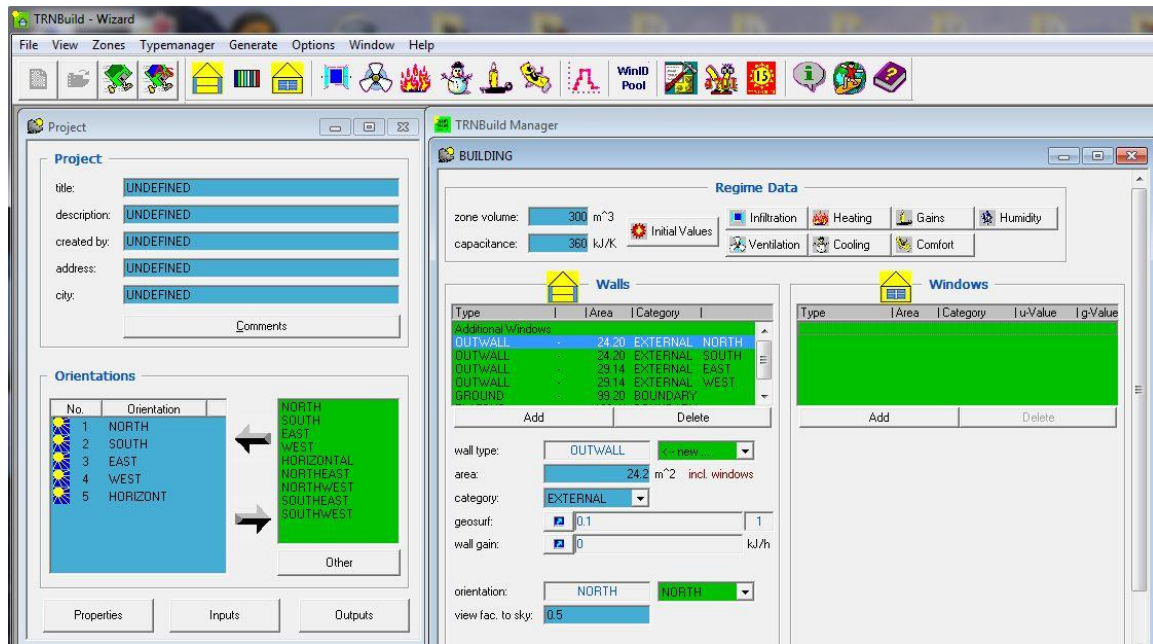


Figure II.7: The zone window

To define a new wall type, select new from the pull-down menu of wall type within the zone window and a window as shown in Figure II.8 will pop up.

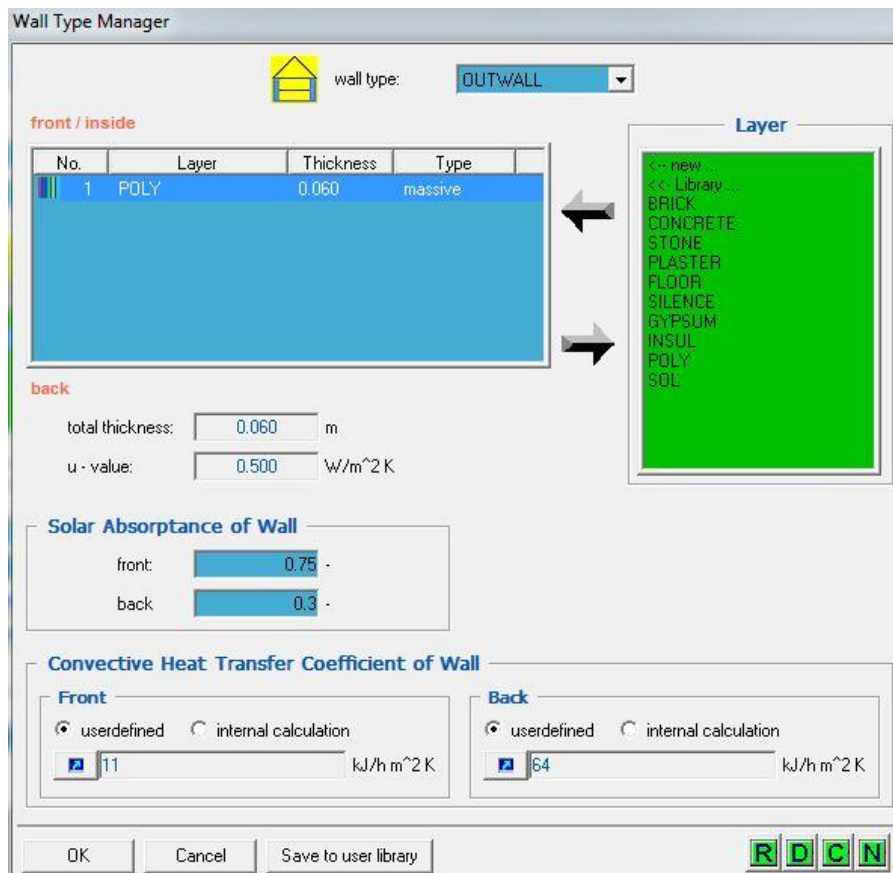
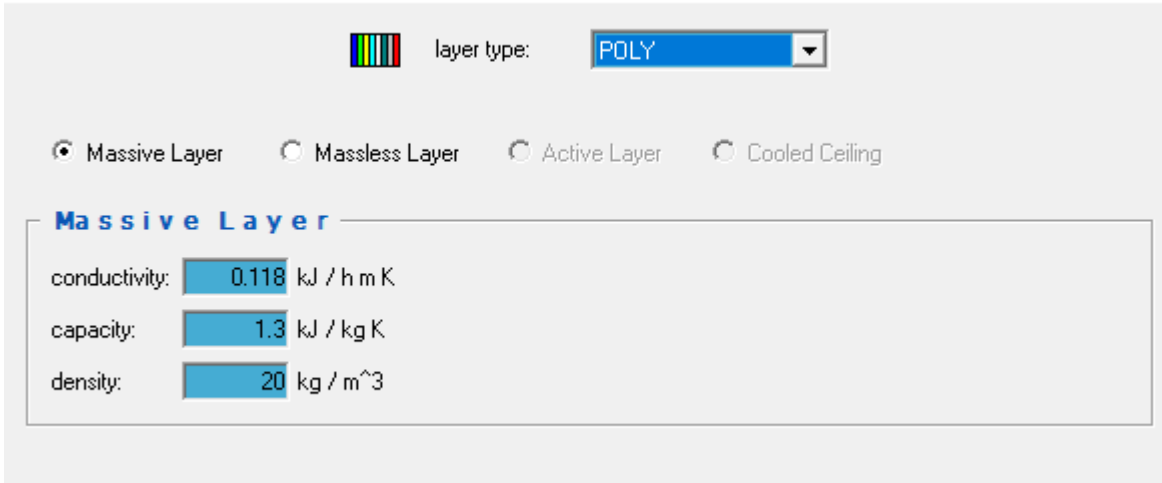


Figure II.8: The new wall type window

If the user selects a new layer, a new layer definition window opens (see Figure II.9). The user can now enter the material properties corresponding to the layer.

#### Layer Type Manager



layer type: POLY

Massive Layer
  Massless Layer
  Active Layer
  Cooled Ceiling

**Massive Layer**

conductivity: 0.118 kJ / h m K

capacity: 1.3 kJ / kg K

density: 20 kg / m<sup>3</sup>

Figure II.9: The new layer window.

The following table II.2 represents the characteristics listed in the figure II.9

Table II.2: Material properties.

Material	Conductivity $\lambda$ [kJ/(h·m·K)]	Density $\rho$ [kg/m <sup>3</sup> ]	Capacity $c_p$ [kJ/(kg·K)]
Sol	1.044	1600	0.83
Air	0.09432	1.225	1.006
Pvc	0.576	1380	0.9
Polystyrène	0.118	20	1.3

### VII.3. Third step:

The coupling of the source elements is shown in the figure below

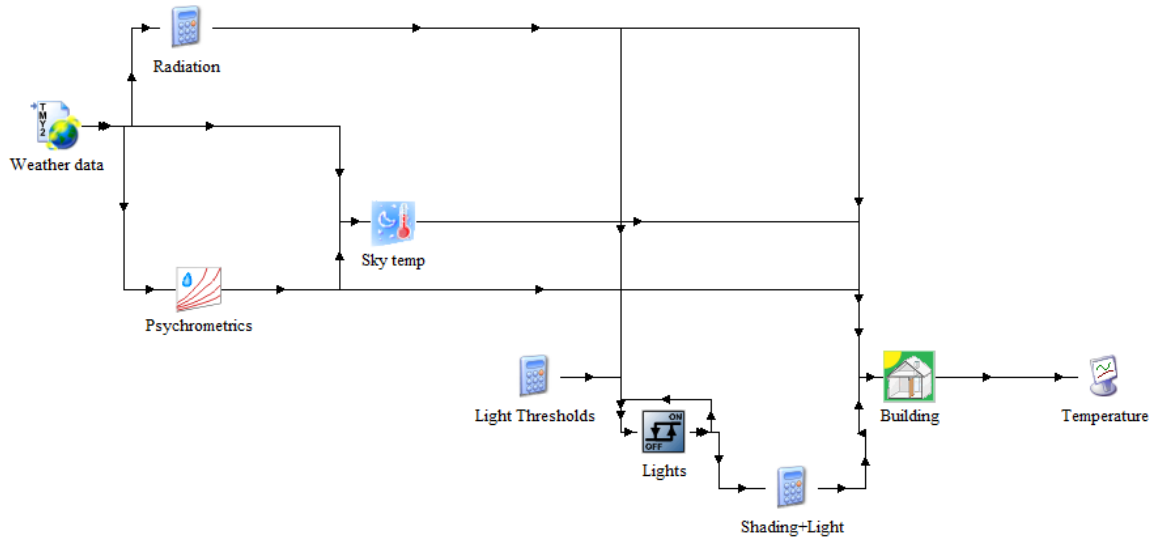


Figure II.10: Planned trnsys building.

**VII.4. Last step:**

The main objective of this step is to read the simulation results using type 65d and export them to an Excel file format using type 25a:

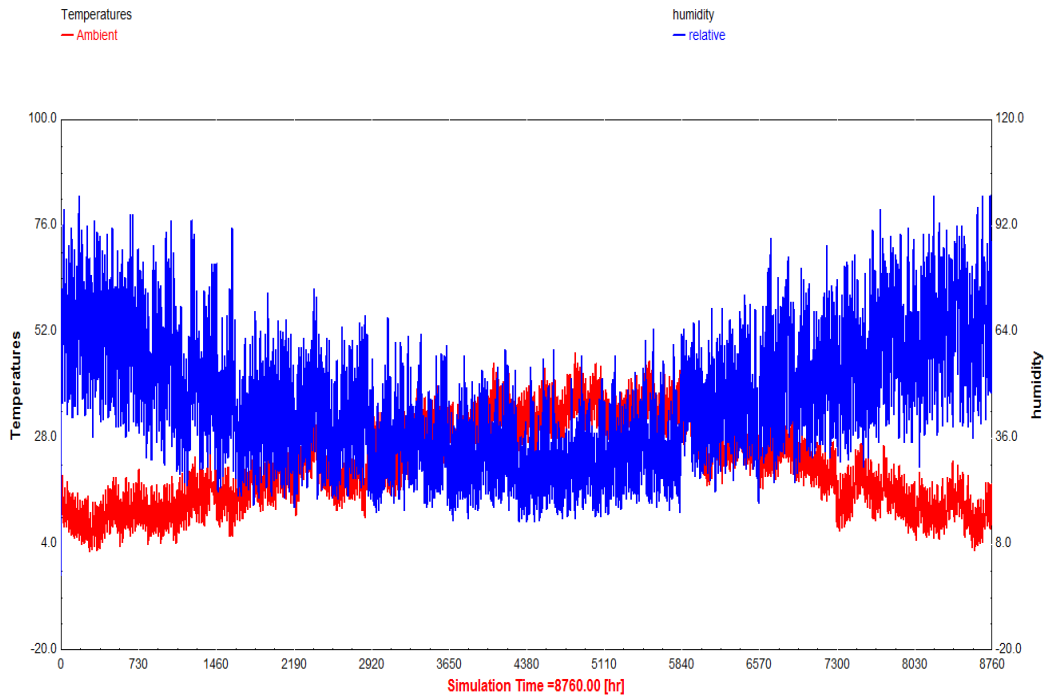


Figure II.11: Temperature ambient and humidity relative for El-Oued region

## VIII. Simulation tools

Gear for simulating the energy behavior of homes has been developed around the sector. 398 tools associated with the evaluation of strength performance, renewable energies, or the sustainable improvements of homes were diagnosed by the branch of the united states of strength in 2010. A list of thermal conduct simulation software among, the most used, at the international stage is presented in table II.3.

The combination of power simulation tools into the layout method has numerous advantages, however also consider barriers and challenges such as the absence of a default fee, the variant within the degree of precision, the complexity of the equipment, and the inter - polarity among applications for facts entry and switch.

*Table II.3: Application of the software simulation [33].*

Software	Commercial use	Characteristics
TRNSYS	Transient simulation tool for ground temperature simulation.	It predicts the thermal performance of the air-to-ground heat exchanger system.
FLUENT	It is one of the examples of software used for the CFD simulation of EAHE.	The heat transfer model of an EAHE system was simulated by considering a three-dimensional transient turbulent flow.

## IX. Energy gain assessment brought by the exchanger

The energy benefit introduced via the exchanger (EAHE) relies upon on several parameters: mass go with the flow fee of air blowing, temperature distinction enter/outlet, and calorific ability of air. These parameters being defined allowthe calculation of the gain strength inside the shape [34].

$$Q_c(EAHE) = \dot{m}_{air} \cdot c_{p_{air}} \cdot (T_{in} - T_{out}) = 1/R_{total} \cdot (T_{in} - T_{out}) \quad (8)$$

Based on the outcomes obtained and the refreshing length considered (august 2020), the energy furnished with the aid of the percent is the same as 900 kwh.

The total thermal resistance among the fluid and the undisturbed soil is written:

$$R_{total} = R_{conv} + R_{tube} + R_{sol} \quad (9)$$

### IX.1. Thermal resistances

Are given by the following equations

$$R_{conv} = 1/2 \cdot \pi \cdot r_2 \cdot h_{conv} \quad (10)$$

$$R_{tube} = \ln(r_1/r_2)/2\pi\lambda_{tube} \quad (11)$$

$$R_{sol} = \ln(r'_1 / r'_2)/2\pi\lambda_{sol} \quad (12)$$

### IX.2. Air temperature at the exit of the exchanger

Looking at the energy needed to copy the air temperature is the same as that exchanged with the Earth. Its thermal rating is written in the following figure

$$T_{s.air} = T_{sol} + ((T_{in.air} - T_{sol}) \cdot \exp\left(-\frac{L}{\dot{m}_{air} C_{p.air} R_{total}}\right)) \quad (13)$$

### IX.3. Definition of the heat exchanger efficiency

The efficiency of the air-ground exchanger is defined as being the ratio between the difference in the temperature of the air (entering-leaving) and the difference in temperature of the ground and that of the entering air given by the next expression [35]:

$$\varepsilon = (T_{out} - T_{in})/(T_{out} - T_{sol}) \quad (14)$$

## Chapter III

# Results and discussion

## I ANSYS Simulation Building

Ansys software was used to simulate the dynamic heat inside the building and it allows to correctly determine the effect of the geothermal converter for pumping air and allows to enter the boundary conditions of temperature, indoor air flow and other conditions necessary to conduct the simulation, the purpose of this is to simulate the dynamic heat and indoor air leakage when Integration of the internal system with the geothermal heat exchanger.

Based on these principles we have the problem of the temperature of the walls and the interior medium and the temperature of the air force into the building, the boundary conditions are given in Table III.1, and the heat distribution in the building is studied using the Ansys program.

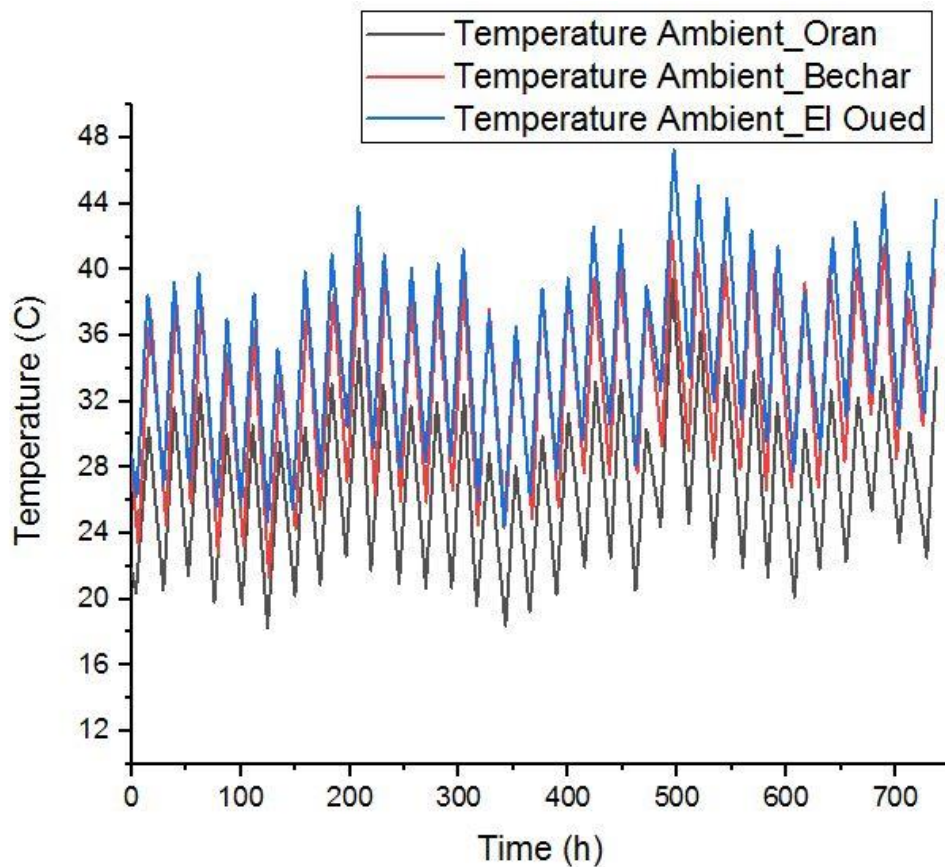
Table III.1: Boundary conditions.

wall	Temperature[°C]	Heat convection coefficient [w/(m <sup>2</sup> .k)]	Outflow[m <sup>3</sup> /s]
walls	42	0.033	/
floor	42	0.20	/
ceiling	45	0.033	/
blowing	24	/	38.36317

## II Validation of simulations

### II.1 Ambient temperatures

The plots of ambient temperature evolution in the Oran, El Oued, and Bechar region in the month of August are depicted in figure III.1.



*Figure III.1: Ambient temperatures in the regions of El-Oued, Oran, and Beshar, in the month of August.*

It is observed that, the temperatures fluctuate with varying values in different regions, and the El Oued region occupied the highest values, and followed by the Bechar region and finally the Oran region with the lowest temperature.

## **II.2 Humidity relative**

The below plots present the evolution of the relative humidity in the regions of Oran, El Oued and Bechar in the month of August.

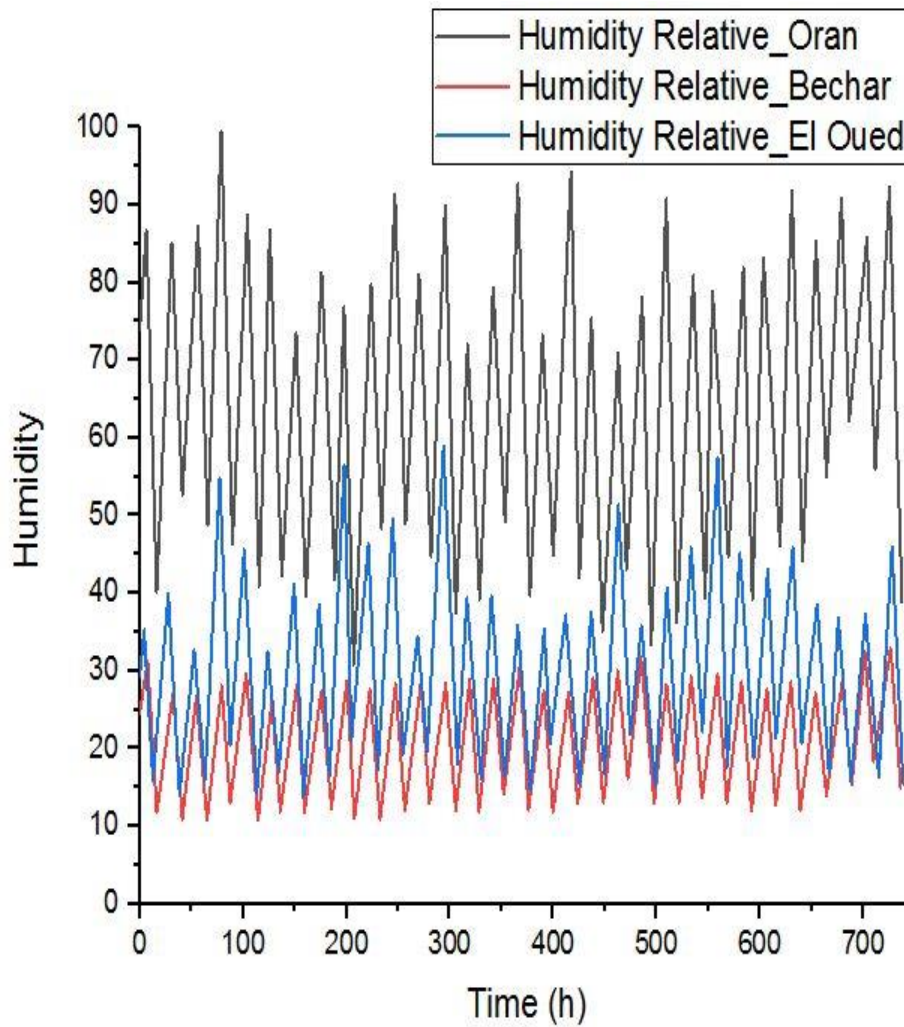


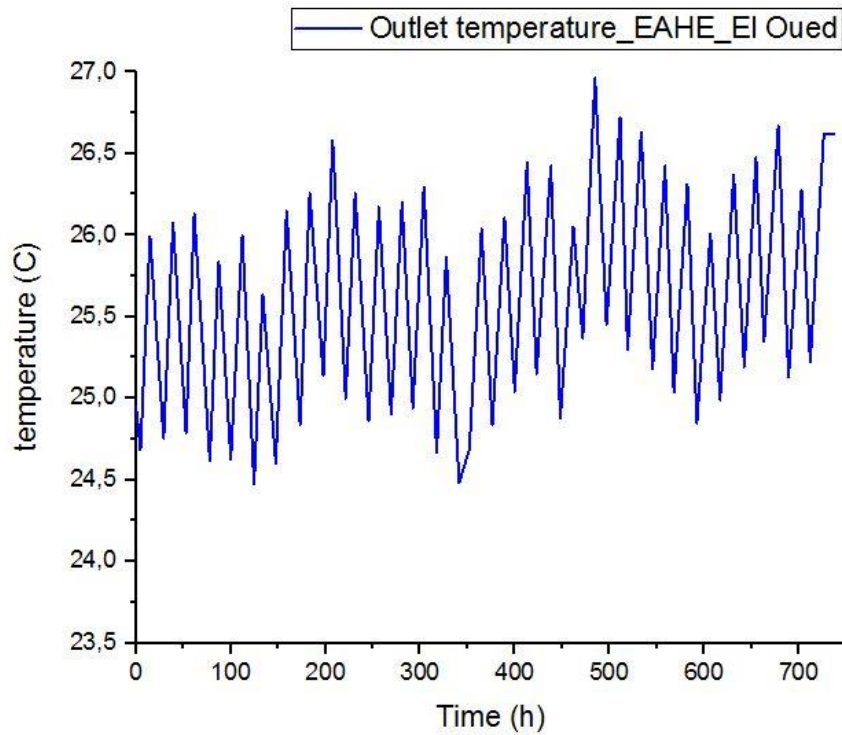
Figure III.2: humidity relative in the El-Oued, Oran, and Bechar July 2020.

It can be seen that, humidity fluctuates with varying values in different regions, and the Oran region occupied the highest values and followed by the valley and finally the Beshar region with the lowest humidity.

Tables III.2: Heat exchanger properties values

<b>Rtotal</b>	<b>Lm</b>	<b>Vair</b>	<b>Tsol</b>
<b>0.3881</b>	<b>42</b>	<b>20</b>	<b>24.5</b>

The below plot presents the temperature changes emanating from the heat exchanger in terms of hours in the month of August 2020 in El-oued region.

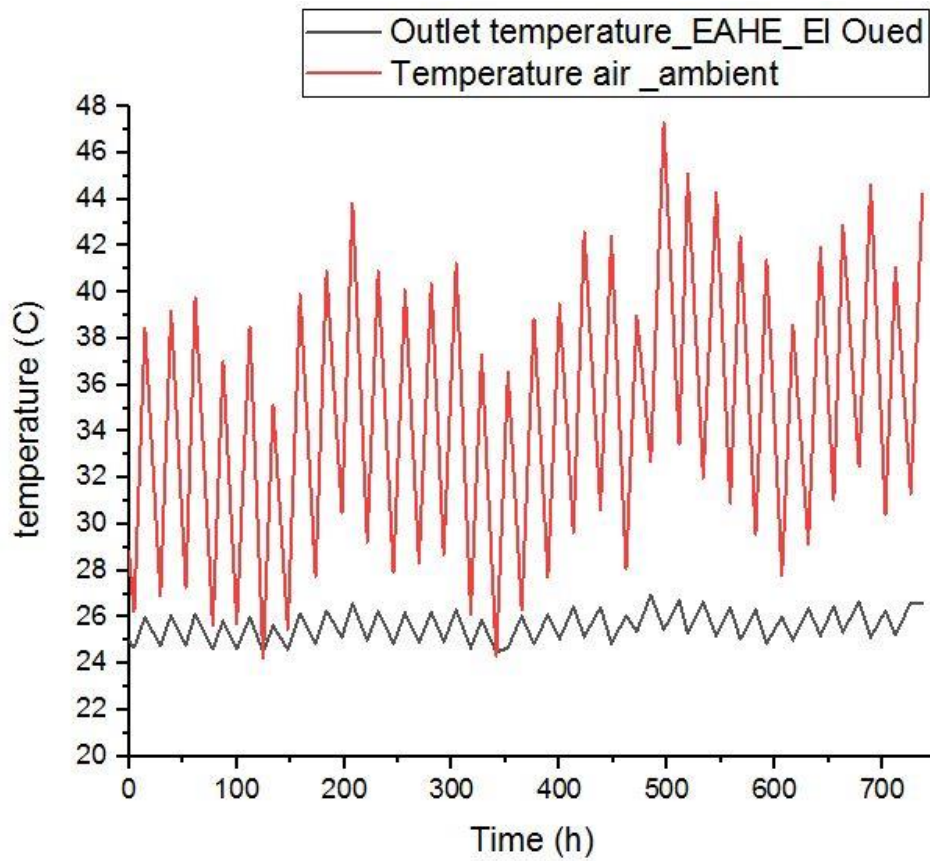


*Figure III.3: Air temperature changes at the exchanger outlet during August.*

It is noticed that, the temperature fluctuates over the hours due to the difference in the temperature of the external medium.

### **II.3 Evolution of the air temperature**

The below figure presents the changes in the air temperature surrounding and leaving the heat exchanger in the month of August.

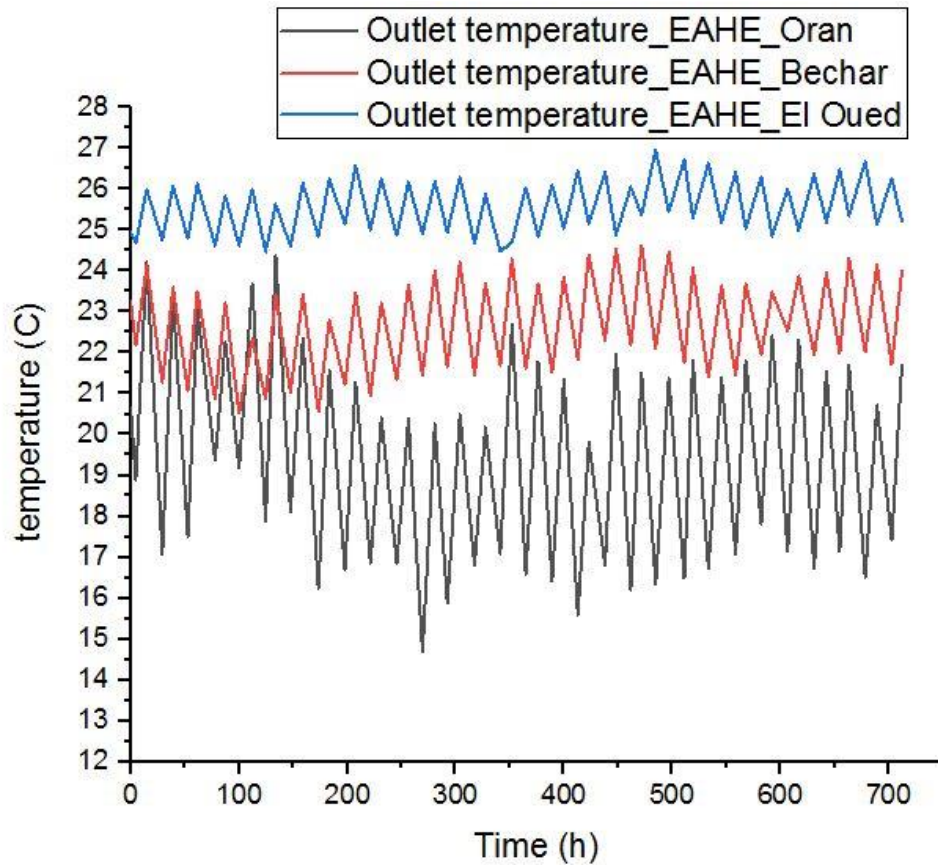


*Figure III.4: The evolution of the air temperature at the outlet of the exchanger in the month of August 2020.*

It can be seen that, the ambient air temperature ranges between 24 and 47 °C. The air temperature leaving the heat exchanger ranges between 24 to 26.5 °C.

#### **II.4 Outlet air temperature of the exchanger**

The following plots present the temperature changes leaving the heat exchanger in terms of hours in the month of August 2020 in Oran, Bechar and El Oued.

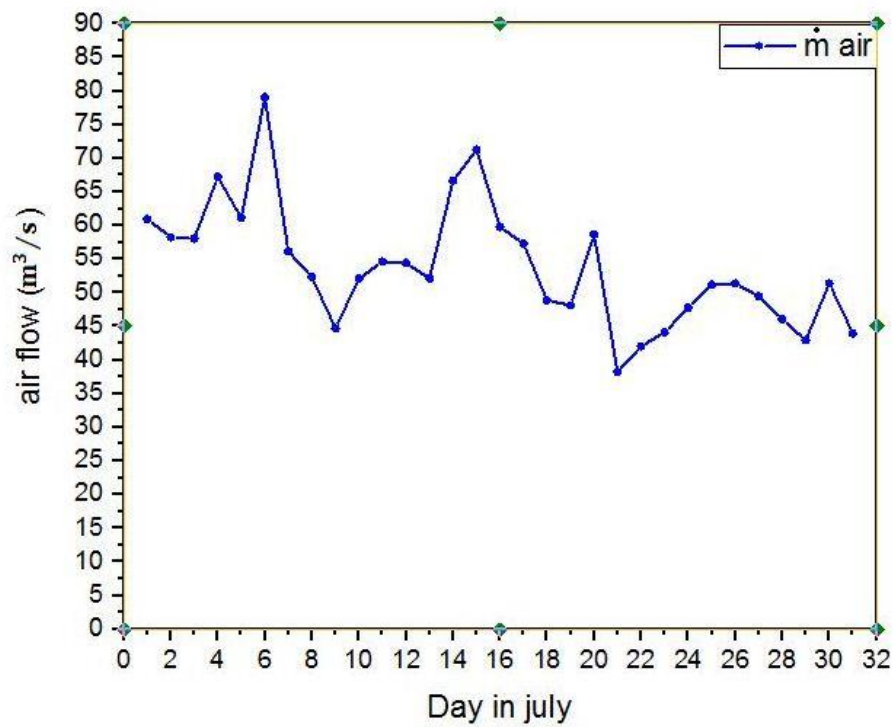


*Figure III.5: Simulation of outlet air temperature of the exchanger.*

It is noticed that, the dissipation in all the curves and each region has its own heat field. Where it is observed that, the Oran region, the temperature leaving the exchanger is confined between 14.5 to 24.5°C, while the Bechar region is confined between 20.5 to 24.5°C and the El-Oued region is confined between 24 to 26.5°C.

## **II.5 Indoor air flow**

The below plot presents a change in air flow in terms of days in July 2020.



*Figure III.6: Indoor air flow changes during July month.*

It is noticed that, the curve is tapered across the days as the highest value was 78.94 on the sixth day; the lowest value was 38.36 on the twenty-first day.

## **II.6 Heat exchanger efficiency**

The below plot presents a change in the efficiency of the heat exchanger in terms of days in July 2020.

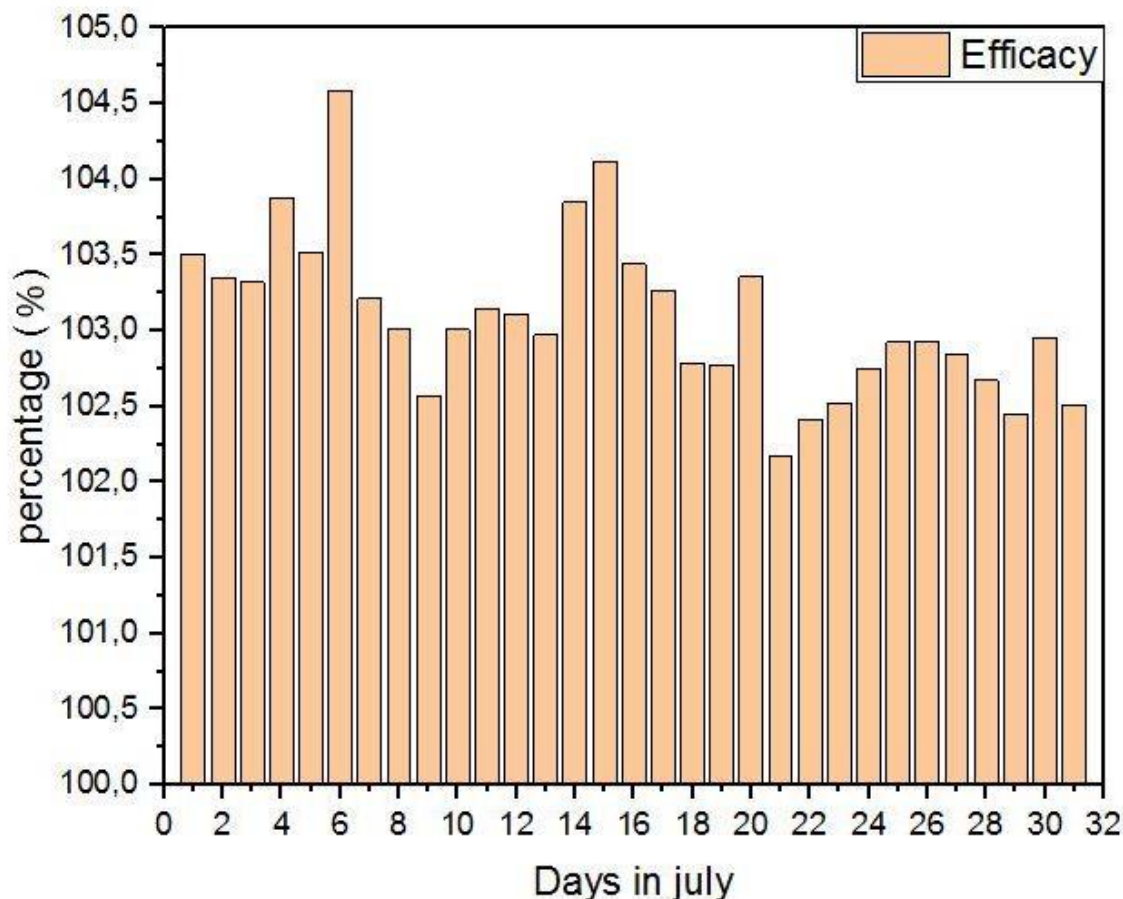


Figure III.7: Heat exchanger efficiency changes during July.

It is noticed that, the fluctuation in the efficiency of the exchanger is due to the change in the temperature.

### III Ambient temperature and relative humidity in the El-Oued:

The Figure III.8 presents the changes in the average temperature and relative humidity in terms of hours in July 2020 in El Oued. It is noted that the ambient temperature fluctuated with the passage of hours, as the lowest temperature was 25 and the highest was 47. We also note that relative humidity also fluctuates. The lowest percentage is equal to 13, and the highest percentage is equal to 58.

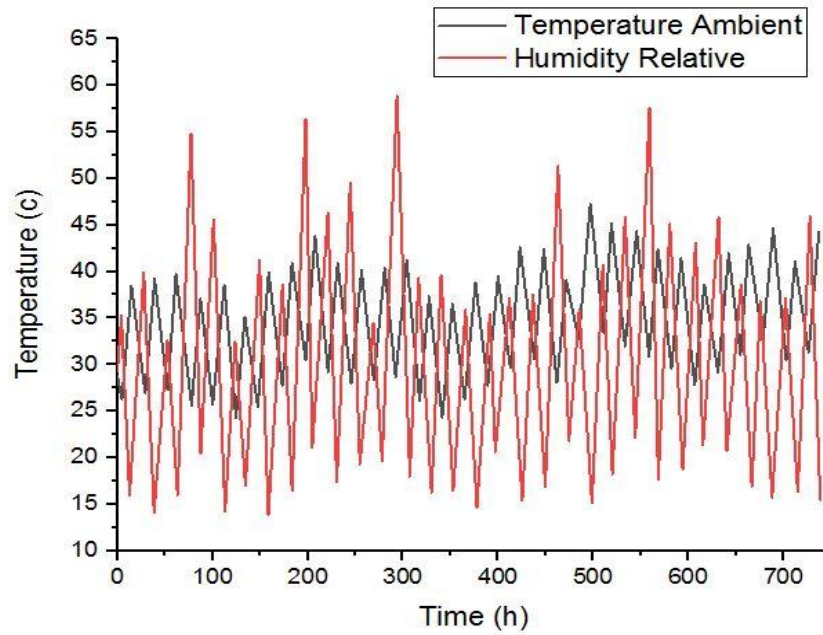


Figure III.8: Evolution of ambient temperature and relative humidity for the month of July.

#### IV Cooling and heating

Figure III.9 represents the results of the energy consumption of a building over a full year for heating and cooling in Raguiba El Oued.

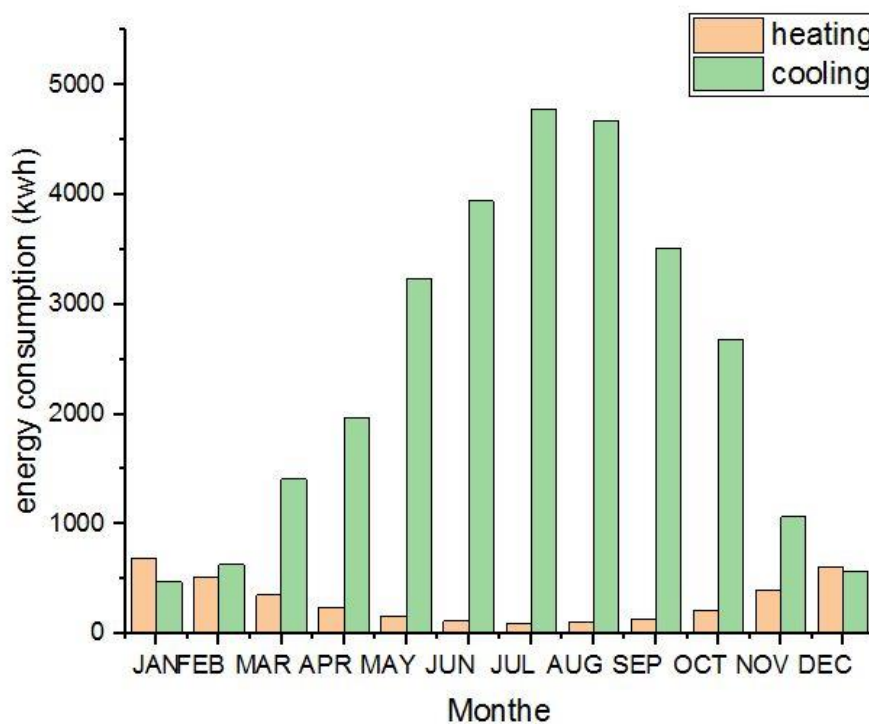


Figure III.9 :Cooling and heating needs for a building for a year.

It is observed that, the demand for cooling is very large compared to heating in July and August. We also note that heating demand is large compared to cooling in December and January

## V Coupling TRNSYS–FLUENT

Figure III.10 shows the change of air blowing location and two programs are taken into consideration (a) blowing air from the top and (b) blowing air from the bottom

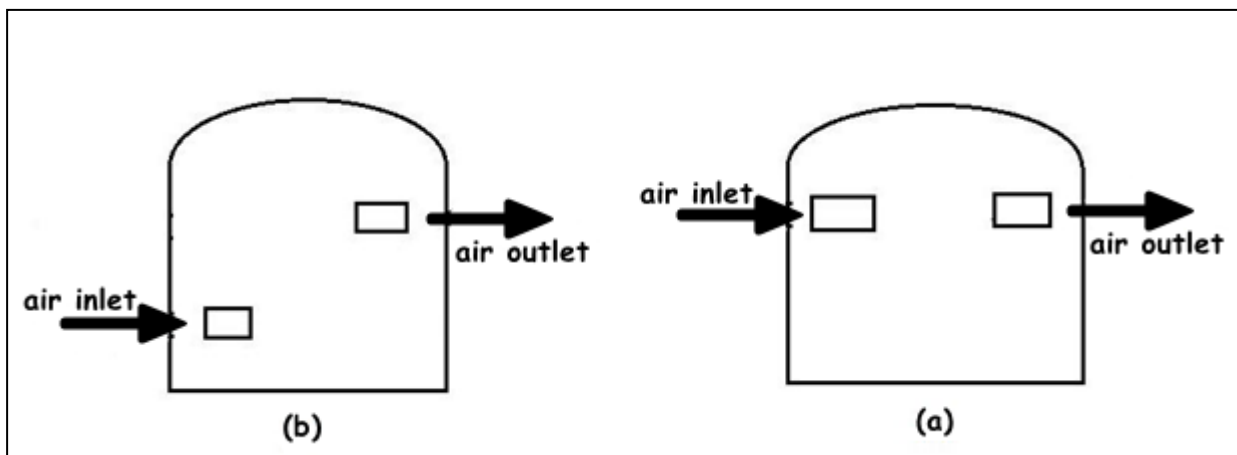


Figure III.10: Air blowing location: (a) blowing air from above and (b) blowing air from below.

In Figure III.10, air is blowing from above. (a) Temperature 24 is located in the working area. The indoor air temperature drops near the cooling floor system and moves from the top to move to other areas.

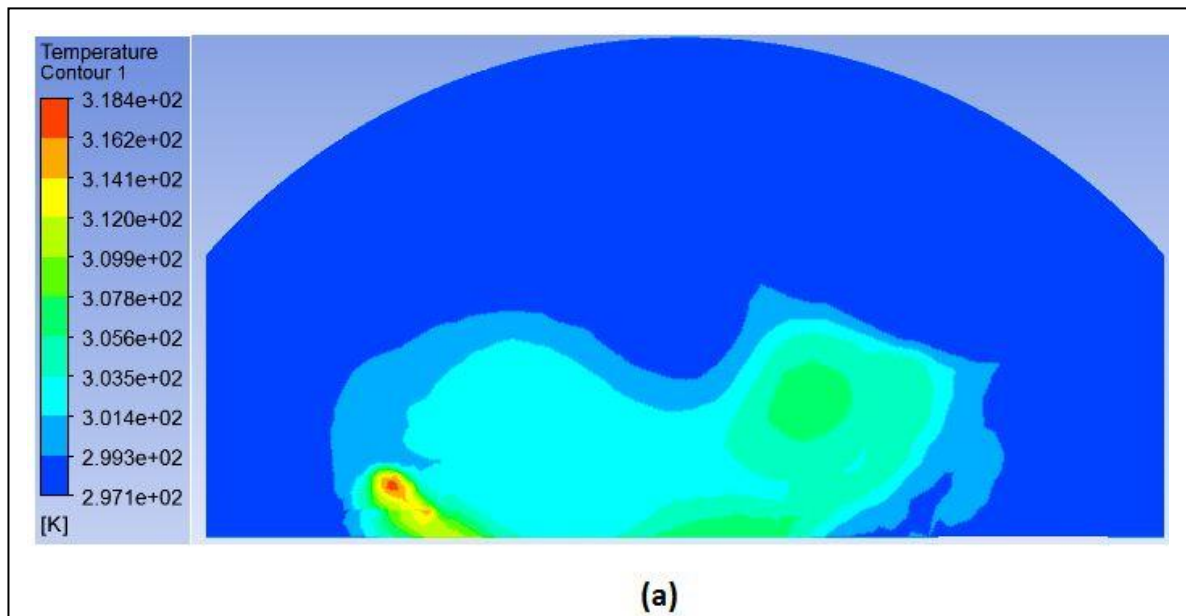


Figure III.11: blowing air from above.

In Figure III.11, air is blowing from below. (b) Temperature 24 falls in the working area. The indoor air temperature drops near the cooling floor system and moves from below to move to other areas

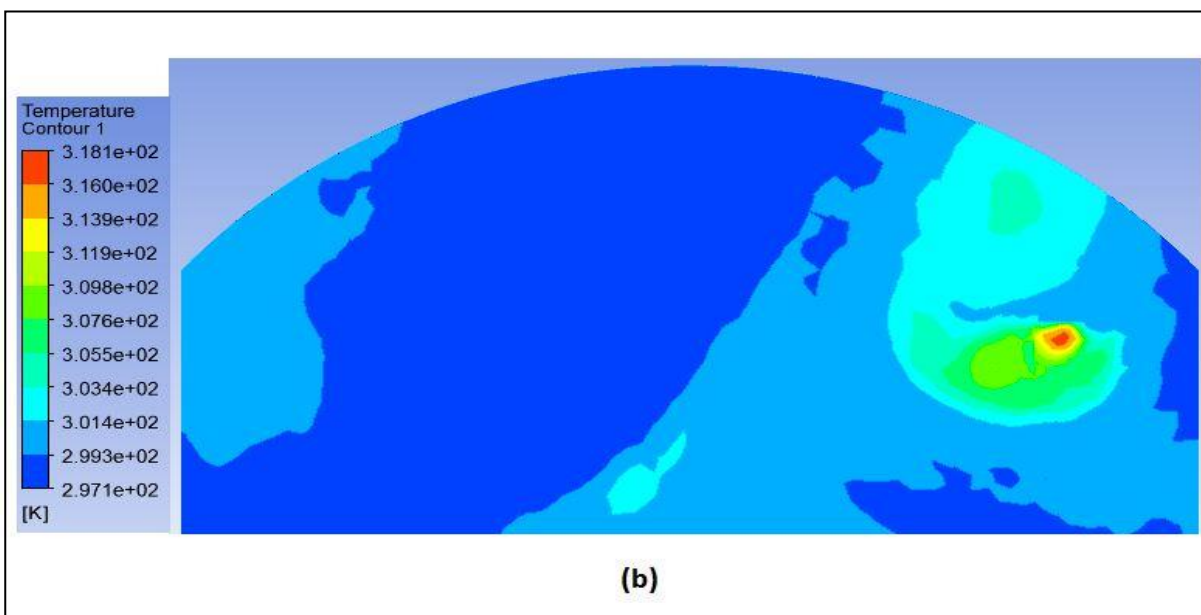


Figure III.12: blowing air from below.

Figure III.12 shows that blowing air from the bottom (b) gave a better result than blowing air from the top (A). This continuous flow of fresh air produces the best thermal comfort from the top blowing port (A).

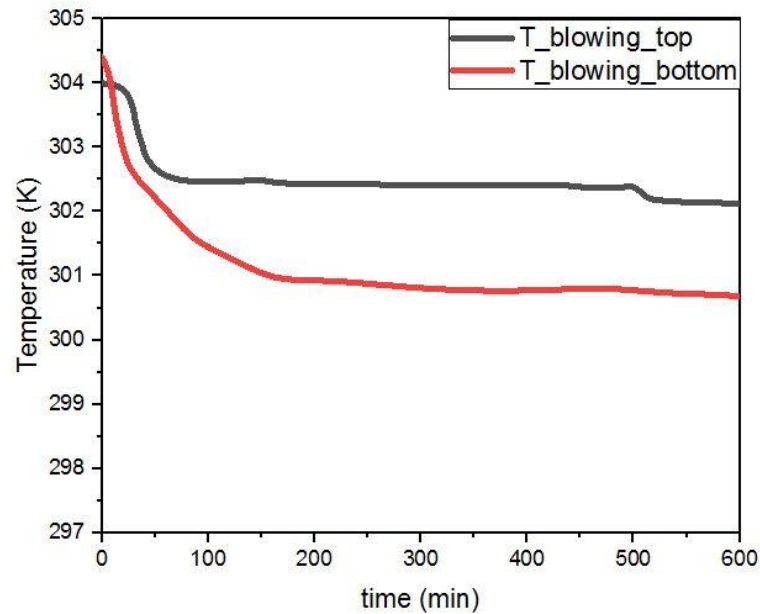


Figure III.13: Internal temperature changes over time.

Both plots illustrate the change in internal temperature in terms of time (minutes) by blowing air once at the top and again at the bottom. It can be seen that, both curves gradually decreased in the first minutes, and then both curves were fixed with a difference in both. Whereas, blowing air from below had a lower temperature than blowing air from above.

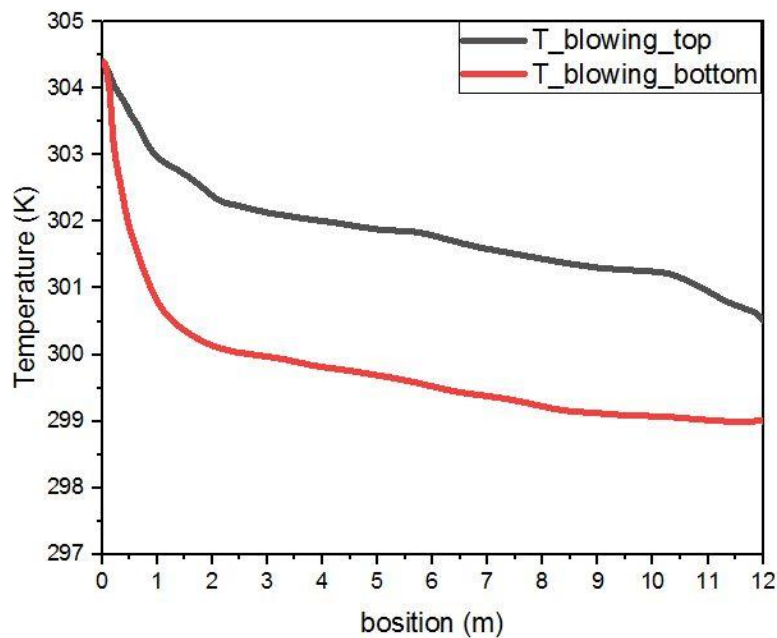


Figure III.14: The evolution of indoor air temperature throughout the building.

Both plots indicate the change in internal temperature in terms of position (meters) by blowing air once at the top and again at the bottom. It is noticed that, both curves gradually decrease to the last position with a difference in both. Whereas, blowing air from below had a lower temperature than blowing air from above.

## **GENERAL CONCLUSION**

In this work the energy performance of geothermal systems embedded in buildings is conducted. We have studied the thermal behavior of the buried earth-air exchanger. This type of exchanger provides reduced ventilation in the building.

In the present study we showed that the ground to air heat exchanger is an essential factor for heating and cooling building. Good agreement was obtained by comparing the experimental results with those obtained by simulation. Previous studies made it possible to improve the engineering properties of the geothermal-air heat exchanger as a key factor in the climate effect in buildings and to compare the energy performance of three climatic locations (Oran, Bechar and El Oued). It has been proven that the feasibility of this geothermal system is more attractive in terms of increasing energy in El Oued , Bechar than in Oran.

We have shown that the ventilation of the room by blowing air from the surrounding bottom inside the room allows a significant reduction in the temperature of the indoor air in the summer period

The use of geothermal energy by simple and inexpensive devices can be a solution for cooling and heating indoor building environments. This can reduce the energy bill and thus contribute to reducing greenhouse gas emissions.

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## Summary

This thesis presents a feasibility and performance study of vertical ground heat exchanger used for cooling and heating of Rabbit breeding center under the meteorological conditions of Saharan environment in El Oued, city located in Southeast of Algeria. A dynamic simulation system is developed using TRNSYS software for modeling and estimate the demand cooling and heating of Rabbit breeding center. The obtained results depicted that the exploitation of geothermal energy is very attractive option for this kind of application.

**Key words:** Geothermal energy, Building, Heating, Cooling, Ventilation, Trnsys, Heat Exchanger

## Résumé

Cette thèse présente une étude de faisabilité et de performance d'un échangeur géothermique vertical utilisé pour le refroidissement et le chauffage d'un centre d'élevage de lapins dans les conditions météorologiques d'environnement saharien à El Oued, ville située au Sud-Est de l'Algérie. Un système de simulation dynamique est développé à l'aide du logiciel TRNSYS pour modéliser et estimer la demande de refroidissement et de chauffage du centre d'élevage de lapins. Les résultats obtenus montrent que l'exploitation de l'énergie géothermique est une option très intéressante pour ce type d'application.

**Mots clé :** énergie géothermique, bâtiment, Chauffage, refroidissement, ventilation, Trnsys, échangeur de chaleur

## الملخص

تقدم هذه الرسالة دراسة جدوى وأداء لمبادل حراري أرضي عمودي يستخدم لتبريد وتدفئة مركز تربية الأرانب تحت ظروف الأرصاد الجوية للبيئة الصحراوية في مدينة الواد الواقعة جنوب شرق الجزائر. تم تطوير نظام محاكاة ديناميكي باستخدام برنامج TRNSYS للنمذجة وتقدير الطلب على التبريد والتدفئة لمركز تربية الأرانب. أظهرت النتائج التي تم الحصول عليها أن استغلال الطاقة الحرارية الأرضية هو خيار جذاب للغاية لهذا النوع من التطبيقات.

**الكلمات المفتاحية :** الطاقة الحرارية الأرضية ، المبنى ، تدفئة والتبريد ، التهوية ، ترانسيس ، مبادل حراري