



ENVIRONMENTAL ECONOMIC DESIGN OF MEDIUM CLASS HOUSING BUILDING MODELS



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ABSTRACT

This research addresses measuring the amount of produced solar energy in residential buildings and integrating and complementing them with the most appropriate design for the outer covering of housing units, and What is the amount of energy consumed and the amount of savings and rationalization required monthly and annually, So The solar thermal cooling system has been designed with absorption technique to cover the thermal loads inside the housing unit with a south-west orientation on the roof floor as the most housing unit exposed to external and internal thermal loads. Therefore, it is the most appropriate to check and test the efficiency of the performance of the absorptive solar cooling system. The highest temperature day in the summer season was chosen to read simulation results according to the climate inputs of the weather data for the city of Cairo under study with the use of the TRNSYS - simulation program. An equivalent of 83% of the monthly consumption of electricity was provided, and then an economic evaluation study was conducted for the solar thermal cooling system using the Payback Method. A system recovery period was recorded about (1.5) years and five months, and then a set of academic recommendations were reached that call for more research studies in the field of energy and sustainable environmental design.

Contribution/ Originality: This study is one of the very few studies that investigated the desire to participate in general, to achieve efficiency in renewable solar energy generation and reduce carbon emissions within medium housing units using the TRNSYS simulation program.

1. INTRODUCTION

The depletion of traditional energy sources, on which most buildings, especially residential buildings depend and results in carbon dioxide emissions that cause global warming and the rise in the earth's temperature, which leads to climate variability, and environmental pollution. Since energy is the first engine and the mainstay for achieving sustainable development in all its economic, social and environmental aspects. The environmental aspect remains the cornerstone of the sustainable development process. Therefore, the imperative must be directed towards the inexhaustible renewable energies which can secure twice the current rate of energy consumption in the world if it is properly utilized. The indicators confirm that electricity consumption in Egypt is increasing significantly, especially the housing sector, as it represents 45% of the total electricity consumption of traditional energy sources, in accordance with statistics of the Ministry of Electricity and Energy in 2019 [1] and The

research gap is that this scientific project has not been previously applied in Egypt or other countries, which makes this project very special and a great opportunity to save energy by applying it in the future.

2. RESEARCH PROBLEM

The usual outer covering of the housing unit alone is not sufficient to achieve the required thermal comfort within the housing space. Accordingly, research was done and other means were found using renewable energies that provide the required thermal field, and also in light of the presence of an appropriate environmental design for the outer cover through an appropriate economic perspective.

3. PURPOSE

Achievement of thermal comfort in the residential space by activating the solar thermal cooling systems.

4. EMPIRICAL STRATEGY

First: Determination of the applied sample and study area.

Second: Design of the outer covering that is best suited for the housing unit to save energy.

Third: The integration of the solar thermal cooling system in the housing unit with the most appropriate outer covering.

Fourth: The economic evaluation of the solar thermal cooling system.

The elements of the previous research methodology are discussed in detail as follows.

First: Determining the applied sample and study area:

APPLIED STUDY SAMPLE (MEDIUM HOUSING PROJECT (NEW CAIRO)):

4.1. Characterization of the Applied Study Sample:

Among the projects of the Ministry of Housing, Utilities and Urban Communities - New Urban Communities Authority and Mediterranean Housing Project in New Cairo City for middle-income with areas ranging from 100 to 116 m². The project includes 132 housing buildings consisting of four floors by 16 residential units in the building with a total of 2112 residential units, which is a number of typical housing models inside an integrated services community.

4.2. Applied Study Sample Site:

Mediterranean Housing Project (Egypt Housing) in New Cairo City, the application of the study was selected on the city of New Cairo as in [Figure 1](#) this is because the TRNSYS simulation program supports climate input and its own weather data.



Figure-1. The applied study sample illustrates: Mediterranean Housing Project (Egypt Housing) in New Cairo City.

4.3. Models of Residential Units in the Applied Study Sample

The project consists of two typical housing models, Figure 2 illustrates the typical model chosen for the analytical study, it consists of typical residential unit with four units per floor and the height of the housing building from the ground floor and three floors repeated [2].



Figure-2. The typical model chosen for the analytical study.

4.4. Building the Model in the Program (TRNSYS)

The model has four residential units per floor as in Figure 3 the analytical study was conducted on the residential unit (3) with guidance: southern simulation as the most residential unit exposed to external and internal thermal loads.

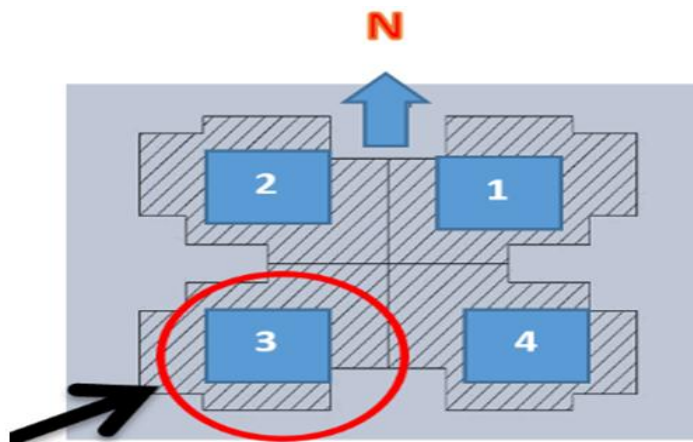


Figure-3. Selection of Southwest Unit No. (3) on roof for the research study.

4.5. Analytical Study Hypotheses (Simulation)

A fixed set of hypotheses inserted on the program's natural simulations throughout the duration of the experiment, it is as follows:

- Specifying the period of time applied to the simulation is four months i.e. summer season (June-September). June 19 was selected to read the results of the simulation because it was recorded the highest temperature in the summer season of the Cairo “Applied study place”.
- Thermal comfort at a temperature of 24 degrees Celsius.
- There are no internal devices working other than the typical devices for each housing.
- Working to achieve thermal comfort by cooling only (during the summer season).
- The work of the space for 24 hours a day (assuming the existence of users of the space throughout the day).

- Air conditioning works for the reception and bedrooms only and there is no air conditioning works in the bathroom, kitchen and the main staircase of the housing building.
- Occupancy rate according to the average number of family members (5 members per each family).
- Climate data used for Cairo, provided by TRNSYS program.
- The thermal properties of the materials used determined according to the Egyptian code of thermal insulation items specifications.

Second: Designing the outer envelope that is best suited for the housing unit (South-West) in energy saving:

Determination of the variables and alternatives to the outer covering of the housing units:

The outer covering of the building with a direct impact on the thermal comfort of the space, and by extension the direct effect on the consumption of electrical energy in a residential unit in the rooftop floor of the research study, is divided into as follows:

- Roof.
- External walls.
- External vents

What is required is the design of the outer covering that is best suitable for the southwestern unit in the roof. First, it is necessary to identify the basic alternative to the outer covering. Second, of the alternatives and variables in the outer covering of the roof floor are mentioned in the following tables as follows:

First: The basic alternative to the outer covering of residential units in the roof floor:

The residential unit was designed according to the basic alternative used by the Urban Communities Authority in the medium housing project as in [Table 1](#).

Second: The alternatives and variables of the outer covering of the southwestern unit in the roof floor.

Table-1. The basic alternatives to the outer covering of the housing unit in the roof floor.

The basic alternative to the southwestern unit is the roof floor	
The basic alternative to the roof	Reinforced concrete ceiling 20 cm / moisture insulation / sand and mortar 8 cm / tiles 2 cm
The basic alternative to walls	External walls, 12 cm thick, of clay brick
The basic alternative to vents	Aluminum and clear glass, 6mm.

Table-2. Alternatives to the variables of the elements of the outer covering for residential units in the roof floor.

Alternative number and code	Description
Alternatives to the outer covering of the housing unit (south-west) in the roof floor:	
First: Ceiling alternatives:	
Alternative (2) / Ceiling	Basic Alternative + 3cm polystyrene insulation.
Alternative (3) / Ceiling	Basic Alternative + 5cm polystyrene insulation.
Second: Alternatives to external walls:	
Alternative (2) / wall	External walls, 25 cm thick, of clay brick
Alternative (3) / wall	External walls, 25 cm thick, of solid cement bricks
Alternative (4) / wall	External walls, 12 cm thick, of solid cement bricks
Alternative (5) / wall	Double outer walls, 12 cm thickness, Red Perforated Brick, 5 cm air vacuum
Alternative (6) / wall	Double outer walls, 12 cm thickness, brick, Red Perforated Brick, with thermal insulation, 5 cm, polystyrene.
Third: The alternatives to the external vents:	
Alternative (2) / vent	Vents of wooden blinds outside and inside 6 mm clear glass windows
Alternative (3) / vent	External windows of Aluminum and Single Blue glass - 6mm
Alternative (4) / vent	External windows of Aluminum and Single Reflected glass - 6mm
Alternative (5) / vent	External windows of Aluminum and 6mm Glass (Low-E)

The alternatives for each of the previous elements were determined according to the basic alternative, for which the housing unit was designed, in addition to the alternatives of the element according to what is commonly used in Cairo and within the limits of available technology and economic. The effect of each variable has been

studied with the stability of the rest of the variables according to the basic alternative. Table 2 shows alternatives to the outer covering of the residential unit (south-west) in the roof floor.

Energy consumption results for the basic alternative of the outer covering of the unit (South-West) in the roof floor.

Figure 4 shows the energy consumption of the basic alternative to the housing unit (the roof floor on June 19:

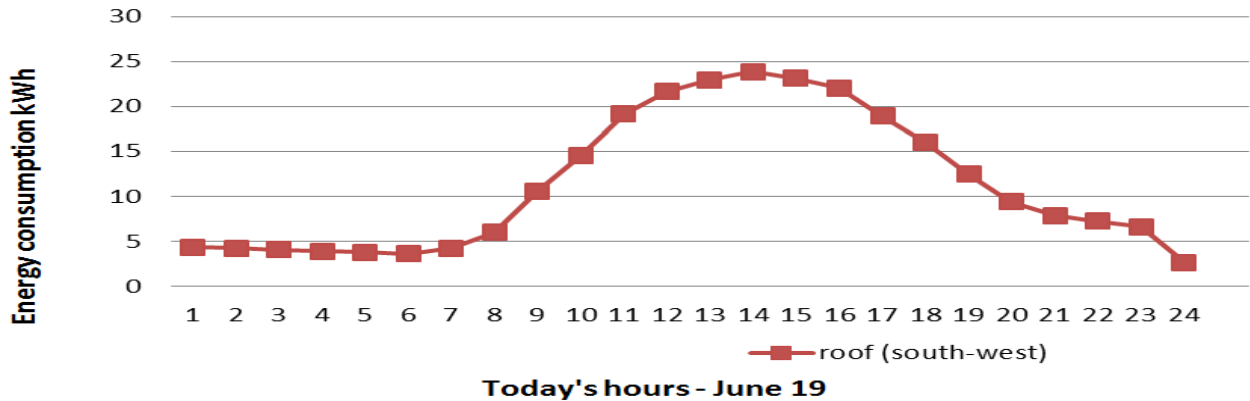


Figure-4. Results of energy consumption (heat load) in kilowatt / hour for the basic alternative to the residential unit (south-west) in the roof floor: in June 19.

5. RESULTS

The outer covering of residential units on the roof floor is more exposed to solar radiation than the outer covering of residential units on the identical floor because they are exposed to solar radiation from the ceiling, external walls and external vents, while in identical floor, it is exposed to solar radiation from external walls and external vents only. Thus, the amount of thermal loads in the roof floor exceeds the amount of thermal loads in the identical floor. As a result, residential units on the roof floor need to consume more electrical energy that may reach twice as much as in the identical floor, to cover those thermal loads as the highest daily consumption value was recorded at about 23 Kw / hr for the roof floor on June 19. Results of energy consumption of the alternatives and variables of the unit's outer shell (South-West) in the surface floor:

5.1. Ceilings

Energy consumption of roof alternatives for the unit (south / west) on the roof floor (last floor) on June 19 in Figure 5.

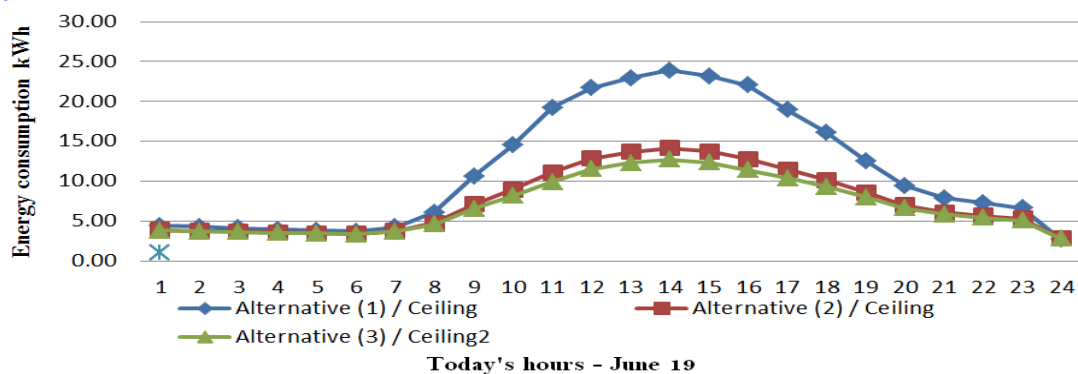


Figure-5. Results of energy consumption in kilowatt / hour for the roof alternatives for the unit (south / west) for the roof floor on June 19.

5.2. Results

- The effect of thermal insulation layers on reducing consumed energy is more apparent than the effect of lack thereof in the basic alternative to the ceiling, where the use of the heat insulation layer reduces consumed

energy significantly, reaching an approximate percentage of 80% of the consumed energy without the use of thermal insulation on the ceiling.

- The variance in the thickness of the thermal insulation layer of polystyrene – thickness: 3 cm to 5 cm on the consumed energy has a limited effect, where the rate of energy consumption in the larger thickness of 5 cm reaches approximately 95% of the consumed energy for a thickness of 3 cm.
- We conclude that the alternative (ceiling / 3) of the roof alternative is the best alternative because it is the least energy consumed in the unit (south / west) for the roof floor.

5.3. External Walls

Energy consumption of alternatives to the unit's external walls (south / west), the roof floor for June 19 in

Figure 6:

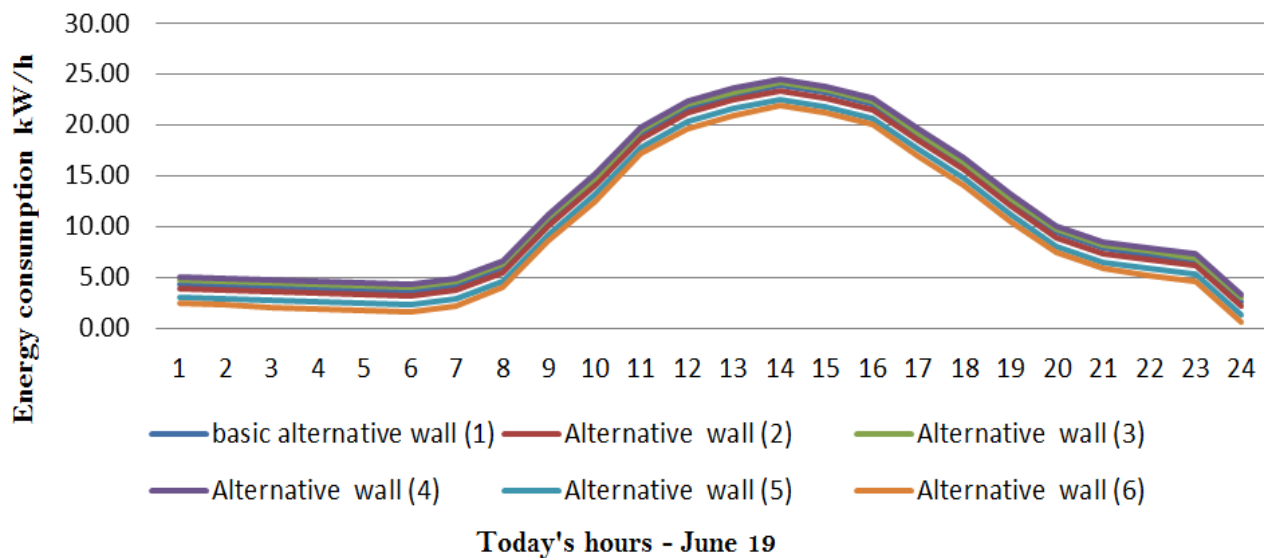


Figure-6. Results of energy consumption in kilowatt / hour for alternatives to the external walls of the unit (south / west) for the roof floor on June 19.

5.4. Results:

- The differences in energy consumption between alternatives to the external walls of the unit (south / west) for the roof floor. This is because the ceiling in the roof floor units is exposed to solar radiation.
- The effect of using double wall insulation - 5 cm on energy consumption is slightly less than the use of double walls with air vacuum 5 cm.
- The use of solid bricks in energy consumption reaches 20% more than the basic alternative, due to the increase in the value of its thermal conductivity.
- We conclude that the alternative (wall / 6) of the alternatives to external walls is the best alternative because it is less energy consumed in the unit (south / west) for the roof floor.

5.5. External Vents

Energy consumption of alternatives to external vents of the unit (south / west) on the roof floor for June 19 in

Figure 7.

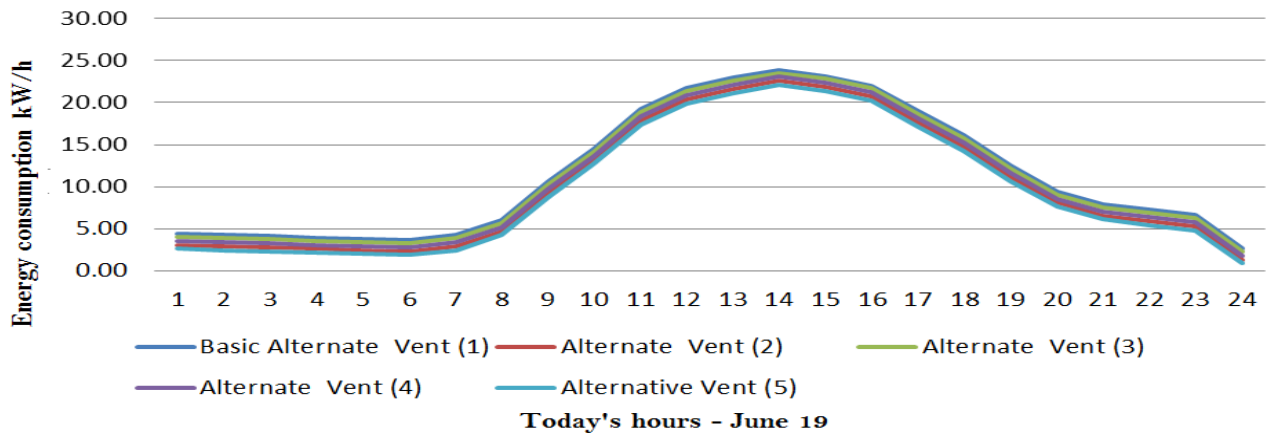


Figure-7. Results of energy consumption in kilowatt / hour for alternatives to the external vents of the unit (south / west) for the roof floor on June 19.

5.6. Results

- The differences in energy consumption also converge between the alternatives of the external vents in the unit (south / west) for the roof floor, because the ceiling in the units of roof floor is exposed to a large amount of solar radiation, while the ceiling in the identical floor is not exposed to the sun.
- The effect of using LOW-E GLASS on energy consumption is at an average rate less than using reflective glass.
- We conclude that the alternative (vent / 5) of the alternatives to the external vents is the best alternative because it is the least energy consumed in the unit (south / west) for the roof floor.

5.7. The Results

Table 3 shows a matrix of alternatives for the elements of the outer covering of the southwest housing unit in the roof floor under study. It shows the total value of consumed energy with calculating the percentage of savings in energy consumed in the housing unit in the basic alternative, where according to the calculations of the energy rationing ratio, it is clear that the best solutions for designing the most suitable outer covering for the southwest residential unit in the roof floor are:

- Alternate ceiling (3), which is (the basic alternative to the ceiling + 5 cm polystyrene insulation).
- Alternate wall (6), which is (double outer walls, 12 cm thickness, clay bricks with a thermal insulation of 5 cm, polystyrene).
- Alternate vent (5), which is (aluminum external windows and (Low-E) glass).

Third: The integration of the solar thermal cooling system with the housing unit with the most appropriate outer envelope.

5.8. Definition of Solar Thermal Cooling Systems

The thermal cooling system runs by heat instead of electricity to operate the compressor in the conventional cooling system, and it is better to install the thermal cooling system when the amount of wasted thermal power is huge especially in hot areas with a large solar amplitude such as Egypt which located at the Sunbelt area, in this case it is better to use the solar power in the cooling and air-conditioning systems at this areas [3].

5.9. Evaluation of Alternatives According to the Total Savings in Consumed Energy Annually

Table-3. Calculations of total energy consumption over the year (kilowatt / hour) (percentage) for savings according to alternatives to the outer cover of the residential unit (south / west) in the roof floor:

Residential Units	Alternatives to the variants of the outer covering of residential units for the roof and the identical floor												
	Basic alternative for the last floor	Roof alternatives		Basic alternative for the identical floor	Alternate wall (2)	Alternate wall (3)	Alternate wall (4)	Alternate wall (5)	Alternate wall (6)	Alternate vent (2)	Alternate vent (3)	Alternate vent (4)	Alternate vent (5)
Roof unit (south – west)	7292.8	4470.7	4131.5		6631.	7730.	8240.	5039.	4011	5083.	6680.	5878.	4280.9
		38.69%	43.34%		9%	-6%	12.9%	30.9%	45%	30.3%			41.3 %

5.10. Types Used In the Solar Thermal Cooling Systems

The solar thermal cooling systems are divided into open system and closed system as follows [4]:-

1- Cooling Systems with Open Cooling Ring:-

- Solid Desiccant System.
- Liquid Desiccant System.

2- Cooling Systems with closed Cooling Ring:-

- Absorption System.
- Adsorption System.

5.11. Reasons for Selecting Absorptive Solar Thermal Cooling System to be applied in the Case Study

Absorption System is selected as the best system of the case study for cooling and air conditioning in the residential buildings, it also one of the most important types used in thermal cooling systems, and it is the most efficient one and the biggest in coefficient of performance ranging from (0.7-0.8) [5].

5.12. Absorption Cooling Unite

Absorption Definition:

Absorption is a process in which two substances are mixed, each in a different physical state. For example, one is gaseous and the other is liquid, when these substances are mixed, we get a mixture (dilute solution).

The substances commonly used in the absorption cooling process (water-lithium bromide) ($H_2O-LiBr$), and water is the absorbed chiller and lithium bromide is the absorber due to lithium bromide absorption glut in liquid state of water vapor in gaseous state [6].

5.13. Absorption Chiller Unite Components

Absorption Chiller Unite consists of four main components, as shown in Figure 8:

- Generator.
- Condenser.
- Evaporator.
- Absorber.

In addition to the other components of Solar Thermal Cooling System as follows [7]:

5.14. Components of Absorption Solar Thermal Cooling System

The actual components required for designing and operating the Absorption Solar Thermal Cooling System:

- Absorption chiller Unite.
- Storage Heater Tank.
- Solar Collector.
- Cooling tower.
- Cooling Coil.
- Heat exchanger Auxiliary.
- Pumps.
- Valve Extension.
- Controller.

When the components are inserted into the simulation, the climate inputs of the area, place of the study:

1. Data Weather

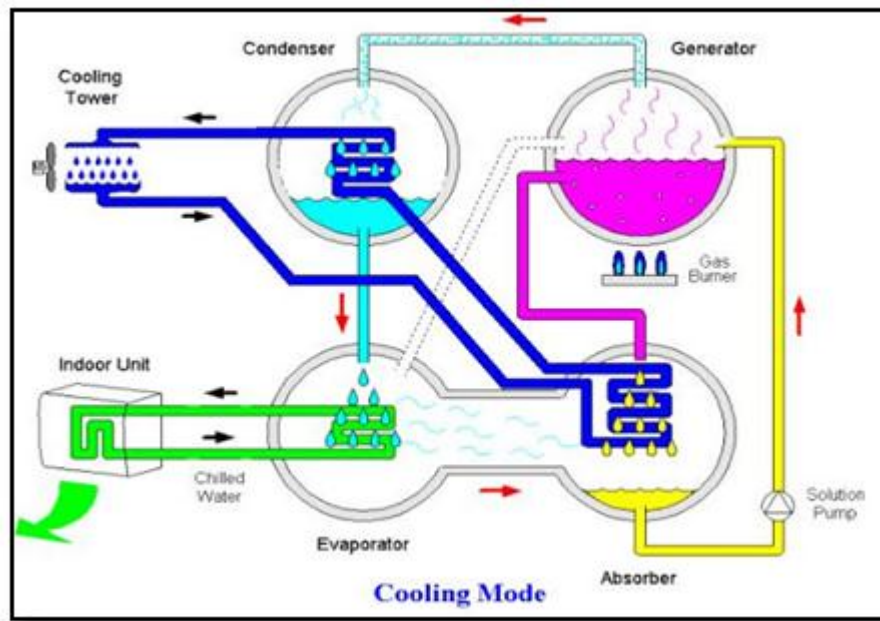


Figure-8. Showing the internal main components of absorption chiller unite.

5.15. Methodology of Absorption Solar Thermal Cooling System [8]:

Working steps:

- 1- Within the experiment, the absorption cooling cycle bases upon two substances (water- lithium bromide) (H_2O -LiBr), as the water is the absorbed chiller and lithium bromide is absorber at 65% of lithium bromide and 35% of water, which means that the absorption cooling cycle contains coolant (water- lithium bromide).
- 2- The diluted solution (water- lithium bromide) included in the Chiller Unite absorber and the diluted solution is pumped to the generator through coil. The generator heats the diluted solution it includes by the heat from the solar collector connected to it.
- 3- As a result of the high heating inside the generator, the lithium bromide becomes separated from water which evaporates to the top of the generator. The remaining concentrated solution (lithium bromide) is lowered to the bottom of the generator and returned through the coil to the absorber.
- 4- The steam moves from the generator towards the condenser and since the steam of the generator is hot, the condenser temperature becomes high, it needs to be cooled in order to condense. Consequently, the cooling tower should be installed to the condenser and the coil containing $32^\circ C$ water should be connected to the condenser. The steam in the condenser condenses and turns into $10^\circ C$. chilled water and accumulates in the bottom of the condenser, then transmits to the evaporator through coil and expansion valve.
- 5- Since the atmospheric pressure is under the pressure of a vacuum in the evaporator by the expansion valve, water temperature becomes $4^\circ C$, then the chilled water evaporates and turns into a chilled water vapor passing through the cooling coils, which is the air conditioning internal unit of the building and connected to the evaporator and containing the chilled water at $7^\circ C$. When the external air contacts these chilled coils, the air temperature lowers and enters the building, in its cool state, and thus the air conditioning is achieved.

5.16. Design of the TRNSYS Solar Thermal Cooling System

5.16.1. Solar Cooling Simulation System

To conduct the dynamic simulation of the Absorption Solar Thermal Cooling System, it was designed using (TRNSYS) program which provide us with several components and elements required for designing cooling and heating systems of several renewable energies, such as Absorption Solar Thermal Cooling System, subject of the practical study. The mentioned-above Cooling System components were imported in addition to climatic inputs of the area, place of the practical study and printer icon to extract readings and results of the program library to

conduct a bio-simulation of the system methodology. The Cooling System has been designed cooling system using the above-mentioned elements, as shown in Figure 9 knowing that the simulation is conducted in the southwest unit on roof after merging and integrating the Cooling System.

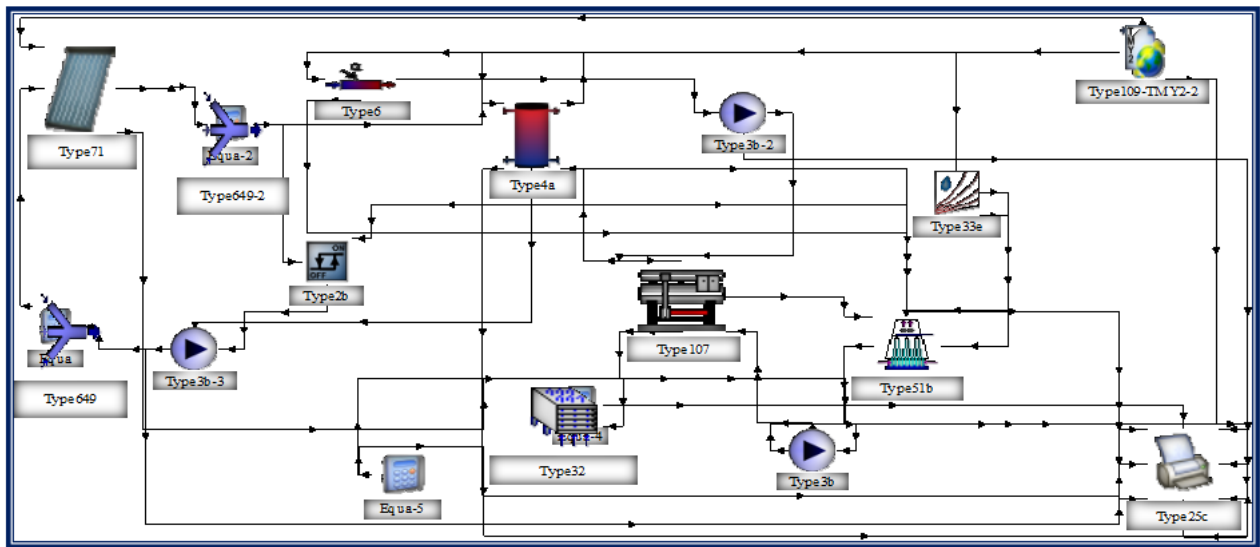


Figure-9. shows the design model of the Absorption Solar Thermal Cooling System for cooling the residential unit and water flow directions within the system cycle and replication in the simulation program to cover the normal cooling loads during the summer season (June, July, August, September) in TRNSYS program.

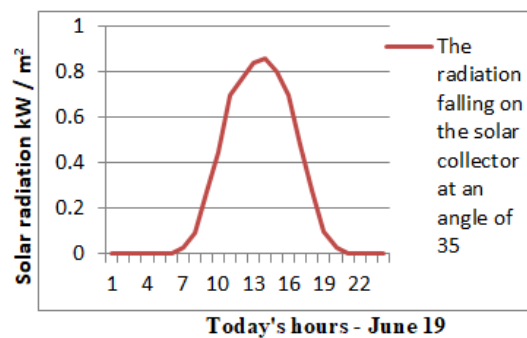
5.17. Readings and Results of Simulating the Integration of the Solar Cooling System in the Residential Unit (South / West) in the Roof Floor in the Most Appropriate Outer Covering as shows in Table 4:

Table-4. Readings and results of the natural simulation of the integration of the solar thermal cooling system in the residential unit (South / West) with the most appropriate outer covering on June 19 in the roof floor.

1- The intensity of solar radiation on the Solar Collector of the city of Cairo on June 19: Solar radiation on the oblique surface of the solar collector in kW / m², for the unit (south-west) for the roof floor in the most appropriate outer covering on June 19.

Analytical notes:

- To simulate the system dynamically, it is necessary to provide solar radiation data of the place under study. Weather and solar radiation data available for the city of Cairo have been used within the simulation program databases (TRNSYS). The figure shows the amount of total solar radiation falling on the solar collector used at an angle of 35 degrees, during the day of June 19.
- The amount of solar radiation increases gradually from morning until noon as the maximum intensity (0.86) kilowatts / m² and then begins to decrease gradually until night hours.



- The best angle of inclination for the solar system is 35 degrees, so the inclination angles of solar collector in solar projects in Egypt are always 35 degrees toward the south¹.

2- Temperatures of water entry and exit from the solar collector on June 19:

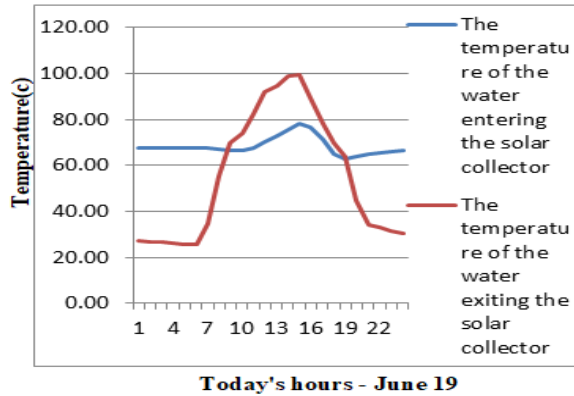
Water entry and exit temperatures from the pool for the unit (south / west) of the rooftop floor with the most

¹ <https://ise-eg.com/ar.on> 25/12/019

appropriate outer covering on June 19.

Analytical notes:

- At hours when the cooling system stops operating at night, the water temperature in the solar collector is the same as the temperature in the surrounding environment.
- Then, since sunrise, the water temperature in the solar collector begins to rise before the cooling system starts up.
- While starting up the system, the temperatures of entry and exit of water from the solar collectors varies and differs, and the temperature of the exiting water reaches its peak after midday at two o'clock (100 degrees Celsius) due to the strength and intensity of the solar radiation at that time.



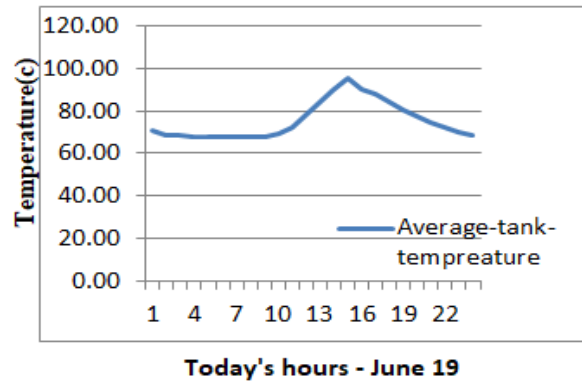
3- Average temperatures inside the tank heat on June 19:

Average temperatures inside the unit's tank heat (south - west) for the roof floor with the most appropriate outer covering on June 19.

Analytical notes:

After the hot water exit from the solar collector, it passes by an auxiliary heater to maintain the water temperature and as an auxiliary heat exchanger in the case of cloudy days or in the case of weak solar radiation, and the heat is transferred from it to the thermal tank. The figure shows an average of the temperature of the tank heat, hourly throughout the chosen day, June 19 in the unit (south - west) of the roof floor in the most appropriate outer covering. The following has been observed:

- At hours when the cooling system stops operating, we find that the water temperature inside the thermal tank begins to decrease without a significant loss in its temperature due to the good insulation of the thermal tank.
- The temperature of the tank also decreases at the start-up phase of the cooling system and is 67 ° C due to the low water temperature coming from the auxiliary heat exchanger.
- Gradually, with the increase of solar radiation falling on the solar collector during the day, the temperature of the water inside the tank heat begins to rise noticeably and reaches its highest value at two o'clock in the afternoon (96 ° C) at the maximum solar radiation.

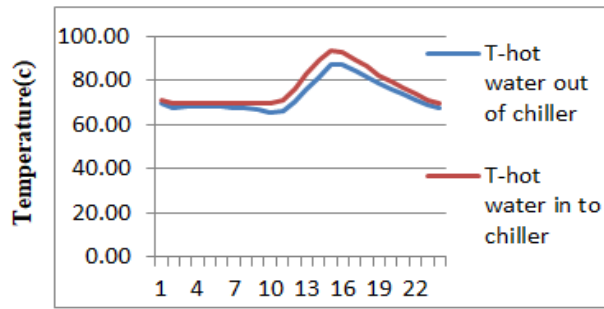


- At the beginning of the work of the cooling system, we notice a decrease in the thermal energy inside the thermal tank. This decrease in temperature is compensated by the auxiliary heat exchanger connected to the tank heat so that the system works at its full efficiency and the required cooling cycle is completed.
- We note that the temperatures inside the tank heat decrease at the start-up phase of the cooling system and are 67 ° C, that is less than the water temperature required when entering the system (not less than 80 ° C) to complete the cooling. This is because the water temperature coming from the heat exchanger decreases. It increases gradually with the increase of the solar radiation falling on the solar collector during the day. The temperature of the water inside the thermal tank starts to rise noticeably and reaches its highest value of 96 ° C at the maximum solar radiation.

4- Temperatures of hot water entry and exit from the generator inside the Absorption chiller unite for June 19:

The degrees of hot water entry and exit from the generator unit (south-west) of the roof floor with the most appropriate outer covering on June 19

- When the cooling system stops working at night, a gradual decrease occurs in the temperature of hot water coming from the solar collector to the generator and outside it towards the condenser inside the absorption chiller unit.
- The temperatures of hot water entry and exit reach its maximum after two hours at midday due to the strength of solar radiation at that time.
- The temperatures of hot water entry and exit to the generator are close to (65-70) degrees Celsius, 70 degrees hot water inside the generator, 65 degrees hot water coming out of the generator.



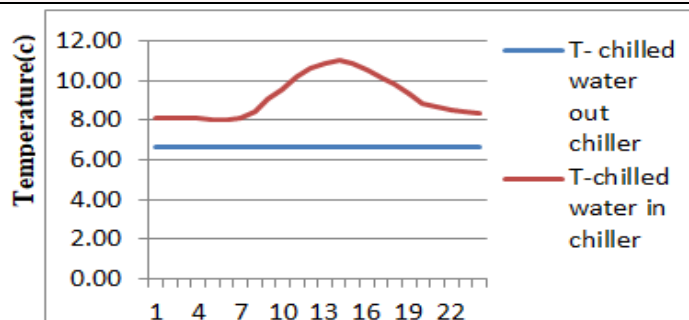
- Temperatures begin to increase gradually with the first daylight hours from seven O'clock in the morning until they reach their peak at two and three O'clock at noon, ranging between (87-94) degrees; 94 degrees hot water entering the generator, 87 degrees hot water coming out of the generator, and then begins.

5- The temperatures of entry and exit of cooled water from the evaporator inside the Absorption chiller unite for June 19:

The degrees of entry and exit of cooled water from the evaporator of the unit (south-west) of the roof floor with the most appropriate outer covering on June 19.

Analytical notes:

- Simulation the temperature of chilled water that comes out of the absorption chiller unite is an important variable and a key indicator in measuring the success of the system's performance or not. The temperature of the chilled water is (7 ° C) as we mentioned earlier when identifying the method of operation of the system. Therefore, when the simulation is performed, the temperature of the chilled water is (7 ° C) throughout the hours of the day, this indicates the success of the simulation, but in the case of a significant difference from the temperature of the known chilled water, this indicates an error in the simulation of the cooling system.



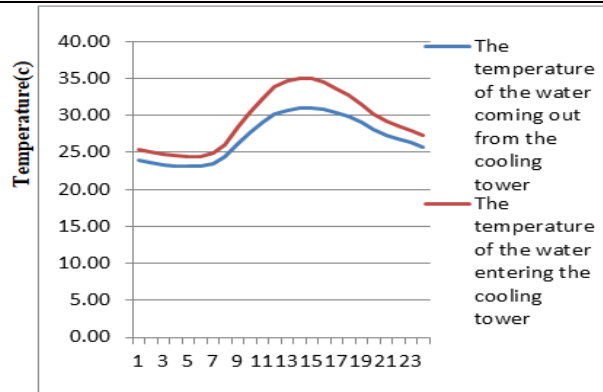
- When operating the system, the chilled water comes out of the cooling coil connected to the evaporator inside the absorption chiller unite at 7 ° C, absorbs a portion of the thermal load and returns again to the evaporator coming from the condenser at 12 ° C, as the temperature of the return water does not rise much due to the high flow rate.
- In the roof floor, in the most appropriate alternative to the outer covering of the unit (south-west), we find that the chilled water coming out of the cooling coil and connected to the evaporator inside the absorption chiller unite at 7 ° C is constant, while the temperature increases of the cooled water Inside the evaporator until it reaches a maximum of 11 ° C per second at two o'clock in the afternoon and then gradually decreases again.

6- Temperatures of Water entry and exit from the cooling tower on June 19:

Temperatures of Water entry and exit from the cooling tower for the unit (south - west) of the roof floor with the most appropriate outer covering on June 19.

Analytical notes:

- The temperatures of water entry and exit from the cooling tower converge at night hours, and begin to vary with the first hours of the day, increases gradually until they reach the highest values at two o'clock in the afternoon and then gradually decline again by evening.



Today's hours - June 19

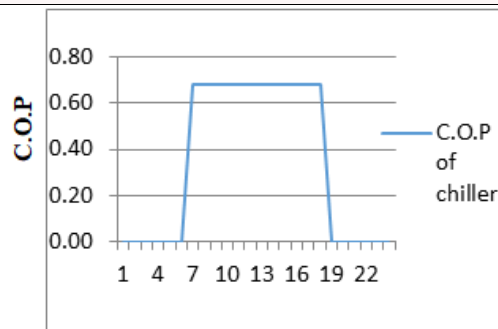
- The temperature of the water entering the cooling tower increases as a result of the increase in the cooling load resulting from the high temperature inside the condenser inside the absorption chiller unit and reaches its maximum temperature in the afternoon (37 ° C) in the unit (south - west) with the most appropriate outer covering in the roof floor.
- The temperature of the water coming out from the cooling tower is lower than the water entering the cooling tower and towards the evaporator, and reaches its maximum temperature (31 ° C).

7- Coefficient of Performance of Absorption chiller unite on June 19:

Coefficient of Performance of the cooling system of the unit (south - west) for the roof floor with the most appropriate outer covering on June 19

Analytical notes:

- By simulating the work of the solar thermal chiller system during the summer season (June - September), it was found that the average coefficient of performance of the absorption chiller unite in the unit (south-west) of the roof floor in the most appropriate outer covering is equal to 0.7) than 1 during the hours of the day, which is an acceptable range for the performance efficiency of the absorption chiller unit.



Today's hours - June 19

- The measurement of the performance index of the cooling system starts from the start up in the early morning hours; at seven in the morning until it stops working by the evening at eight in the evening, and except that hours of the day, the value of the coefficient of performance is zero.

8- Entry and exit energies charts from the storage tank on June 19:

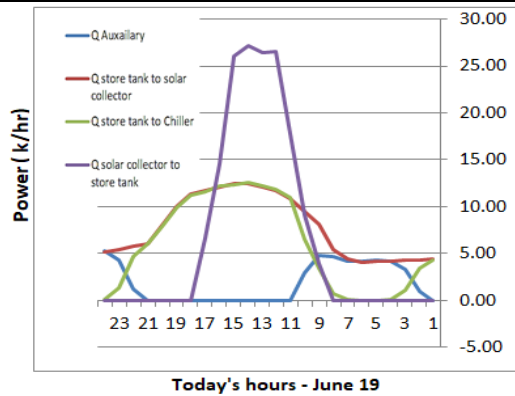
The storage tank is considered the main cornerstone and the source of the energies that occupy the absorption chiller unit and consequently the operation of the solar thermal cooling system as a whole. The following is an illustration of the energies coming in and out of the thermal tank, and they are four types of flowing energy as follows:

- 1- Energy added by auxiliary electric heater "Q Auxailary".
- 2- Energy flow from the storage tank to the solar collector "Q store tank to solar collector".
- 3- Energy flow from the thermal tank to the absorption chiller unit " Q store tank to Chiller..
- 4- Energy flow from the heat tank to the storage tank "Q store tank to Chiller".

Energies flow inside the storage tank of the unit (south-west) for the roof floor with the most suitable outer covering on June 19.

Analytical notes:

- The rate of energy flow added by the auxiliary electric heater is inversely proportional to the rate of energy flow from the solar collector to the storage tank, and this is logical because the auxiliary electric heater does not work except in the case of weak solar radiation intensity or in cloudy days or during the desire to operate the system at night.



- While the rate of energy flow from the storage tank towards the absorption chiller unit and the rate of energy flow from the heat tank to the solar collector are directly proportional throughout the system's working hours.
- The highest rate in the flowing energies are those which are produced from the solar collector towards the storage tank, as it reaches 28 kilowatt hours / hour at its maximum during the day, June 19.

9- Calculating the value of savings in electrical consumption resulting from the incorporation of the Solar Absorption Cooling Chiller system into the residential unit:

The value of the saving in electrical consumption resulting from the integration of the cooling system of the unit (south - west) of the roof floor in the most appropriate outer covering:

The dynamic simulation was conducted to test the system's performance throughout the year and it was found that the most influential months in assessing its success are the months of the summer season, as for the exception of the rest of the months of the year, readings and results of the solar cooling system can be neglected, because their performance values are negative or zero. This is logical because the cooling system works efficiently and fully at the summer season, so based on the result of dynamic simulation readings throughout the year, the seasonal saving of electricity over the summer season (June-September) is considered the annual indicator for what is provided by solar chiller system in the usual electrical consumption for cooling the residential unit (South - west) for the roof floor under study. The calculations are according to the ascending prices of the household electricity slides announced through the Ministry of Electricity and Renewable Energy for the year (2019-2020). The calculations were made on the basis of providing support for the first three slides, the calculations were divided by monthly consumption according to the specific slides and calculating the monthly consumption value and then adding to calculate the annual total value for each unit for both the basic alternative and the alternatives to the outer covering to extract the difference value which is the value that was provided.

As in the following table:

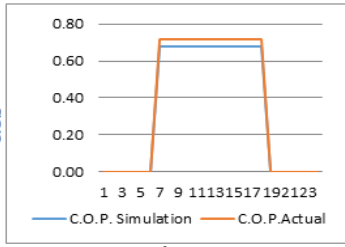
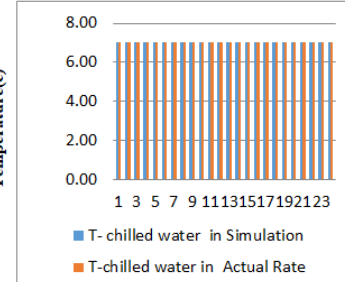
rate	Monthly consumption before solar cooling Q generator K.W (Usual consumption)	The energy generated by solar cooling Q solar K.W (Energy savings)	Monthly consumption after solar cooling Qg-Qs K.W (Paid rate)	Monthly consumption after solar cooling Qg-Qs Egyptian Pound (Paid rate)	Monthly consumption before solar cooling Q generator Egyptian Pound (Usual consumption)	Monthly savings In percentage (%)	The energy generated by solar cooling Q solar Egyptian Pound (Energy savings)
Month							
June	6559	4962	1597	2315	9510	75%	7194
July	6883	5022	1861	2698	9980	72%	7281
August	6940	4853	2087	3026	1006	69%	7036
September	6587	4642	1945	2820	9551	70%	7630
Total	26969	19479	7490	10859	30047	-	30114
Average monthly	6742	4869	1872	2714	7512	72%	7060

The result of the dynamic simulation of the performance of the Solar Absorption Cooling Chiller system in the unit (South / West) in the roof floor with the most appropriate outer covering:

After performing the dynamic simulation of the cooling system, the results were achieved as follows:

- The simulation dynamic simulation process data converges for all stages and steps of the cooling system with the actual stages and steps of its operation.
- A comparison of the most important readings and indicators affecting the work of the cooling system between

simulation results in the residential unit and the manufacturer's indicators (the most indicators indicating of the efficiency of the system's work were chosen according to the manufacturer² of them):

Body Indicator	(Actual Rate)	(Simulation Rate)	Comparison between the actual rate and simulation rate of the most important indicators of the efficiency of the Solar Absorption Cooling Chiller system.
System Coefficient of performance and efficiency C.O.P	Manufacturer of the cooling system C.O.P.= 0.72	Simulation of the system in a residential unit (south / west) surface C.O.P.= 0.70	
The temperature of the chilled water coming out of the absorption unit Chilled Water	Manufacturer of the cooling system Chilled Water = 7c	Simulation of the system in a residential unit (south / west) surface Chilled Water = 7c	

Fourth: The economic evaluation of the Solar Absorption cooling Chiller system.

5.18. Calculation of the Payback Method Standard for the Solar Absorption Cooling Chiller System after its Incorporation into the Residential Unit

The value of the year payback of the Solar Absorption cooling Chiller system, for the residential unit (South / West), in the rood floor:

In view of the importance and failure to neglect the economic dimension in the applied toponymy of the project, economic studies were conducted with the aim of completing the main pillar of the study, which is the achievement of rationalization and saving in the usual costs. This was done through a study of the extent of economic savings and the use of the (Payback Method standard study) to apply it in the project and use it as a guide and a simple acceptable economic guide for testing the possibility of using the cooling system economically:

It can be calculated from the following simple equation:

$$\text{Payback (year)} = \frac{\text{Investment cost}}{\text{The expected return per year}}$$

Through this research study, the following can be considered:

The investment cost: It is the cost of the solar cooling system, and it will be calculated by the actual cost according to the market prices during that year.

The expected annual return: It is the value of the amount saved through the rationalization of energy consumption annually. It will be calculated through the actual cost of electricity consumption according to the ascending slides as in the Table 5 as follows:

² www.lgeaircon.com on 1-1-2020

Table-5. Calculation of the payback method standard for the solar absorption cooling chiller system.

The cost of installing a solar cooling system	The value of savings in the annual energy	Payback (year)
480000	30141	1.5

6. CONCLUSION

- The most appropriate outer covering for the southwest residential unit in the roof floor:
 - Alternate ceiling (3), which is (the basic alternative to the ceiling + 5 cm polystyrene insulation).
 - Alternate wall (6), which is (double outer walls, 12 cm thickness, clay bricks with a thermal insulation of 5 cm, polystyrene).
 - Alternate vent (5), which is (aluminum external windows and (Low-E) glass).
- The success of the system's work indicators and readings was confirmed as successful and their conformity to the acceptable extent of the actual readings and indicators of the absorbable solar chiller system according to the manufacturer to cover thermal loads within the residential unit. The convergence and consistency of the readings and indicators are evidence of the success of the dynamic simulation of the absorptive solar chiller system in the unit (south / west) in the roof floor with the most appropriate outer covering. In providing thermal comfort inside the spaces 24 Celsius and also rationalizing the usual electric energy consumption by 72%.
- It was confirmed that the required thermal comfort was achieved throughout the summer season if the installation of the residential unit was actually applied.
- Savings were obtained in the usual monthly electrical consumption of 72%, equivalent to 7060 EGP.
- The economic study was conducted on the feasibility of using the Solar Absorption Cooling Chiller system in the unit (south / west) in the roof floor with the most appropriate outer covering by applying the standard of the recovery period and it was found 1.5 years, which is an economically acceptable period.
- To cover the usual thermal loads in the residential unit and rationalize it by solar energy instead of electric energy, an air conditioning system has been designed that operates according to the solar energy absorption cycle to achieve the thermal comfort in the residential unit by an area of 100 square meters. TRNSYS dynamic simulation program was used to calculate the cooling loads hourly for the summer season (June - September) and have peaked in the basic alternative to the residential unit (25 kilowatt hours / hour) on June 19 in Cairo, the subject of the applied study. Application was done and repeated simulations have been done and integrated after integration and complementarity of the solar thermal cooling system with the most appropriate external alternative for the southwest residential unit on the roof floor.
- Solar Absorption Cooling Chiller system has been chosen to be applied to the study. Returning to the products available in Egypt in the markets of solar thermal cooling systems, an Absorption Chiller Unite was chosen with a design capacity of about 15 kilowatts, the works with water as absorption cooling fluid and lithium bromide as an absorbent, and this unit produces cooling water at 7 o C. Two solar collectors with an area of 16 square meters connected respectively, were designed to supply hot water 85 o C to a heat tank with a capacity of 2 cubic meters. A cooling tower, cooling coil, auxiliary heat exchanger, pumps and expansion valves) were connected to design and operate the aforementioned solar thermal cooling system.
 - The cooling system achieved a solar participation rate of 95%.
 - Average coefficient of performance of the cooling unit is about 0.7.
 - The efficiency of solar collectors is 88%.

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REFERENCES

- [1] Ministry of Electricity and Renewable Energy, Retrieved from: <http://www.nrea.gov.eg/Technology/SolarIntro>. [Accessed 3-11-2019], 2019.
- [2] Brochure, "Brochure of the conditions of the middle housing project (SAKAN Egypt) in New Cairo," 2018.
- [3] T. Otanicar, R. A. Taylor, and P. E. Phelan, "Prospects for solar cooling—An economic and environmental assessment," *Solar Energy*, vol. 86, pp. 1287-1299, 2012. Available at: <https://doi.org/10.1016/j.solener.2012.01.020>.
- [4] R. Best and W. Rivera, "A review of thermal cooling systems," *Applied Thermal Engineering*, vol. 75, pp. 1162-1175, 2015. Available at: <https://doi.org/10.1016/j.applthermaleng.2014.08.018>.
- [5] I. Sarbu and C. Sebarchievici, "Review of solar refrigeration and cooling systems," *Energy and Buildings*, vol. 67, pp. 286-297, 2013. Available at: <https://doi.org/10.1016/j.enbuild.2013.08.022>.
- [6] A. Ghafoor and A. Munir, "Worldwide overview of solar thermal cooling technologies," *Renewable and Sustainable Energy Reviews*, vol. 43, pp. 763-774, 2015. Available at: <https://doi.org/10.1016/j.rser.2014.11.073>.
- [7] K. Ullah, R. Saidur, H. Ping, R. Akikur, and N. Shuvo, "A review of solar thermal refrigeration and cooling methods," *Renewable and Sustainable Energy Reviews*, vol. 24, pp. 499-513, 2013. Available at: <https://doi.org/10.1016/j.rser.2013.03.024>.
- [8] M. Noro and R. Lazzarin, "Solar cooling between thermal and photovoltaic: An energy and economic comparative study in the Mediterranean conditions," *Energy*, vol. 73, pp. 453-464, 2014. Available at: <https://doi.org/10.1016/j.energy.2014.06.035>.

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