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RESEARCH ARTICLE

Modeling and simulation of absorption solar air conditioning to reduce energy consumption: A case of some cities in tropical region

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Abstract: Buildings are one of the most important infrastructure sectors in today's society. However, in Madagascar, most hotels, malls, hospitals use fossil fuels to meet energy needs, especially in the traditional air conditioning system. they consume a considerable amount of energy that has negative effects on the environment. The emergence of solar cooling systems is a very interesting solution to this problem because the use of renewable energies in this sector contributes to a significant reduction of greenhouse gas emissions in the environment. Madagascar is one of the countries with high renewable energy potential, notably solar energy estimated at 2000kWh/m^2.an.At present, the rate of exploitation of this potential for the operation of the solar absorption cooling system coupled with the building is still non-existent. This energy is clean, sustainable, profitable and environmentally friendly. This is the main objective of this work which uses this energy source to ensure thermal comfort in a building in Madagascar and contributes to the development of this system. The TRNSYS software helped us to model and simulate this system. To do this, first we will select 4 big cities of the big island, a building of total surface 80 m^2 was used. Then, the hourly thermal loads of this building for the whole year were simulated using the TRNbuild sub-program using meteorological data for a typical year of the selected cities. The dimensions of the components of the solar absorption air conditioning system were obtained using the maximum loads of the building. The results of the simulations show, the system meets the cooling load needs of the building with the climatic conditions of each selected city.

Keywords: solar cooling Madagascar, TRNSYS simulation, solar thermal cooling, building air-conditioning, LiBr-H_2O

1 Introduction

Since the beginning of the industrial revolution, the exploitation of primary energy sources (fossil fuels) has been very developed. These sources of energy pollute the environment and lead to disturbances on the climate system of the present world. This climate disorder is characterized by the increase of the average temperature of the globe. The use of this energy source to supply energy for transportation, industry, heating, cooling in the building and electricity production leads to carbon dioxide emissions. This carbon dioxide is the main source of current global warming. While the latter is one of the most known major problems faced by governments and various private organizations worldwide today. According to the 2014 Intergovernmental Panel on Climate Change [1], the average temperature of the earth's surface increases from 3.7 to 4.8 until the end of the 21st century. In November 2021, the 26th Conference of the Parties COP 26 in Scotland United Kingdom the signatory countries commit to the neutralization of carbon emissions "net-zero".

Nowadays, the building industry is responsible for a quarter of the greenhouse gas emissions due to the increase in the standard of living of the current human beings as well as the need for comfort and the use of natural air-conditioning due to the increase of the summer temperature. In addition, natural air conditioning uses chlorofluorocarbons (CFCs) as the working fluid since its existence. However, the latter contributes to global warming [2, 3]. To help reduce environmental and human challenges, the use of renewable energy sources, particularly solar energy in this sector, is very interesting in order to reduce the production of greenhouse gases in the atmosphere. This energy is abundant, clean, and sustainable.

Several studies have been conducted in the field of solar technology, among these different systems, the solar absorption machine seems very promising in the air conditioning of homes. Solar cooling is a clean and cost-effective technology, it respects the environment and contributes to the significant reduction of greenhouse gas emissions. The biggest advantage of using this system is its simple, clean and durable construction.

Absorption systems are similar to mechanical compression air conditioning systems, but the mechanical compressor is replaced by a boiler (B) - absorber (A) - pump (p) system. The mechanical work to be done to the agent is very low because the compression is done on a liquid and not on a vapor. All moving parts can be removed by using a thermosiphon pump. The rise in pressure necessary in this system requires a second liquid fluid (solvent) and calorific operations. This is called a thermal compressor. As in the case of mechanical compression refrigeration machines, absorption refrigeration systems have a low pressure side, that of the evaporator, and a high pressure side, that of the condenser. In any absorption refrigeration machine, two circuits must be distinguished: the refrigerant circuit between the boiler, condenser, evaporator and absorber, and the binary solvent/refrigerant mixture circuit between the absorber and the boiler. In general, the most used refrigerant-absorber pair in this system are the lithium bromide-water [LiBr-H2O] and ammonia-water [NH3-H2O] pairs. These two pairs offer good thermodynamic performances and respect the environment. The ammonia-water pair is not suitable for solar applications because of the high temperature required in the generator which can vary from 125°C to 170°C [4].

Nowadays, two types of absorption chiller technologies exist on the market, such as single-acting and double-acting absorption chillers. These chillers use lithium bromide-water [LiBr-H2O] as the refrigerant-absorber couple and use hot water as the heat source. The single effect absorption chiller is for cooling use in buildings. The system performance coefficient varies from 0.6 to 0.8. Single-effect chillers can operate with hot water temperatures ranging from 70 to 100 °C when the water is under pressure. These technologies are already available on the markets with much cheaper prices. Figure 1 showed a simple absorption system.

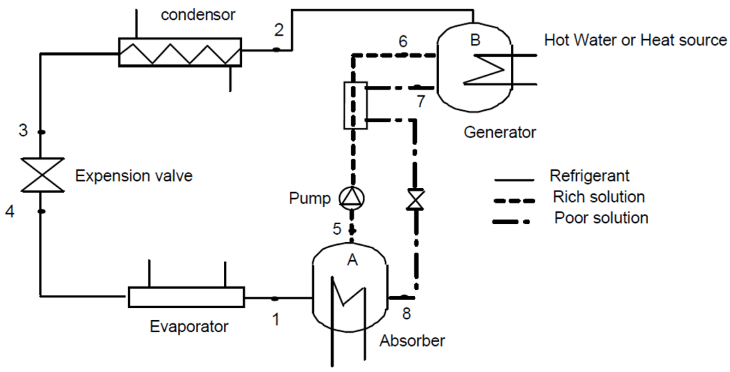

Figure 1 Basic principle of absorption system

Over the past decades, many researchers have published work on the simulation and experimental investigations of this system using TRNSYS as the simulation software. As the summaries of the following articles, most of these articles focus on absorption cooling systems coupled with building. Tiago and Armando (2009) [5] analysis of an integrated solar absorption cooling and heating system in different types of buildings and climates. The objective of this work is to evaluate the potential of integrated solar absorption cooling and heating systems for building use. They used TRNSYS software to evaluate the energy and economic consumption of this system. Asim et al.,2015, TRNSYS simulation of a solar cooling system for the hot climate of Pakistan. In this study the simulation and modeling of the solar absorption cooling system integrated in a building was performed with TRNSYS software. Their results showed that for a typical building in Pakistan a 12 m^2 collector can maintain the temperature below 26°C of this building during the cooling period. Modeling of a solar absorption cooling system for Guayaquil, Ecuador. In this work, they used TRNSYS software to model and simulate the solar absorption cooling system to meet the energy needs of an office building with the weather conditions of the city of Guayaquil, Ecuador. Their results show that the optimal system could achieve an annual solar fraction of 0.6. Florides et al. (2002) [4] in Modelling, simulation and warming impact assessment of a domestic-size absorption solar cooling system. This work uses

TRNSYS to model, simulate and optimize the system. Their results showed that for a 15 m^2 parabolic collector inclined at 30° to the horizontal and a 600l tank, the system is optimal. This system is competitive with conventional cooling systems according to their economic analysis. B. Mebarki et al. in 2014 , Modeling and simulation of an absorption solar air conditioning system. This performs an experimental study of the absorption cooling system coupled with the building. They used TRNSYS software for modeling and simulation of this system. The aim of this work is to see the influence of the meteorological conditions of the study area. T. O. Ahmadu et al., in 2016. Modeling, Simulation and Optimization of a Solar Absorption Air Conditioning System for an Office Block in Zaria, Nigeria. In this work an office of 90 m^2 area was simulated and modeled with TRNSYS software. The hourly energy demands of the building were simulated with the TRNbuild sub-program. Their results showed that the system achieve an average annual solar fraction of 0.79. Al-Alili et al. (2010) [6], Optimization of a solar powered absorption cycle under Abu Dhabi's weather conditions. This work performs, modeling and simulation of solar absorption cooling system of Abu Dhabi city using TRNSYS and MATLAB simulation program. Their results show that the optimization methods with MATLAB and TRNSYS software are in good agreement. Thermo-economic analysis and optimization of high efficiency solar heating and cooling systems for different Italian school buildings and climates [7]. This work studied the energetic and economic feasibility of a solar heating and cooling system coupled with different types of school buildings in Italy. The analysis of this system has been carried out using TRNSYS software. It proposes an economic model to evaluate and analyze the operating and investment costs of this system. Simulation and Optimization of a Solar Absorption Cooling System Using Evacuated Tube Collectors [8]. In this work, a single stage solar absorption cooling system using a lithium bromide water solution was presented. The modeling, simulation and optimization of this system was studied to determine the optimal solar collector area, tank volume and chiller capacity. They used TRNSYS software to study this system. Calise et al., 2012), Transient simulation of polygeneration systems based on PEM fuel cells and solar heating and cooling technologies. In this work, a dynamic simulation of an innovative polygeneration system based on solar heating and cooling and PEM fuel cell technologies was presented. The polygeneration system is composed on the following main basic elements: evacuated solar collectors, absorption chiller and PEM fuel cell. The analysis of this system was performed using TRNSYS software and the dynamic behavior of the building modeled with the TRNBUILD subroutine. Their results of the economic analysis show that it is very interesting from the point of view of energy saving. TRNSYS modeling of a positive energy house. In the framework of a collaboration between CEGELY and CETHIL, this study proposes the design principle of a positive energy house for one year of operation [8]. The whole system is modeled with TRNSYS 16 software using meteorological data from Lyon France.

TRNSYS (2010) is a dynamic systems simulation software developed by the Solar Energy Laboratory, University of Wisconsin, USA. It allows to perform dynamic thermal modeling and simulation applied to the building according to its location, its construction materials and its architecture. It can also evaluate the hourly energy needs of the building such as the heating system, or cooling. The use of this software, allowed us to simulate and model the air conditioning system by solar absorption to maintain the comfort temperature in a building for the five selected cities during the hot season.

In Madagascar, many buildings (hotels, shopping malls, hospitals) use the traditional air conditioning system that operates with electrical energy from fossil fuels. These energies are very expensive and lead to environmental degradation because of its greenhouse gas emissions. As, Madagascar is among the countries vulnerable to climate change. Therefore, governments must have ideas to reduce the negative impact on the climate, to use clean energy, from renewable resources.

Madagascar has a huge renewable energy potential, especially in solar energy estimated at 2000kWh/m^2.an. Currently, the rate of exploitation of this potential to operate the cooling system by solar absorption coupled with building is still non-existent. However, the objective of this article is to contribute to the development of this system in different climatic zones in Madagascar in order to ensure thermal comfort building. To achieve this goal, first we will select 4 cities such as Mahajanga, Antsiranana, Toliara and Toamasina. Then, an 80 m^2 building was treated along this study. This building was modeled and simulated in the TRNbuild TRNSYS sub-program to have its cooling loads using the meteorological data of each selected city. Then the elements of the absorption cooling system were selected from the TRNSYS library. The technical characteristics of these elements were chosen according to the cooling needs of the building. The set was simulated with a time step of 1h and we got a result.

2 Presentation of the study area

Geographically, Madagascar is attached to the African continent from which it is separated by the Mozambique Channel. It is located in the Indian Ocean. It has an area of about 587,000 km^2 with a length of 1,580 km and width of 580 km. It is divided into six historical provinces such as: Antananarivo, Diego-Suarez, Fianarantsoa, Mahajanga, Toamasina and Toliara. Its capital is Antananarivo. It is one of the countries that has the largest solar deposit in the world with an average duration of sunshine or insolation can reach about 2800 hours annually in all regions. The solar energy potential of the country is estimated at 2000 kWh/m^2.year for the central and eastern regions of the island and can reach 2168 kWh/m^2.year in some northern and southwestern regions. This study takes place in the five provinces of the country mentioned above and the geographical coordinates and their meteorological conditions are presented in Table 1.

Table 1 Geographical location and weather conditions of the different study areas

City	Coordinates			Temperature °C		Sunshine W/m²		Wind speed m/s		Type of climate
	Latitude	Longitude	Altitude	Max	Min	Max	Min	Max	Min	
Mahajanga	15° 43’ 00” S,	46° 19’ 00” E	20	36.6	15.7	1167	0	12.1	0	Hot tropical Climate
Antsiranana	12° 16’ 58” S,	49° 17’ 33” E	6	34.7	16.4	1164	0	23.6	0	Transitionnal tropical climate
Toliara	23° 21’ 13” S	43° 40’ 34” E	8	34.2	12.9	1171	0	15.8	0	Tropical sub-desert climate
Antananarivo	18° 54’ 44” S	47° 31’ 18” E	1276	31.7	3.9	1344	0	11	0	Tropical climate Altitude
Tamatave	18° 08’ 50” S	49° 23’ 43” E	10	34.3	14.2	1228	0	10.5	0	Humid tropical climate

Figure 2 (World Solar, 2022) show the average annual global horizontal irradiance and normal direct irradiance for Madagascar. The average daily sunshine in Madagascar varies between 4785 to 6672 Wh/m^2/day and with a sunshine duration of 10 to 12 hours per day, as showed in Figure 2.

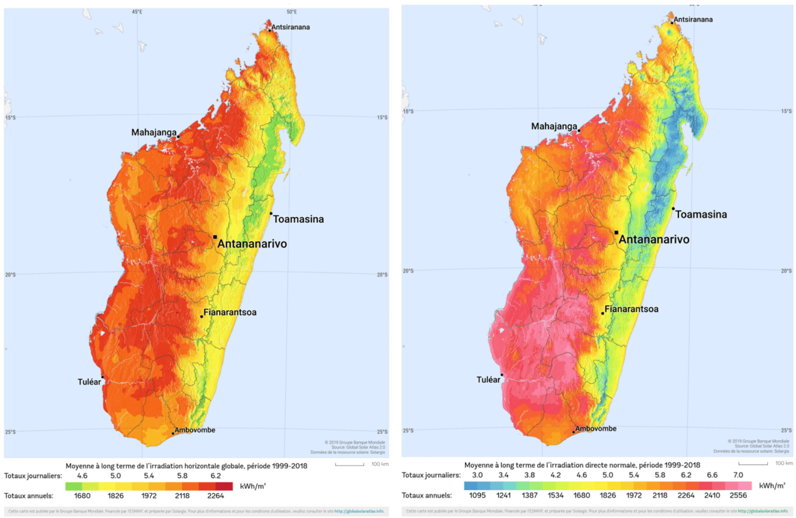

Figure 2 Horizontal global irradiation [left], and normal direct irradiation [right] for Madagascar 199-2018 [17]

3 Methods and materials

The objective of this work is to model and simulate the solar absorption cooling system case of Madagascar using TRNSYS 16 software. In order to model this system, it is important to note that a building of the same constructive design was used in the selected cities, which are located in different climatic zones. A building with a surface area of 80 m^2 has been used in this work and the different characteristic parameters that constitute this building are presented in Table 2. Figure 3 shows the plan view of this building and its 3D view.

Using hourly climate data from the selected city, this entire system was simulated and modeled with TRNbuild. Section 4. Below describe the steps for modeling and simulating this work in TRNSYS 16 software.

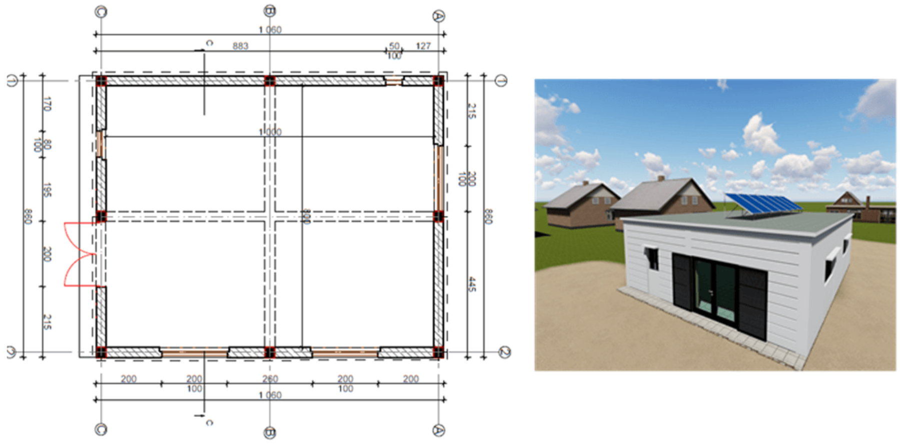

Figure 3 Plan view and 3D view of the building

Table 2 Constituent materials of exterior walls

Materials	Thickness (m)	Conductivity (kJ/h.mK)	Capacity (kJ/kg.K)	Density (kg/m^3)
Plaster-Ex	0.015	4.152	1	1700
Parpaing 25	0.25	3.466	0.65	1300
Plaster	0.015	1.264	1	1500

4 Modeling under trnsys 16 and TRNbuild

TRNSYS is a comprehensive and extensible simulation environment for transient system simulation, including multi-zone buildings. It is used by engineers and researchers worldwide to validate new energy concepts, from simple hot water systems to the design and simulation of buildings and their equipment, including control strategies, occupant behavior, alternative energy systems (wind, solar, photovoltaic, hydrogen, etc). It can also evaluate the hourly energy needs of the building such as heating, cooling, etc. Typical annual weather data for a number of regions in the world are available in the TRNSYS libraries as for example these four selected cities in Madagascar. A single room building with a single pane window has been proposed in this work.

4.1 Modeling the building under TRNbuild

To model a building in TRNbuild, first we choose the building model type 56 in TRNSYS, then specified its geometry as length, width and height. Then define the different characteristics of the materials that make up the walls and windows, as well as the roofs in the TRNSYS library. To enter the meteorological data of the study area, select the meteorological model type 109 and select the meteorological data of the study area, then enter the different heat gains such as the number of people in the building, the materials used (e.g. light, computer, printer etc.). To see the hourly heat loads of the building, we need to activate the cooling and choose the cooling temperature in the building. In this work, we choose this temperature 25°C as the comfort temperature. Finally run the simulation to see the results. Figure 4 shows the results of all the steps and Table 3 given the different characteristics of building.

4.2 Modeling in TRNSYS

A complete library that makes up the solar cooling system is available as separate modules in TRNSYS. Creating a simulation and modeling with TRNSYS involves identifying the modules to be used, having them connected appropriately, and defining the operating parameters of each module in the actual system.

The descriptive diagram of a solar absorption cooling system obtained using TRNSYS is presented by Figure 5. As presented by this figure, this system is mainly composed by an evacuated tube solar collector of type 71 to transform the solar radiation it receives into heat energy through a heat transfer fluid (water), it ensures the production of hot water and then store the water directly in a storage tank of type 4a, This storage tank is used to store hot water and allow the absorption chiller to operate when the available solar energy is insufficient

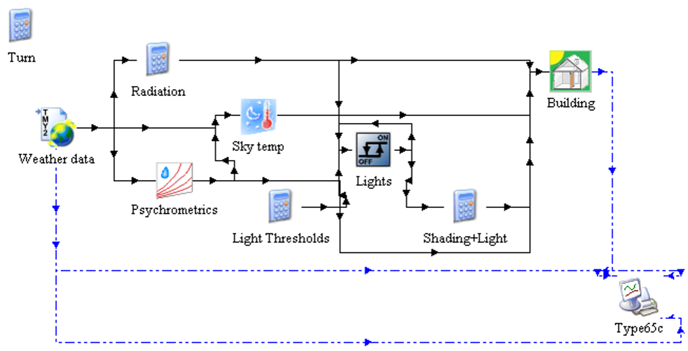

Figure 4 Modeling the building with TRNbuild

Table 3 Characteristic parameters of building on TRNbuild

Components	Parameter	Values
Building (Type 56)	Capacitancy	480 kJ/K
	Volume of building	200 m^3
	Height	2.5 m
	Area of building	80 m²
	Wall thickness	0.23 m
	Wall U-Values	2.219 W/m².K
	North double window	2 m²
	South double window	2 m²
	Window g-values	0.6
	Ground floor thickness	0.315
	Ground Floor U-Values	0.262 W/m².K
	Roof U-Values	1.141 W/m².K
	Number of persons in building	10
	Spécific gain from the equipment	700W
	Air change inflitration	0.5
	xWeather data	TMY2, Mahajanga, Antsiranana, Toliara, Toamasina, Madagascar

during the night, absorption machine is used to produce cold, pumps to circulate water in this system. The hot water produced by the solar thermal collector provides the function of a lithium bromide absorption chiller to maintain the comfort temperature in this building. The size of the storage tank has been chosen to guarantee the cooling load needs at all times without auxiliary heat input. All these materials are available in the TRNSYS library. Type 107 is a single effect absorption chiller in the library, it is supplied with hot water from the storage tank to operate the generator from the refrigerant-absorbent mixture solution. The performance of this machine is pre-determined according to the range of data such as hot water inlet temperature and cooling temperature. Type 109 provides the processing of meteorological data for the selected cities. In the TRNSYS library, one can see the meteorological data of several cities of different countries in the world including Madagascar like Mahajanga, Antsiranana, Tamatave, Tuléar, Fianarantsoa, Nosy-be, Fort-dauphin, Antananarivo, Sambava, etc. (see Figure 5).

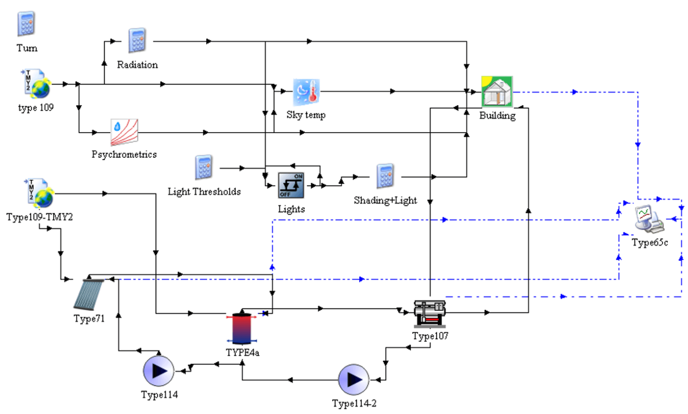

Figure 5 TRNSYS absorption cooling system model

Other important simulation settings are showed in Table 4 and 5

Table 4 Characteristic parameters of the simulations

Description	Specification
Room floor area	80 m²
Cooling set point	25°C
Operation hours	Continuous
Désign cooling load	72000 kJ/hr
Chiller type	Hot water fired absorption
Collector type	Tube à sous vide
Collector area	10 m² to 60 m²
Collector slope	15° à 23° depending on location
Hot water storage tank volume	1 m3 to 4 m3
Weather data	TMY2, Mahajanga, Antsiranana, Toliara, Toamasina, Madagascar

Table 5 Characteristic parameters of absorption system equipment

Components	Parameter	Values
Type 71	Collector area (Ac))	10 to 60 m²
	Slope angle of the collector (β)	15° to 23° (Depending on location)
	Tested mass flow rate (mc)	40kg/hr.m²
	Fluide Specific heat capacity	4.19kJ/kg.K
Type 3b	Maximum flow rate	100kg/hr
	Maximun power	60 kJ/hr
	Rates power	1800 kJ/hr
Absorption chiller Type (Type 107)	Rated cooling capacity	72000
	Rated COP	0.53
	Cooling water flow rate	800 kg/hr
	Hot water inlet temperature	142°C
Storage Tank (Type 4a)	Tank volume	1m3 to 4 m3
	Tank loss coefficient	

5 Results and discussion

When using this software, there are still some difficulties encountered in the building model type 56 with its TRNbuild interface. The choice of the model of the walls is very limited, this can lead to errors on the results of the calculations considered. Despite its limitations, the use of this software, allowed us to evaluate the performance of an air conditioning system by solar absorption to maintain the comfort temperature in a building for the city of Mahajanga, Antsiranana, Tamatave and Tulear during the hot season. The results and model of simulations has been verified and validated with several works published by different researchers of the world because the experimental study or the real installation of this system is not yet existed in the country. The simulation was executed with a time step of 1 hour and the results were obtained. The different characteristic parameters of this system such as cooling loads, collector area, hot water storage volumes were analyzed and studied to evaluate the performance of this system for the selected cities. In this work, the coefficient of performance of the chiller was set at 0.53 which corresponds to the temperature of its operation.

5.1 Building energy simulation

The evaluation of the cooling load of a building is a very important part of the cooling system design. TRNbuild offers the possibility to predict the performance of the designed building or selected systems. It allows a more complete description of the real phenomena of the installation to be designed. When modeling with TRNbuild, the internal gains due to the lighting system, the electrical appliances, the users and the occupancy schedules are set according to the office use, according to the rules of art of the building construction. The presence of the occupants is taken into account throughout the day. The light usage program is set to ”On” from 5:00 p.m. to midnight. The presence of occupants in the building has been programmed using the schedule function of the TRNbuild. The building infiltration rate is estimated to be 0.5 vol/hr. The setpoint temperature for cooling is 25°C. The simulations were performed over one year and the results are saved in Excel format. To define the cooling requirements for the building for the selected cities, we chose a relatively sunny day and the cooling load demands are very high. Figure 6 to 9 show the simulated cooling load variations and outdoor temperatures of the selected city and the day and month where the cooling requirements are very high. From these results, it was found that the month where the cooling needs are more important are the same. Figure 6 shows the daily simulation of January 3, 2010 for the city of Mahajanga. This figure represents the hourly variation of the ambient temperature of the city and the hourly cooling needs of the city. As shown by this figure, between 8am and 9am, the temperature increases gradually until it reaches the maximum 34°C around 3pm. At the same time, the cooling needs increase progressively until it reaches the maximum 18.255MJ around 18h. Figure 7 represents, the hourly variation of the cooling needs of the city of Tulear and the variation of the outside temperature. On this figure, we can see that the cooling load is maximum around 17 to 18 o'clock in the evening and with a maximum value of 19.095 MJ. And the maximum temperature is 35°C, it occurs between 14h to 17h afternoon.

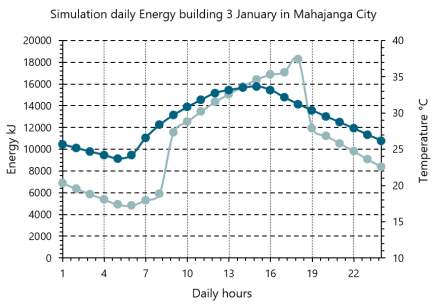

Figure 6 Simulation hourly Energy building 3 january in Mahajanga city

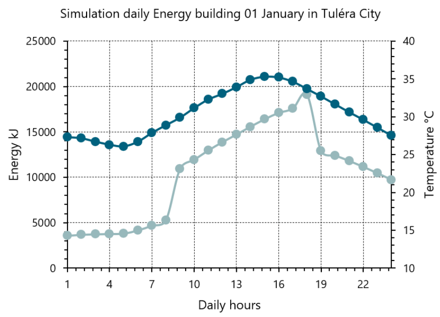

Figure 7 Simulation hourly Energy building 01 january in Tuléar city

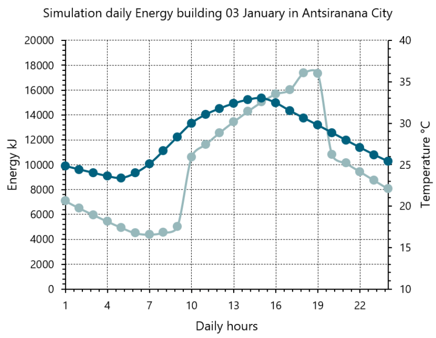

Figure 8 Simulation hourly Energy building 3 january in Antsiranana city

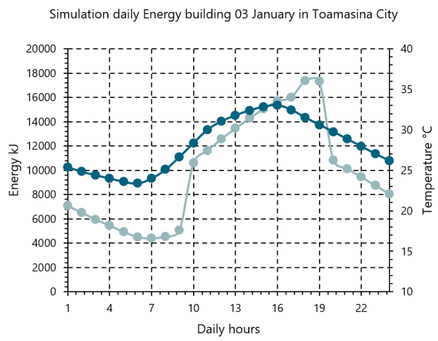

Figure 9 Simulation hourly Energy building 3 january in Toamasina city

Figure 8 and 9 represent respectively the hourly variation of the cooling needs of the city of Antsiranana and Toamasina. On these figures, we can see directly the maximum loads of these cities and their maximum temperatures. For the city of Antsiranana, the maximum load is 17.361MJ while for the city of Toamasiona is 17.236 MJ. We note that the cooling needs of these two cities the same. At the level of the maximum temperature, we note the city of Antsiranana is a little hotter with temperature 33°C against 32° C Toamasina.

According to the results of the simulation of the cooling needs of each city, it was found that the loads vary little (almost the same) by one of the other. The city of Toliara has the most important cooling needs compared to the others, it has maximum values of 19.095 MJ, then the city of Mahajanga with a value of 18.255 MJ and for the cities of Antsiranana and Tamatave have respectively 17.361 MJ and 17.236MJ. It was also noted that these maximum loads occur at around 5:00 to 6:00 pm in the afternoon. This is explained by the inertia of the building. To ensure the cooling of this building a 20 kW chiller was chosen. When the power of the chiller is defined, the last step is the simulation of the solar cooling system and the building.

5.2 Simulation of absorption air conditioning system performance

Climatic conditions and cooling loads have strong influences on the performance of the absorption air conditioning system. The evaluation of the energy performance is a very important point in the economic evaluation of an installation.

To illustrate the performance of this system in this paper, we have chosen a typical day of operation for all the selected cities, we have presented the results of January 2010, on a relatively sunny day. Figure 10 to 13 show the hourly evolution of the temperature at the outlet of the evacuated tube solar collector and the temperature in the storage tank for the cities studied in this work. As Figure 10 represents for the city of Mahajanga of January 03, 2010. As we can see in this figure at 7:00 am, the temperature of exit of the solar collectors increases gradually to exceed the temperature of the hot water tank. At the same time, the temperature of the hot water storage tank increases progressively until it reaches the maximum value of 129°C at about 15:00 and then goes down slightly. Around 10:00 am, as presented by Figure 6, the ambient temperature in the building increases slightly to reach the maximum value 34°C around 3:00 pm. Between 10:00 and 11:00, Figure 10, the temperature in the storage tank reaches 80°C, this temperature is the operating temperature of the absorption chiller [4, 9–14]. That is, between these times the absorption chiller starts up. These results show that the absorption chiller starts at the time when the building needs to cool down. As it can be seen on the different curves representing each selected city, the use of solar air conditioning system by absorption is very feasible on the climatic conditions of these cities. They present very interesting solar potentials to this system. The application of this system in the country is very interesting because this system contributes a huge decrease in the emission of greenhouse gases in the environment.

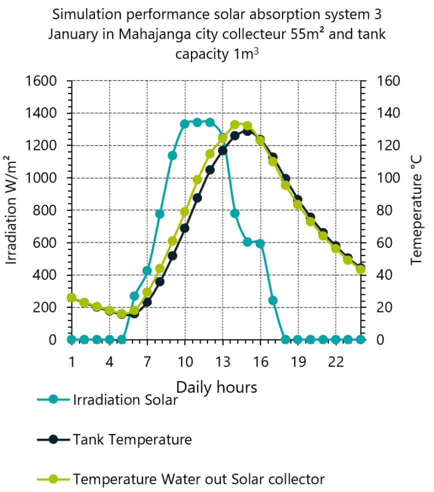

Figure 10 Simulation solar abasorption in Mahajanga

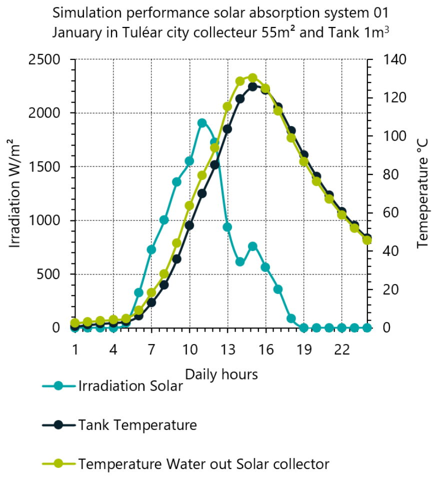

Figure 11 Simulation solar abasorption in Tulear

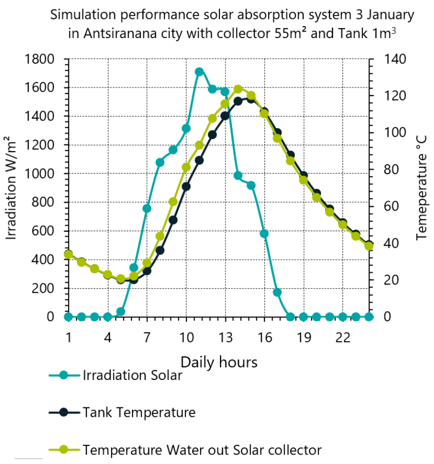

Figure 12 Simulation solar abasorption in Antsiranana

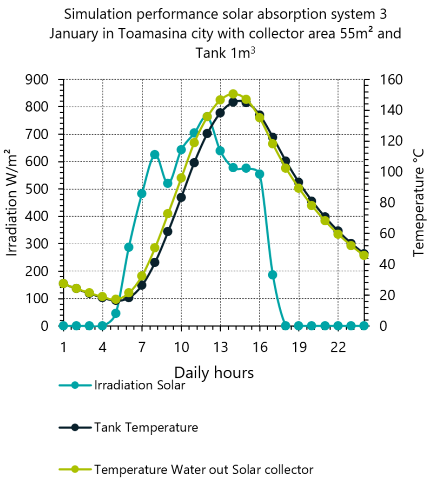

Figure 13 Simulation solar abasorption in Tamatave

6 Parameters that characterize the installation of solar absorption

According to several tests that we have carried out along this study, we could notice that there are several parameters that define the performance of the installation of this system such as the angle of the inclination of the solar collector, the solar fraction, the surface of the collector and the volume of the hot water storage tank. Only these last two parameters have been evaluated in this work and the other parameters will be studied in the next study with the economic analysis of this system by optimizing all these parameters [15–18].

6.1 Influence of the solar collector surface

Figure 14 shows the variation of the temperatures of the heat transfer fluid at the exit of the collector and the temperature in the storage tank according to the surface of the collector, by making varied the surface of the collector we could note that the more the surface is big the temperatures of the heat transfer fluid increase. If we increase the surface of the collector, the duration and the surface of heat exchange between the heat transfer fluid and the absorber increases because the solar collector is a heat exchanger that transforms the surface density of the energy flow of the sun into thermal energy. For this reason, the temperature of the heat transfer fluid increases. The temperature of the heat transfer fluid increases as the collector surface increases. Figure 14 shows the variations of the solar collector surfaces for the selected cities with a storage volume of 1 m^3.

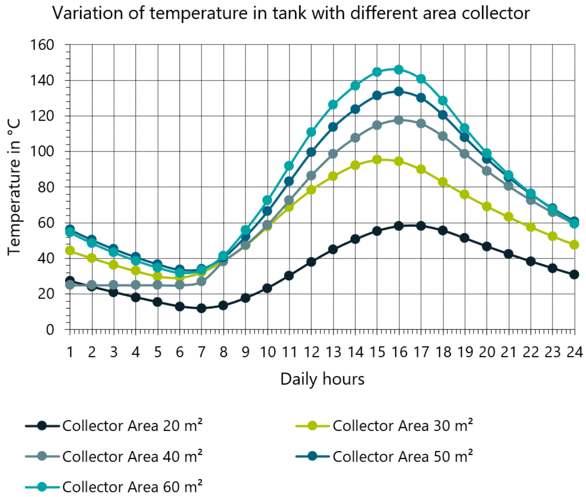

Figure 14 Temperature variation at the storage tank outlet as a function of the collector area

6.2 Influence of the storage tank volume

By varying the volume of the storage tank from 1m3 to 4m3, it was found that the larger the storage volume, the lower the temperature of the heat transfer fluid. If the volume of the storage tank is increased, the duration and the surface of heat exchange between the heat transfer fluid and the tank increases (large quantity to be heated). This is why the temperature in the storage tank decreases. Figure 15 shows the variation of temperatures in the storage tank as a function of its capacity. The temperature in the storage tank decreases as its volume increases [19–21].

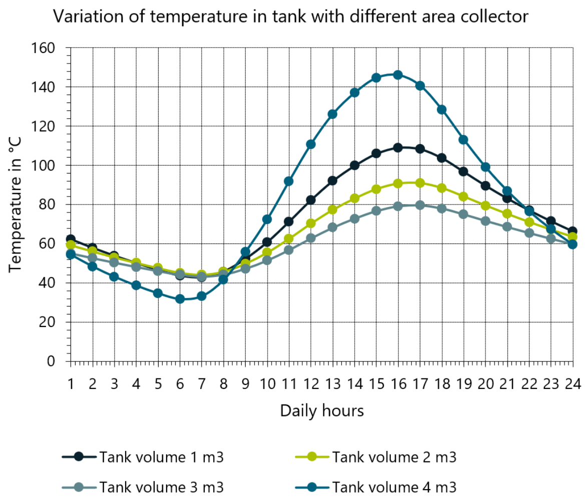

Figure 15 Temperature variation at the storage tank outlet as a function of its volume

7 Conclusion

This research aims to model and simulate the solar absorption air-conditioning system for the case of the island Madagascar and more precisely for the city of Mahajanga, Antsiranana, Toliara and Tamatave using TRNSYS software. The cooling loads for the building were simulated and evaluated in the TRNSYS subroutine TRNbuild interface. The different maximum cooling loads per hour for the selected cities are as follows Mahajanga 18.225MJ, Toliara 19.095 MJ, Tamatave 17.236 MJ And Antsiranana17.361MJ, these maximum loads occur only in the afternoon due to the inertia of the building. Thanks to TRNbuild, we can see the behaviors and energy needs of the building. Once the cooling requirements are determined, we selected a 20kW chiller to provide cooling in the building. This entire system was modeled and simulated using TRNSYS software using weather data from the cities chosen in this work. The simulation results show that the climate of Madagascar has a huge potential to use this system to meet the energy needs of the building during the hot period. The C.O.P of the chiller was fixed 0.53 which corresponds to an operating temperature higher than 100 °C ensuring the functioning of the installation in the chosen site.

According to several tests that we carried out along this study, we could note that there are several parameters which define the performance of the installation of this system such as the angle of the inclination of the solar collector, the solar fraction, the surface of the collector and the volume of the storage tank of hot water. Only these last two parameters have been evaluated in this work and the other parameters will be studied in the next study with the economic analysis of this system by optimizing all these parameters. By varying the solar collector surface, the collector temperatures oscillate between 80 °C and 160 °C. This result shows the good functioning of the machine in the selected cities. And the increase of the storage volume leads to a decrease of the storage tank outlet temperature. This leads us to propose an increase of the solar collector surface to ensure the increase of outlet temperature.

Considering the problem of pollution of the planet due to the combustion of fossil fuels, the adoption of solar energy for the cooling of a building has many considerable environmental advantages in the country. The optimization of the different parameters that have positive influences on the performance of the installation of this system will be treated in the following of this research.

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