Mixed Methods Research about Solar Cooling and Heating Systems in Buildings

Milad Rahmani[1*]
1- MSc student, Department of Civil Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran
* Corresponding Author: Milad.Rahmani.Eins@gmail.com

ABSTRACT

Fossil fuels used on large basis to produce electricity, When they are burnt, the carbon stored inside them is released which combines with oxygen in the air to create carbon dioxide, It's clear that how much cooling and heating systems effect on environment by increasing amounts of carbon dioxide which is the main gas responsible for increasing greenhouse effect and finally global warming. Over the past years, scientists try to find a way to use solar energy and make electricity to change cooling systems in buildings. The solution here suggested is formed by absorption machines powered by solar panels used to air-condition small residential building. This paper seeks to consider two valuable papers in this field to give a general insight about these Methods.
Keywords: air-conditioning, renewable energy, solar energy, solar collectors

1. INTRODUCTION

1.1.Renewable energy and solar air conditioning

In the 24th January 2008 South Africa issued a state of emergency grid was brought to near collapse. Inadequate maximum load planning wider mass electrification and economic growth are the main areas that demand more power and that began to outstrip supply it is for this reason that renewable energy remains contested topic in south Africa.

Over the past few years the demand of air-conditioning in residential building has been increasing in particular in the developed countries. Traditional air conditional systems are usually powered by electrical energy

The demand for electricity is increasing day by day which cannot be fulfilled by non-renewable energy sources alone. Renewable energy considers the primary energy from recurring and no depleting indigenous resources it is clean from of energy which is required for almost all natural proses on the earth

Renewable sources of energy now stand poised to lead the world in new electricity supply these resources are enormous, nonpolluting and virtually in exhaustible

In the summer, it is necessary to cool the environment because of the presence, during the day, of a high solar radiation, hence it might be useful to plan a system able to cool houses without any expenses, by using a renewable energy, as the sun. Nowadays the decision to power air-conditioning systems through the energy generated using photovoltaic panels is too expensive, due to high installation costs. The solution here suggested needs a system formed by absorption machines requiring a thermal energy source to function, in this case solar collectors. The system presents one machine with a heat transformer and an absorption refrigeration machine powered by solar collectors. The heat transformer allows to increase the temperature of the heat taken from the collectors to improve the efficiency of the refrigeration machine (Fig.2). Such combination might be a valid solution because it exploits the heat generated through a free energy source that is the sun, with a low environmental impact devoid of any CO2 emissions.

Nomenclature

A	absorber;
AR	absorption refrigerator;
C	condenser;
E	evaporator;
G	generator;
HT	heat transformer;
R	refrigerator fluid (H2O);
S	solution = refrigerator fluid (H2O) + absorbent salt (LiBr).
T_A	temperature absorber;
T_C	temperature condenser;
T_E	temperature evaporator;
T_G	temperature generator;
P	pressure;
x	concentration of fluid;
g	mass flow;
$r(T)$	refrigerator transformation heat;
$s(x,T)$	differential heat of solution;
m	g_s/g_r;
c_{PS}	specific heat of the solution;
c_{PR}	specific heat of the refrigerator;
L_{Ps}	solution pump work;
L_{Pr}	refrigerator pump work;
v	vapor
l	liquid

1.2 .Potential for solar air conditioning:

As of 2000 to 2008, the worldwide installed capacity of solar heating and cooling system increased globally growing with an average of 20.1annually.analyst Inc .announced that the global air conditioning market will reach 137.8 million units by 2020 driven mainly by global warming, rising standards of living and urbanization. According to a report published by BSRIA Inc. the world air conditioning market continued to expand in 2014 compared to previous years.it has reached US $97.7billin in value, an increase of up to 7%compared to 2013.

1.3 .Solar air conditioning market: UNEP reported that 789.6 million m2 of solar heat capacity was installed by end 2015 compared to 77.3 million m in 2012.data collected from 58 countries including Europe, north America ,Brazil, South Africa, India, China ,and Australia indicate that 95% of the solar thermal market is installed in these countries. Globally solar thermal accounts for about 1.2% of water and space heating in building. According to Yang 2012china has 57.6% of the world`s record solar heating and cooling capacity with 21.7 GWth of new installations which makes p 74.6% of the solar heating and cooling market in the world.

1.4. Local solar irradiance

Conventional heating and cooling systems are responsible for large amounts of carbon dioxide release to the environment as well as for the use of harmful refrigerants the greenhouse effect and the ozone depletion potential. Solar radiation is a clean form of energy, which is required for almost all natural processes 0n renewable energy sources in South Africa is vast whereas solar irradiance offers considerable potential.

The sun is approximately 1.4 million km in diameter and 150 million km from the earth.it has a surface temperature close to 5500 c and it emits radiation at a rate of 3.8xkw per second on an average daily basis. Most areas in south Africa average more than 2500 hours of sunshine per year and the average solar radiation averages at 150w/m for USA and 100 w/m for Europe compared to 220 w/m day for south Africa .this this makes south Africa’s local resource one of the highest in the world.

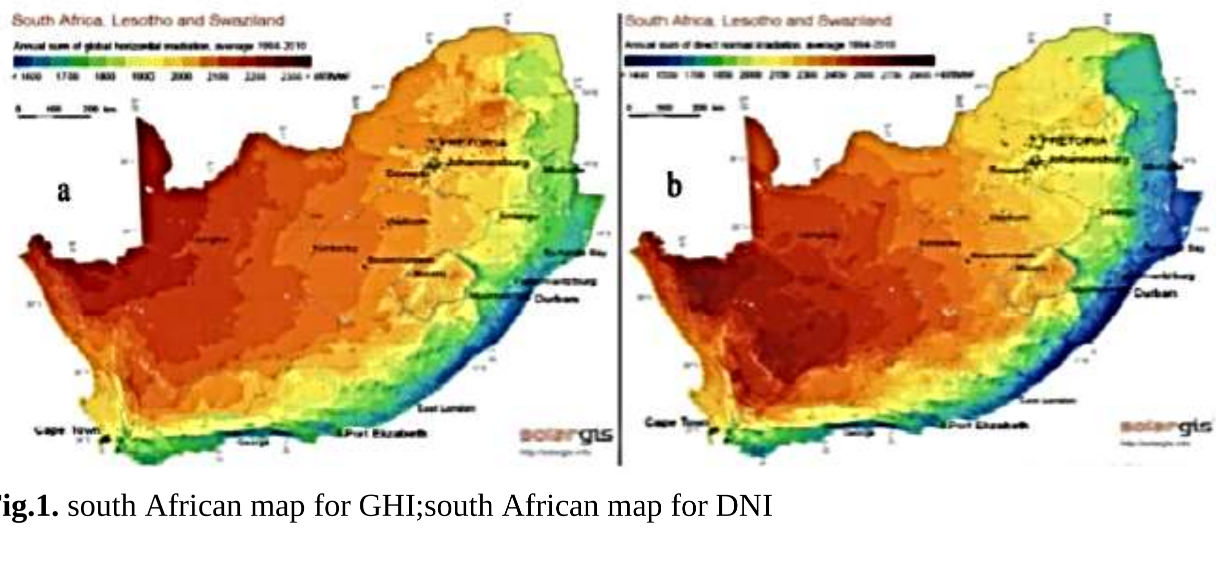

Fig.1. south African map for GHI;south African map for DNI

2. LITERATURE REVIEW

Gugulothu et al. (1) investigated the feasibility of solar powered air conditioning and in their observation they highlighted that solar energy needs. The main motivation for solar cooling is the substitution of electricity as the premium energy sources for air conditioning system by renewable heat source, i.e. low grade heat from solar collectors

Solar cooling is a good example of addressing climate changes

Jiun Hao and GhaffarianHosseini(3)installed400units of traditional air conditioning and 400nits of solar air conditioning at Limkokwing University of creative Technology ,Cybrjava,Malasia and compared the saving and performance. The results revealed that not only the application of solar air conditioning systems result in reduction of energy consumption and greenhouse gas

emissions but, the investment capital required for the new solar air conditioning systems can be recovered after a short period of time.

Badran et al. (6) performed a comparison and analyses of solar thermal and solar photovoltaic air system for two single family houses in two different locations and climates in Egypt (Aswan and Aquaba Jordan) Three scenarios were compared :thermal air conditioning

With storage (absorption chiller), Photo vocalic air conditioning without storage and photo vocalic air conditioning with storage.

Mousa et l. (14) conducted a survey on energy consumption in buildings in Jordan and the results indicated that 61% of energy consumption was used for space heating and 76.8% energy savings were achievable when polystyrene insulation for both wall and roof were used

Nkwetta et al.(15) conducted review of theoretical and experimental methods of powering solar air conditioning early design stage to select optima systems before fabrication and experimental analysis and system performance predication will further reduce cost and time. the major driven force reported from the experimental evaluation of single components and whole systems lies in the selection and optimization of the right collector type to provide the needed generator input temperatures and still be cost effective

Henning(27) performed are view and established that about70 solar _assisted air conditioning systems at the time were installed in Europe. The conclusion was that this is a clean indication that this technology is still in an early stage of development. Almost no standardized design guidelines exist and there is still a lack regarding common practices for design and construction. Furthermore in some cases the expected energy savings could not be achieved in practice

Ma et al.(28)studied the performance of a hybrid air conditioning system, which consists of vapor compression desiccant dehumidification and adsorption refrigeration. The results show that the performance of this system is 44.5% higher than conventional vapor compression refrigeration system at a latent load of 30% and the improvement can be achieved by 73.8% at a42% latent load.

Ha(29) addressed the modeling and control problem of a fully developed hybrid solar assisted ,split system air conditioner to target energy saving in buildings the system was fully instrumented to examine its performance under different operation conditions and modeling validated by extensive experimental tests. The experimental results obtained demonstrated higher system efficiency.

Fu et al. designed a photovoltaic solar-assisted heat-pump system to investigate both actual demand and energy savings .The energy and energy analyses were used to investigate the total performance of the system. The results showed that the photovoltaic system could reach a daily average energy efficiency of 61.1-82.1% and an energy efficiency of 8.3-9.1%

when operating in the solar-assisted heat-pump mode. The daily average heat-pump coefficient of performance could reach 4.01 when solar radiation was strong.

Chen developed a novel method for the rational selection of coincident solar irradiance, and drybulb and wet-bulb temperatures. The results indicated that traditional design solar irradiance, dry-bulb and wet-bulb temperatures may be significantly overestimated in many conditions. The new method allows engineers to determine the peak cooling load directly without the need for calculating 24-hour cooling loads on one design day for every month of the year. This greatly simplifies the design cooling load calculation.

Tork studied the performance of a solar air conditioning system based on adsorption chiller operated by hot water produced by a field of flat plate solar collectors of 59 m2 area under joranian climate. The experimental analysis was conducted using monitoring devices for five days and theoretically using TRNSYS simulation software. The experimental results indicated that the system operates with an average thermal and electrical coefficient of performance (COP) during the experimentation days of May and June 2014 of 0.33 and 2.1 respectively.

Abbasi et al. conducted an investigation on the performance of aground source heat pump that is coupled with a photovoltaic system to provide cooling and heating demands of a residential building with no energy source. The results show that utilization of this hybrid system can reduce CO2 emissions by almost 70 tons per year.

Baniyounes et al. conducted a feasibility study to assess a solar assisted air conditioning system for an office building under three of Queensland's subtropical climates. The results of analysis proposed indicated that 80% of the primary energy savings can be achieved by installing 50 m2 of solar collectors and 1.8 m3 of hot water's storage tank under the three selected climates.

Daut et al. studied and constructed a direct current air conditioning system integrated with photovoltaic system which consisted of photovoltaic panels, solar and can be used in nonelectrified areas. The results indicated that the photovoltaic air conditioning storage and require less storage to cover the same amount of cooling load.

Zawilskaet al. in Durban, investigated the sustainability and availability of solar irradiance in order to quantify the solar resource available to the city of Durban, in order to reduce its dependence on fossil fuel-based energy sources and obtained indicated a direct normal radiation of 5.25 kWh/m2/day in summer and 4.94 kWh/m2/day in winter. These results confirmed Durban's solar resource potential which remains to be exploited.

3. THE SYSTEM SUGGESTED

The solution here suggested is formed by evacuated tube solar collectors powering a heat transformer and an absorption refrigeration machine. The heat transformer, powered by solar collectors, while increasing the temperature of the fluid, improves the efficiency of the absorption refrigeration machine which in turn powers the air-conditioning system. The evacuated tube solar collectors allow to have higher temperatures than traditional glass panels. The temperature of the fluid in output was set to 75°C. Fig. 1 and Fig. 2 report the diagram of the system suggested and the functioning conditions of each component of the machine. The absorption systems work with water and lithium bromide.

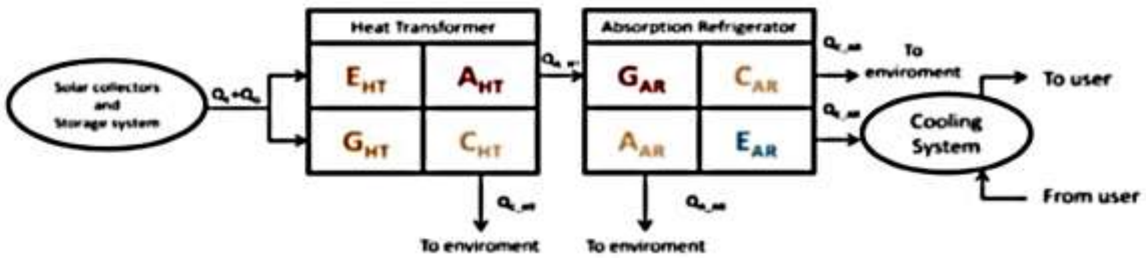

Fig.2. Functional diagram of the air-conditioning system during the summer in low-density residential buildings located in hot climate

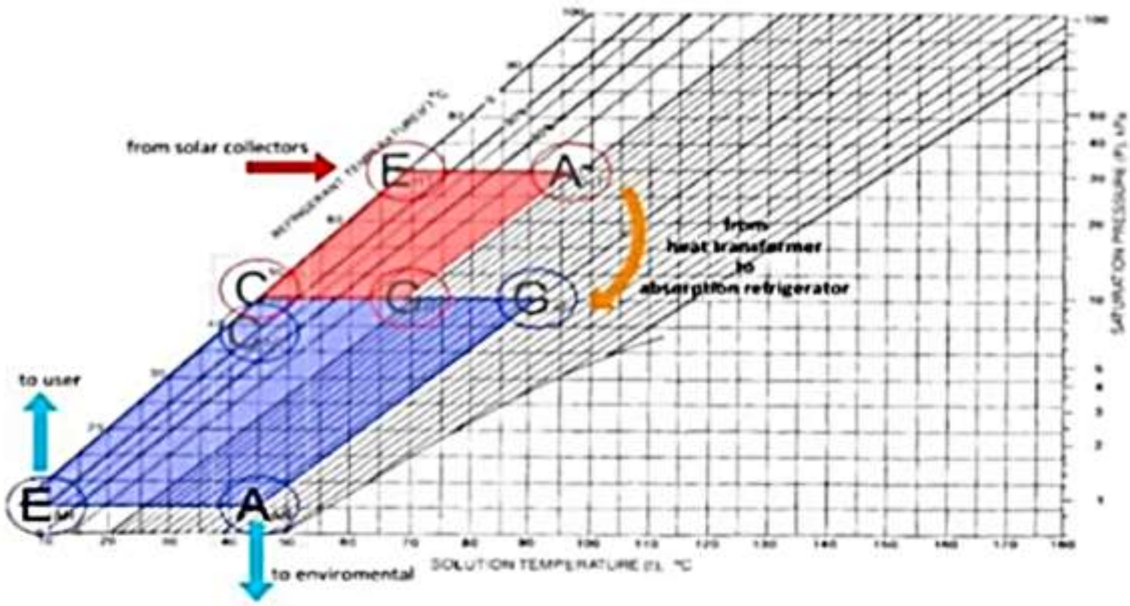

Fig.3. Functioning conditions of each component of the machine here sugested

The heat transformer is a machine whose functioning conditions depend on the chemical-physical properties of some absorbent-refrigerant solutions. While functioning the heat Q will be transferred from a temperature T1 to a temperature T2 (T2>T1). In the system suggested it collects thermal energy from the solar collectors and increases the energy quality (hence the temperature) of part of the heat provided by the absorber "AHT". In this way, it is possible to power an absorption refrigeration machine that otherwise it would have not functioned if it was directly powered by the collectors. The coefficient of performance of a heat transformer, that is the ratio between the thermal output of the absorber and the total energy provided to the machine, is:

$$COP = \frac{Q_{A_{HT}}}{Q_{G_{HT}} + Q_{E_{HT}} + L_{PS} + L_{PR}} \tag{1}$$

$$Q_{A_{HT}} = r(T_A) + s(x_A, T_A) - m \cdot c_{PS}(T_A - T_C)(1-\alpha) - c_{PR.v}(T_A - T_E) \tag{2}$$

$$Q_{G_{HT}} = r(T_G) + s(x_G, T_G) - \alpha \cdot m \cdot c_{PS}(T_A - T_G) \tag{3}$$

$$Q_{E_{HT}} = r(T_E) + c_{PR.l}(T_E - T_C) - \alpha \cdot m \cdot c_{PR.v}(T_G - T_C) \tag{4}$$

$$L_{Ps} = \frac{m \cdot \gamma_S(P_A - P_G)}{\eta_p} \tag{5}$$

$$L_{Pr} = \frac{g_r \cdot \gamma_{Rl}(P_E - P_C)}{\eta_p} \tag{6}$$

For what concerns the air -conditioning in the building, the heat transformer will be connected to an absorption refrigeration machine. As the heat transformer, the machine exploits the thermophysical properties of an absorbent refrigerant solution, though presenting a different configuration of its components; this allows the refrigeration of the thermal vector fluid of the hydronic system of the building. The heat with a high temperature will be transferred from the absorber “ATC” of the heat transformer to the generator “GMF” of the refrigeration machine. Thanks to the energy provided, it is possible to have through the evaporator “EMF” cold water whose temperatures are compatible with the cooling of domestic environments, realizing degraded heat (with room temperature) into both the condenser “CMF” and the absorber “AMF”. Through the evaporator of the refrigeration machine “EMF” the refrigerated fluid will be provided to a hydronic system which guarantees the air-conditioning in the building when it is hot.The coefficient of performance of an absorption refrigeration machine, that is the ratio between the thermal output of the evaporator and the overall energy provided to the machine, is:

$$COP = \frac{Q_{E_{AR}}}{Q_{G_{AR}} + L_{PS}} \tag{7}$$

$$Q_{E_{AR}} = r(T_E) + c_{PRl}(T_E - T_C) \tag{8}$$

$$Q_{G_{AR}} = r(T_G) + s(x_G, T_G) - [m(1-\alpha) + \alpha] \cdot c_{PS}(T_A - T_G) \tag{9}$$

$$L_{Ps} = \frac{m \cdot \gamma_S(P_A - P_G)}{\eta_p} \tag{10}$$

It was assumed a difference of 5°C for every heat exchanger used among the components of the system here suggested. The system examined requires electrical energy just for the circulator pumps to make the fluids flow into the system. The configuration of the system can be easily applied in those environments characterized by a good solar radiation during the summer and in all those urban contexts where the population lives in low density houses with outdoor environments able to have solar collectors. Moreover, to have an efficient system the heat fluxes exchanged between the building and the outside must decrease, in this way the thermal power of the system will be reduced. This is possible if the building is properly planned while complying with the transmittance set by the regulations. In this study, to evaluate the feasibility of the system suggested, the energy required for the cooling of small single family buildings (located in the north, center and south of Italy with different climatic conditions) was examined keeping in mind the current regulations . 4. Dimensioning of the components of the system and the area of the solar collectors.

The system was dimensioned while taking into consideration the maximum thermal power required to cool the indoor environment. In particular, it was possible to determine the maximum thermal power exchanged among the different parts forming the heat transformer (HT) and the absorption refrigeration machine (ARM). Moreover, the surface of the solar panels was also dimensioned together with the volume of the storage system during summer (April - October). Tab. 1 reports briefly the planning specifications concerning the HT, AR and solar collectors.

Table 1. Solar tube collectors area necessary to cool the buildings during the summer in each city examined, volume of the storage system and thermal power of the components of the heat transformer and absorption refrigeration machine.

				Absorption refrigeration machine		Heat transformer		
City	Maximum thermal power [kW]	Solar collectors area m^2	Volume of the storage system m^3	Power of the generator [kW]	Power of the evaporator [kW]	Power of the generator [kW]	Power of the evaporator [kW]	Power of the absorber [kW]
Milan	1.81	4.7	0.55	2.05	1.81	2.09	2.06	2.05
Naples	2.17	3.85	0.2	2.45	2.17	2.51	2.47	2.45
Palermo	2.18	3.25	0.2	2.47	2.18	2.52	2.49	2.47
Pisa	2.01	3.5	0.25	2.27	2.01	2.42	2.29	2.27
Rome	2.00	3.45	0.2	2.26	2.00	2.31	2.28	2.26

4. ENERGY ANALYSIS OF THE SYSTEM ACCORDING TO DIFFERENT CLIMATIC CONDITIONS

The energy required to cool an environment considered was examined thanks to the annual simulations in a dynamic regime. It was evaluated the amount of electrical energy necessary if a heat pump had to cool the indoor environment (Table 2) with a variable COP according to the temperatures of the condenser.

Table 2. Annual CO_2 non-emitted in the environment in the case study, annual thermal energy required by the building and annual electrical energy consumed.

City	Carbon dioxide tonne/year	$E_{building}$ [kWh/year]	$E_{electric}$ [kWh/year]
Milan	0.18	1,525.9	508.6
Naples	0.44	4,081.3	1,236.7
Palermo	0.6	5,818.1	1,711.2
Pisa	0.31	2,751.7	887.6
Rome	0.36	3293.5	1029.2

In order to estimate the amount of carbon dioxide and other gases damaging the environment, it was used the emission coefficient (mass of CO2 for every kWh consumed); such coefficient, in Italy, is 0.3524 kgCO2/kWh [2426]. Table 2 reports the amount of gas that, thanks to the system suggested, was not emitted into the atmosphere, since traditional systems powered by electrical energy were not installed. 6. Economic feasibility: installation and energy costs

The commercial price of the system suggested depends on the price of the solar collectors and in particular on the price of the machine formed by the combination of the heat transformer and the absorption refrigeration machine once it will be available on the market. After the quantification of the investment cost, it can be assessed the return on the investment of the different system solutions:

(B): exertion of the solution here suggested. In order to be able to compare these systems, it was taken as a reference point the costs of the low-voltage electrical energy (€/kWh) according to the national markets [27-29] (Italy: 0,1 €/kWh) together with the cost of the devices and the labour according to the official regional price list [30]. For what concerns solution (a) it was used an autonomous multiple air-conditioning unit characterized by a highly efficient rotary hermetic compressor, thermal exchange battery and helicoidally fan. The cost of the functioning system is 4,400.00 €, this price includes installation costs and does not take into consideration exertion costs determined by the electrical energy used.

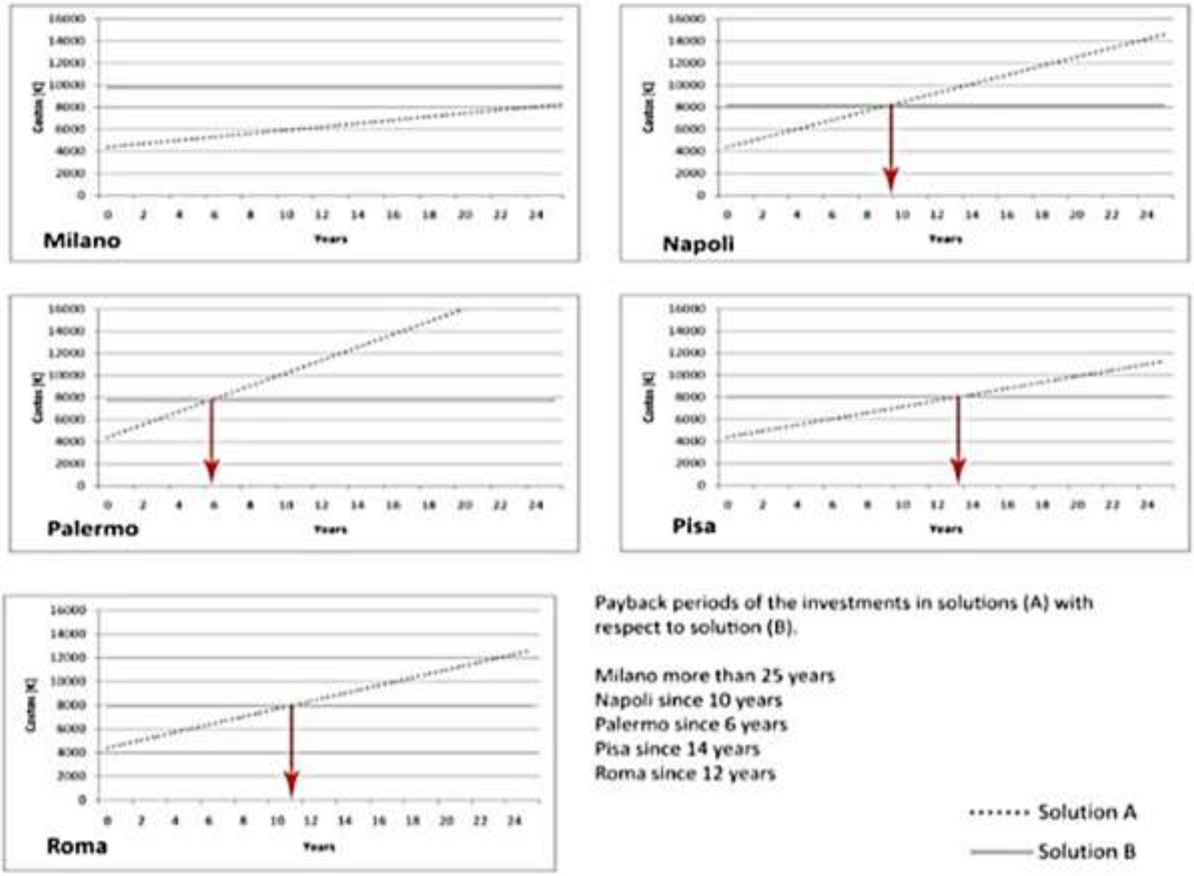

Fig.4. Payback periods of the investments in solutions (A) with respect to solution (B).

For what concerns solution (b) the cost of the solar collectors together with the storage system (including installation costs) were evaluated. A maximum cost of the machinery here suggested was assessed. The cost of the solar collectors and their installation, while considering the regional price list [30], is 650 €/m2. On the other hand, for the storage, the regional price list reports 3,11 €/liters. The machine here suggested, formed by a heat transformer and an absorption refrigeration machine, not being on the market, was assumed to have a maximum cost of 5,000 €. For both solutions, the cost of the distribution system inside the building was not estimated. The return on investment is reported in Fig. 4. The solution can be considered advantageous if the return on investment, with respect to a traditional system, does not exceed 20 years. While observing Fig.4 it can be noticed that it is not possible to have an amortization of the solution (b) in every city examined. In Milan, whose climatic zone is E [23], the solution suggested is not advantageous because the amortization period exceeds 20 years. Solution (b), though presenting higher installation costs than solution (a), during the exertion does not present extra energy expenses, since it exploits the solar energy to make them function. They do not depend on the national electrical grid being a zero-carbon dioxide emissions solution.

7. Conclusion

It is evident from literature that extensive work is being conducted around the world to investigate the feasibility of solar air conditioning. More countries are taking steps to exploit renewable energy than ever before. The availability of sunshine all year round makes it easier to be captured all over the world.it has been established that the air conditioning market is currently in an unsustainable situation and solar cooling technologies are emerging. Systems are known to use natural refrigerants which are not harmful to the environment. it can be concluded that solar cooling and heating is a suitable and sustainable alternative to lower electricity consumption reduce dependence on fossil sources and to save greenhouse gas emissions also the solution suggested, in order to achieve a thermal comfort in low-density residential buildings, without weighing on the exhaustible energy sources, is characterized by absorption machines exploiting absorbent-refrigerant solutions (H2O and LiBr) for the refrigerant production (absorption refrigeration machines) or to ennoble, thermally speaking, part of the energy they use (heat exchangers). This study suggests a machine that thanks to the combination of these characteristics can exploit the solar heat to air-condition small residential buildings. What has been showed was the possibility to have a proper powering system, through solar collectors and storage systems, of these thermal machines. Future scenarios might extend this study to the functioning of the system during winter while using heat exchangers to increase the temperature of the fluid provided by solar collectors to power a heating system.

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