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SOLAR COOLING AND NATURAL VENTILATION INVESTMENT PAYBACK

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Abstract: *The methods described in the article are part of two different categories, absorption heat pump using solar radiation fit into the category of using renewable energy sources and natural ventilation fall in the category of reducing energy consumption for cooling rooms and for reducing the pollutant in the rooms. Both increase the energy performance of buildings and installations. Therefore they are suitable for a complementary function. If at first, the initial investment seems high, its depreciation is in a reasonable time period. Of course the use of the two systems creates a high environmental comfort and can be used in almost all types of buildings.*

Key words: *solar absorption heat pump, natural ventilation.*

1. Introduction

Energy efficiency is not going without it is about getting more for your money and stopping the waste.[6] It is also about lowering the CO_2 emissions which have an important contribution in global warming.

This paper presents a comparative study concerning an absorption heat pump (AHP) on one hand and a traditional system based on a fuel gas boiler (GB) and conventional equipment i.e. a mechanical compression heat pump (MCHP) on the other hand.

The AHP is covering both the heating and the cooling needs in contrast with the traditional system which uses GB based on fuel gas for heating only and MCHP for cooling only. We will evaluate both AHP: first the gas-fired and second the solar absorption heat pump (SAHP) operating with heat from solar panels. Demand for cooling in non-production buildings often coincides with the peak of solar irradiation.

According to European current regulations EN 15251(indoor environmental quality-IEQ) and EN 13779(indoor air quality-IAQ) an interior equipment for fresh air is necessary to support the comfort and health of the occupants. The referenced system is a mechanical one consisting of supply and exhaust-fans with heat recovery. This system is compared with an organized natural ventilation system being composed of grilles with adjustable dampers depending on humidity and CO_2 emissions plus wind towers placed at the top of the building.

2. Systems Description

Because of the need to improve the air quality inside a building and to respect the

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new regulations regarding energy consumption people refocused on two known solution as natural ventilation and absorption cooling/heating machines.

2.1. Natural ventilation

The main objective of ventilation is to replace the polluted indoor air with the fresh outdoor air containing a reduce concentration of carbon dioxide CO_2 which is an important indicator of IAQ.

Ventilation is necessary for a proper indoor air quality and also at some rates for cooling, reducing the energy consumption for air conditioning.

If mechanical ventilation is a controlled one trough the fan power that moves the air in the building, natural ventilation is done by the natural forces like wind, pressure/temperature difference, buoyancy.

Natural ventilation can be a controlled-one or not.

To avoid energy wasting and uncomfortable indoor conditions the uncontrolled natural ventilation i.e. infiltration and random leakages must be limited. If in new airtight buildings air changes per hour through infiltrations can be around 0.1 - 0.2 the ACH in old buildings can be around 2 - 3 ACH [1].

Fresh air ventilation rates (FAVR) provide human comfort and health through removing odour, contaminants and respiration products also excessive heat and humidity.

FAVR have been changed through the last century from 14 l/s/person at the beginning of the 20 century to about 5 l/s/person for more than 50 years from 1936 to 1996 and now to about 10 l/s/person (36m^3/h/person) [2].

Natural ventilation is the result of pressure difference in the building caused by wind- cross or sided ventilation, Figure 1, or by temperature - stack effect, Figure 2.

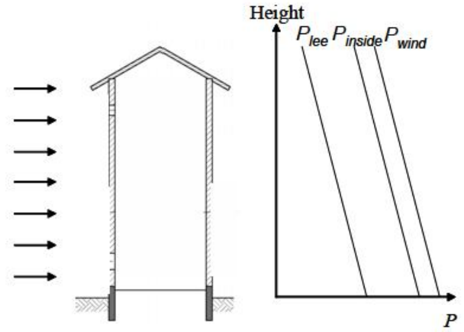

Fig. 1. *Pressure difference caused by wind [7]*

When stack and wind pressure act simultaneously on a building, their combination will determine the air flow through the building openings.

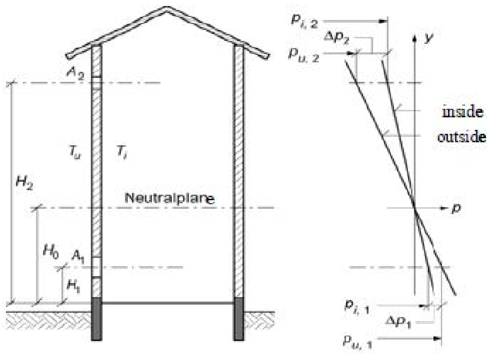

Fig. 2. *Pressure difference caused by buoyancy [7]*

The total driving force ΔP is the sum of the driving forces induced by buoyancy (P_t) and wind (P_w)[6]:

$$\Delta P = P_t + P_w \qquad (1)$$

In our study we considered the combined effect of the wind and temperature for organised natural ventilation (ONV). Fresh air is provided by grilles in the walls and for exhaust air are used penthouse turrets. The grilles and turrets are also fitted with dampers controlled by humidity, CO_2 and temperature sensors which can be overwritten by the program schedule controller. Fresh air grilles are provided in the living, bedrooms and kitchen and the penthouse turrets are connected to bathrooms and separately to kitchen.

Mechanical ventilation (MV) system proposed for the study is a classical one composed from grilles for intake and exhaust, piping, dampers and ventilation equipment composed of fans, coils and a heat recovery. As natural ventilation, fresh air will be supplied to bedrooms, living, kitchen and exhaust air will be from kitchen and bathrooms.

2.2. Absorption heat pump and solar absorption heat pump

In order to evaluate the potential of solar energy for the different solar cooling systems, a classification has been made by the scientists Best and Ortega (1998). It is based on the two main concepts – solar thermal technologies for the conversion of solar heat into hot water and the solar cooling technologies for the cold production.[3]

The solar thermal technologies are:

- Flat plate collectors
- Evacuated tube collectors
- Stationary, non-imaging concentrating collectors
- Dish type concentrating collectors
- Linear focusing concentrators
- Solar pond
- Photovoltaic

The solar cooling technologies are mainly classified into two main groups depending on the energy supply: a thermal/work driven system and electricity (Photovoltaic) driven system. [3] Each group can be classified as the following:

1. Thermal/work driven system
    - Absorption refrigeration cycle, Figure 3
    - Adsorption refrigeration cycle
    - Chemical reaction refrigeration cycle
    - Desiccant cooling cycle
    - Ejector refrigeration cycle
2. Electricity (Photovoltaic) driven system
    - Vapour compression refrigeration cycle
    - Thermo-electric refrigeration cycle
    - Stirling refrigeration cycle

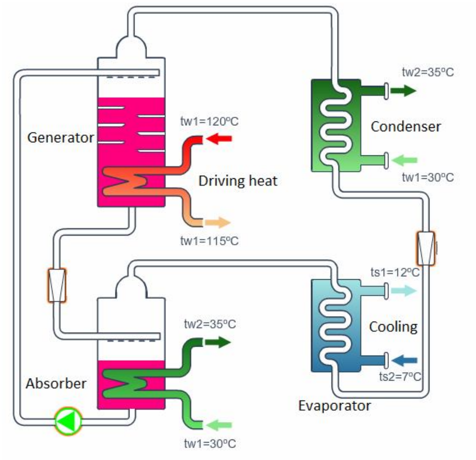

Fig. 3. *Absorption heat pump-cooling [10]*

The solar-powered cooling system, Figure 4, generally comprises three main parts: the solar energy conversion equipment, the refrigeration system, and the consumer.

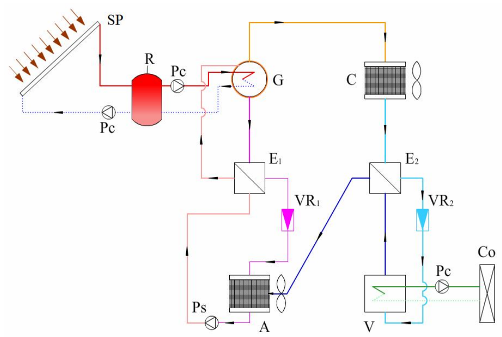

Fig. 4. *Solar cooling [10]*

An absorption heat pump uses heat as driving energy, as compared to vapour compression chiller (VCC) that use electricity. For a solar absorption cooling system, this heat is taken from sun energy. Vapour compression chillier are the most commonly used chiller type in the world today. Apparently the absorption cooling (single effect) has a lower coefficient of performance, COP, somewhere between 0.6 - 0.8 according to literature compared to that of vapour compression equipment, which is in the range of 2 and 5. But the general conversion factor for electricity about 0.36 leads to a final efficiency of the compression systems very closed to the one specific for absorption equipment. Considering the CO_2 emissions and refrigerants, solar absorption cooling machine is friendlier environmentally. Using solar energy or heat waste the consumption of electricity will be reduced that makes the technology desirable.

The difference between solar absorption air-conditioning and traditional fossil fuel fired unit is that energy supplied to the generator is from solar collector units. The heat from the sun can be used directly to the absorption machine or can be first stored in a thermal storage tank and then used in absorption machine. Due to intermittent nature of solar energy, it is a better option to use a thermal storage tank to store this heat first. This serves two purposes: first the intermittent nature of solar energy can be overcome; second the stored heat can be utilized in night time when sun is not available. In case hot water storage tank is not available, a buffer tank of suitable capacity is recommended. The second option is to use a chilled water thermal energy storage tank. In this case absorption chiller that matches with the peak solar energy available is used and chilled water is produced for off-peak loads [4].

For our study we provided AHP gas fired for the first alternative to classical system for heating and cooling and SAHP with tank storage for heat and cold water plus solar collectors for the second alternative.

3. Energy Price of Solutions, Investment Costs and Utilization

In the comparative study the start point was the energy classification scales based on specific annual energy consumption. In the temperate climate of Romania domestic heating costs prevails over cooling and ventilation but as mentioned above for normal indoor climate quality we need heating, ventilation and cooling. Therefore the energy performance of air conditioning systems need to be studied overall: heating, ventilation and cooling.

The simulated calculation assumes that the building system analysed is part of group B energy classifications scales namely in the middle. It is hoped that all of the new buildings that will be constructed in the current period to fall into this class from the point of view of energy consumption. Thus we have 93.5 kWh/m²year for heating, 35 kWh/m²year for cooling and 6.5 kWh/m²year for ventilation [8-9]. Because the first simulation for an area of about 100 square meters of the building resulted in a payback period of about 30 years we continued analysis for other surfaces, until 1500 square meters. Following graphs will present each step in assessing the payback period.

First step is calculating the price for each kWh of energy obtained by different system analysed. As can be seen in Figure 5, the kWh for cooling or heating, produced by AHP and SAHP is lower than the one produced by conventional boiler because of the extra energy brought from the air. So are prices for cooling.

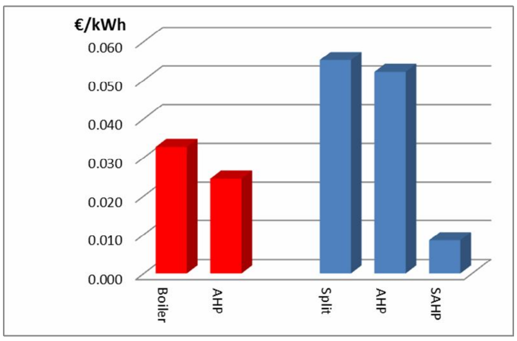

Fig. 5. *Price per kWh obtained by different systems*

Sure the price for kWh of the AHP is not so low than the Split one, but the same system can be used in winter also with good performance.

After that of course we calculated the cost of investment and the cost of utilization for all systems seen in Figures 6 and 7.

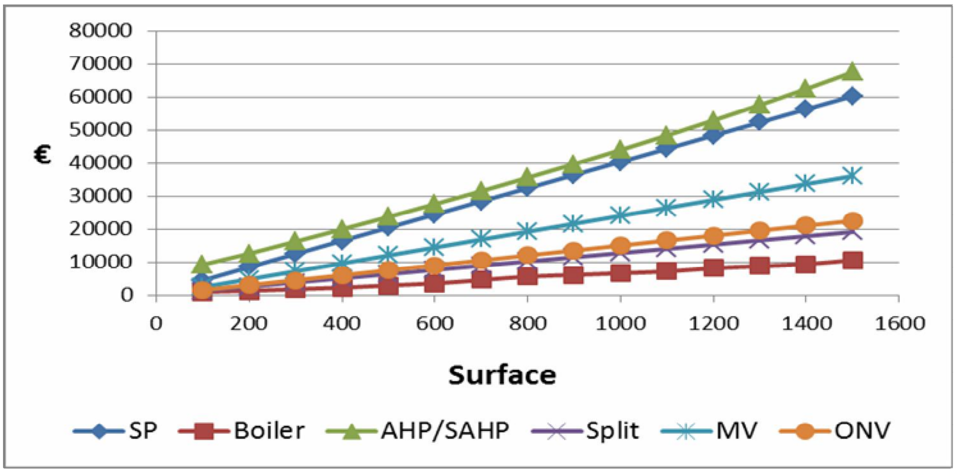

Fig. 6. *Costs of investments*

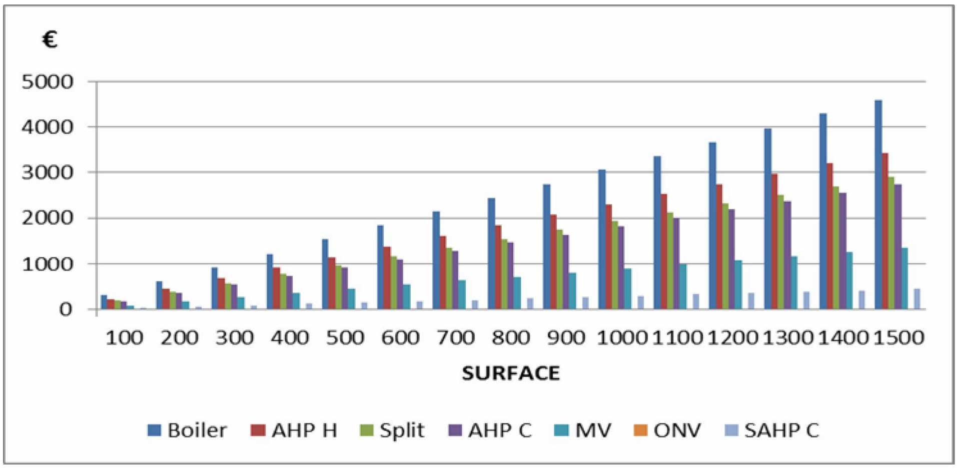

Fig. 7. *Costs of utilization*

Because of the higher price of boiler energy produced the cost for utilization will be the highest of them all, cost for natural organized ventilation nearly zero and the cost for SAHP for cooling is also very small because we use free energy from the sun. To compare the alternatives proposed for study must know the investment and operating costs by type of variant: the classic V1 – boiler, split and MV, V2 - AHP and ONV, V3 – SAHP, solar panels (SP) and ONV. They are presented in Figures 8 and 9.

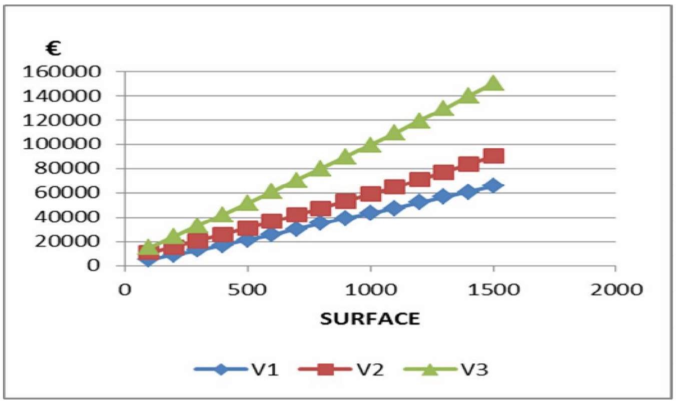

Fig. 8. *Costs of investments by variant*

Sure can be seeing that solar heat pumps are the most expensive ones because of the solar panels needed that can be an impediment in the investment of the beneficiary. To assess costs and consumption have considered the following: boiler performance 0.9, AHP for heating 1.5 COP and for cooling 0.6 and for split 2.5. Price for gas is 0.305 €/Nmc and 0.138 €/kWh [11]. Prices for equipment's are price list ones taken from different producers and making an average.

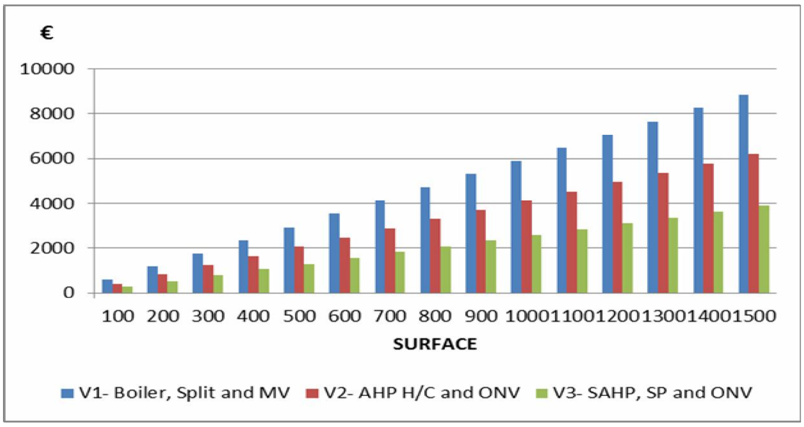

Fig. 9. *Costs of utilization by variant*

4. Payback Period

Sure that solar heat pump are the most expensive ones because of the solar panels needed as specified before but the principle they used make them a competitive selection for the beneficiary who wants to be in compliance with the new regulation and to protect our climate. In the Figure 10 is presented the payback period for the alternatives to boiler and split system completed by mechanical ventilation.

Because of the use of free energy from the sun the payback period for system composed from SAHP with solar panels and ONV is shorter but we have to say that such a system must have also a heat source for winter which increases the price of investment. This source was not considered but the cost of using it was. To cover this omission we can say that it is covered more than necessary for gas and electricity price rises announced by the Memorandum taken by the Government on the phasing of regulated prices for natural gas that rise the price from 36% convergent price with import price of 100% convergent price. This result in a double price for 2018 compared with that in 2013. Figure 10 shows the history of the natural gas price for the period 2004-2013.

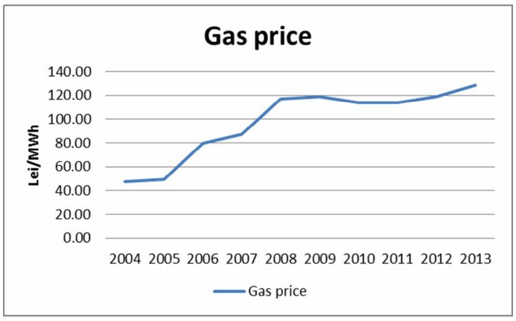

Fig. 10. *History of the natural gas price*

Small buildings have a bigger payback period because the price of small equipment is not proportional with the produced power as can be seen in Figure 11.

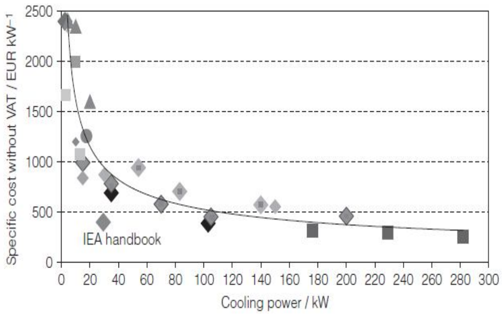

Fig. 11. *Investment costs of low-power thermal absorption chillers[5]*

Automation and small pieces of the equipment, assembling also might be the reasons that small one are more expensive than bigger equipment. Also the prices for the installation decrease with the amount of work for installation that can be see also in the Figure 12.

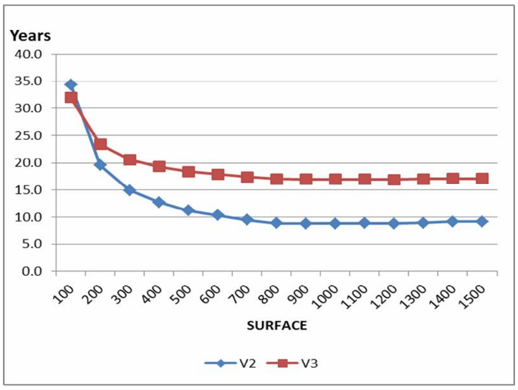

Fig. 12. *Payback period*

5. Conclusion

An efficient energy building is one with low energy consumption but with good quality environment.

High protection of the environment is done due to the energy used and the refrigerants, NH_3-H_2O, which have zero ODP and GWP thus protecting the ozone layer and does not contribute to global warming as chloro- fluorocarbons.

SAHP energy saving potential seen in the exploitation costs is from to 15% to 40% compared with to the conventional vapour compression chiller system - Split.

SAHP will be a better solution for cooling in the future because of the rising prices announces for fossil fuels and the return payback will be shorter. Also SAHP shall become a cheaper solution with the more research and manufacturer of smaller equipment in mass productions.

Also innovation in solar collector making them cheaper and more effective it will add to the reason for using SAHP.

Owing to the fact that there is always enough roof area to install solar collectors, solar-powered integrated energy systems are capable of supplying cooling, heating, and hot water supply. For the purpose of all-weather operation, it is necessary to install auxiliary heat sources to supplement solar-powered cooling systems.

By using a thermal energy storage tank with solar cooling, an integrated solution for 24 hrs. cooling can be provided.

A SAHP is a complex, dynamic system and it is difficult to predict with any certainty the annual energy saving, and therefore, the return on investment. This uncertainty in system evaluation is a further obstacle to the wider application of solar cooling.

In order to improve the system design of a solar powered absorption air-conditioning system, a parametric study must be carried out to investigate the influence of key parameters on the overall system performance. If experiments were used to perform the parametric study, effects of one key parameter on the overall system performance would normally require several cooling seasons and hence, years to establish a conclusion [3].

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