NEW CONCEPT OF SOLAR AIR HEATER INTEGRATED IN THE BUILDING

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Abstract: We present a new solar air collector totally integrated in a shutter. The air is moved by a fan provided in electricity by a PV module, this air pass a first time in the cover then between the cover and the absorber, and is injected in the house, this solar shutter is reversible and can run in all positions, The concept of this new solar air heater is described in this article and the experiment is presented.

Key-words : Solar shutter, Heat demand, Simulation, Energy consumption, Parietodynamic envelope

1 Introduction

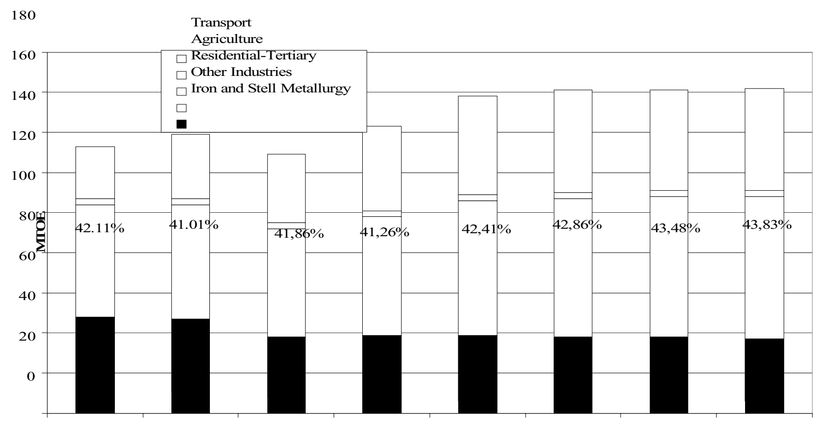
There's no doubt that the fossil energy resources of our Earth are being decreasing and that the strong economical development of the developing countries as China or India will increase the resources drop. In the other hand, it appears that the massive utilization of fossil fuels (and nuclear ones) endangers our Environment.

The part of the used energy for building is very important and hasn't stopped increasing; to limit or to reduce this building energy consumption, it is necessary to develop some actions concerning the rational energy management in parallel with the utilization of renewable energy sources. The decreasing of the energy consumption in its abode does not be realized to the detriment of the life quality of its occupiers and mainly of their health.

We present a new patented concept of solar air heater totally integrated in a shutter and able to produce with a total autonomy hot air from sun radiations and to introduce it inside the house. It allows conserving the integrity of the architecture of the house of the building.

1.1 Problems of the Energy Consumption in France

The residential and tertiary sector is the first energy consumer in France (Fig. 1) with 71 MTOE in 2006 [1] i.e. 43.83 % of the total final energy. The Green house gases produced bay this sector in 2000 are estimated at 119 MT of CO_2 (25% of the total emission). The part of the residential and tertiary sector stays stable (around 42-43%) but in absolute value, the energy consumed in this sector increase.



The total energy consumption of the building sector increased of about 50% during these twenty last years with a high penetration of electricity (+130%) which covers 40% of all the needs whose 50% for captive use as lighting, domestic appliances, etc ….)

The final consumption in the residential sector in 2002 corresponds to 452 TWh and 100 TWh for wood energy. The repartition of the consumption by type of use for a main home (i.e. 83% of the total of the housings) is : 69% for heating, 12% for specific use of the electricity, 11% for water heating and 7% for cooking.

Moreover, for housings built before 1975 (65% of the total of the housings), we can estimate that 50% have been thermally rehabilitated but it stays some energy economies to realize in these housing which have an energy consumption higher than in new buildings.

The final energy in the tertiary sector, with 29.2 MTOE increases of more than 25% in 15 years, is due particularly to the multiplication of specific uses of electricity as office automation and lighting. We note a high and increasing part of the energy in building of residential or tertiary type; the heating is the more energy consumer. Improving the energy efficiency in building is a research and development domain very important and has a very good future. The utilization of renewable energies to participate to the improvement of the energy efficiency in Building is very important. In France, the part of renewable sources in the energy production is always very low (Fig. 2).

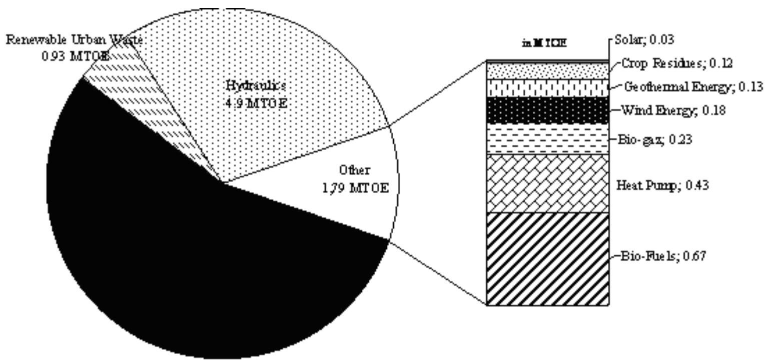


Figure 2: *Renewable energy production by type in France (2006) [1]*

1.2 The house of future

An Austrian study showed that the house of tomorrow must meet all following requirements [2-3]:

- the final or primary energy consumption must be low. Table 1 shows the objectives to reach for a low energy house and a passive house. These goals can be reach by:

- a decreasing of the heat losses by transmission (minimization of the exterior walls areas, improvement of the thermal insulation, ...);

- a reduction of heat losses by air conditioning (thermal envelop, re-heating of exterior air, …);

- an utilization of renewable energies;

- an utilization of high efficient appliances;

- the potable water consumption must be limited to 30 litres per day and per person. This objective can be reached by a used water recycling and the use of raining water;

- the polluting emissions in water, air and ground must be low;

- a high air quality must be reach by a total air replacement at least every three hours. The CO_2 concentration must stay under 1000 ppm.

- a high thermal quality can be obtained :

- when the air and the inside surface temperatures are between 18 and 22°C in winter and between 22 and 25°C in Summer;

- when the relative air humidity varies between 35 and 70% and when the absolute air humidity is under 12 g/kg.

- a high visual quality is reached when there are a sufficient day light and a sufficient direct lighting by the sun;

- a high acoustic comfort must be reach with a acoustic level less than 20 dB in life rooms;

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Table 1
Values to reach for the energy consumption of a low energy house and a passive house compared to an existing house in kWh/m² of inhabitable area. (Climate corresponding to 3500 ° day per year)

	Existing House before 1980	**Low Energy House**	**Passive House**
Heating Consumption	150-250	<40	<15
Final Energy Consumption		<70	<42
Primary Energy Consumption		<160	<120

Engineers and builders recognize more and more that build high energy efficient housings is a sensible, ethical, ecological idea and workable at medium and long-term. A lot of them think that innovation is an essential component of their job. But, if we observe the majority of recent or in process buildings, we note easily that the previous considerations are not taken into account when arrive the moment to concept or to build the house.

Often, we hear the ideas men say "we have a lot of good ideas, but we had not been able to realize them because it was not the good moment or because our clients did not want to apply them or because it is too expensive, too risky, …

To be an innovator it's to know how to put into practice or how to give concrete expression of its creativity. Introduce innovating and environmentally positive solutions are a difficult work. The obstacles are numerous and various: financial obstacles, technical obstacles, psychological obstacles, incompetent professionals or building standards too conservatives [4]

1.3 Thermal comfort, healthy inside atmosphere and energy savings

The ventilation is the process allowing to renew the inside air (polluted air) by an outside air (new and clean). Its function is to obtain, in an inside environment, good health, comfort and optimal productivity conditions for the human inhabitant. A good ventilation system should carry out three essential actions:

1) to supply an air with a sufficient quality for respiration in diluting the polluting substances existing in the inside environment;

2) to control the indoor humidity level;

3) to heat or cool the indoor spaces.

But using such ventilation has a double negative impact: creation of thermal losses and if it is not perfect, it may cause a discomfort due to a cold air-stream. From an energy point of view and taking into account the progressive increase of the building thermal insulation, the losses due to ventilation accounts for a more and more large part of the heating needs (up to 30%).

Primary, the various factors exposed before i.e. :

- increasing part of the residential sector in the total energy consumption;

- dominating part of the heating in the residential energy consumption;

- heating losses by ventilation being able to reach 30% of the thermal losses of the building, explain the interest to find efficient methods to reduce these losses in increasing the comfort of the occupants. Secondly, the objectives to reduce the utilization of fossil energies lead the architects to use more and more renewable energies in the building.

Thus these two observations conduce us to research new technical solutions, technological and/or architectural using renewable sources to reduce the thermal losses of houses by aeration and to add a complementary heat gain improving also the indoor environment quality for its occupants.

1.4 Brief analysis of existing solutions

The purpose of this paragraph is not to present precisely the various solutions to provide a hot and healthy air in the building, but to give some general considerations about these solutions, which are :

- Passive solar systems and buildings : bio-climatic design of building envelopes allowing to regulate the thermal behaviour of buildings by using natural means, without supplementary energy contribution. These system are walls or windows with parietodynamical effect; The principle of these ventilated opaque facades (walls) or translucent (windows) is to preheat fresh air by forcing it to circulate in one or two serial air gaps [5-8].

- Active systems : solar air collectors, the air is heated by a solar collector and injected in the house.

The advantages of a parietodynamic envelopes are to evacuate the heat during summer and to improve the comfort during winter limiting the heat losses. This solution induces adding costs and the installation must be realized perfectly. This solution can be only applied to new constructions and not to old ones, and this is a problem because the old buildings have always the worst energy performances.

Concerning the classical air solar collectors, the most important disadvantage is that they are not integrated in the building and their visual impact is negative.

These solutions are efficient but the aesthetic problem and the no-applicability of passive solutions to existing buildings limit their utilization. Thus, we developped a new solar collector with a good efficiency and without negative visual impact (perfectly integrated). It is applicable to existing and new buildings.

Between all the surfaces available in the house, excepted the walls, the only part with large available area is the shutters and we gave to them an active function. Our new concept of solar air collector have the following advantages :

- a new active function is added to the shutter;
- they can produce heat in all positions between open and closed thanks to their symetrical conception;
- the vertical inclination allow to produce more energy during winter and less during summer;
- it can be sized and produced for all the windows because each part of the shutter can be made-to-measure;
- the installation of these solar shutters are very easy for old (existing) and new houses. The old shutter must be replaced easily by a new solar one.
- The air is directly introduced into the house by a rotative air collector without costly and big air distribution systems
- the classical functions of the shutter are preserved : sound and thermal insulation and mechanical resistance;
- the solar air shutter is an autonomous heater because the fan is directly supplied by the PV modules integrated in the shutter and it can be used in remote areas;

But there are also two disadvantages : it is impractical to rolling shutters, the number of windows in the house implies the size of the heating system.

2 Presentation of the solar air shutter

The solar air shutter has the same aspect than a classical shutter (Fig.3.). The internal area is used as a heat converter and the frame can be built in various material (wood, aluminium, PVC). The heat converter is composed by a black aluminium absorber between two clear covers in extruded polycarbonate. This new solar air shutter is patented. This configuration allows not to use a thermal insulation area as in a classical solar collector.

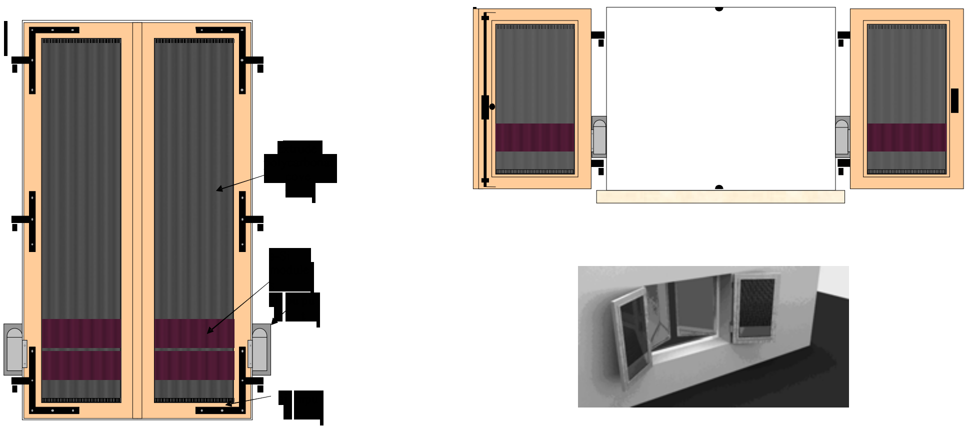

Figure 3: *The new solar air collector: the solar shutter*

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The air flow system is composed by a rotative part attached to the shutter, a fixed part including the fan embedded in the wall. A a-Si photovoltaic module is integrated in the low part of the shutter and allows to provide electricity to the fan via an electronic device specially conceived.

The air flows enter in the shutter by the lower part of the extruded polycarbonate cover as seen in Fig.4 and they pass at first into the extruded polycarbonate cover then the air flows are mixed and pass between the cover and the absorber; the total air flow is collected in the lower part of the shutter and is evacuated into the room by the slice of the shutter.

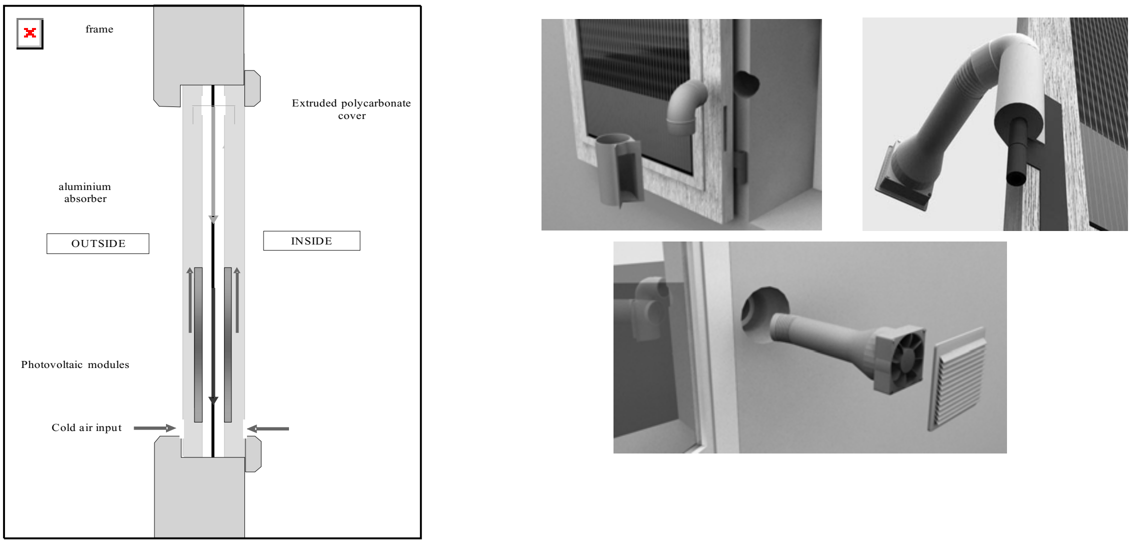

Fig. 4. *Principle of the new solar air shutter and the air collector: the rotating part on the shutter, the fixed part in the wall and a view of inside house*

This technique does not use a classical thermal insulation. More the air is heated more it penetrates into the solar collector and limits the conductive and convective losses towards the outside and the outside surfaces of the shutter are maintained the more cold possible limiting the heat losses with the ambient.

The advantage of the absence of a thermal insulation is a reduction of the thickness of the shutter and a low stagnation temperature reducing, during summer, the temperature of the shutter and the radiative exchanges between the shutter and the inside of the house. We can consider that it is a dynamical thermal insulation what it makes this solar collector unique and original. The air inputs are in the lower part of the shutter to avoid the rain to enter.

We chose a 3 mm cover in polycarbate because this material is well adapted [9], it is light, supple and solid and usable for temperatures up to 323 K, nowadays, it is treated against UV and guaranted 10 years before the ageing. In the solar air shutter, we use a double air flow and the absorptance of polycarbonate in IR radiation is near 90%, thus this cover participates strongly to the heat production.

The absorber is built in aluminium with a matt black coat of paint. It is not necessary to use a method to reduce the IR emmissivity of the absorber because the cover absorbs this type of radiation.

For the PV modules, we had some constraints : a power and a voltage adapted to the fan, a correct size to be able to be integrated in the shutter, a good aestheticism. Thus, we chose ASI® OEM Outdoor solar modules from Schott available in various power and easily to integrate [10].

2.1 The experimentation

We set up an experimentation with three objectives :

- to test the thermal and electrical behaviour of the solar shutter, to collect experimental data for various meteorological conditions and to measure its energy performances;
- to validate a thermal model that will be developped in a furture work;

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- to make adjustments necessary to improve the performances and the efficiency of the solar shutter.

We build an experimental wall with two window-openings able to receive two shutters for french windows and two shutters for classical windows (Fig. 5).

Figure 5: *The experimental wall*

The shutters are composed with a wood or aluminium frame (Fig. 6). One shutter for french-window is implemented with numerous temperature sensors to study more precisely the thermal behaviour of the the solar collector, for the three other ones, only some measures are realized to calculate energy performances.

Figure 6: *The experimentation: window shutter, French-window shutter, data acquisition system*

The meteorological data measured on the experimental wall are :

- the global solar radiations in a horizontal and vertical planes
- the diffuse radiation on horizontal plane
- the ambient temperature
- the air humidity
- the wind speed and direction

for each shutter are measured :

- the output air temperature
-

2.2 Perspectives

After having calibrated the sensors and determined the characteristic curves of the fan, we will be able to realize some experiments :

- experimentation with a constant flow rate (the PV modules will be replaced by a stabilized current generator);

- the output air humidity
- the air flow
- the voltage and current for each PV generator
- the temperature of the absorber
- the temperature of the extruded polycarbonate cover

for the french-window shutter, a lot of temperature sensors have been integrated in the collector (absorber, PV modules, cover) in various positions to follow the temperature evolution in the different parts of the shutter.

- research of the optimal flow rate for the best performance;
- determination of the thermal response time of the solar shutter;
- measure of the stagnation temperature;
- determination of the repartition of the air flow into the shutter (using an IR camera) and optimization of the

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repartition (adding some baffles in the air flow);

- estimation of the influence of the double- air flux (one in the sunny side and the other one in the shaded side).

The experimentation will be running in September 2008 and all the tests will be able to begin. In the same time, a thermal modelization of the solar shutter will be realized in view to analyse the behaviour of this new solar collector and to envisage the modifications to implement for a optimization of this solar shutter.

3 Simulation of the ”solar shutter”

We tried to study the thermal behavior of the solar shutter and the potential energy savings for heating, by using a dedicated environment tool, called TRNSYS (TRNsient System Simulation). Therefore, we selected a simple, one-storey, house (with a surface heated S=120 m^2 and a height H=3m), having the following geometric and thermal characteristics:

- one wall facing South, having the total surface $S_{wall,S}$ = 31.6 m^2 and containing two windows equipped each one with a solar shutter, and having the total surface $S_{windows,S}$ = 7 m^2;
- one wall facing East, having the total surface $S_{wall,E}$ = 31.6 m^2 and containing two windows equipped each one with a solar shutter, and having the total surface $S_{windows,E}$ = 5 m^2;
- one wall facing West, having the total surface $S_{wall,W}$ = 31.6 m^2 and containing two windows equipped each one with a solar shutter, and having the total surface $S_{windows,W}$ = 4 m^2;
- one wall facing North, having the total surface $S_{wall,W}$ = 31.6 m^2 and containing no windows;
- the global heat transfer coefficient of this house was taken G=0,9 W/m^3K;
- the total airflow infiltrated in the house is equivalent to 0,3 ach (airchanges/hour);

By simulating the thermal behavior of this house equipped with ”solar shutters”, we observed an increase of temperature of the air supplied by the shutters depending on the period with solar radiation incident on the shutter. In the figure 7 is depicted the evolution of both outside temperature (T_outside) and air supply temperature (T_air_supply) during a winter 2-days simulation period (in January).

This figure clearly outlines the role of the shutter in heating directly the fresh, outside air, and thus reducing the room heating load in winter period. The hours when the temperature of the air supplied is above the outside temperature correspond to the period when solar radiation occurs on this orientation (in this case, the South).

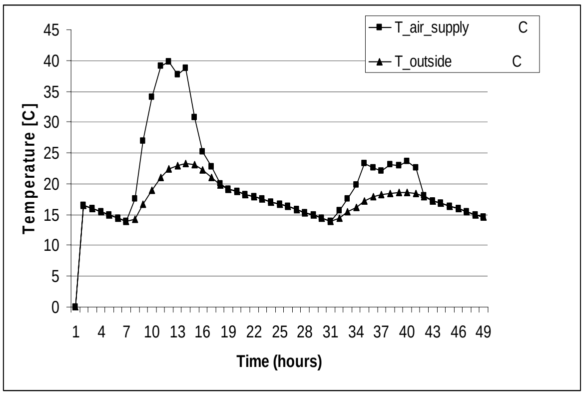

Figure 7: Variation of outside and supply temperatures with solar shutters during a 2-day winter period

Moreover, we made a comparison between the heat demand of the building for two cases: ”with solar shutter” and ”without solar shutter” during an entire heating season, assuming this could take place between 15th October and 15th March. The simulations were performed for a typical meteorological year (TMY) charged from the TRNSYS library, for the town of Ajaccio, France. The airflow of fresh air needed for respiratory purposes was taken the same in the two cases, equal to 0,3 airchanges per hour, with the difference that in the case ”with solar shutter”, the air is heated inside the shutter during the sunlight periods and then supplied to the rooms.

The results of these simulations are very interesting ones:

- in the case ”without solar shutters”, the heat demand of the building over the 6-months winter period was 3470 kWh;
- in the case “with solar shutters”, the heat demand for the same period was only 2469 kWh, so a reduction with 29% in relation to the first case

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This observation leads to the conclusion that the presence of the solar shutters reduces the heat demand in winter, without the contribution of any fossil energy to the system, knowing that the electricity for the operating fans embedded in the shutter is produced only by the PV cells contained in the device.

4 Conclusion

A new concept of solar air collector with a high integration level in the building was presented. The «solar shutter» called «Volet'air®» can be applied not only in new houses but also in old and existing buildings. The technical particularities of this solar shutter are that it works in all positions and it does not use thermal insulation. An experiment has been implemented and the first results concerning its thermal behaviour will be available in some weeks.

It was outlined by means of numerical simulations that the presence of the solar shutter in a typical building could lead to important reduction of the heating load of the building, because the fresh outside air is warmed within the shutter during the sunny periods of the day.

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