IMPACT OF A VERANDA ON THE REDUCTION OF THE ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS : AN APPLICATION OF THE CLIM2000 SOFTWARE

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ABSTRACT

In this paper, the impact of a veranda (attached sunspace) on energy consumption is analyzed by numerical simulations (Clim2000 software) for two different configurations : a (existing) residential individual house and a (new) apartment building. The simulations are run by October to May (warm season).

The model of veranda used in these studies is described with a focus on the calculation of the sun patch location.

The main parameters are the lodging type and insulation (bad, average or very good), the veranda type (projecting or built-in), glazing (classical, strong insulation or low emissivity) and size, the separation between the veranda and the lodging (type and surface of the glazing part).

The utilization of a veranda allows energy savings from 4% up to 23% with the best parameters and adds a comfortable room for autumn, best days of winter and spring.

INTRODUCTION

Different studies are being held at the Research and Development division of EDF (Electricité de France) on the energy efficiency and the use of renewable energies in buildings.

In this context, specific efforts are made on simulations and modeling of bio-climatic and passive solar buildings. An illustration of this work is presented in this paper: a model of veranda was developed for the Clim2000 simulation program to calculate the energy-saving due to this architectural element.

SIMULATION SOFTWARE : CLIM2000

The Clim2000 dynamic simulation program is developed by the Research and Development Division of EDF.

Clim2000 is based on a modular description of buildings and HVAC equipment. This description corresponds to an assembly of independent elements (doors, walls, windows, convectors, heat pumps,...) brought into relation by different thermal phenomena or control channels. Each element is represented by an independent deterministic numerical model based on the physical laws characterizing its behavior. After the user has assembled these elementary models a series of algebraic and differential equations which express the overall behavior of the building is generated. These equations are then solved by the ESACAP solver. There is an automatic adaptation of Clim2000 time step to the stiffness of the problem (with a maximum time step of one hour) [1].

THE VERANDA MODEL

The veranda model was developed in cooperation with the CETHIL Research Laboratory (INSA Lyon, France).

Main characteristics of the model

- Two kinds of window characteristics can be defined: one for the lateral and front windows and one for the top window of the veranda.
- The slope of the veranda can be changed.
- The window between the lodging and the veranda and the faces of the veranda remain closed (there are no mass flows between veranda / inside and veranda / outside).
- We can cover the faces of the veranda with blinds which induce the total occultation of solar flux for studying summer comfort (to avoid very high temperature in the veranda).
- We can also ventilate and heat the veranda.
- The sun patch location (short wavelengths) is calculated by a simplified model based on a discretisation of each window (see below).

Heat and mass transfer in the veranda, general considerations

In the model proposed in this article, heat transfers are very classically treated :

- Heat exchanges due to mass transfer is evaluated with an hour by hour given air flow coming from the outside.

- Conduction heat flows trough the windows are taken into account by the global U values.
- Conduction heat flows trough the " walls " (wall between the veranda and the house or veranda's floor) are calculated using finite volumes technique.
- Convection heat flows between all the internal faces of the veranda and the inside air volume are calculated using classical temperature correlation depending on the slope of the concerned face. Wind speed correlation is used for the external faces.
- A simplified approach has been used to evaluate internal longwave radiation heat flows. We suppose that, in this application, it is possible to linearise longwave radiation exchanges. For internal surfaces exchanges, this assumption lead us to the mean radiant temperature (form factors are evaluated using a surface prorate and surfaces are supposed to be black). [2],[3].
- The external exchanges are not linearised and occurs between the veranda faces and the ground, the surrounding obstruction (at the external air temperature) and also the sky (which temperature is consigned in the meteorological data base).
- External shortwave radiation processes : Calculation of the intensity of direct and diffuse radiation on external inclined surfaces has been described in a lot of papers or books [4]. These calculations essentially depends on solar position and do not presents any difficulty.
- Internal shortwave radiation processes : after transmission of the direct and diffuse solar radiation by the transparent faces of the veranda, we need to know the primary solar intensity (E^0_{iCLO}) on each internal faces of the veranda. If we consider all the reflections to be diffuse, the final intensity E_{iCLO} (due to multi reflections plus the primary intensity) on the face number i can be expressed as follow [5]:

$$S_i E_{iCLO} = S_i E^0_{iCLO} + \sum_{j=1}^{n} S_j F_{ji} \rho_j E_{jCLO}$$

, using reciprocity of view factors (Si Fij=Sj Fji) , this expression is simplified in : $E_{iCLO} = E^0_{iCLO} + \sum_{j=1}^{n} F_{ij} \rho_j E_{jCLO}$ (Si and ρi respectively the surface and the diffuse reflection coefficient).

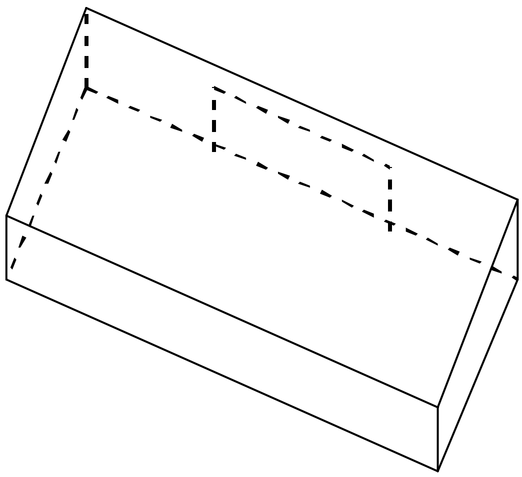
The set of equations is solved in a matrix form for the whole internal faces of the veranda.

The only difficulty in solving these equations is the evaluation of the E^0_{CLO} vector. Knowing the external direct and diffuse solar radiation intensity on each face of the veranda and the variation of the reflection, absorption and transmission coefficients of each glazed face, what is the percentage of solar flux going trough the i^{th} face and reaching the j^{th} one ? That is to say where is the sun patch location ?

<u>Sun patch location : a simplified model based on windows discretization</u>

Many of the design tools used by practitioners to analyze the energy aspect of solar utilization are very simple and do not give very accurate representation of sun patch location or shadows position. In order to have a good representation of such effects, a well known technique is the " polygon clipping " one [6]. The veranda is projected on a plane perpendicular to the sun beam direction. Using polygon intersection technique it is possible to determine for example the solar flux coming in the veranda by the roof and which faces of the veranda are reached (figure n°1).

Figure 1 : veranda view from the sun



One difficulty when implementing this method is that it needs a lot of tests because of a lot of specials cases can occur depending on the solar position and the veranda geometry.

In order to avoid these difficulties we choose an other method to evaluate primary solar intensity on each face of the veranda. The retained simplified method consist in a discretization of each transparent part of the veranda (figure n°1) . All the points are projected on the same plane used for the projection of the veranda : that is to say a solar beam perpendicular surface. Then to know the percentage of solar flux going trough the i^{th} face and reaching the j^{th} one , we only need to count the number of points belonging to the i^{th} face projected on to the i^{th} face. From a numerical point of view we only need to know how to project points on a plane and to decide if a point belong to a defined polygone or not. This is very simple, very robust and no special cases to prevent from.

In the table n°1, we compare the " exact method " (polygon clipping) and the simplified method (faces discretization) in term of solar flux going trough the i^{th} face and reaching the j^{th} one : PSOL[i,j]. All the tests we have done give excellent accuracy In table n°2 we can see that a lot of the incoming solar fluxes is coming out the veranda because of multi-reflections (a little part) and because of direct transmission of the reached windows (a big part).

Table 1 : percentage of solar flux going trough the i^{th} face and reaching the j^{th} one (4h in the afternoon, june 21th, latitude 45° north , veranda south orientated)

PSOL[i,j]	Simplified model %, (W)	" Exact "model %, (W)
PSOL[2,1]	25.19 (3)	26.23 (4)
PSOL[2,7]	74.79 (10)	73.76 (10)
PSOL[3,5]	1.80 (33)	2.05 (38)
PSOL[3,7]	98.19 (1787)	95.84 (1744)
PSOL[4,1]	64.59 (1706)	62.85 (1660)
PSOL[4,5]	0.19 (5)	0.53 (14)
PSOL[4,6]	2.19 (58)	3.73 (99)
PSOL[4,7]	32.99 (872)	32.88 (868)

Table 2 : Percentage of solar energy coming out the veranda after multi-reflections

Solar time	Incoming flux (W)	Outcoming flux (W)	Outcoming flux / Incoming flux (%)
5	11	7	61
6	437	183	42
7	1898	604	32
8	4478	1147	32
9	7560	1704	23
10	9447	1204	13
11	11255	458	4
12	11561	0	0

RESULTS AND ANALYSIS

Many studies have been realized with the model of veranda. Two of them are retained.
The first one deals with a residential individual lodging, 100m^2 of floor area, on one floor without adjoining house, heated with electrical convectors. This study was included in a project concerning renovation of existing buildings. The questions were : is it possible to realize energy savings with a veranda ? Is the veranda comfortable enough to use it as a room?
The second one deals with an apartment building, 66m^2 of floor area between two adjoining apartments, with two another apartments under the floor and above the ceiling. This study was included in a project of a new « HQE » (High Environmental Quality) collective building. A veranda allows to collect free solar energy which is included in HQE ideas.

The simulations are run from October to May (heating season).
In both cases, the lodging is modelised with two thermal areas : the first area includes the livingroom, the hall and the kitchen (day area), the second area includes the bedrooms, the bathroom and the toilets (night area). The exchanges between the day and night areas are only thermal (no air exchanges).

The estimated internal heat supply is about 100 W.h/(m².day) due to occupants and electrical equipments (light, electrical appliance).

We are interested in energy consumption of the day and night areas, and the temperature of the veranda (average, minimum and maximum temperatures).

In the analysis of the impact of the veranda on energy consumption, the following parameters are studied :

- the climate (cold, middle and hot),
- the building thermal insulation (bad, middle and good insulation),
- the orientation of the veranda (south, north, east and west),
- the dimensions of the veranda (small or big),
- the type of the veranda (projecting or built-in veranda),
- the glazing performances of the veranda (single, double glazing, low emissivity, strong thermal insulation),
- the veranda / house separation window performance (single, double glazing),
- the ventilation strategies (pre-heating of the air in the veranda),

The impact of the type of veranda, the glazing performance of the veranda and the veranda / house separation window, and the orientation of the veranda (south, east and west) are studied on the apartment building configuration. For this study, the following parameters are fixed : a middle climate, a good building house insulation and a small veranda.

The impact of the climate, the house thermal insulation, the dimensions and the orientation (south and north) of the veranda and the ventilation strategies are studied on the individual house configuration. For this study, the following parameters are fixed : a projecting veranda made off classical double glazing, with a veranda / house double glazing separation window.

The values of the absorbtivity, transmitivity are given for a null angle of incidence of the sun on the faces of the veranda. The model of veranda calculates the real values depending of the angle of incidence of the sun as described in the chapter "The veranda model".

The physical specifications of the glazing which are used in the simulations are reported in the table 3 (specifications given by a manufacturer).

Table 3 : physical specifications of the glazing

	U (W/m².K)	α (%)	τ (%)
Single glazing	**5,7**	**14**	**79**
Double glazing			
Classical	**2,9**	**17**	**70**
Strong thermal insulation	**1,8**	**28**	**50**
Low emissivity	**1,4**	**40**	**36**

Apartment building configuration

Tables 4 and 5 present the simulations results concerning the temperatures of the veranda (average, minimum and maximum) and the energy consumption, depending on the glazing of the veranda, the size of the separating window, the type and the orientation of the veranda.

Table 4 : temperatures of the veranda

	Tmoy (°C)	Tmin (°C)	Tmax (°C)
Glazing of the veranda			
Classical double	11,4	-1,0	31,7
Strong thermal insulation	11,7	-0,5	32,3
Low emissivity	11,7	-0,4	32,4
Separating window			
Partial single classical	11,8	-0,4	29,2
Total double classical	11,3	-0,5	30,0
Type of véranda			
Buit-in	13,2	3,2	27,4
Orientation of the veranda			
West	10,5	-1,1	30,2
East	10,4	-1,2	25,1

The parameters describing the basic case are : middle climate, good insulation for the building, south oriented veranda, partial double-glazing of the separation between the veranda and the lodging, classical double-glazing for the veranda, new air pre-heated in the veranda for the day area, new air from outside for the night area.
The reference case is the same as the basic configuration without the veranda.

Table 5 : energy consumption

	Day Area (kWh)	Night area (kWh)	Total (kWh)
Without veranda			
Reference	**1042**	**1317**	**2359**
West reference	1381	1298	2679
East reference	1518	1211	2729
Built-in reference	1193	1329	2522
Glazing of the veranda			
Classical double (base)	820	1251	2071
Saving / reference (%)	**21**	**5**	**12**
Strong thermal insulation	674	1252	1927
Saving / reference (%)	**35**	**5**	**18**
Low emissivity	703	1268	1971
Saving / reference (%)	**33**	**4**	**16**
Separating window			
Partial single classical	820	1251	2071
Saving / reference (%)	**21**	**5**	**12**
Total double classical	802	1226	2028
Saving / reference (%)	**23**	**7**	**14**
Type of veranda			
Built-in	658	1284	1942
Saving / reference (%) Saving / built-in reference (%)	**37** **45**	**2** **3**	**18** **23**
Orientation of the veranda			
West	959	1266	2225
Saving / West ref (%)	31	2	17
East	1008	1181	2189
Saving / East ref (%)	34	2	20

Type of glazing of the veranda

Concerning energy, the glazing with a strong thermal insulation is the most efficient (table 5). If we take into account both efficiency and cost of the glazing of the veranda, the classical double glazing seems to be the best solution.

Concerning comfort in the veranda (table 4), the influence of the type of glazing is not significant.

Type of the separating (veranda / lodging) glazing

Concerning energy, the double glazing is the most efficient (table 5). A lower thermal exchanges factor (U) induces more savings because the temperature into the veranda is generally lower than the temperature of the lodging.
Concerning comfort in the veranda (table 4), the influence of the type of glazing is not significant.

Size of the separating (veranda / lodging) glazing
Concerning energy (table 5), energy savings decrease with the increasing of the glazing part of the separation. On the one hand, a really big glazing part (figure 3 : 100% of the separation) is good for the solar flow and the light, but the thermal exchanges factor is worst than a wall factor. On the other hand, it is necessary to have a part of wall (figure 2 : 39% of the separation) which constitute a thermal capacity and which have a good thermal exchanges factor (we could find an optimum by running other simulations).

Concerning comfort, the influence of the glazing part is not really significant (table 4).

Figure 2 : partial separated window (71%)

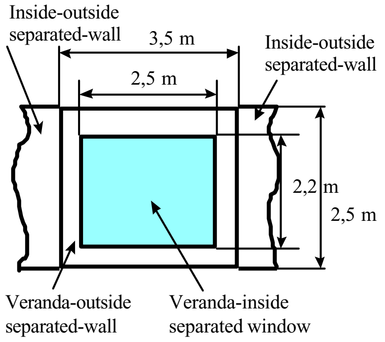
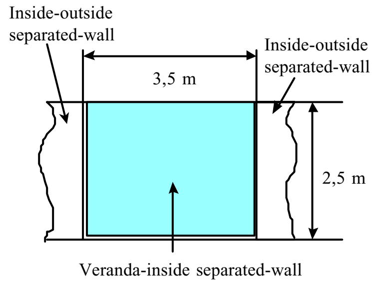
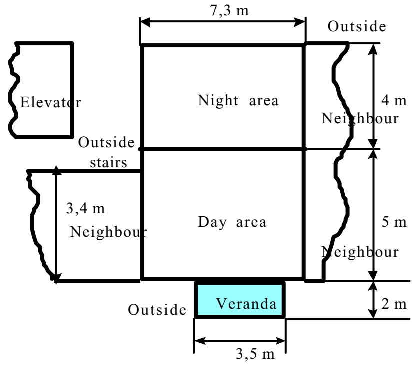


Figure 3 : total separated window (100%)



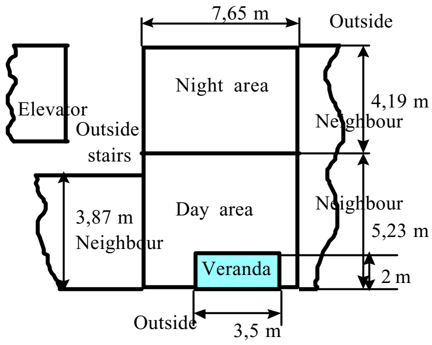
Type of veranda (projecting or build-in)
Whatever the type of veranda is, we must have the same floor area for the day and the night areas. Therefore, the lodgings are different (figures 4 and 5). On the one hand, without veranda, an apartment with a built-in veranda has (figure 5) more heat loss than the corresponding apartment with a projecting veranda (figure 4) : it has larger outside walls (about 10m² more). On the other hand, a built-in veranda is more efficient than a projecting veranda. Therefore, the consumption is sensibly equal, whatever the type of veranda is (table 5).

Figure 4 : projecting veranda



Concerning comfort (table 4), average and minimum temperatures are higher (13,2°C and 3,2°C compared to 11,4°C and -1°C for the basic case), the maximum temperature is lower (27,4° compared to 31,7°C).

Figure 5 : built-in veranda



Orientation of the veranda (south, east and west)
Compared to a reference apartment (without veranda) with the same orientation, consumption savings do not depend on the orientation (table 5).
Concerning the savings for the day area, they are higher with a south-oriented veranda than with another orientation, but this tendency is not confirmed if we consider the whole apartment (table 5).

Concerning comfort (table 4), the orientation induces an important difference of the maximum temperatures (6,6°C) between south and east oriented veranda.

Conclusion
With an apartment building configuration, regarding to the model characteristics, to the energy savings, to the building cost of the veranda and the comfort, the best veranda is made off classical double glazing, built-in, south oriented, with a partial glazing separation with the day area.

Individual house configuration

Tables 6 and 7 present the simulations results concerning the energy consumption and the temperatures of the veranda (average, minimum and maximum).

Table 6 : temperatures of the veranda

	Tmoy (°C)	Tmin (°C)	Tmax (°C)
Climate			
H1 (cold)	10,9	-4,5	38,0
H2 (middle)	12,4	0,8	38,9
H3 (hot)	16,5	3,2	40,4
Insulation level			
Before 1974	10,6	-4,2	35,8
After 1989 loss-10%	11,0	-3,7	38,0
Orientation of the veranda			
North	9,7	-5,0	27,8
Size of the veranda			
Big	11,9	-3,9	45,5
Ventilation			
Air from outside	12,0	-2,0	41,9
Air from veranda	10,2	-6,1	35,9

The parameters describing the basic case are : cold climate (called H1), middle insulation for the building (French thermal rules of 1982), south oriented veranda, partial classical double-glazing (59%) of the separation between the veranda and the lodging, classical double-glazing for the veranda, new air pre-heated in the veranda for the day area, fresh air from outside for the night area.

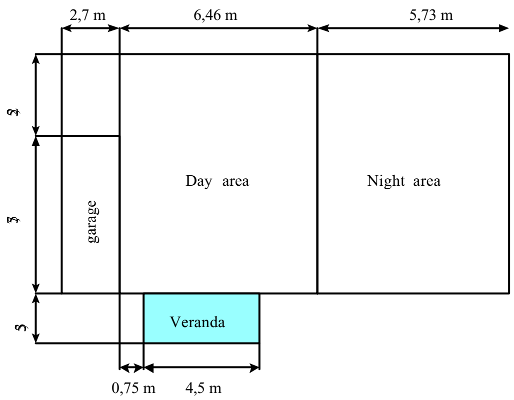
The reference case is the same as the basic configuration without the veranda.

Table 7 : energy consumption

	Day Area kWh	Night area kWh	Total kWh
Without veranda			
Reference	**6739**	**5815**	**12554**
Reference H2	5372	4849	10221
Reference H3	2970	2568	5538
North Reference	6655	5953	12608
Ref before 1974	18852	19040	37892
Ref after 1989	4917	4222	9139
Climate			
H1 (cold)	5227	5850	11077
Saving / reference (%)	**22**	**0**	**12**
H2 (middle)	3905	4905	8810
Saving / reference H2 (%)	**27**	**0**	**14**
H3 (hot)	1910	2611	4521
Saving / reference H3 (%)	**36**	**0**	**18**
Insulation level			
Before 1974	17488	19030	36518
Saving / reference before 1974 (%)	**7**	**0**	**4**
After 1989 GV-10%	3732	4192	7924
Saving / reference after 1989 (%)	**24**	**0**	**13**
Orientation of the veranda			
North	5699	6019	11718
Saving / reference north (%)	**14**	**0**	**7**
Size of the veranda			
Big	4861	5824	10685
Saving / reference (%)	**28**	**0**	**15**
Ventilation			
Air from outside	5722	5861	11583
Saving / reference (%)	**15**	**0**	**8**
Air from veranda	5388	5373	10761
Saving / reference (%)	**20**	**8**	**14**

Sizes of the individual house and associated veranda are reported on the figure 6.

Figure 6 : sizes of the individual house and the veranda



Climate

We have three climatic areas in France : H1 (cold), H2 (middle) et H3 (hot).

Concerning energy, the more clement the climate is, the more significant the savings are, by 12% in H1 to 18% in H3 for the basic configuration (table 7) because the solar contribution increases with the clemency of the weather.

Concerning comfort (table 7), the more clement the climate is (with as sun as possible), the more comfortable the veranda is : average, minimum and maximum temperature are really higher in H3 than in H1 (respectively 16,5°C, 3,2°C and 40,4°C in H3 compared to 10,9°C, -4,5 °C and 38°C in H1).

Insulation level

Three different insulation levels are studied, depending on the building thermal rules when the house was built : before 1974 (no rules), between 1974 and 1982 (rules of 1974), between 1982 and 1989 (rules of 1982), after 1989 (rules of 1989). There are some houses which are built with a better insulation level than the required level of the rules of 1989 (10% less on the thermal loss, called "after 1989 - 10%"). Results are given for three insulation levels : before 1974, between 1982 and 1989, after 1989 - 10%.

Concerning energy, the better the insulation level is, the better the savings are (table 7) : by 4% for a lodging built before 1974 to 16% for the same lodging build after 1989 with the rules "after 1989 - 10%.

Concerning comfort, the increase of the level insulation of the building is not really significant (table 6).

Orientation of the veranda

South and north oriented verandas were studied. The north orientation means that all the frontages undergo a rotation of 180° (compared to a south oriented house).

Concerning energy, the south orientated veranda receives much solar contributions than a north oriented one. Thus, a house equipped with a veranda oriented in the south will see its consumption in heating decreasing by 12% compared with only 7% for a veranda directed in north (table 7).

Concerning comfort (table 6), the maximum temperature is really lower for a north oriented veranda (10°C). The north oriented veranda is thus less usable during the semi-season, but it is not essential to dismount it or to ventilate it a lot in summer.

Sizes of the veranda

Savings carried out (table 7) increase with the size of the veranda, by 12% (veranda of 4,5*3 = 13,5m2) with 15% (6,5*3 = 19,5m2).

Indeed, the surface of wall in contact with the outside covered by the veranda as well as the solar contributions on the air of the veranda increase with the size of this one.

Concerning comfort (table 6), the maximum temperature of the veranda increases by 7,5°C (compared to the maximum temperature of the small one). The large veranda is thus more comfortable in mid-season but the temperatures reached during the hot period of the year are very high.

Ventilation strategies of the lodging

The fresh air of housing can be drawn outside, or preheated in the veranda. A mixing of these two solutions can be carried out (basic case). Indeed, the air of the day area can easily and naturally be drawn from the veranda which is next to this zone, the fresh air of the night area being naturally taken from outside.

Concerning energy, savings increase with the quantity of fresh air which forwards by the veranda (table 6), of 8% (fresh air completely drawn outside and directly injected into the zones of housing) with 14% (the totality of the new air forwards by the veranda).

This gap of 6 points does not hold account of the necessary energy to supply the ventilator which insufle the preheated air in the night area and which is estimated at more than one point of the consumption savings.

The direct distribution of housing with surrounding air makes it possible to increase minimum temperature of the veranda (table 6) of 2,5°C (compared to the reference), of 4,1°C compared to a distribution where the totality of the fresh air forwards by the veranda. The maximum temperature of the veranda (table 6) decreases with the increase of the quantity of fresh air which forwards by the veranda.

Conclusion
With an individual house configuration, regarding to characteristics of the model, to the energy savings, to the building cost of the veranda and the comfort, the best conditions for adding a veranda are : a good climate (H3), a good insulation (rules of 1989 -10%), a south orientation. Larger the veranda is, better the energy saving are. It is better to preheat as many fresh air as it is possible in the veranda.

CONCLUSION

The undertaken studies make it possible to quantify potential energy saving by using a veranda (i.e. solar energy) in individual and collective lodgings. The calculation of the temperature in the veranda also enables a first estimation of the comfort. The simulations are run by October to May (heat season).

The interest to equip a lodging with a veranda is thus double : it allows significant energy saving (from 4% to 23% according to the type of housing, of veranda, of glazing) and offers an additional space of life to the occupants of the lodging during the sunny hours of the mid-season.

In summer, it is essential to be able to open or to dismount the veranda because very significant overheatings are foreseeable (especially when the veranda is south oriented).
The results reported in this document are to be handled with care. It is necessary to keep in mind the hypothesis which were retained.

According to the studies conclusions, for optimal energy saving, building cost and comfort, the veranda should be in a built-in configuration, south oriented. Separation between the veranda and housing should be partially glazed to let enter a maximum of light, but a considerable proportion of this separation should be a wall (to constitute a thermal mass). The glazed part of the separation between the veranda and the lodging should be in double glazing. A traditional double glazing for the veranda offers a good ratio between the building cost of the veranda and the energy savings.

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NOMENCLATURE

E : solar intensity
F : view factor
P : flux
S : area
Tmoy : average temperature of the veranda
Tmin : minimum temperature of the veranda
Tmax : maximum temperature of the veranda
Ref : reference
U : thermal exchanges factor
α : energetic absorbtivity
ρ : diffuse reflection coefficient
τ : energetic transmitivity