



# THE PASSIVHAUS STANDARD IN EUROPEAN WARM CLIMATES: DESIGN GUIDELINES FOR COMFORTABLE LOW ENERGY HOMES

Part 2. National proposals in detail  
*Passivhaus France*





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## THE FRENCH PASSIVHAUS

### 1.1 BUILDING GEOMETRY

For the French case, the *PassivHaus Institut* has undertaken the simulation, choosing to transpose a German house in two locations of South of France – Carpentras and Nice – in order to assess a given passive construction strategy in warmer context.

We consider a two-storey end-of-terrace dwelling with an inclined roof and a basement (see drawings). The thermal envelope contains the ground floor, the first floor and a storage/mechanical services room in the attic. The basement is unconditioned, the insulation layer runs below the ceiling of the basement.

The sum of the living areas of all habitable rooms is  $120 \text{ m}^2$ ; in the following, all performance data are referred to this area. For comparison: The gross floor area of all three floors sums up to  $220 \text{ m}^2$ .

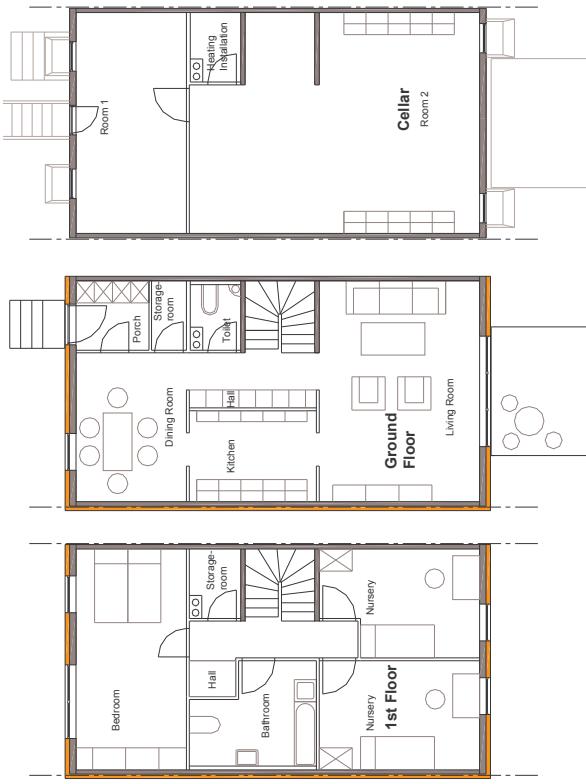


Fig. 1. 1 – Plans of the first floor, ground floor and basement

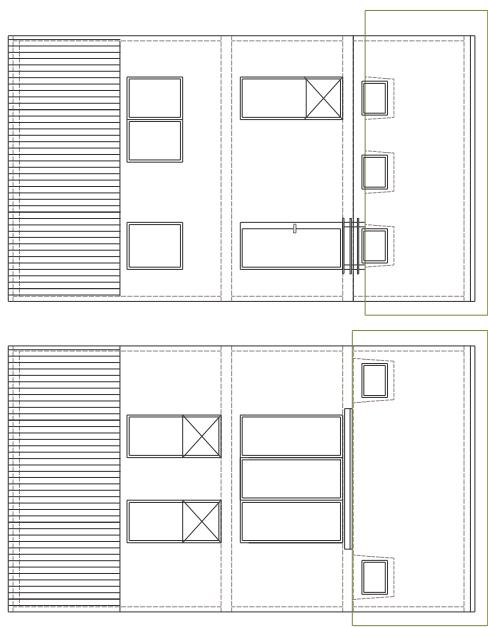


Fig. 1. 2 – South and North elevation

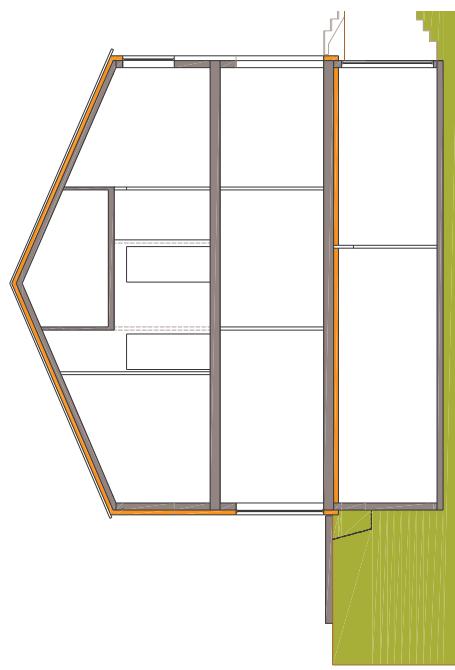


Fig. 1. 3 – Section seen from the east

## 1.2 WEATHER

In the simulation, we used climatic data of Carpentras and Nice in Southern France.

Carpentras (Vaucluse) is situated in the Southern Rhône valley close to Avignon at an altitude of 95 m above sea level. Compared to Northern France, the climate is mild and sunny, still influenced by the Mediterranean sea. The lowest temperature in the data set is  $-5^{\circ}\text{C}$ . In winter, the daily average temperature hardly drops below  $0^{\circ}\text{C}$ , and there is a significant amount of solar radiation available for passive solar heating.

The highest ambient temperature is  $35^{\circ}\text{C}$ , but daily average temperatures in summer do not exceed  $25^{\circ}\text{C}$ . This means that a considerable potential for cooling by means of night ventilation exists, although dew point temperatures may reach  $20^{\circ}\text{C}$  during a few hours of the year.

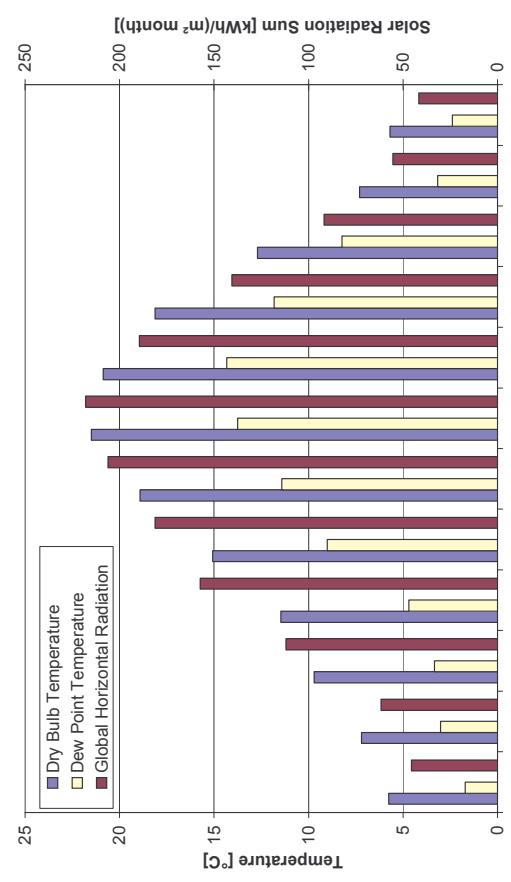


Fig. 1.4 – Monthly average climatic parameters for Carpentras

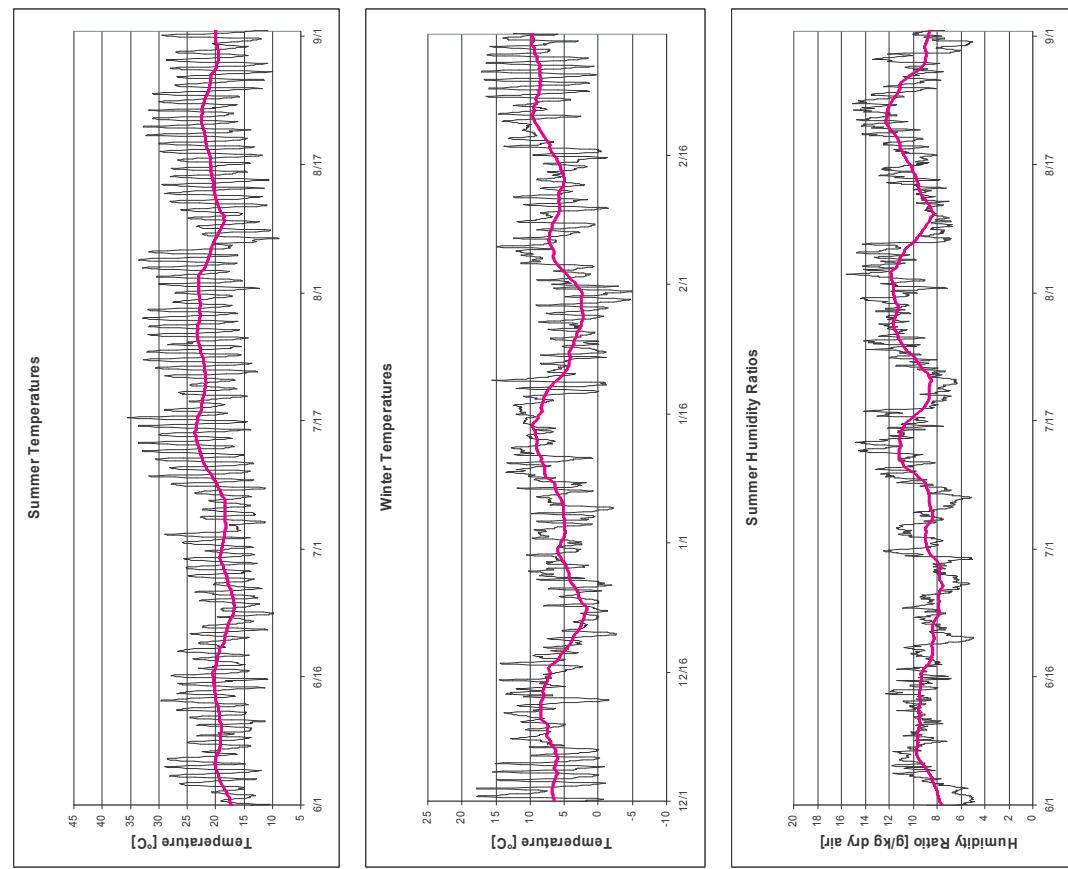


Fig. 1.5 – Hourly temperatures and summer humidity ratio for Carpentras

Nice is a major tourist center on the Côte d'Azur. Due to its protected location it is one of the warmest places on the French Mediterranean coast. Temperatures below 0 °C are very rare; the lowest temperature in the data set is 1.8 °C. The monthly average winter temperatures are 2 to 3 K higher than in Carpentras. Solar radiation levels are similar in both locations.

The influence of the sea reduces both annual and daily temperature variations. The highest ambient temperature in the data set is 28 °C, the maximum daily average temperature in summer is 23.7 °C. On the other hand, temperatures do not drop considerably during nighttimes.

The sea also influences the humidity level. Compared to Carpentras, the climate is a lot more humid in summer. The dew point temperature is above 17 °C, indicating an uncomfortably high humidity ratio, during 14% of the year.

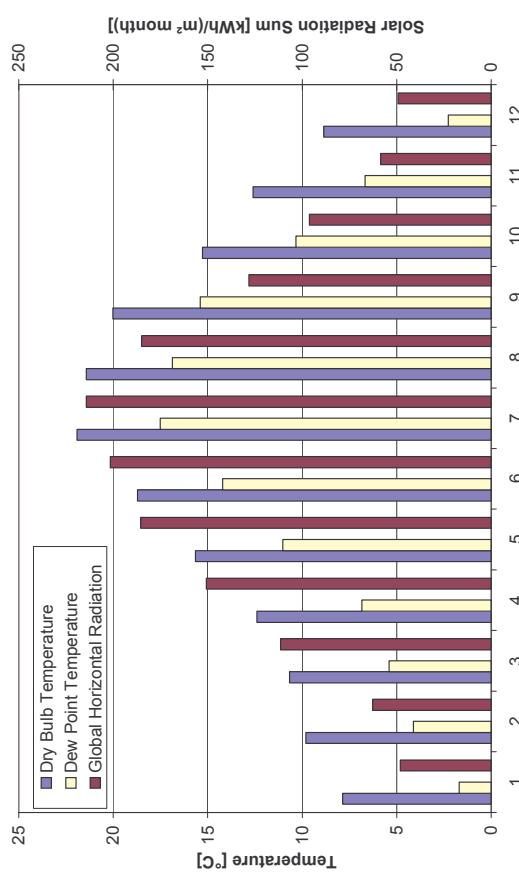


Fig. 1.6 – Monthly average climatic parameters for Nice

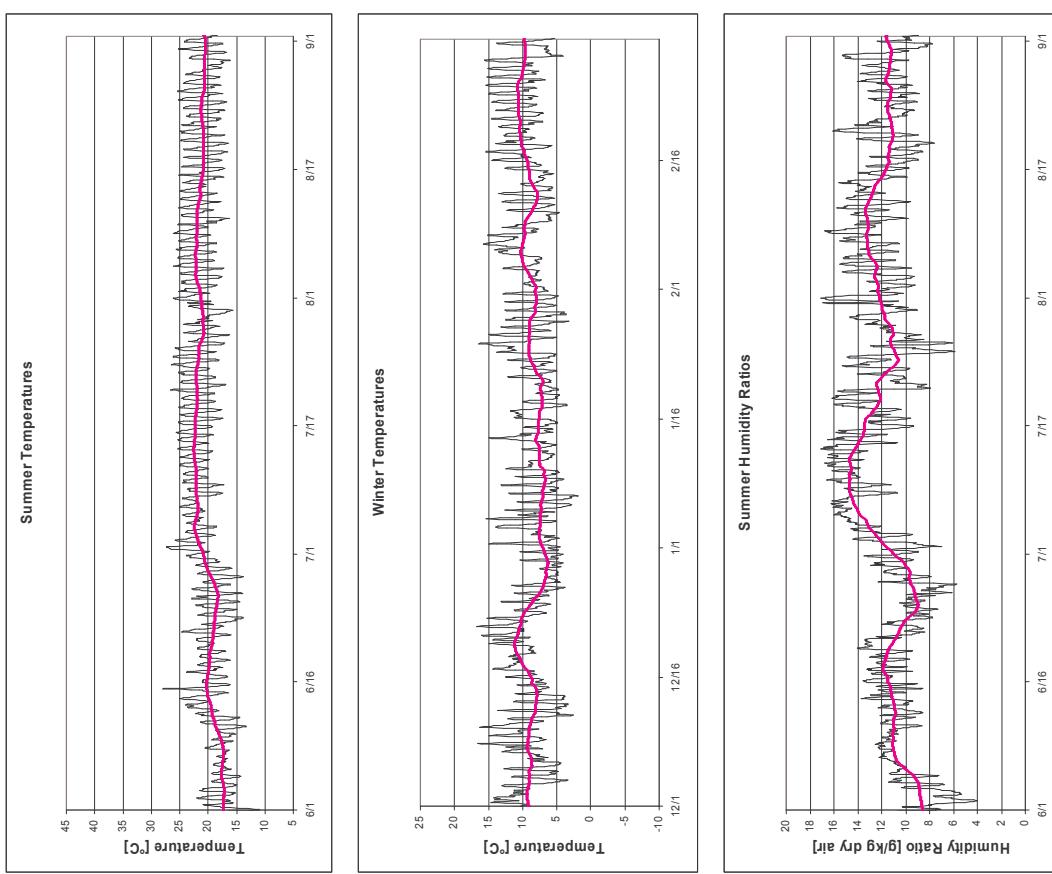


Fig. 1.7 – Hourly temperatures and summer humidity ratio for Nice

### 1.3 CONSTRUCTION

The following drawings show the construction types that were chosen for Carpentras. In Nice, due to the milder climate, the insulation thickness was reduced to 10 cm in the roof, 6 cm in the walls, 2 cm in the basement floor. For Nice, this design results in an insulation level which is slightly below the legal requirements for this location, concerning the floor insulation level.

The U values are slightly lower than the minimum required for the roof and the walls, by the French Thermal Regulation act (RT 2005). The U value chosen for the roof is slightly above the U value used as the reference value ( $U_{ref}$ ). But this should not affect the model in reaching the total Uvalue requested by RT 2005.

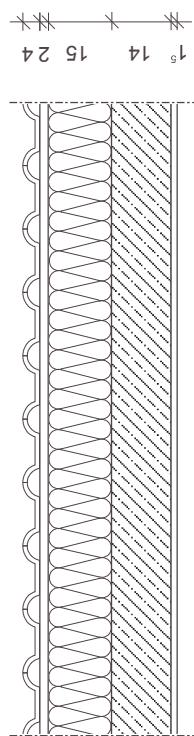


Fig. 1.8 – Concrete roof from outside to inside: Dark roof tiles (72 % solar absorption), air gap, insulation, concrete load-bearing panel, plaster. Lightweight constructions can also be used, the effect is comparably small.

Even though French houses in South France rarely have an inclined concrete roof, and their tiles may show a smaller absorption coefficient value, it was decided to keep to these characteristics as they do not greatly influence the results (c.f. 1.11).

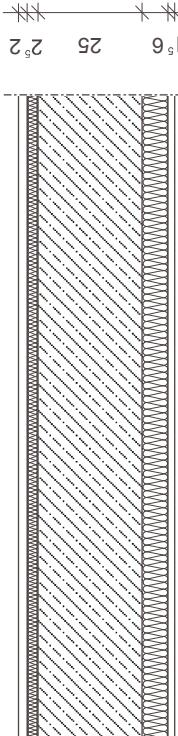
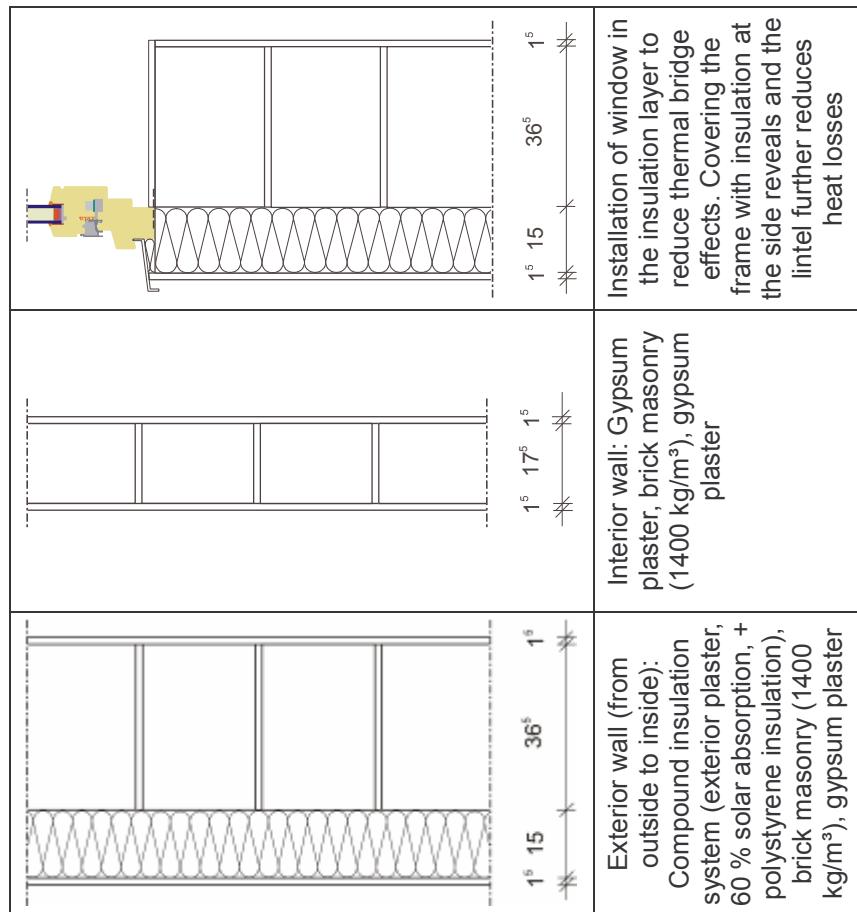


Fig. 1.9 – Basement floor (i.e. the floor between the basement and the ground floor) from inside to outside: Wooden flooring, impact sound insulation, concrete, thermal insulation at the ground floor ( $\Psi = 0.6 \text{ W}/(\text{mK})$ )

could be accepted. Apart from slightly reducing building cost and planning effort, this increases the thermal coupling of the basement and the interior. Thus, to a small extent, more heating is required, but summer cooling requirements are reduced. All other building element junctions are free from thermal bridges as described in Part 3 of these guidelines.



Windows: Wooden frame, 68 mm thick,  $U_f = 1.6 \text{ W}/(\text{m}^2\text{K})$ , double low-e glazing,  $U_g = 1.2 \text{ W}/(\text{m}^2\text{K})$ , total solar heat gain coefficient 64 %, aluminium spacer,  $\Psi_g = 0.08 \text{ W}/(\text{mK})$ , thermal bridge coefficient due to installation 0.01  $\text{W}/(\text{mK})$ .

Due to the mild climates, thermal bridges at the ground floor ( $\Psi = 0.6 \text{ W}/(\text{mK})$ )

## 1.4 INTERNAL HEAT GAINS

In the following, the internal heat gains that were assumed in the building are detailed. As the temperatures in the building do not differ much between thermal zones, the data are not given on a per zone, but on a per building basis.

Table 1. 1 – Internal gains (average of 24 h)

Gain	Unit	Value
Infiltration	ach <sup>-1</sup>	0.07
Ventilation	ach <sup>-1</sup>	0.3
Occupancy Sensible	W/m <sup>2</sup>	2.2
Occupancy Latent	W/m <sup>2</sup>	1.1
Equipment and Lighting Sensible	W/m <sup>2</sup>	1.5
Sensible Heat Loss	W/m <sup>2</sup>	-0.7
Equipment Latent	W/m <sup>2</sup>	0.2

The infiltration rate corresponds to reduced leakages and drafts that are represented by an  $n_{50}$ -value of  $1.0 \text{ h}^{-1}$ . The ventilation system has been designed to provide the airflow volume that is required for good indoor air quality, but not to bring excessive airflows into the rooms. This prevents relative humidities below 30% during wintertime, unwanted noise and high electricity consumption of the fans.

The sensible heat due to occupancy and equipment is released in the living room and the nursery during the day (7 a.m. to 10 p.m.) and in the upstairs bedrooms during the night. The sensible heat losses due to evaporation, heating of cold water, running off of hot water, etc. are evenly distributed throughout the aboveground rooms.

The sensible internal gains sum up to an average of  $3 \text{ W/m}^2$ . This is a relatively high value – for design purposes in the heating case a typical value of  $2.1 \text{ W/m}^2$  is used [1]. The main focus of this work is to describe energy-efficient solutions for cooling. In order to demonstrate that the suggested solutions are robust, the higher value for the internal gains is assumed here.

## 1.5 VENTILATION

A controlled ventilation system with heat recovery (80% efficiency) is used in order to provide fresh air and reduce ventilation losses. The air is supplied to the rooms which are continuously inhabited, flows through the corridors and is extracted from functional rooms. The airflow rates shown in Table 1.2 have been used.

Table 1. 2 – Airflow rates of the mechanical ventilation system

Room	Supply air [m <sup>3</sup> /h]	Exhaust air [m <sup>3</sup> /h]
Living room	50	
Kitchen		33
WC		33
Nursery	25	
Bedroom	25	
Bathroom		34



Fig. 1. 10 – Ventilation unit with 78% heat recovery efficiency and low electricity consumption, proven in field measurements (from [2])

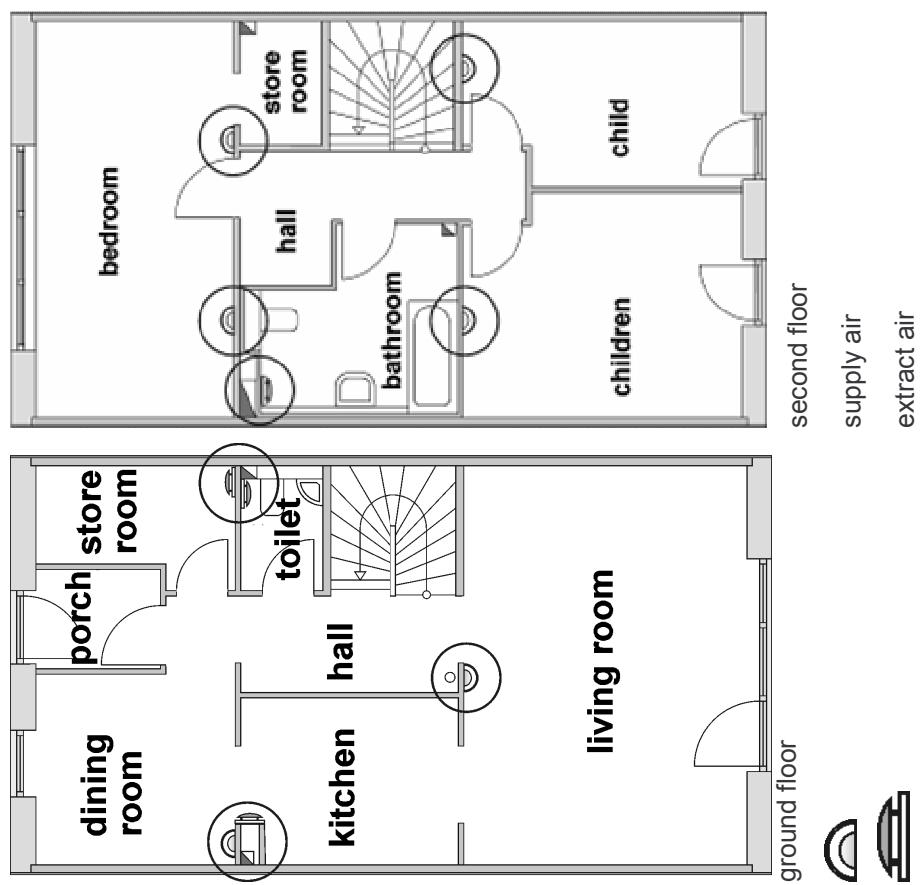


Fig. 1.11 – Position of the supply and extract air outlets and respective nozzles on both floors (floor plans similar to simulated building, from [2])

Inhabitants may open windows just like in conventional buildings. In general, this is not required in wintertime because the ventilation system continuously provides fresh air in all rooms. We assume that windows are kept closed during the heating period.

## 1.6 HEATING

The heating setpoint is 20 °C without night setback. In well-insulated buildings, night setbacks have no significant effects on the energy consumption or the temperature, but will result in higher heating power demands at daytime, thus impeding low-power heating systems. For the calculation of the heating energy demand, an 'ideal' air heating was assumed which is able to keep the temperature at the desired level in each room individually with unlimited power.

The daily average heat load is 8.8 W/m<sup>2</sup> in Carpentras and 10.3 W/m<sup>2</sup> in Nice. It is thus small enough to be covered by simply pre-heating of the supply air. Radiators and the heat distribution system are not necessary any more. The principle of heat generation is not of great importance: Condensing gas boilers, heat pumps, pellet stoves, district heat, etc. all provides an efficient means of heat supply. Direct electrical resistance heating has to be avoided though, because electricity has a primary energy factor between 2.5 and 3, i.e. 3 kWh of fuel are needed to produce 1 kWh of electricity (in France the official coefficient is set at 2.58).

A heat pump can balance this effect, such that the primary energy demand of electrical heating with heat pumps is about the same as with other fuels.

Due to the small heat load, building services may be significantly simplified. This reduces overall investment costs and thus justifies the higher investment for the efficient envelope. A significant cost reduction can often be achieved when compact heat pump units are used. These units use the exhaust air after the heat exchanger as a heat source for the integrated heat pump. The heat pump also heats a DHW storage. All required building services are integrated in one unit, with its own integrated and tested control, that can simply be plugged in without the need for refrigerant handling on site. No energy carriers except electricity need to be connected and/or transported to the building. List prices for compact heat pump units in Germany currently range from 6000 to 10000 Euro (10000 Euro in France), with discounts to be negotiated individually. Future cost reductions may be expected with increasing market penetration.

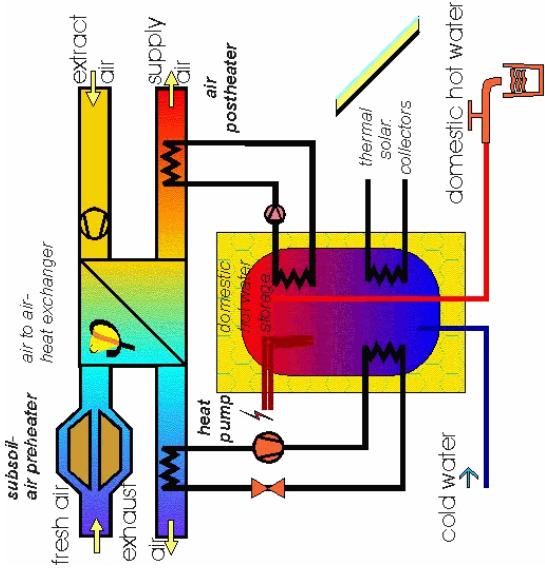
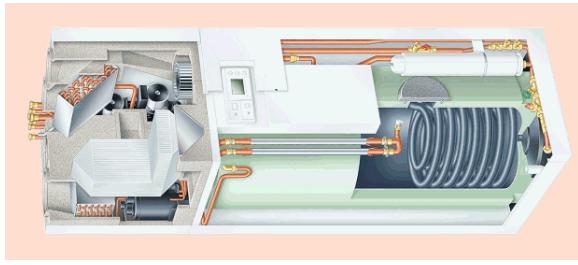


Fig. 1. 12 – Basic principle and drawing of a compact heat pump unit

## 1.7 SOLAR CONTROL

For good summer comfort, reduction of solar loads is of vital importance. In this example, conventional dark-colored Persian shutters are used which reduce the total solar heat gain coefficient of the windows from 64 to 8%. From April to October, the shutters are closed if the indoor air temperature rises above 23 to 24 °C (cf. sketch)

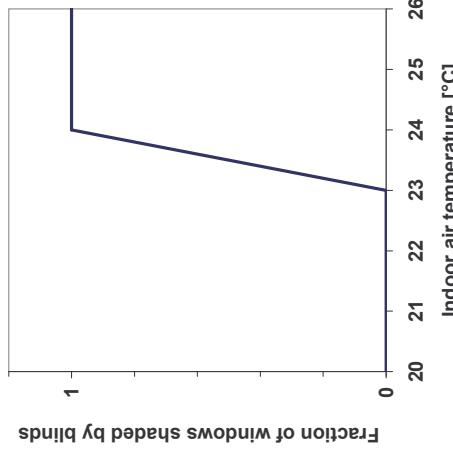


Fig. 1.13 – Summer shading strategy employed



Fig. 1.14 – Persian shutters from [3]

## 1.8 COOLING

Cooling strategies differ between the two locations. In Carpentras, night flushing with open windows is sufficient to keep temperature and humidity levels in the comfort range.

For Nice, temperatures can be kept comfortable by passive cooling, too, but dehumidification may be required for optimum comfort. Therefore, the Nice example uses only moderate window opening. Part of the cooling is realised by cooling and thereby dehumidifying the supply air.

In the climates considered, heat recovery will be counterproductive to reduce indoor temperatures during most of the summer. The heat recovery of the ventilation is bypassed in the cooling season. For simplicity, this takes place from May 1 to September 30.

In the following, the different cooling strategies for the two locations are described separately.

### Carpentras

In Carpentras, due to the low night time temperatures and the acceptable levels of humidity ratio, a passive cooling concept is realised. The ventilation system itself already provides a certain amount of cooling. Alternatively, the mechanical system can be switched off in summer. Ventilation is then realised by suitable operation of the windows.

In any case, additional summer cooling by opening of windows is assumed. Two of the tilt-and-turn windows in the living room and the nursery, respectively, and one window in the bedroom are opened wide at operative room temperatures above 22 °C, provided that the ambient temperature is below the indoor temperature.

The total additional airflow due to opened windows is limited to an air change rate in each of the three rooms of  $8 \text{ h}^{-1}$ , which equals a total of  $2200 \text{ m}^3/\text{h}$ . The airflow rate is assumed to be purely temperature driven. In order to keep the design conservative, cross ventilation, use of stack effect between different rooms or wind-driven ventilation were not considered. All these can provide considerable additional night ventilation, but may result in practical difficulties due to sound and light transfer between rooms. Nevertheless, due to the large

and high openings, the maximum airflow rate is reached at small indoor-outdoor temperature differences of between 1 and 3.5 K.

The combination of shading and night time ventilation is sufficient to provide summer comfort; no active cooling is required.

#### Nice

Typically, the difference between summer maximum and minimum temperatures during one day is around 6 K in Nice. Although the temperatures stay moderate, the high humidity ratios call for a certain degree of dehumidification. Therefore, for the Nice example, a supply air cooling was assumed.

The cooling device cools the supply air with a maximum power of 1200 W ( $10 \text{ W/m}^2$ ), including the resultant latent loads. It is using a PI control to limit the average temperature of the living room, nursery and bedroom to 24 °C, or the humidity ratio to 11.5 g/kg, whatever occurs earlier.

In some of the compact heat pump units that are available today, the heat pump can be inverted. Then, the supply air is used as a heat source and the hot water storage or the exhaust air can be used as a heat sink. It is technically possible to reduce the supply air temperature to around 0 °C. If the airflow rate is restricted to the hygienically necessary, this temperature results in a sensible cooling load of approximately  $7 \text{ W/m}^2$  that can be distributed in the building. Supply air ducts and air inlets need to be built appropriately in order to prevent surface condensation or uncomfortable drafts.

For buildings with good protection from solar loads, some thermal mass and reasonable insulation, it is sufficient to balance the cooling demand with the supply on a daily average. The Nice example has a daily average sensible cooling load of  $4.4 \text{ W/m}^2$ .

It may be expected that the inhabitants will not wish to stay inside a closed building at agreeable ambient temperatures. The simulation model takes this into account by assuming additional summer cooling by open windows. The same windows as in the Carpentras case are used, but as there is no need for offensive night ventilation, they are tilted – not turned – at operative room temperatures above 22 °C, if the ambient temperatures are more than 3 K below the indoor temperature. At 4 K temperature difference, the total additional airflow due to tilted windows is  $290 \text{ m}^3/\text{h}$ .



Fig. 1. 15 – Tilted window for summer ventilation

#### 1.9 DAYLIGHTING

Day-lighting was not considered in detail because it was not deemed particularly important for dwellings. It is often stated that closed shutters may result in additional use of artificial lighting during daytime, thus reducing the effects of the solar control. Especially if direct sunlight hits the window area, shading devices may usually be adjusted such that sufficient daylight gets into the rooms for living purposes without excessive solar gains. Even if this should not be the case, reasonably efficient artificial lighting may result in heat loads of less than  $1 \text{ W/m}^2$  which occur only in the occupied zones, thus raising the room temperature less than natural light would do. (See also [4]).

## 1.10 PERFORMANCE

In Carpentras, the annual heating demand of the building is 14.8 kWh/(m<sup>2</sup>a) at an operative temperature setpoint of 20 °C. Occasionally, on sunny winter days, the temperature will rise 1-2 K above the setpoint. The Nice example has a slightly lower heating demand. Temperatures above the setpoint in winter are a little less pronounced.

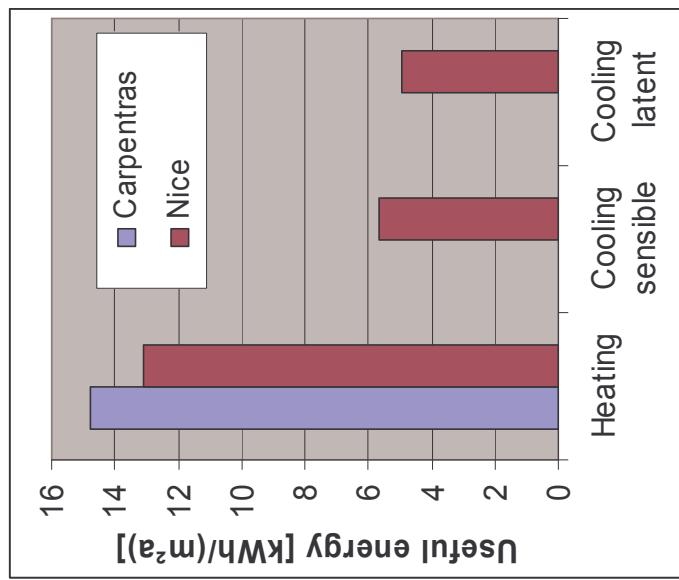


Fig. 1. 16 – Annual heating and cooling demand

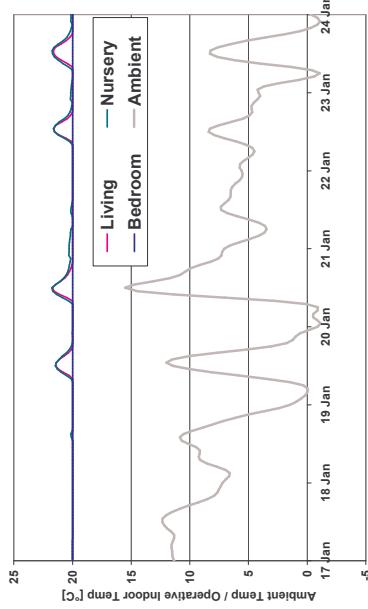


Fig. 1. 17 – Carpentras: Temperatures for one week in winter

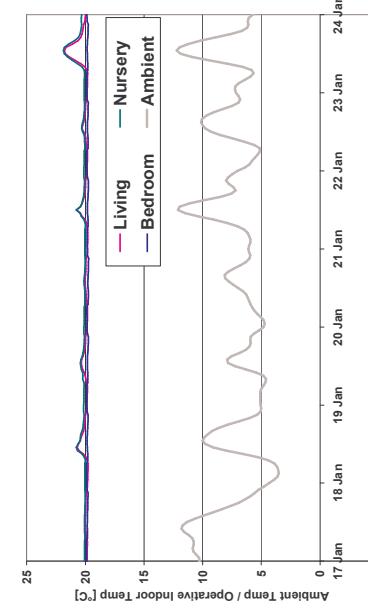


Fig. 1. 18 – Nice: Temperatures for one week in winter

As described above, the examples in Nice and Carpentras follow different approaches for summer cooling. In Carpentras, due to the passive cooling concept, no cooling energy is required. Solar control and strong window ventilation during favourable periods (mainly at night) keep the temperatures below 25 °C during more than 99 % of the year in all rooms. In Nice, a similar result is achieved with supply air cooling and only moderate additional window ventilation. In both cases, the resulting temperatures stay well below the adaptive comfort temperature during summertime (cf. Part 1 of these guidelines).

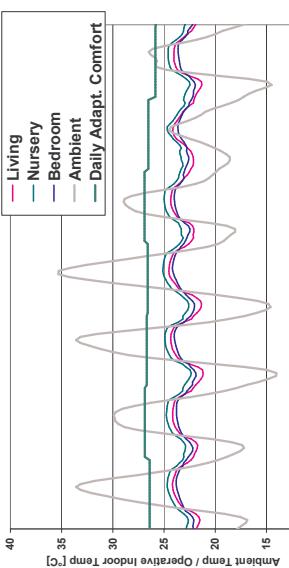


Fig. 1.19 – Carpentras: Temperatures for one week in summer

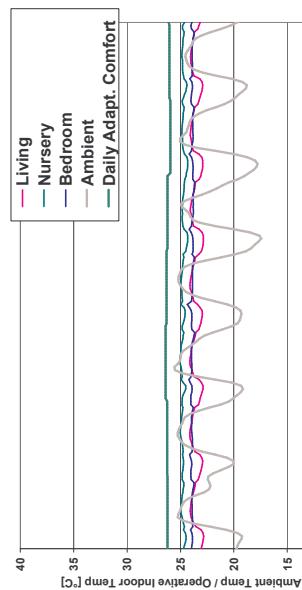


Fig. 1.20 – Nice: Temperatures for one week in summer

An issue that deserves further consideration is humidity. Several references, e.g. [5] and [6][6], state that there is a humidity ratio above which people feel uncomfortable regardless of the temperature. Although this level appears to depend on the region, with people in the tropics being less sensitive, for industrialized countries the limit is reported to be 12 g/kg. This corresponds to a dew point temperature of 17 °C.

In addition, [7] requires the relative humidity to be in the range of 30 to 70 %.

In the case of Carpentras, it was found that these requirements can be met with the passive cooling strategy during most of the time. The upper limit for the relative humidity is exceeded during less than 4 % of the year in the living room; for all other rooms as well as for the absolute humidities this fraction is lower.

In Nice, on the contrary, the humidity ratios of the ambient air are significantly higher than farther inland. If only temperatures were concerned, passive

cooling would easily be possible in this climate, similar to Carpentras. Without dehumidification, however, both upper humidity limits would be exceeded during 13 to 15 percent of the year in all zones. Air cooling and the corresponding dehumidification, on the other hand, result in comfortable conditions.

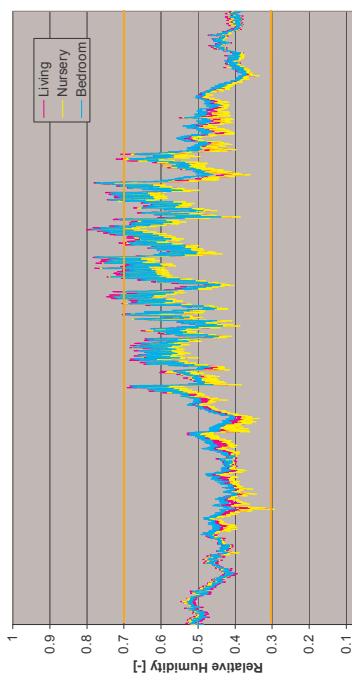


Fig. 1.21 – Carpentras: Relative humidity in the most important rooms

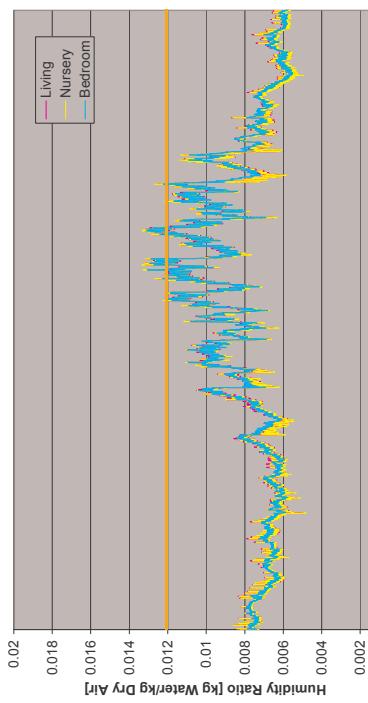


Fig. 1.22 – Carpentras: Humidity ratio in the most important rooms

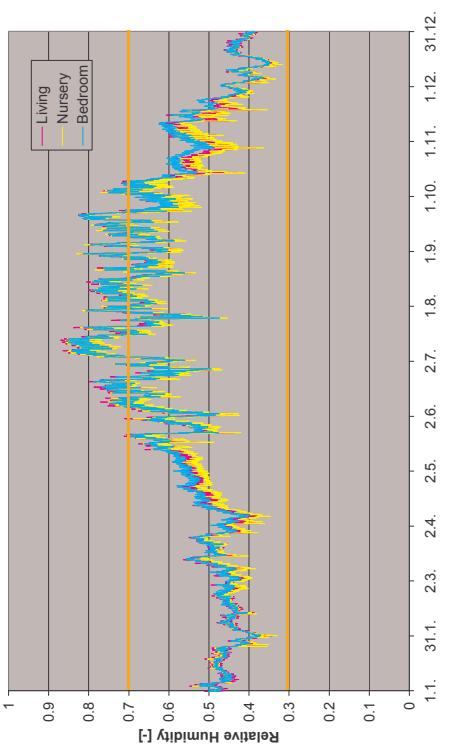


Fig. 1.23 – Nice: Relative humidity in the most important rooms for a case with purely passive cooling (not recommended)

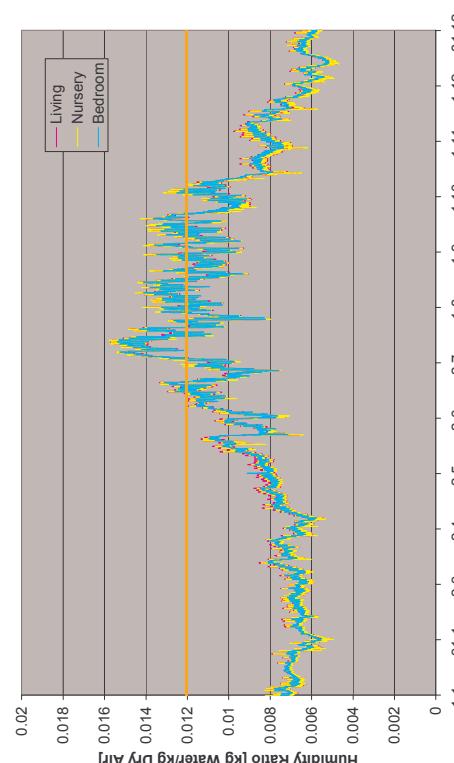


Fig. 1.24 – Nice: Humidity ratio in the most important rooms for a case with purely passive cooling (not recommended)

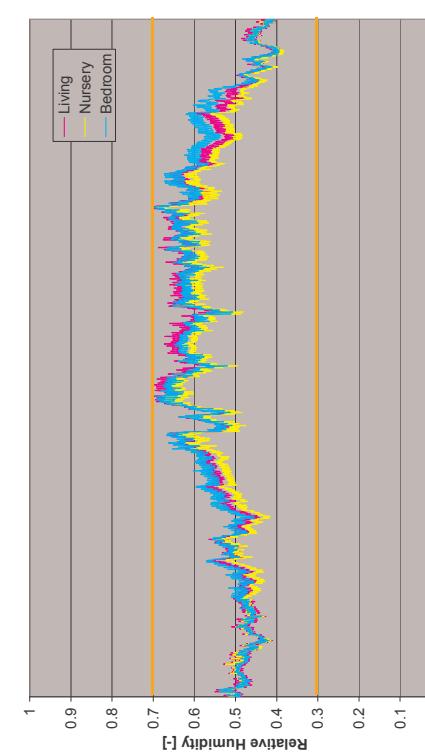


Fig. 1.25 – Nice: Relative humidity in the most important rooms for the case with supply air cooling

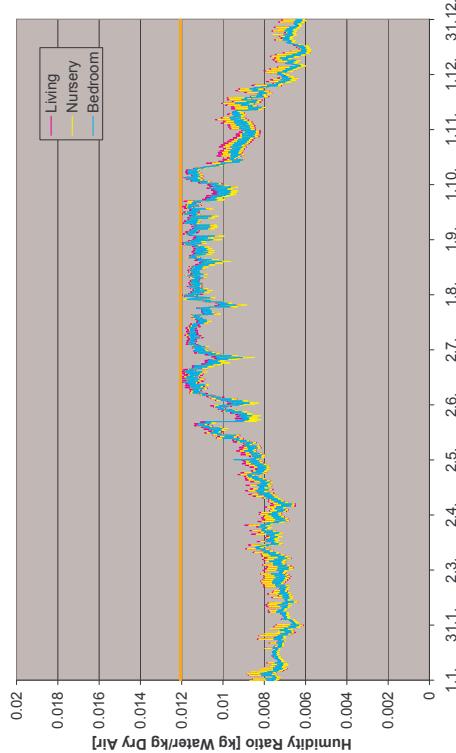


Fig. 1.26 – Nice: Humidity ratio in the most important rooms for the case with supply air cooling

## 1.11 DISCUSSION: THERMAL MASS

In warm climates, especially if night ventilation is an option, it is advisable to use a minimum amount of thermal mass. Contrary to typical contemporary building in France, insulation should be placed on the exterior of the building elements. In fact, there are three major reasons for this:

In winter, the construction materials of the walls and roof stay warm, the risk of condensation within the wall and resulting building defects is strongly reduced.

Thermal bridges can easily be avoided, whereas with interior insulation all interior walls and ceilings penetrate the insulation layer and reduce the effectiveness of the insulation.

Finally, summer comfort is improved if the thermal storage mass of the exterior building elements is accessible from the rooms.

The last effect is often overestimated. The following example for the Carpentras case shows the effects of reduced thermal mass. In Figure 27, the same summer week that has already been shown 1.10 is shown in comparison with the same period for a lightweight building. In the latter, not only the exterior, but also most aboveground interior walls and ceilings have been replaced by light constructions. The temperature swing becomes more pronounced in the lightweight version, and the maximum temperatures are about 1 K higher than in the heavyweight case – it does not go above the adaptive comfort temperature.

It should be noted that a heavy construction becomes more important in buildings with poor solar protection, bad insulation or high internal loads, in which cases more energy needs to be stored in the building construction.

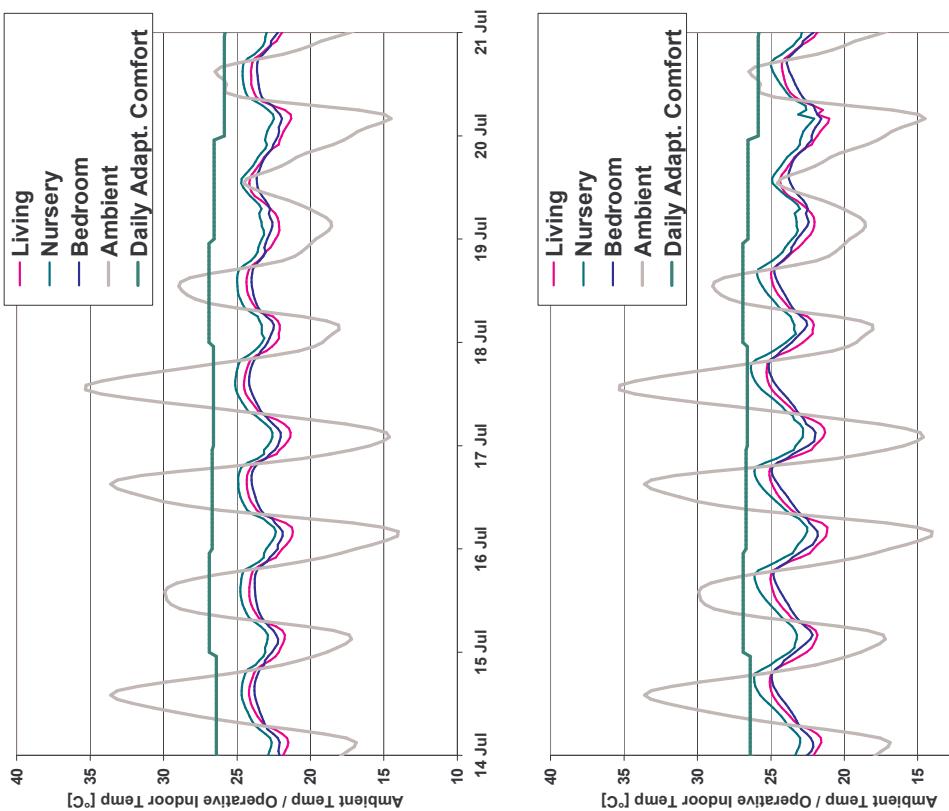


Fig. 1.27 – Carpentras: Temperatures for one week in summer with heavyweight (above) and lightweight construction

## 1.12 DISCUSSION: HEAT RECOVERY VENTILATION

### 1.13 REFERENCES

Both examples for Southern France use a ventilation system with heat recovery. Such systems, together with highly reduced leakage of the building envelope, provide excellent air quality and substantially reduce ventilation losses. Good ventilation heat recovery systems save much more energy than they need for air transport and do not cause acoustical problems.

Provided the users were ready to accept a poorer air quality and/or an increase in draft risk, would it be possible to achieve similar energy demands without ventilation heat recovery? In Carpentras, in order to achieve a space heat demand of 18.1 kWh/(m<sup>2</sup>a) without heat recovery, the following configuration is required: Walls and roof are insulated with 30 cm of polystyrene, resulting in U-values of 0.10 and 0.12 W/(m<sup>2</sup>K), respectively. The basement floor is insulated with 20 cm of polystyrene (U = 0.14 W/(m<sup>2</sup>K)). Finally, window frames as they are used in German Passivhäuser (U<sub>f</sub> = 0.72 W/(m<sup>2</sup>K),  $\Psi$  = 0.035 W/(mK)) are installed. In order to reduce the space heat demand to 15 kWh/(m<sup>2</sup>a), the building shell would still have to be improved further. It can be concluded that ventilation heat recovery is an appropriate solution for a Passivhaus in Carpentras.

In Nice, due to the much milder climate, insulation thicknesses between 10 and 20 cm would be sufficient to reduce the space heat demand to 15 kWh/(m<sup>2</sup>a). Here, heat recovery does not appear to be obligatory. As a dehumidification device is required anyway, a heat recovery ventilation system was chosen because it can simultaneously provide fresh air, adjust humidity levels and reduce energy consumption.

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