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Passive-On

A First-Guess Passive Home in Southern France

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1 Introduction

As part of the Passive-On project, it is required to determine the characteristics of Passive Homes in warmer climates. One of the first steps towards this goal is to find a ‚First-Guess Passive Home‘ for several climatic regions.

The Passive House Institute (PHI) was asked to provide guidance for the partners in developing their First-Guess Passive Homes. At the same time, the PHI was supposed to support the French partner in finding First-Guess Passive Homes for France. The following report tries to combine these two tasks by describing the process of finding a Passive Home solution for Marseille.

2 What is a Passive Home?

Passive Homes provide high comfort in both winter and summer without the need for a conventional heating/cooling system.

For Central Europe, dynamic building simulations as well as practical experience have shown that a reduction of the space heat requirement eventually requires a controlled ventilation system with highly efficient heat recovery. From a certain point, such a building does not need the conventional radiators any more; it can be kept warm by heating the supply air that is required for reasons of air quality. The ventilation system distributes this air to the different rooms and thus, at the same time, serves as a heat distribution system.

The maximum temperature of the supply air is 55 °C. Above this temperature level, dust carbonization will lead to smells. Typical air change rates are around 0,3 h^{-1}: Lower air change rates result in bad air quality, whereas with higher air change rates the relative humidity of the indoor air becomes uncomfortably low. A simple calculation then shows that the resulting heat load that can be distributed in the building via the ventilation system is around 10 W per m² *living area*.

If this standard is reached, building services may be significantly simplified. This reduces overall investment costs and thus justifies the higher investment for the efficient envelope. Therefore, the Passive House standard represents a relative (not necessarily absolute) minimum for the capitalized cost of the building (Figure 1). Depending on the boundary conditions, e.g. average energy costs and financial support, the Passive House may be the building standard with the lowest lifecycle cost.

A significant cost reduction can often be achieved when compact heat pump units (Figure 2) 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 refrigeration technology work on site. List prices for compact heat pump units in Germany currently range from 6000 to 10000 Euro. Future cost reductions with increasing production are expected.

For southern Europe, the possibility to use the heat pump (with a typical heating design power of 10 W/m² living area) also for cooling brings up interesting perspectives. The unit could then still heat the DHW with its waste heat and at the same time deliver approx. 7 W/m² of cooling power to the house.

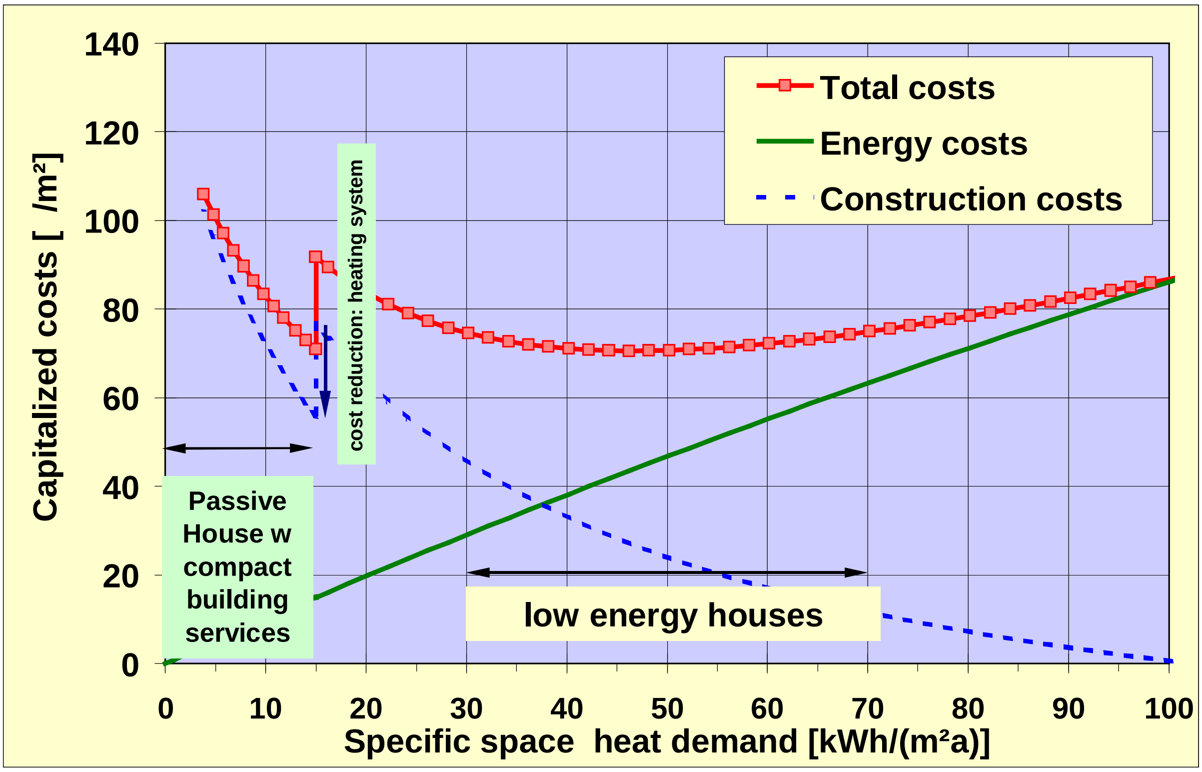
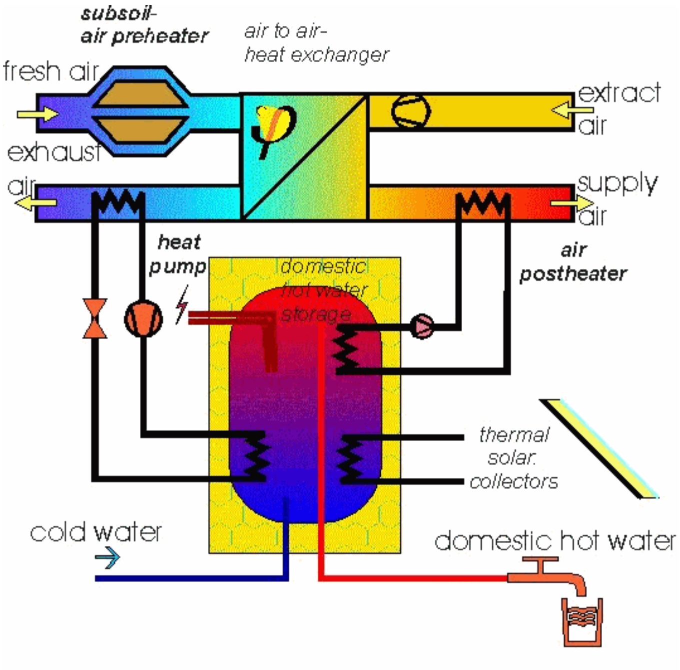


Figure 1: Life-cycle cost for different building standards



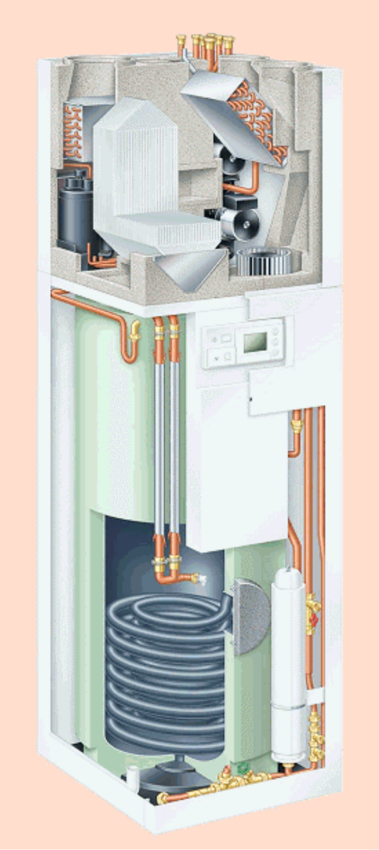


Figure 2: Basic principle and drawing of a compact heat pump unit

3 The First-Guess Passive Home in Marseille

3.1 General remarks

What would a Passive Home be like in Marseille, then? Ideally, it should be similar to a typical, newly built home in southern France. Furthermore, we start investigating an end-of-terrace house. We are looking for a building that fulfils the following conditions:

- The aim of an extremely low energy demand for heating and cooling shall be reached cost-efficiently. In the long run, with the required components being mass-produced and builders being used to the new standard, the lifetime costs must be smaller than for a conventional building. This means that the focus must be to improve the quality of components which are needed anyway, such as the building envelope, instead of introducing additional technological systems.
- The daily mean heat load, determined by means of a dynamic building simulation, is below 10 W/m². Looking at a smaller time scale for the heat load is not necessary because daily temperature variations in well-insulated buildings tend to be negligible. This very small heat load automatically results in a very small annual space heat requirement and thus a low energy consumption.
- High thermal comfort in winter. If we do not use radiators under the windows, the surface temperature of the window must not become too small in order to prevent excessive radiation asymmetry and cold downdraughts. Extensive research has shown that the temperature difference between the operative room temperature and the average surface temperature of the windows must not exceed 4 K. Drafts due to a leaky building envelope are to be avoided, too.
- Good air quality. This means that a controlled ventilation (maybe a simple exhaust system as they are already obligatory in France) is necessary.
- High thermal comfort in summer. As a well-tried criterion for comfortable summer conditions, we require that the room temperature exceeds 25 °C in no more than 10% of the hours of the year. Ideally, this should be achieved with purely passive means. Using a small power cooling device on the order of 7 W/m² might be permissible, though: The energy consumed will probably be small, and the additional investment will be near to zero. As a matter of fact, Passive Homes will have to compete with standard buildings that are equipped with cheap though inefficient split units, and they should be able to offer better overall comfort.

At the time of writing of this report, no information about typical French homes was available. Therefore, we decided to use a different starting point: An existing, verified dynamic building simulation model for the end-of-terrace Passive Homes that have been built in Hannover-Kronsberg. A photo can be ssen on the title page of this report, Figure 3 shows the floor plans and the zones of the dynamic simulation model. A detailed description of the building geometry and of the performance of the actual buildings can be found in [Feist 2005].

Climate data from [ASHRAE 2001] for Marseille were used. They represent a typical year which does generally not contain extreme weather conditions. Nevertheless, for a first guess, and lacking more suitable data, the building was designed for these conditions.

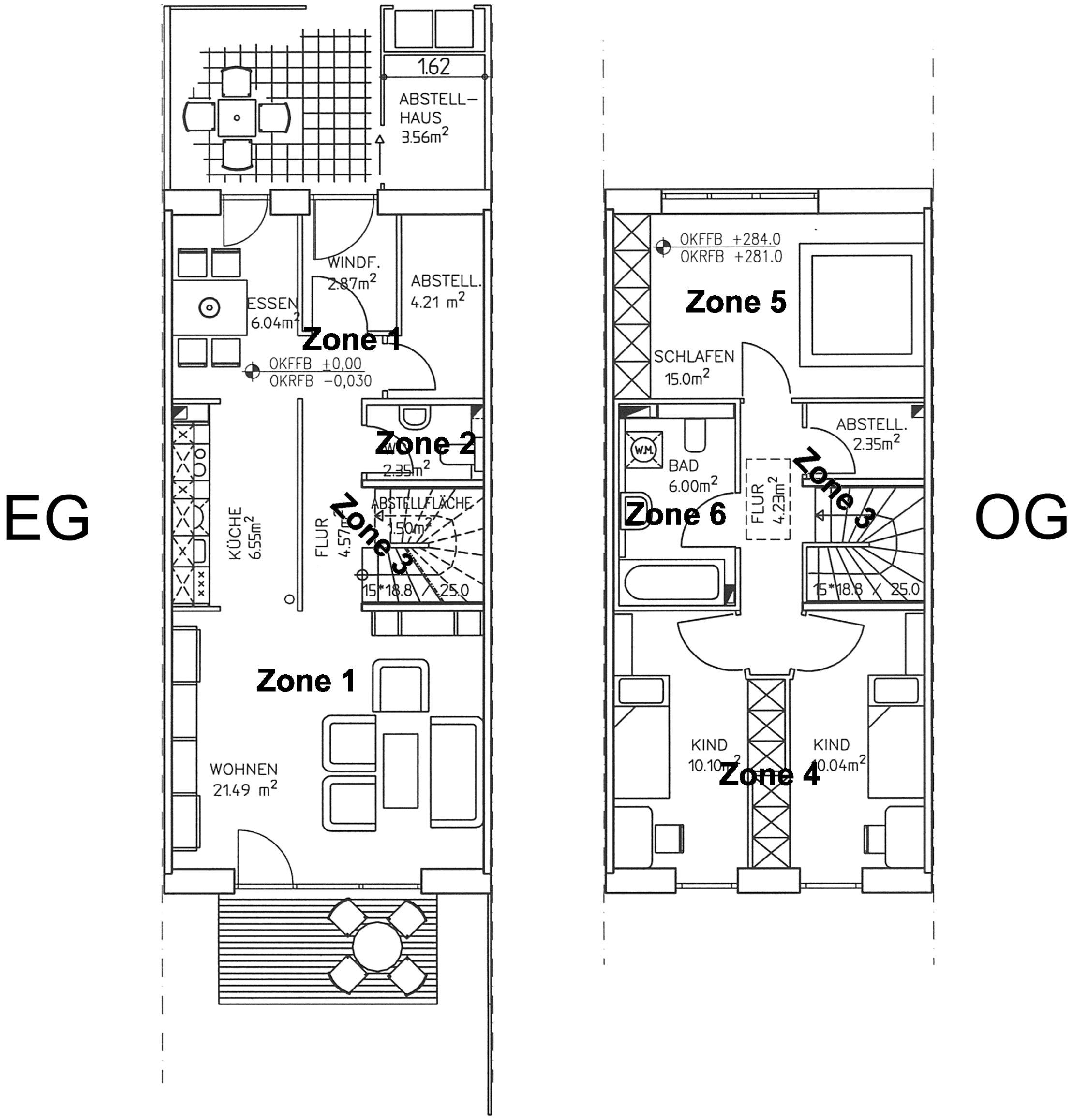


Figure 3: Floor plans of the Passive Homes in Hannover-Kronsberg. The attic (zone 7) is not shown.

3.2 Climate conditions

The average annual ambient temperature in Marseille is 15 °C. The average monthly temperature of the climate data set ranges from slightly above 5 °C in winter to around 25 °C in summer (Figure 4).

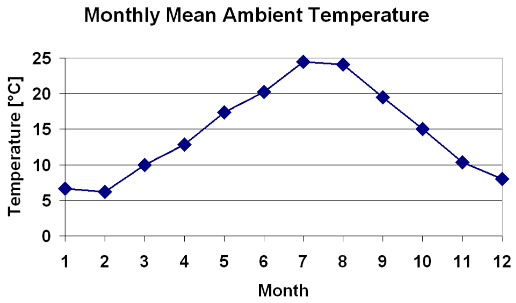
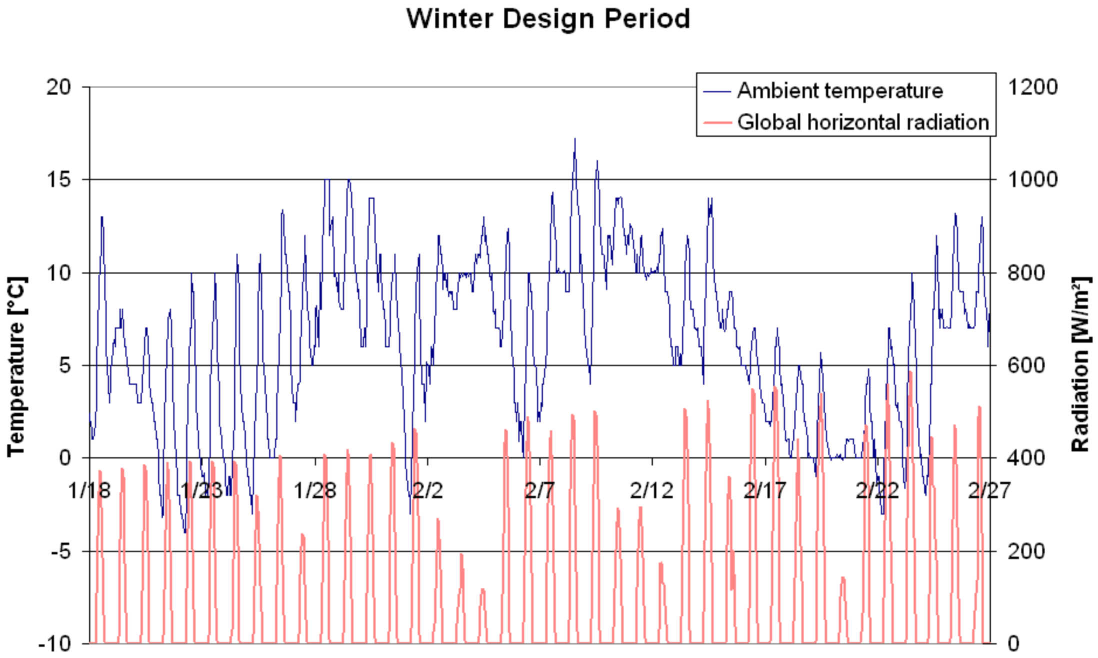


Figure 4: Average monthly temperatures



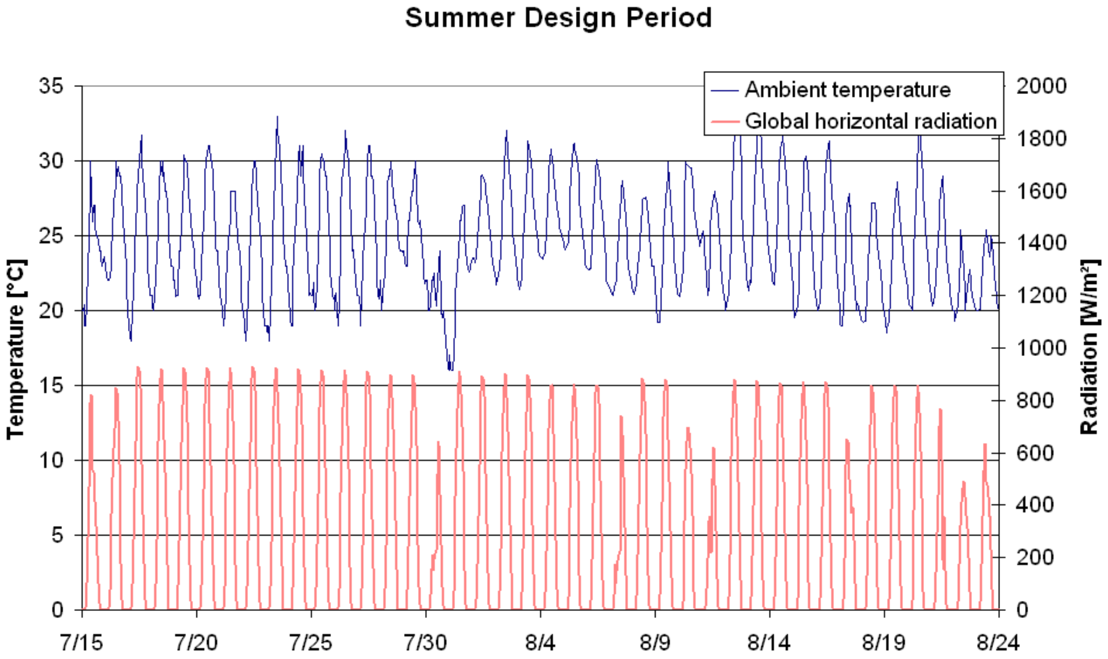


Figure 5: Winter and summer design periods

Figure 5 shows that, even in winter, it is generally sunny with no more than two or three overcast days in series. The minimum temperature is -4 °C, the miminum daily average is 0.4 °C. Thus, building designs which make use of solar energy may be functional here.

Solar radiation is also present abundantly in summer. The maximum temperature is 34 °C, the hottest day has an average of 27.1 °C. In summer, protection from solar radiation is obviously an important issue. During the hottest days, the temperature drops to 25 °C in the night, but in most cases 20 °C are reached. Night ventilation may therefore be an option.

A comfort problem may also result from humidity. Several national and international standards recommend to keep the humidity ratio below a limit of 12 g water per kg dry air. Figure 6 shows that the ambient air already exceeds this limit during longer periods (13% of the year). Adding the humidity that is produced within the room may lead to uncomfortably humid conditions during longer periods of the year.

On the other hand, the humidity ratio is often reduced to below 12 g/kg during nighttime; high ventilation rates during the night and buffer effects may lead to a sufficient reduction of indoor air humidity. The dew point temperature of the ambient air stays below 20 °C during most of the time, such that passive cooling or even moderate active cooling of ceilings will not lead to condensation.

The question of humidity in summer will need further investigations in a later stage of the project.

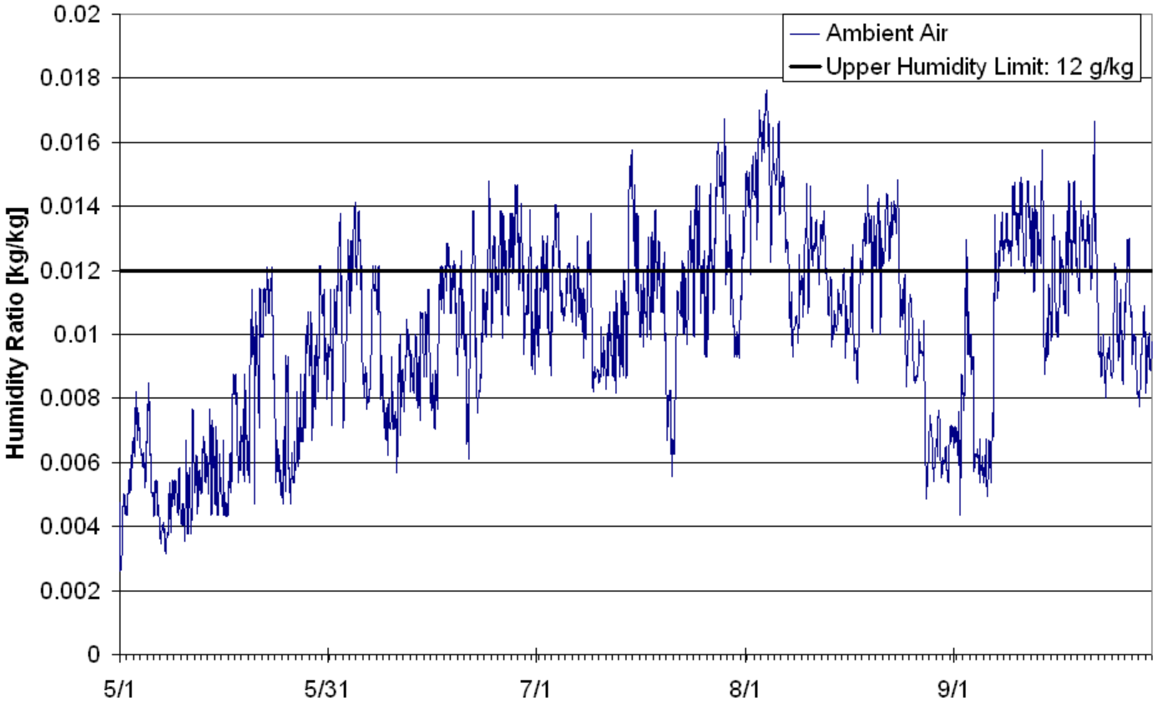


Figure 6: Humidity ratio (kg water / kg dry air) in summer in the ambient air in Marseille

3.3 Design for winter performance

To achieve the minimum window surface temperature as stated above, the overall window U-value, including frame and thermal bridges, has to be below 1.2 W/(m²K) for an ambient temperature of -4 °C. The thermal comfort would then be comparable to a triple-glazed Passive House window in Germany. This can be achieved with either triple glazing in a (German) standard window frame or with an insulating frame and double glazing. Standard window qualities will not be sufficient.

A parametric study using the geometry of the Kronsberg house resulted in 4 different variants. All variants have the following common characteristics:

- The living area (TFA) within the thermal envelope is 120 m². See [Feist 2005] for details.
- The building envelope is extremely airtight: $n_{50} = 0.6\ h^{-1}$. This is a prerequisite for the use of mechanical ventilation with heat recovery to make sense, as well as for high thermal comfort without radiators.
- Thermal-bridge-free construction: Using exterior dimensions for the calculation of transmission losses, no thermal bridges need be considered.
- A mechanical ventilation system with 110 m³/h airflow volume is installed.
- The average internal heat gains are 2.5 W/m² TFA. This value is relatively high, due to increased heat losses of the solar thermal system storage tank in the attic: The PHPP standard value is 2.1 W/m², in the Kranichstein Passive House (with highly efficient domestic applicances throughout) a value of 0.99 W/m² was measured.
- An ideal heating system is assumed, i.e. in every room an air heater is present that can heat the room air to the desired temperature of 20 °C at all times.

Heat load and annual space heat requirement were calculated with the dynamic building simulation programme DYNBIL. Two different solution sets were investigated: One has a heat recovery with 75% efficiency (‘HR75’), the other one has no heat recovery (‘HR0’).

In the first step, the insulation level of the building shell was adjusted for a heat load of slightly below 10 W/m², using triple glazing with low-e coating and argon gas filling. For the first variant, with heat recovery, standard window frames can be used whilst keeping the insulation thicknesses of the opaque building elements on a moderate level. For the secont variant, without heat recovery, an insulation thickness of 25 cm and Passive House quality window frames are required.

In southern France, a lot more solar radiation is available than e.g. in Germany (cf. section 3.2). Therefore, the overall energy balance of double glazing may be better than that of triple glazing. For both variants, the triple glazing was exchanged for double glazing, resulting in two more variants.

The following table sums up the most important thermal building data.

Variant	HR75/3p	HR75/2p	HR0/3p	HR0/2p
Roof U-value W/(m²K)	0.197	~	0.147	~
Roof insulation thickness cm	18	~	25	~
Façade wall U-value W/(m²K)	0.252	~	0.149	~
Façade insulation thickness cm	14	~	25	~
Gable wall U-value W/(m²K)	0.249	~	0.154	~
Gable insulation thickness cm	15	~	25	~
Floor slab U-value W/(m²K)	0.331	~	0.148	~
Floor insulation thickness cm	10	~	25	~
Glazing U-value W/(m²K)	0.71	1.19	0.71	1.19
Glazing g-value	0.5	0.64	0.5	0.64
Frame U-value W/(m²K)	1.6	~	0.57	~
Ψ_{frame} W/(mK)	0.04	~	0.031	~
$\Psi_{\text{installation}}$ W/(mK)	0.04	~	0.027	~
Efficiency of heat recovery %	75	~	0	~
Heat Load W/m^2	9.48	9.65	9.65	9.75
Annual Space Heat Requirement kWh/(m^{2}a)	14.5	13.5	14.5	13.4

In both cases, double glazing results in a very similar heat load as triple glazing, but in a slightly lower consumption. Assuming a location where there is not too much shading of the windows, it seems to be advantageous to use double glazing, which is also cheaper, in southern France. Nevertheless, we investigated the effects of both possibilities in summer, too.

3.4 Design for summer performance

A Passive House has to offer comfortable indoor temperatures also in summer. It is evident that, in Marseille, this is only possible with an efficient exterior sunshade. We assumed that venetian blinds are present which reflect 58% of the solar radiation and absorb 25%, resulting in a reduction of the total solar transmittance to about 20% of the unshaded value. These blinds are gradually closed at indoor air temperatures between 23 and 25 °C.

Two different summer strategies were investigated: Opening windows during colder periods, and a small, cost-efficient active cooling contribution. The results are described in the following sections.

3.4.1 Night Ventilation

Additionally, night ventilation was assumed. At room temperatures (defined as a weighted average of twice zone 4 and once zone 1) above 23 °C, the heat recovery of the ventilation system is switched off. The airflow rates through windows for single-sided and cross ventilation were calculated by means of the PHPP SummVent sheet for air changes driven by wind and/or temperature differences. Depending on the respective climate and indoor conditions, the windows were assumed to be opened at room temperatures between 22 and 25 °C.

The same algorithm was applied to all four variants. The following table shows the results.

Variant	**HR75/3p**	**HR75/2p**	**HR0/3p**	**HR0/2p**
Percentage of hours of the year with average operative temperature above 25 °C				
Zone 1	5.5	6.6	9.7	10.4
Zone 2	4.9	5.7	13.3	14.3
Zone 3	10.5	12.2	15.2	15.4
Zone 4	**16.2**	**16.8**	**17.3**	**17.8**
Zone 5	7.3	8.8	11.1	12.2
Zone 6	14.0	14.9	15.5	15.9
Zone 7	17.1	17.4	17.7	17.8
Maximum operative temperature [°C]				
Zone 1	26.2	26.3	26.7	26.8
Zone 2	25.5	25.6	26.1	26.2
Zone 3	26.0	26.1	26.5	26.6
Zone 4	**27.6**	**27.8**	**27.9**	**28.1**
Zone 5	26.3	26.5	26.7	26.8
Zone 6	26.1	26.2	26.6	26.7
Zone 7	27.2	27.3	27.5	27.6
total	27.6	27.8	27.9	28.1
Average window air change rate (Jun - Sep) [1/h]				
Air change rate	1.04	1.10	1.14	1.19

Small differences in the comfort levels of the variants can be seen in the table:

- Better insulation (in this case: lower glazing U-values) tends to provide *better* comfort.
- The variants that use heat recovery (with highly efficient DC ventilators!) have better summer climate than the variants that use better insulation instead of heat recovery. Short-term peak temperatures appear to have less effect if more of the heat flows into the building is dampened by thermal mass.

The air change rates (ventilation through windows only, the reference volume is the living area multiplied by a standard room height of 2.50 m) that are required to achieve the above temperature levels are slightly higher than 1 h^{-1}. If the temperature level in the building rises (from left to right in the table), the windows are kept open during longer periods, resulting in higher average air change rates.

The goal to exceed a temperature of 25 °C no more than 10 % of the year is not totally achieved. The hottest room is zone 4: It is on the top floor, i.e. with less shading by the horizon, south oriented and with high heat flows from the relatively hot attic (zone 7). By using more elaborate shading and ventilation patterns it will probably be possible to reduce the temperature level further. This optimization was not yet performed in this stage; it is important to assume a plausible user behaviour. Predictions of user behaviour in Southern France will have to be discussed with the French partner.

3.4.2 ‚Supply Air Cooling'

If the building is heated by a compact heat pump unit, the heat pump can easily be constructed to optionally work as a cooling device, too. In this case, a cooling load of about 7 W/m² can be covered without high additional investment cost (if the heat pump has a higher design power, this value can be larger, of course). Using a very small heat pump for active cooling would at the same time reduce the indoor air humidity. The aim of a first study was to investigate the potential of this approach.

In the following simulations, the windows have the same exterior shading devices as in the cases described in section 3.4.1 above, but no additional window ventilation takes place. The air temperature of all zones is kept below 25 °C by an active cooling system. Some results of the simulations are listed in the following table.

Variant	**HR75/3p**	**HR75/2p**	**HR0/3p**	**HR0/2p**
Hourly average cooling load [W/m²]	4.67	5.00	6.25	6.58
Hourly average cooling load for supply air only [W/m²]	0.66	0.66	2.65	2.65
Daily average cooling load within building [W/m²]	3.23	3.42	3.24	3.44
Useful cooling energy [kWh/(m²a)]	3.1	3.4	4.4	4.8

The cooling load stays below 7 W/m² in all cases. As could be expected from the results of section 3.4.1, it is considerably lower in those cases where

- insulation is better and
- a ventilation system with highly efficient heat recovery is installed.

Cooling is mainly required in zones 1, 4 and 5, i.e. in those rooms that will be connected to the supply air. Thus, cooling could actually work in a similar way as heating does in winter: Due to the well-insulated building envelope, a central heater/cooler that uses the ventilation system for distribution of the thermal power can provide comfortable climate throughout the building.

The (useful) energy which is required to operate the cooling system in summer is a lot lower than the heating energy required: It ranges between 3 and 5 kWh/(m²a).

Some further considerations are necessary if this principle is to be implemented:

- In these first simulations, the cooling power does not contain the energy needed for dehumidification. This will probably not be a real problem because of the buffer effects of building materials: If dehumidification is done during times where the peak cooling power is not needed, some humidity can be stored in the building during extremely hot and humid periods. This issue will need further investigation.
- If the windows are operated properly in order to support the ‘supply air cooling’, the cooling load will become even smaller. The same is true if the thermal mass of the building is used more efficiently: The cooling device can cool down the building during periods of less extreme temperatures, thus distributing the cooling work over a longer period. More detailed simulations will show the effects.
- Only part of the available cooling power can be distributed by the ventilation system without additional investment cost: Suppose that the cooling device succeeds in keeping the humidity ratio of the indoor air below 12 g/kg. This corresponds to a dew point temperature of 16.9 °C. Now, if the supply air duct shall not be insulated against condensation (which is relatively expensive), at 25 °C room air temperature and a supply airflow volume of 1 m³ per m² living area and hour, the ventilation system can distribute a maximum cooling load of 2.6 W/m² within the building, which equals roughly the internal heat load. The

above table shows that about 3.5 W/m² would have to be distributed within the building in order to cover the solar, internal and transmission loads – provided that certain daily temperature fluctuations are accepted. Further research will have to show what comfort level can be reached if the cooling power is limited to the above value.

4 Conclusions

In this paper, a preliminary study of the possibilities to transfer the Passive House concept to southern France is described. It is shown that well-insulated buildings are suitable to provide high winter and summer comfort with miminum energy consumption in warmer climates than Germany, too.

The simulations are based on a climate data set in which the temperature generally drops to 20 °C during the night in summer and in which overcast periods that reduce solar gains in winter do not last for more than two days. If different conditions apply (e.g. ambient temperatures above 25 °C during summer nights in city centres), the results may change substantially.

A rough estimate for a simple example shows the limits of the principle: Suppose the ambient air has an average temperature of 30 °C and is continuously above 25 °C. The total transmission heat flow coefficient H of the building with 25 cm insulation throughout, Passive House frames and triple glazing equals 60 W/K. At 25 °C indoor temperature, this results in an average transmission heat load of 2.5 W per m² living area. Average solar heat gains through the windows, on a hot day, with external shading closed, are about 1 W per m² living area. Internal gains are about 2.5 W/m², (although they may be reduced). This means that a cooling load of ca. 6 W/m² must be covered, even if solar gains and infrared radiative losses for opaque exterior surfaces balance approximately.

This cooling load can, in principle, still be covered with the supply air, but it requires the ducts to be insulated against condensation and the air inlets to be constructed in a way that no draught can occur. In even hotter climates, ways for further reduction of the cooling load would have to be found.

The following general tendencies can be derived from this first study:

- Insulation of the building envelope is not only advantageous in winter, but also in summer. During hot periods, the reduction of transmission loads helps to keep the building cool, whereas during cooler periods in summer, an efficient reduction of the indoor temperature is possible by means of window ventilation.
- Ventilation systems with heat recovery and highly efficient DC ventilators have several benefits:
  - The air quality is improved, higher comfort in winter can be achieved.
  - The insulation level of the building shell that is required to limit the heat load to 10 W/m² can be reduced, in the present case from 25 to 15 cm of insulation.
  - The summer climate is improved; cooling loads (if applicable) are substantially reduced.
- Reducing electricity consumption is important for two distinct reasons:
  - It reduces the overall primary energy consumption: Household electricity is the highest share in the primary energy consumption of Passive Homes.

  - It is crucial for the success of passive or low-energy cooling strategies in summer.
- Other means of passive cooling require further investigation:
  - Ground coupling, using less insulation in the floor slab or ground heat exchangers with air or water may help to reduce summer temperatures. Ground coupling is not useful in multi-storey houses.
  - Increasing ventilation rates by cross-ventilation or stack effect may reduce the summer temperatures.
  - In German climate, thermal mass is not particularly important for reducing the space heat consumption in winter, but improves the summer conditions. It was found, though, that only very light-weight constructions result in higher summer temperatures; as soon as a mixed construction is used, increasing thermal mass does not reduce the temperatures significantly any more. The influence of thermal mass in Mediterranean climate should be systematically investigated.
  - …
- Parametric studies should be performed on the effects of e.g. window sizes, overhangs and reveals, optimum distribution of insulation between floor slabs, roof, walls and windows, ground heat exchangers, …

5 References

[Feist 2005]	Feist, Wolfgang, Søren Peper, Oliver Kah, Matthias von Oesen: Climate Neutral Passive House Estate in Hannover-Kronsberg: Construction and Measurement Results. PEP Project Information No. 1. ProKlima, Hannover 2005.
[ASHRAE 2001]	ASHRAE: International Weather for Energy Calculations 1.1 (IWEC Weather Files). Atlanta 2001