Passive house optimization for Southern Italy based on the "New Passivhaus Standard"

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Abstract

In Germany and in other countries of Central and Northern Europe more than 8,000 homes conforming to the *Passivhaus* standard have been built since 1991. The applicability of this Standard has not yet been sufficiently tested in European areas with warm climates, where reducing cooling needs under growing summer comfort requirements poses a challenge.

The IEE *Passive-On* project has drafted a proposal to adapt that Standard to the conditions that characterize Southern Europe, which is described in this paper together with its rationale. Compared with the original definition, one of the main changes is the introduction of explicit requirements on internal comfort during summer, in parallel to a limit to energy needs for cooling.

The dynamic simulations conducted to test the new definition of the Standard in the context of Southern Italy (e.g. Palermo) show that the requirements identified by the *Passivhaus* Standard can be met by simplifying the envelope technologies (e.g. relaxing air-tightness design value) used in the context of Central Europe and adopting passive cooling strategies appropriately adjusted. Some simplifications of the ventilation system can be compensated by an increased role of thermal insulation of the building envelope and some of the choices can make energy needs tend to zero. In accordance with EN 15251, thermal comfort is characterized according to Fanger's PMV in cases where mechanical cooling is still required for peak situations, and according to the adaptive model where no mechanical cooling is required.

Introduction

The success of the Passivhaus Institute in developing and implementing an approach to house design in Central European climates which is not only very energy efficient, but also meets year-round comfort criteria, naturally led to the question of whether this is applicable in other countries and other climates.

This question is central to two recent research projects funded under the IEE programme by the European Commission (the *Passive-On* and the *PEP* projects). The *Passive-On* project primarily addresses the question of its applicability in Southern Europe (Portugal, Spain and Italy).

In this context, the *Passive-On* Consortium has worked for a **new *Passivhaus* Standard**, extension of the original one for warm climates and for an 'affordable' house proposal which was designed to meet the *Passivhaus* Standard in terms of both predicted energy consumption and thermal comfort criteria.

New Passivhaus Standard

In 1991 Wolfgang Feist and Bo Adamson applied the passive design approach to a house in Darmstadt, with the objective of providing a show case low energy home at reasonable cost for the German climate. By 1995, based on the experience from the first developments, Feist had codified the Passive Design into the ***Passivhaus* Standard**. The Standard fundamentally consists of three elements:

- an energy limit (heating);
- a quality requirement (thermal comfort);

- a defined set of preferred passive systems which allows the energy limit and quality requirement to be met cost effectively.

It already featured all characteristics of what is today known as the current **German *Passivhaus* Standard**: very good insulation, including reduced thermal bridges and high thermal resistance windows, good air-tightness and a ventilation system with highly efficient heat recovery. For Central European climates, it turned out that these improvements in energy efficiency finally result in the possibility to simplify the heating system. It becomes possible to keep the building comfortable by heating the air that needs to be supplied to the building to guarantee good indoor air quality. Then the whole heat distribution system can be reduced to a small post-heater to the heat recovery system. This fact renders high energy efficiency cost-efficient: considering the lifecycle cost of the building, a *Passivhaus* need not be much more expensive than a conventional new dwelling.

In total more than 8,000 houses have now been built in Germany and elsewhere in Central and Northern Europe (e.g. Austria, Belgium, Switzerland, Sweden ...) which conform to the current *Passivhaus* Standard. To most professionals in Germany and to many in the general public a Passive House now equates with the *Passivhaus* Standard but its applicability elsewhere in Europe has yet to be tested.

Defining a standard for low energy homes has offered a number of advantages both for the building industry as a whole and the German market in particular. In fact it has been a major reason for the explosion of the construction of low energy homes in Germany. Here are the five points that define the original German *Passivhaus* Standard for Central European Countries:

- Heating criterion: the energy need for space heating does not exceed 15 kWh per m² net habitable floor area per annum.
- Primary energy criterion: the primary energy demand for all energy services, including heating, domestic hot water, auxiliary and household electricity, does not exceed 120 kWh per m² net habitable floor area per annum.
- Air-tightness: the building envelope must have a pressurization test result according to EN 13829 of no more than 0.6 h[1].
- Comfort criterion on room temperature in winter: the operative room temperatures can be kept above 20°C in winter, using the abovementioned amount of energy.
- All energy demand values are calculated according to the Passive House Planning Package1 (PHPP) and refer to the treated floor area, e.g. the sum of the net floor areas of all habitable rooms, excluding e.g stairs.

However, although in Central Europe (e.g. Germany, Austria, Switzerland ...) passive design is increasingly associated with the *Passivhaus* Standard, this is not necessarily the case in Southern Europe (e.g. Spain, Italy, Portugal, Greece ...). Here to most building designers "passive house" generally means any house constructed in line with the principles of passive solar design. Furthermore many professionals in the field disagree with associating the generic word "passive" with a specific building standard, which proposes an active ventilation system.

The *Passive-On* Consortium has therefore formulated a revised proposal for the application of the *Passivhaus* Standard in Warm European Climates which takes into account the climatic as well as the philosophical issues mentioned above. The six points that define the proposed new *Passivhaus* Standard for Warm European Climates are listed below:

1. Heating criterion: the energy need for space heating does not exceed 15 kWh per m² net habitable floor area per annum;
2. Cooling criterion: the useful, sensible energy need for space cooling does not exceed 15 kWh per m² net habitable floor area per annum;
3. Primary energy criterion: the primary energy demand for all energy services, including heating, domestic hot water, auxiliary and household electricity, does not exceed 120 kWh per m² net habitable floor area per annum;
4. Air-tightness: if good indoor air quality and high thermal comfort are achieved by means of a mechanical ventilation system, the building envelope should have a pressurization test (50 Pa) result according to EN 13829 of no more than 0.6 h-1. For locations with winter design ambient temperatures above 0°C, a pressurization test result of 1.0 h-1 is usually sufficient to achieve the heating criterion;
5. Comfort criterion room temperature winter: the operative room temperatures can be kept above 20°C in winter, using the abovementioned amount of energy;
6. Comfort criterion room temperature summer: in warm and hot seasons, operative room temperatures remain within the comfort range defined in EN 15251. Furthermore, if an active cooling system is the major cooling device, the operative room temperature can be kept below 26°C.

To achieve the *Passivhaus* Standard it now becomes necessary that indoor summer temperatures, more specifically operative temperatures, remain lower than the maximum temperatures defined by the EN 15251 Standard.

According to EN 15251 Standard, acceptable comfort temperatures actually depend on the type of system used to provide summer comfort. If cooling is provided by an active system then indoor temperatures must respect those defined by the Fanger's comfort model. Otherwise, if summer comfort is provided by passive cooling strategies, then the upper temperature limit is set by the Adaptive Comfort model.

The two models are applicable in different conditions; roughly speaking the Fanger's model is applicable in mechanically conditioned buildings (within specified ranges of temperatures, humidity, air velocities ...), and the adaptive model in non mechanically conditioned or naturally ventilated buildings. There is ongoing research on the boundaries of applicability of the two models. A correction should be made when evaluating summer conditions to take into account the increase of comfort

1. See: http://www.passivhaustagung.de/Passive_House_E/PHPP.html

produced by increasing air velocity by using natural ventilation or fans.

The adaptive model generally defines both higher and more variable comfort temperatures than those predicted by the Fanger's model. Often the neutral adaptive comfort temperature can be achieved by using passive cooling strategies, such as window shading and night time ventilation. When this occurs the energy need for cooling may be effectively reduced to zero and no mechanical cooling is required.

However, in some locations applying effective passive cooling techniques can be problematic. Particularly in cities it can be difficult to realize effective night time ventilation strategies (by which cool night air is used to cool the building's thermal mass) both since occupants might close windows at night to cut back outside noise and since diurnal temperature swings are reduced due to local heat island effects. In these cases other cooling techniques can be explored or, alternatively, active cooling systems installed in order to provide acceptable indoor thermal conditions for occupants in summer.

As a consequence, in the proposed revised Standard for Warm European Climates, homes must now meet the following requirements:

- If cooling is provided by mainly passive means:
  - indoor comfort requirements: as defined by the adaptive model of the Annex A.2 ("Acceptable indoor temperatures for design of buildings without mechanical cooling systems") of the EN 15251;
  - energy needs for heating and cooling shall be lower than 15 kWh/m^2/year
  - Total primary energy shall be lower than 120 kWh/m^2/year;
- If cooling is provided by active systems:
  - indoor comfort requirements: as defined by the Fanger's model of the EN 15251;
  - energy need for heating shall be lower than 15 kWh/m^2/year;
  - energy need for cooling: shall be lower than 15 kWh/m^2/year (this value may be updated and possibly reduced based on field studies);
  - total primary energy shall be lower than 120 kWh/m^2/year.

Optimization for Southern Italy

Considering the nature of the new *Passivhaus* Standard, the aim of the study is to identify for a Mediterranean climate (Palermo) at least a package of technological solutions and control strategies capable to have the energy performance requisites (energy need for heating and cooling) and the comfort requisites already mentioned above.

In this context we consider as an advantage for the methodology to begin from the experience already consolidated in Centre Europe and, with a number of sensitivity analysis, to optimize the project results with proper modifications and integrations.

Object of the analysis is a residential building with the following characteristics:

- Geometry, space disposition and use schedules of a typical terraced two floors house;
- S/V Ratio of 0.9 m^2/m^3;
- Medium-high thermal inertia of building components (450 kg/m^2, according to ISO 13786 calculation method);
- Low internal gains;
- Low air permeability of building envelope (n_{50} = 0.6 h^{-1});
- High insulated envelope (U-value of external wall, basement and roof equal to 0.135 W/m^{2}K; U-value of windows equal to 0.7 W/m^{2}K);
- An air distribution system with 10-20 cm diameter ducts and two fans (around 40 W each) for the fresh air inlet and the exhausted air extraction (ach = 0.74 h^{-1});
- A air-air heat exchanger with a 85% efficiency for the preheating of air;
- A heat pump of low power for the additional heating of the thermo vector fluid in order to guarantee the internal 20°C in winter.
- Shading of windows on southern and eastern facades by means of the roof eaves and of the reflecting blinds controlled to block the direct solar radiation,;
- A nigh ventilation strategy realised by windows opening, properly conceived to remove efficiently the heat stored during the day and to avoid discomfort conditions in the sleeping rooms of the building;
- The use of a cooling active system capable to limit inside temperatures to 26°C and bound to intervene when the heat removal by night ventilation is not sufficient for this aim. This additional contribution could be given by a reversible heat pump with low power (the same is used during winter for heating purposes).

Dynamic simulations made on the described building have allowed to quantify the energy need to satisfy the indoor thermal comfort requirements and confirmed the initial hypothesis on the possible transfer and integration of the strategies used in Central Europe. The simulations are also aimed at identifying in a quantitative way the possibilities to relax the requirements of the basic model.

In this direction we have developed two optimization analysis with the aim of defining the possible ranges of modifications and to test, in a sequence of steps, reductions in requirements regarding the permeability and the thermal resistance of the building envelope. The figures 1 and 2 show their effect on energy need for heating and cooling, for the climate of Palermo.

Considering that a value of n_{50} of 1.0 h^{-1} already implies a good simplification of the installation procedures and of windows validation (Blower Door Test), we have chosen to use this value.

About glazed areas, it does not seem to be necessary to adopt triple glazing while it might prove inadequate (from the energy point of view and for local comfort) the use of standard clear

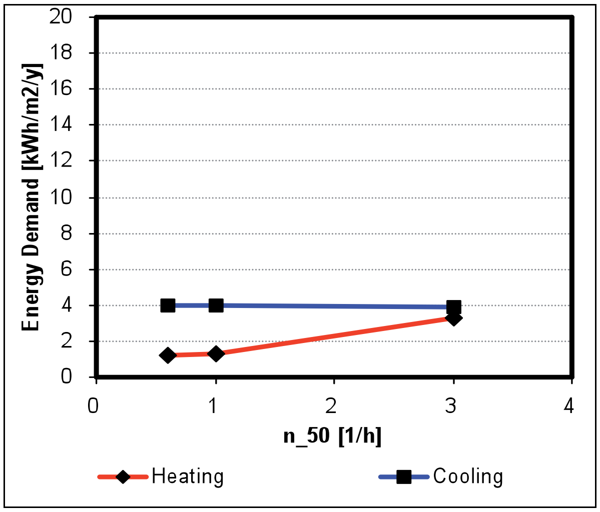


Figure 1. Winter and summer energy needs in Palermo. They are represented as a function of building envelope air tightness (expressed by the n_{50} value).

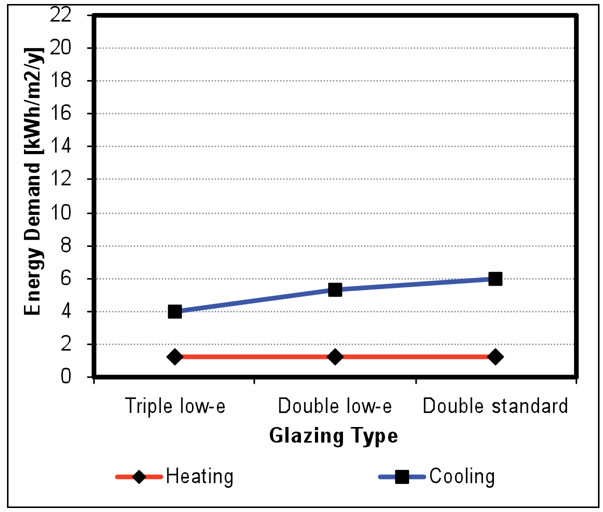


Figure 2. Winter and summer energy needs in Palermo. They are represented as a function of different glazing types: triple low-E (with U-value of 0.7 W/m²/K and solar factor of 0,5), double low-E (with U-value of 1.4 W/m²/K and solar factor of 0.6) and Standard double (with U-value of 2.7 W/m²/K and solar factor of 0.8).

Table 1. Variants of thermal insulation of opaque elements.

Variant		External walls U-value [W/m²K]	Roof U-value [W/m²K]	Basement U-value [W/m²K]
High insulation	+	0.135	0.134	0.134
Medium-high insulation	o+	0.200	0.200	0.300
Medium insulation	o	0.300	0.300	1.000
Medium-low insulation	o-	0.500	0.300	0.700
Low insulation	-	0.540	0.420	1.34
No insulation	n	1.489	1.404	1.404

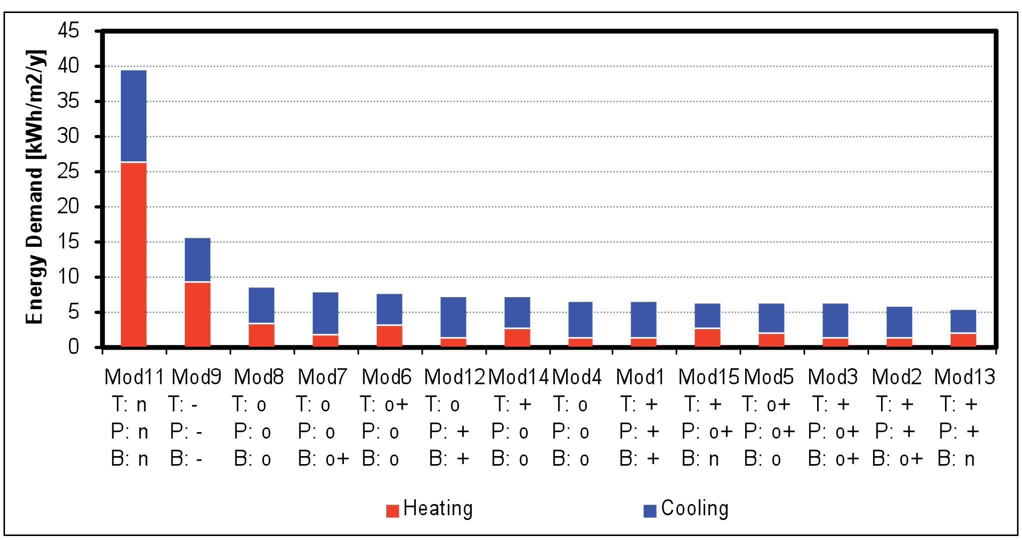
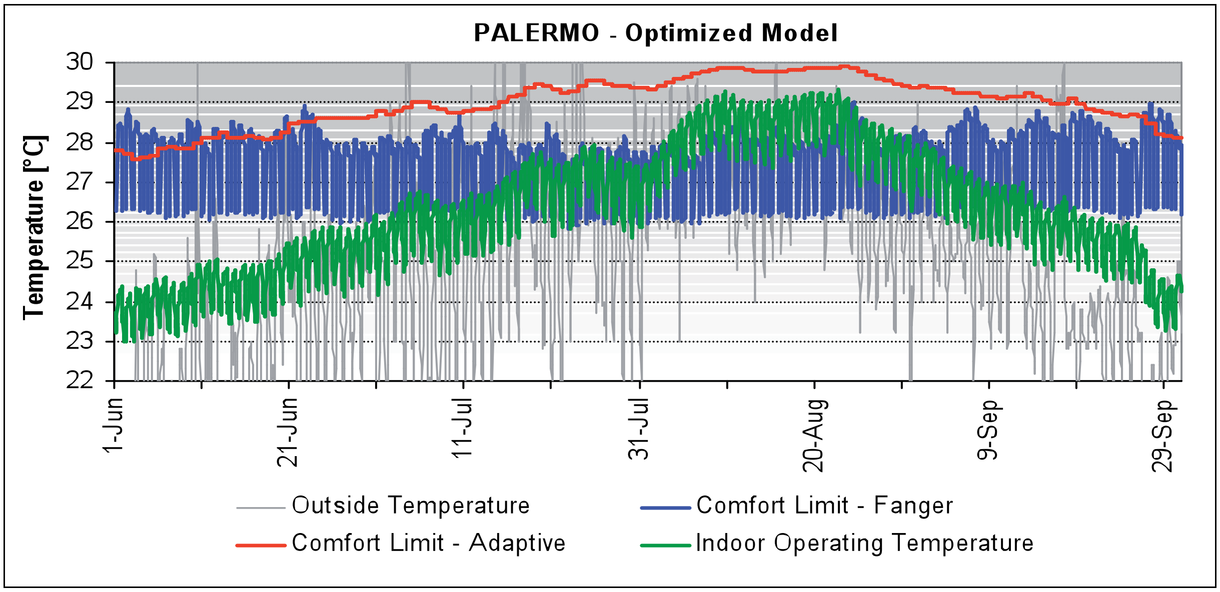
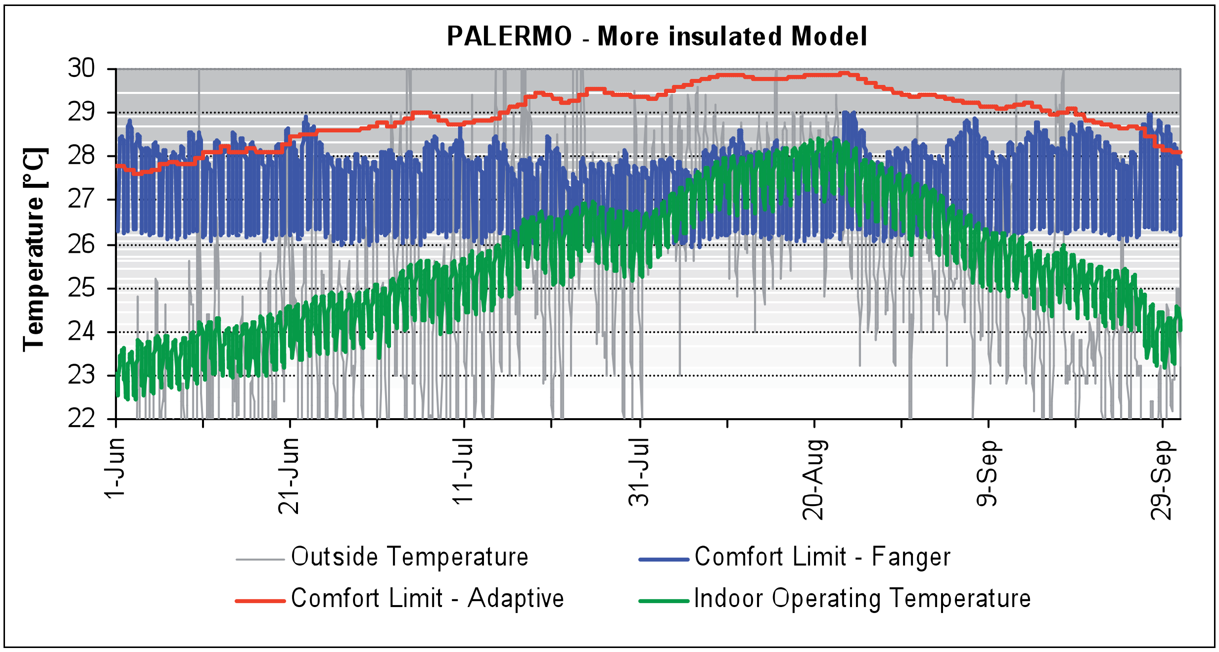


Figure 3. Energy needs for heating and cooling in Palermo. They have been represented as functions of different combinations of thermal insulation of roof (T), external walls (P) and basement (B).





Figures 4 and 5. Indoor Operating Temperatures in free-floating mode of the optimized building and of a more insulated model compared to the acceptable Comfort Temperatures in Summer as defined by the Fanger's model and the Adaptive model for completely naturally ventilated houses according to the EN 15251 Standard.

glazing: we have therefore decided to adopt 2 pane low-E glazing.

About opaque components, the analysis shows that a really high insulation of the building components does not consistently improve the winter behaviour of the building and that the basement insulation penalizes summer conditions in such a low rise building: the importance of this would be lower in a higher rise building). For the considered building the requirements identified by the *Passivhaus* Standard can be met with a lower level of insulation. The first model that meets these requirements is the one with 5 cm insulation in the walls (U = 0.54 W/m²K), with 6 cm in the roof (U = 0.42 W/m²K) and with a non-insulated basement (U = 1.34 W/m²K). In order to avoid misunderstandings, we remind here that these results have been obtained considering buildings with a heat recovery strategy on exhaust air and they would not be valid without this strategy.

It's now interesting to verify how optimized models of buildings would behave with a complete passive cooling strategy, that works only with solar control and natural ventilation.

Figure 4 shows the indoor comfort conditions in free-floating mode for the climate of Palermo. The indoor operative temperatures are closer to the upper value of the adaptive limit (as defined by the EN 15251 norm) and often are higher (for the 15% of the summer period) than the Fanger's limit, even using fans that increase the indoor air speed of 0.5 m/s. In order to improve indoor conditions, it is possible to further improve the building envelope features: if we increase to 25 cm the insulation levels of the perimeter walls and the building roof it is possible to reduce (of about 1°C) the indoor temperature peaks.

Conclusion

An optimization of a prototypical two floor terraced house in order to satisfy the new PassivHaus Standard for southern climates shows that (at least for the explored climate):

- it seems possible to obtain performances that are better that the 15+15 kWh/m^{2}year energy need defined by the standard using moderate levels of insulation, moderate air tightness, solar protections and night ventilation, heat recovery on exhaust air in winter, and a reversible heat pump both for winter space heating and for reducing the summer temperature peaks
- an alternative model, with higher insulation levels, and relying only on heat protection and night ventilation to provide summer comfort, appears capable to meet the adaptive comfort limits, and hence to forego the energy expenditure to achieve summer comfort.

Further investigation is ongoing, in order to explore the behaviour in the field (as did the CHEPEUS Project for the Central Europe) and to analyse possibilities to further ameliorate the standard.

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