Optimization of air tightness and night ventilation for Passive houses in Italian climates under Fanger and Adaptive comfort models

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ABSTRACT

In Central and Northern Europe several thousands homes conform to the Passivhaus standard have been built. The applicability of this Standard has not yet been sufficiently tested in warmer climates, where reducing cooling needs under growing summer comfort requirements poses a challenge.

The IEE Passive-on project has drafted a proposal to adapt the Standard to the conditions that characterize Southern Europe. 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 Standard Passivhaus can be met by simplifying the envelope technologies (e.g with a lower level of air-tightness compared to the northern version) and adopting passive cooling strategies (e.g. night ventilation) appropriately adjusted. Some ventilation plant simplifications can be compensated by an increased role of thermal insulation and some of the choices can make energy needs tend to zero.

Thermal comfort is characterized according to Fanger PMV in cases where mechanical cooling is still required for peak situations, and according to the Adaptive Model where no mechanical cooling is required (see standard EN15251). Authors are performing energy and comfort measurements in recently built Passivhaus in Italy. Some analysis on non-domestic buildings with a similar methodology has been performed in the framework of the KeepCool2 project and some results are presented.

KEYWORDS

Fanger and adaptive summer comfort, new Passivhaus standard, envelope optimization, air tightness optimisation

THE ORIGINAL *PASSIVHAUS* STANDARD

In 1991 Wolfgang Feist and Bo Adamson applied passive design to a house in Darmstadt, with the objective of providing a show case low energy home at reasonable cost for the German climate. By 1998, based on the experience from the first developments, Feist had codified the Passive Design of the Darmstadt and Groß-Umstadt homes into the *Passivhaus* standard,

Table 1 – Original *Passivhaus* standard requirements**.**

Heating criterion	Heating energy need limit of 15 kWh per m² of net useful surface per year.
Primary energy criterion	Primary energy demand for all energy end uses and services (included heating, domestic hot water production, electric consumption for artificial lighting, all electric equipments and electric auxiliary systen like pumps, fun, etc.) of 120 kWh per m² of net useful surface per year.
Air-tightness	Infiltration rate from building envelope limit of 0,6 h^{-1} (at pressure difference of 50 Pa), as result of test made according to EN 13829 standard.
Heating comfort criterion	In heating period, indoor operative temperature can be kept above 20 °C, by using the energy consumptions written above.
Analysis tool	Certification method are applied by using Passive House Planning Package (PHPP) software.

THE *PASSIVHAUS* STANDARD FOR EUROPEAN AREAS WITH WARM CLIMATES

- The research project Passive-on (2005-2007) financed by the Intelligent Energy Europe programme, has evaluated the possible development of the *Passivehaus* standard in warm climates. It also:
- up-dated the PHPP (Passive House Planning Package) software, developed by Passivhaus Institut, in order to consider thermal loads for cooling and to evaluate passive energy strategy;
- disseminated the *Passivehaus* concept in the involved countries by mean of technical workshops and a web-site[1].

By means of dynamic simulation of models of buildings, and with the involvement of the german Passivehaus Institute the consortium of researchers analyzed the previous standard and made a proposal in order to adapt it to climate conditions of the South European regions. This new criteria, summarized in table 2, will be reviewed as experience in designing and realizing passive houses in warm climate will grow.

Table **2** – extended ***Passivhaus*** standard for warm climates.

Heating criterion	energy need for heating lower than 15 kWh per m² of net useful surface per year.
Cooling criterion	energy need for sensible cooling lower than 15 kWh per m² of net useful surface per year.
Primary energy criterion	Primary energy demand for all energy end uses and services (included heating, domestic hot water production, electric consumption for artificial lighting, all electric equipments and electric auxiliary systems like pumps, fans, etc.) lower than 120 kWh per m² of net useful surface per year.
Air-tightness	With good air quality and high thermal comfort guaranted by mechanical ventilation system, infiltration rate from building envelope limit of 0,6 h^{-1} (at pressure difference of 50 Pa), as result of test made according to EN 13829 standard. In climate conditions where design heating outdoor temperature is

[1] www.passive-on.org

	greater than 0 °C, , infiltration rate from building envelope should be ≤ 1,0 h^{-1} (at pressure difference of 50 Pa), as result of test made according to EN 13829.
Heating comfort criterion	In heating period, indoor operative temperature can be kept above 20 °C, by using the energy consumptions written above.
Cooling comfort criterion	In warm and wet periods, indoor operative temperature should be in thermal comfort interval defined in the standard EN 15251. Moreover, with active cooling system indoor operative temperature can be kept below 26 °C, by using the energy consumptions written above.
Analysis tool	All energy values can be calculated with the up-dated version of Passive House Planning Package (PHPP 2007) software.

The use of the German term *Passivhaus* for a standard pertinent to the Mediterranean has been the source of much discussion among the research group. To avoid confusion the choice was made to use *Passivhaus* in relation to those homes which meet the extended *Passivhaus* standard and the term Passive House or its translation in national languages to refer to homes which integrate some general form of Passive Design (and which may or may not conform to the standard).

Importantly the estended Passivhaus standard makes now reference to the most recent standards on thermal comgort (i.e EN15251-2007). Thermal comfort is characterized according to Fanger PMV in cases where mechanical cooling is still required for peak situations, and according to the Adaptive Model where no mechanical cooling is required (see EN15251). Comfort conditions can be further improved by means of air velocity increase by natural ventilation or e.g ceiling fans (see air velocity correction in EN 15251 and – more detailed - in ASHRAE 55-2004).

These paper presents an example of how the extended Passivhaus Standard may be applied in a warm climate such as Italy, and tries to propose some conclusions applicable also in other warm climates.

We have chosen as reference typology the solution of terraced house. The analysis has been developed through the dynamic simulation of the energy behaviour of building models properly defined.

The house considered in this study presents the typical integrated system of the centre European experience, characterized by:

- an air distribution system consisting of ducts with a 10 ÷ 20 cm diameter and two fans (around 40 W each) for the fresh air inlet and the exhaust air extraction;
- an air to air heat exchanger with a 85% efficiency for the pre-heating of air in winter
- a heat pump of low power to be used when additional heating of the thermo vector fluid is needed in order to reach the internal 20 °C setpoint in winter.

It uses the following additional solutions:

- shading of south and east windows by means of the roof eaves and the use of reflecting external blinds, sized and controlled to block the direct solar radiation, but not the diffuse one that can be used for daylighting;
- a night ventilation strategy by controlled frames opening, properly conceived to remove efficiently the heat stored during the day and to avoid local discomfort conditions in the sleeping rooms of the building.

- the use of a cooling active system able to limit indoor temperatures to 26°C[2] activated when the night ventilation is not sufficient for this aim; this additional contribution could be given by a low power reversible heat pump (the same device used during winter heating).

Table 3: main characteristics of base model.

Surface =	103		m^2
Room height =	2,70		m
S/V Ratio =	0,88		m^2/m^3
Air infiltration: n_{50} =	0,60		h^{-1}
Envelope U-value	wall	0,135	$W/m^2/K$
	roof	0,135	$W/m^2/K$
	floor	0,135	$W/m^2/K$
	glazing	0,700	$W/m^2/K$
Thermal mass =	450		kg/m^2 of net floor area
Occupation	n° people	4	
Internal gains (installed power)	appliances	2,0	W/m^2
	lighting	1,2	W/m^2
Heating strategies	Air-Distribution System		
	Heat recovery with efficiency of 85%		
	Reversible heat pump		
Cooling strategies	Solar protections		
	Night natural ventilation		
	Reversible heat pump		
Air change rate =	0,74		h^{-1}

For the characterization of the electric power installed and the electric hourly load we used the data collected trough a metering campaign[3] conducted in 110 Italian houses between 2 000 to 2 002 which derived data on hourly use and consumption of the individual appliances and lighting.

OPTIMIZATION ANALYSIS ON AIR PERMEABILITY OF THE BUILDING ENVELOPE

Uncontrolled external air infiltrations in the indoor space imply potential risk of drafts and the growth of the winter heating needs. In a similar way, in summer, the infiltrations of hot outside air implies an increase of cooling demand. As already discussed, the Passivhaus Standard for cold climate tries to limit the undesired airflows and imposes to the permeability of the building envelope the limit of 0,60 h^{-1} at 50 Pa. Even if achievable, this value implies an increase of the building costs, and its attainment could cause some problems above all due to uncareful installation: it is generally necessary to carry out some test before meeting the Blower Door Test in the verification procedure. Relaxing the limit of the n50 parameter would allow a simplification in the construction process.

As shown in figure 1, our analysis shows that in the considered locations energy limits can be reached by applying less strict specifications than those generally used

[2] For details on this specification, see http://www.passive-on.org/en/.

[3] Monitoring conducted by eERG for the EURECO and MICENE projects, financed by the SAVE programme of the European Community and by the Italian Ministry of Environment.

in the Passivhaus Standard. We found that it is still possible to meet the Passivhaus energy requirements with values of n50:

- in the range 1,0 ÷ 1,5 $^{h-1}$ for Milan;
- values even higher for Rome and Palermo.

Air infiltration has a higher effect on the heating demand than on the cooling demand, since:

- during summer the house, as a consequence of night ventilation, is exposed to the external airflow, so that the percentage weight of infiltrations on the energy balance is reduced; on the other hand, in winter, when the opening of the frames is at its minimum, the relative importance of infiltration becomes relevant;
- the difference of air temperature between indoor and outdoor is in average larger during winter than in summer and consequently winter infiltrations imply an increase of energy need proportionally higher.

Considering that a value of n50 of 1,0 h^{-1} already implies a good simplification of the installation procedures and of windows tests, we have chosen to use this value in all the three climates and proceed with further analysis.

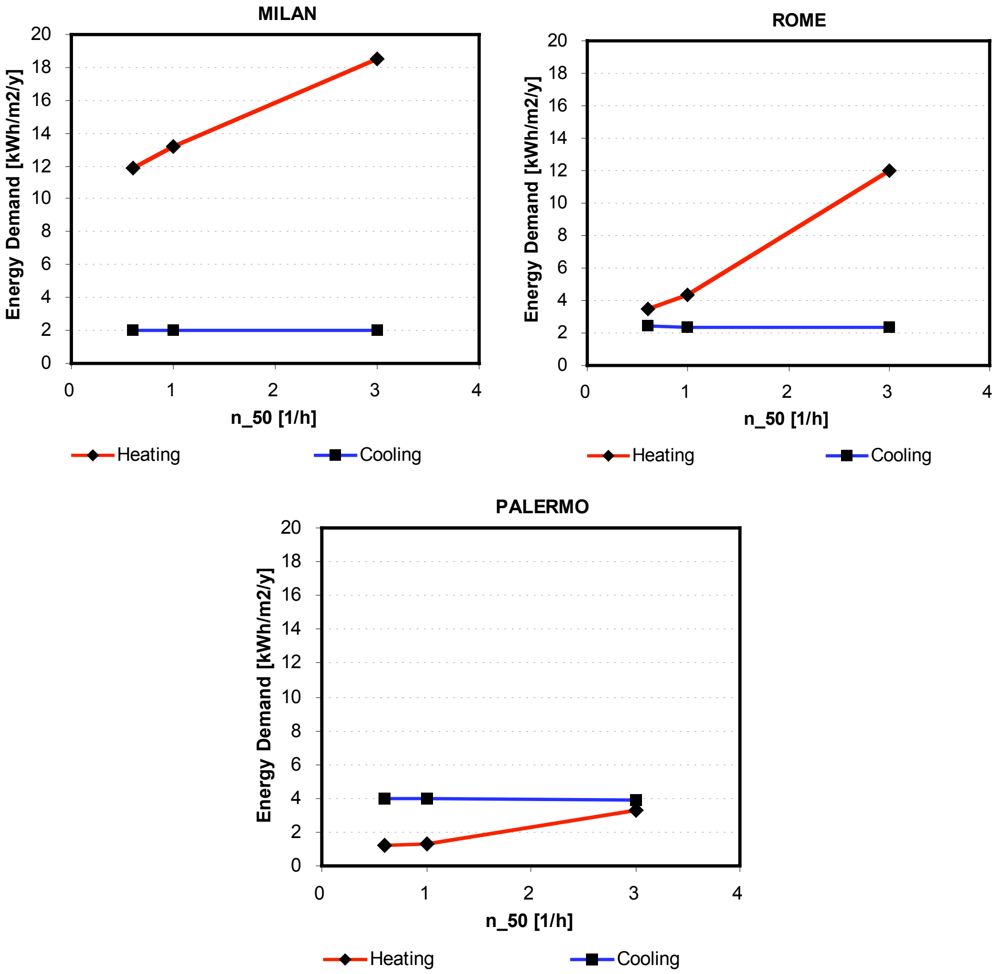

Figure 1: Winter and summer energy need for heating and cooling as a function of the building envelope air tightness (expressed by the n_{50} value).

Table 4: Envelope insulation levels and air tightness required of the proposed Italian Passivhaus

	Air permeability n_{50}	Building envelope transmittances U-value				Insulation levels		
		Roof	Wall	Floor	Glazing	Roof	Wall	Floor
	[h^{-1}]	[$W/m^2/K$]	[$W/m^2/K$]	[$W/m^2/K$]	[$W/m^2/K$]	[cm]	[cm]	[cm]
Milan	1,00	0,134	0,135	0,134	1,400	25	25	25
Rome	1,00	0,200	0,300	1,000	1,400	16	10	1
Palermo	1,00	0,540	0,420	1,340	1,400	5	6	0

A similar method of analysis based on the long term comfort indexes of EN15251 has been used in the project Keepcool2 (http://www.keep-cool.eu/CM.php) . Figure 2 displays the reduction in one of the long term discomfort indexes of EN15251 achievable by the four packages of retrofit actions that have been simulated :

- Package 1: reduction of internal loads (lighting, equipments)
- Package 2: Package 1 + Venetian shading (radiation control)
- Package 3: Package 2 + Over - ventilation (operable openings, Night and Day)
- Package 4: Package 3 + insulation, efficient windows

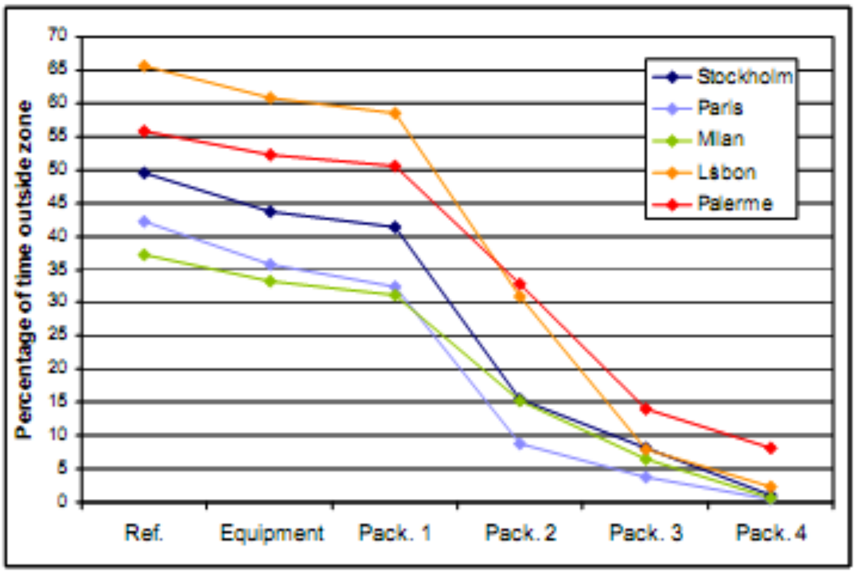

Figure 2: Reduction in discomfort index “percentage ouside range” of EN15251.

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