Energy efficiency and renewable energy – the key technologies for climate change mitigation

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Climate protection, passive-house concept, climatic zones

In the next few decades, carbon emissions from the combustion of fossil fuels will have to be reduced drastically if we are to prevent the unacceptable effects of climate change (melting of polar continental glaciers). Unfortunately, some economists are still sticking firmly to their misconception that any strategy to move away from fossil fuels would simply be too expensive and therefore possibly stunt economic growth.

Yet, the potential energy savings (certainly more than 80%) from efficient use of energy are roughly the same in all economic sectors and will, in many cases, ensure an even higher standard of living at a cost lower than what we now spend on fossil energy carriers. The technologies for efficient energy use therefore offer additional growth potential for national economies that use them consistently and effectively. Passive houses are a prototype of this approach: lower energy consumption for heating and cooling by roughly a factor of 10 under attractive microeconomic conditions even as thermal comfort is improved in both cold and hot seasons.

Analyses at the passive-house conferences have shown that the level of efficiency provided by passive houses for cooling and heating would allow us to switch to a sustainable energy supply for the long term (Vallentin 2008). Passive houses are therefore a concept that is both sustainable and micro-economically affordable.

The passive-house concept is an approach, not a special kind of house. Methods of developing inexpensive approaches for energy-efficient building in various climates were presented earlier (PHPP 2007).

> A passive house is a building in which thermal comfort [ISO 7730] can be ensured without additional air recirculation, simply by heating and cooling the flow of incoming fresh air to ensure sufficient air quality in accordance with DIN 1946. {passive-house definition}

What kinds of solutions have been found to date for the various climatic zones (figure 1)? Where have projects already been completed? What special questions are still to be answered, and who is working on them?

Research institutes in all European countries and in the US are dealing especially with the development and dissemination of passive-house concepts.

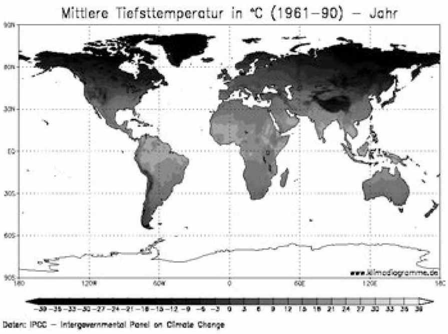

Figure 1: Mean minimum temperatures as an indication of heating demand.

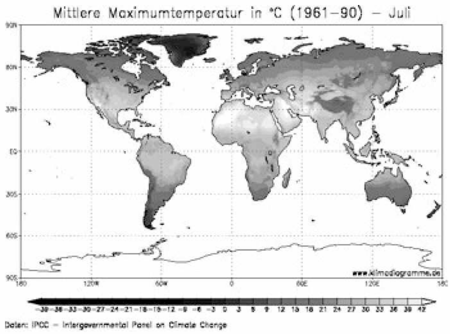

Figure 2: Mean maximum temperatures as an indication of cooling demand.

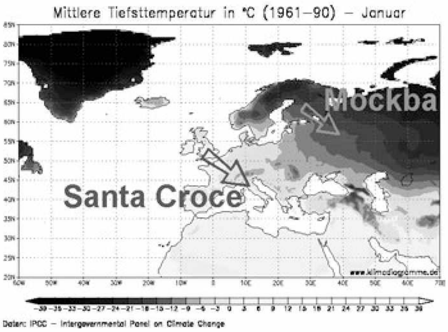

Figure 3: Minimum temperatures in January.

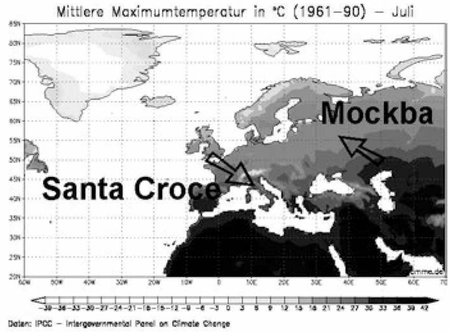

Figure 4: Maximum temperatures in July in Europe.

Extreme example: cold continental climate in winter

A passive house in Moscow? Elokhov/Knecht (2008) discussed this issue in working group 11 of the 12th passive-house conference. The PHPP calculation for the climate of Moscow shows that passive-house criteria can be fulfilled, using currently available construction components, for temperatures down to −19°C, at least for this large, compact building.

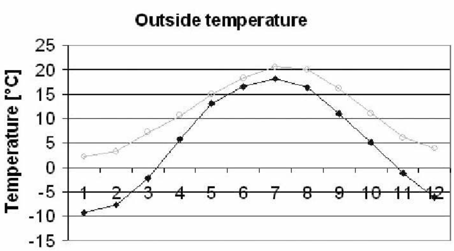

Figure 5: Passive house Moscow Ratmirovo: Climate data, Outside Air Temperature.

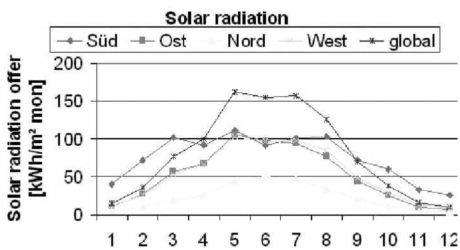

Figure 6: Passive house Moscow Ratmirovo: Solar Radiation, kWh/m²month.

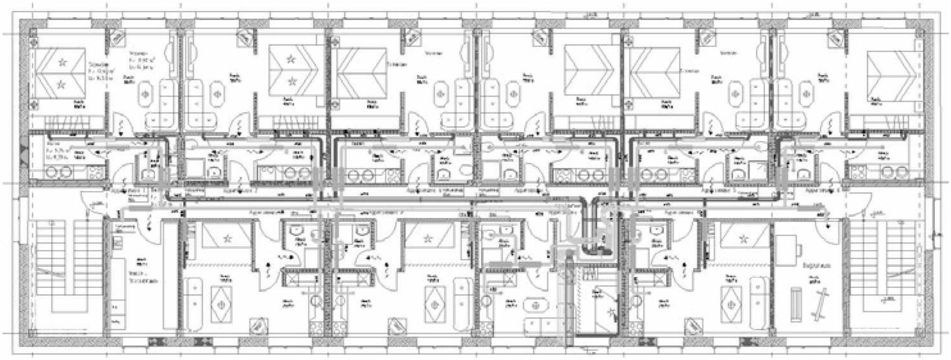

Figure 7: Passive house Moscow Ratmirovo: floorplan.

Figure 8: Passive house Moscow Ratmirovo: construction photo (see contribution by [Elokhov]).

Experience: so far the following projects have been completed in extremely cold continental climates:

1. Passive-house school building "Biohaus Waldsee" in Bemidji, Minnesota (Tanner 2007),
2. Ratmirovo passive-house dormitory (Elokhov & Knecht 2008),
3. Norwegian passive house NorONE A_{TFA} = 340 m² in Sørumsand (−20°C) (Klinski 2008),

Tasks: The extremely low outdoor temperatures pose three essential challenges, all of which have basically been solved, though affordable products are not necessarily available yet:

1. *Better windows for extreme cold*
   a) At outdoor temperatures down to −25°C, the U-value should not exceed U_w = 0.60 W/(m²K). While glazing of this quality is already on the market, frame designs that provide such good U-values for windows are not. Systematic studies by [Schnieders 2000] show that this quality can, however, already be provided.

b) However, in extremely cold climates the outer surface of highly insulated windows can ice over or be covered with condensation, which can cause problems. A special low-emittance coating on the outer surface of the glazing can practically rule out such problems. The technology is already available and has proven its worth to date in roof windows, for instance.

2. *Highly efficient heat recovery* is decisive in cold climates. This technology, however, also suffers from two problems:
   a) potential icing over of the cold side of the exhaust air duct and
   b) a reduction of the relative humidity indoors as very dry outdoor air is blown into the building. Various techniques are available to solve both problems, though one approach that kills both birds with one stone seems especially elegant: the use of highly efficient heat and moisture transmitters that recover some of the humidity from the indoor air keeps the moisture level up indoors, thereby preventing the formation of ice.

Naturally, insulation of the opaque envelope must be especially good for very cold climates. Here, no decisive breakthrough in development is required, however, because the materials and designs already available suffice; indeed, there are even some interesting prospects for further improvements.

Conclusion: passive houses are especially interesting as a design concept for extremely cold climates. The quality of insulation required provides decisively better comfort (much lower asymmetries in radiance temperatures), and the return on investments in heat protection and heat recovery is improved because of the high number of heating degree hours. Nonetheless, a number of further developments in "classic" passive-house components would improve performance and open up a wider array of passive houses to cold, continental winter climates.

Subtropical, maritime climate, such as the Mediterranean

Experience: Projects already conducted and completed in the Mediterranean region include:

1. Borghetti passive house (Cesena, Emilia-Romana; www.casepassive.it)
2. Vinetti passive house (Vicenza; www.casepassive.it)
3. ASSA on the Arno, passive office complex (Santa Croce) (Gantioler 2008)
4. Sampolino office complex (Brescia) (Rossi 2008).
5. Multi-family dwellings as passive houses in Brandzoll (Bozen) (Schmitt 2007; or Castagna et al. 2008).

Other buildings are under construction in Italy, southern France, and Spain. The decisive design properties of passive houses in such climates with hot summers are clear when we take a look at the ASSA office complex near Pisa (see table 1).

Jürgen Schnieders deals with the systematic studies of passive houses in southern European climates in his dissertation (Schnieders 2008).

Table 1: Principal design features of passive houses in dry, summer subtropical regions.

	Design feature	General rule	Example
Building envelope	Insulation of outer wall and roof	Optimal for winter, very good: in the upper range of affordable insulation for heating energy	very high! $U_R = 0.10$ W/(m²K) $U_{OW} = 0.22$ W/(m²K)
	Absorption coefficients for solar radiation/external wall and roof	As low as possible for positive effect on urban climate in the summer	a ≤ 0.6 (high!) (compensated for with better insulation)
	Insulation from the soil or basement	Periphery solution or insulation on the floor slab/basement ceiling (inexpensive). Optimise for regional climate.	Periphery insulation in addition to insulation for floor slab
	Windows	U value ≤ 1.2 W/(m²K) g value ≤ 50% Southern orientation is better otherwise: compensate with smaller window surface, temporary shading. Shading: urgently needed for direct sunlight in the summer	$U_g = 0.7$ W/(m²K) $U_f = 0.73$ W/(m²K) g = 48% shading from „eaves“
Structure	Building structure, internal structure	Masonry, at least a solid floor slab and double (30 mm) gypsum boards or solid walls	Concrete ceilings and masonry
Ventilation	Required fresh air for indoor air quality	Depending on the climate: • waste air system (moderate climate) • heat recovery (hot summer climate) • enthalpy recovery (with high summer moisture)	System with heat recovery
	Ventilation for summer cooling	Greater ventilation at night: system (bypass!) or natural flow (only feasible in dry summer climates)	Greater system air exchange with bypass
Cooling	Do not worry about active cooling and dehumidification with conventional cooling systems. Requirement for useful coolness: $q_{cool} \leq 15$ kWh/(m²a)	In general, active cooling Several solutions: 1. Fresh air cooling (< 8 W/m²) 2. Building component cooling (< 18 W/m²) (in arid zones) 3. Circulation cooling (< 18 W/m²)	Single unit for air recirculation cooling and dehumidification

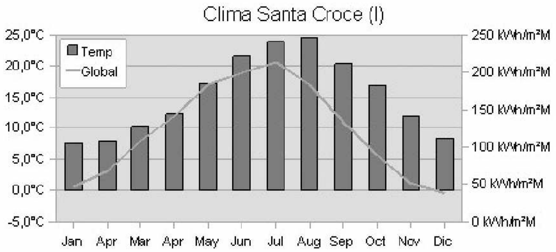

Figure 9: Passive office complex in Santa Croce near Pisa: climate data.

Figure 10: Passive office complex in Santa Croce near Pisa (Gantioler 2008).

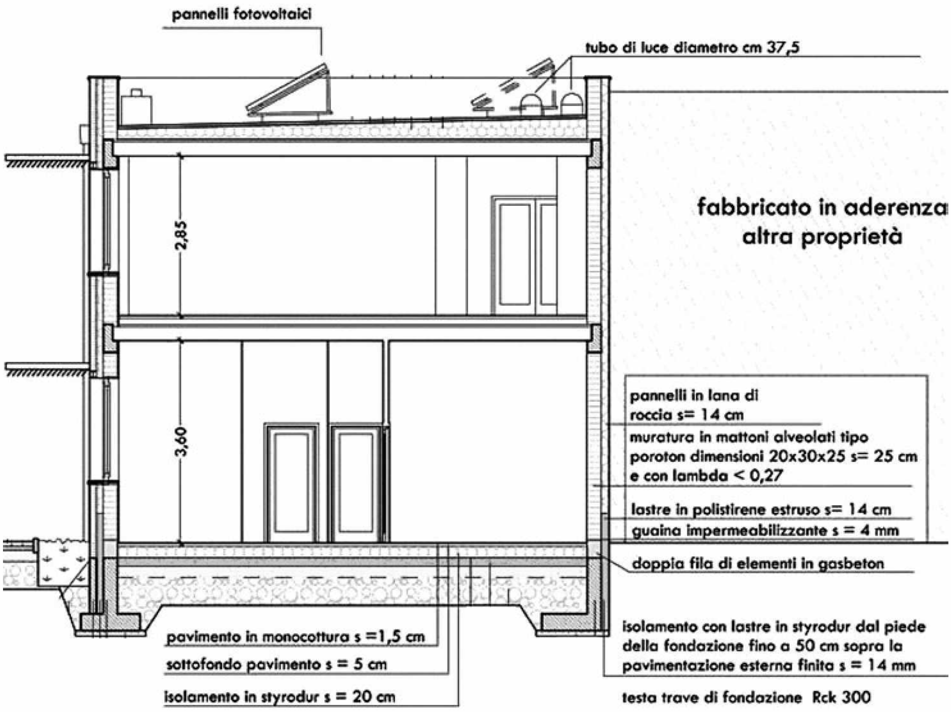

Figure 11: Passive office complex in Santa Croce near Pisa: edit.

Tasks: The extremely high outdoor temperatures pose three essential challenges, all of which have basically been solved, though affordable products are not necessarily available yet:

1. *Better solutions for shading*

Generally, temporary outdoor shading is an expensive solution. A less expensive solution could be mechanically controlled sheets integrated in glazing to reflect the light and IR. Such windows would provide an uninhibited view to the outside even as the g value is greatly reduced, but without worsening the g value in the winter.

2. *Heat recovery with moisture recovery*
The use of highly efficient heat and moisture transmitters which also recover some of the indoor air humidity would keep buildings in humid summer regions relatively dry.
3. *Compact units with cooling and dehumidifier functions*

Conclusion: Passive houses are especially interesting as a design concept for subtropical climates. Good insulation also provides better comfort here; enthalpy recovery would also facilitate moisture regulation, and compact units would considerably simplify building services (heating and cooling).

Summary

Nowadays, the principles for the construction of passive houses are clear for the world's most important climatic zones with large populations. However, a number of developments still need to take place if the passive-house standard is to become the norm in areas where the climate deviates greatly from conditions considered comfortable. These developments will be able to allow passive-house solutions to be used almost everywhere. For instance, especially efficient enthalpy heat transmitters provide for sufficient air circulation even in moderate climates without the need for additional humidification in cold seasons.

It has also proven useful to have local institutes perform research on how passive houses can be adapted to the regional climate and local construction traditions. Partner institutes elsewhere also benefit from such solutions. The components already developed and those being improved are also useful in buildings that need to be renovated for lower energy consumption. In particular, renovation projects offer great savings potential in prospering industrial countries, where the current consumption levels of fossil fuels are unsustainably high and need to be brought down to a sustainable level without a reduction in standards of living.

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