The Passive House Concept as Suitable Basis towards Net Zero Energy Buildings

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1 Background

Over the past two decades, buildings have been constructed worldwide with the aim of balancing either the energy demands for operation or the CO_2 emissions produced. In parallel, the first passive houses appeared [Musall 2010]. Because a suitable planning basis or an appropriate balancing methodology is lacking up to now, a variety of different methodologies for the so-called 'zero-energy', 'zero-emission' or 'plus-energy' houses have been developed to date [Voss Musall; Musall 2011]. In 2005 the 5th Energy Research Program of the German Federal Government declared the 'zero-emission house' as a long-term goal [BMWA 2005]. In May 2010 in the Energy Performance of Buildings Directive (EPBD), the European Union put forward a call for a national implementation of the 'nearly zero-energy building' [EU 2010]. The Energy Concept 2010 as well as the 6th Energy Research Program of the German Federal Republic from mid 2011 followed with the 'Niedrigstenergiegebäude' and the 'climate-neutral building stock up to 2050' [BMWI; BMU 2010; BMWI 2011]. In fact, hardly any practical methodologies are contained in the objectives and also the current Energy Saving Directive (EnEV) does not stipulate how to determine a zero-energy building [Voss 2010; DIN 18599 2009]. However, over 300 buildings, with the same initial aim, have been realized worldwide. The evaluation of these buildings provides information about practical strategies [EnOB 2011b]. The focus here is on reducing consumption and balancing energy through credits received for exporting energy generated at the building.

2 The Passive House Concept as Efficiency Basis

80 international building projects, all constructed with the same initial aim, were analyzed. The results show that in heating-dominated climates, the efficiency of the passive house concept plays a central role for the implementation in the building practice [Musall 2010]. Figure 1 shows the measured primary energy consumption compared to the credits of energy export for own energy generation. This is a simple method of balancing typically used in the building practice. Most of the buildings remain below the limit of 120 kWh/m²a for their total primary energy demand as specified in the passive house concept (with use of location-based primary energy factors).

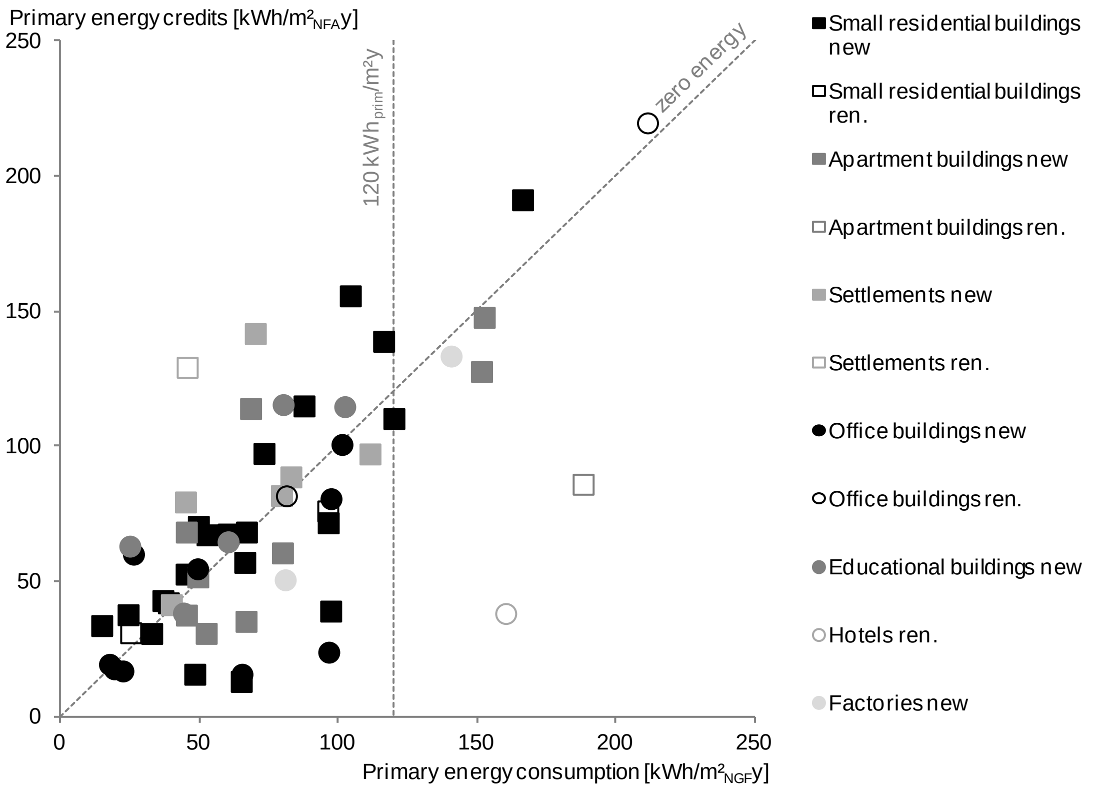

Fig. 1: Primary energy credits for energy generation on the building compared to the measured total primary energy consumption with respect to the net floor area (site locations in heating-dominated climate zones, country-specific primary energy factors, no climate adjustment). The conceptual energy balance of several projects included only the normative consumption. In the total balance shown here, therefore, some of the buildings do not reach the zero energy aim. The vertical line (120 kWh_{prim}/m^2a) shows the total primary energy limit based on the passive house standard (primary energy factors from Germany). University of Wuppertal, see [Voss Musall 2011].

Building-specific Consumption

The average heating consumption for small, new residential buildings is 21 $kWh/m^2_{NFA}a$. Several values even lie below this value. Multi-family homes, housing estates or non-residential buildings already achieve a similar level (Ø ca. 25 $kWh/m^2_{NFA}a$), while renovated objects evidence higher values for the most part (Fig. 2). For renovated projects, restrictions occur due to the unavoidable thermal bridges, lack of insulation in the floor slab, etc. [Voss Musall 2011]. Even when a passive house certification is not the main aim, typical conceptual elements such as an airtight construction, controlled ventilation system with heat recovery (efficiency of Ø 84 % with a power consumption of Ø 0.64 W/(m³/h)) or other components are implemented in the building. For zero-energy buildings in Central Europe, the average mean U-value for the total building facade is 0.23 W/m²K (renovated buildings included). For non-residential buildings, the value is slightly higher (Fig. 3).

Use-specific Consumption

Similar to the passive house approach, the use-specific electricity consumption (household appliances, lighting, consumer electronics, IT, central services, etc.) is, for the most part, included in the used balance calculations. In the funding program ‚EffizienzhausPlus' from the German Federal Ministry of Transport, Building and Urban Development (BMVBS) a requirement is formulated similar to the Minergie©-A-Label publication in Switzerland [BMVBS 2011; Minergie 2011]. Figure 4 shows that the use-specific primary energy consumption plays at least as large a part as the usual consumers like for heating, ventilation and hot water (including cooling and lighting for non-residential buildings) which are considered in the standards [EnOB 2011a; EnOB 2011c].

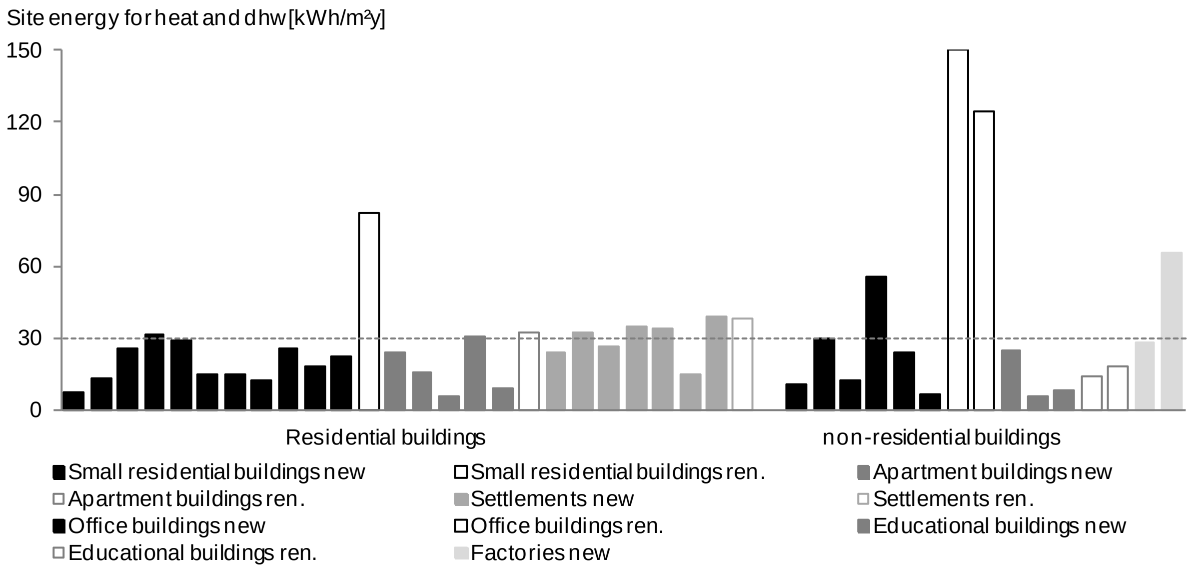

Fig. 2: Measured end energy consumption for heating and domestic hot water for zero-energy projects in heating-dominated climates (no climate adjustment). The reference value is the net floor area (NFA). The horizontal line shows the expected reference value for passive houses. University of Wuppertal

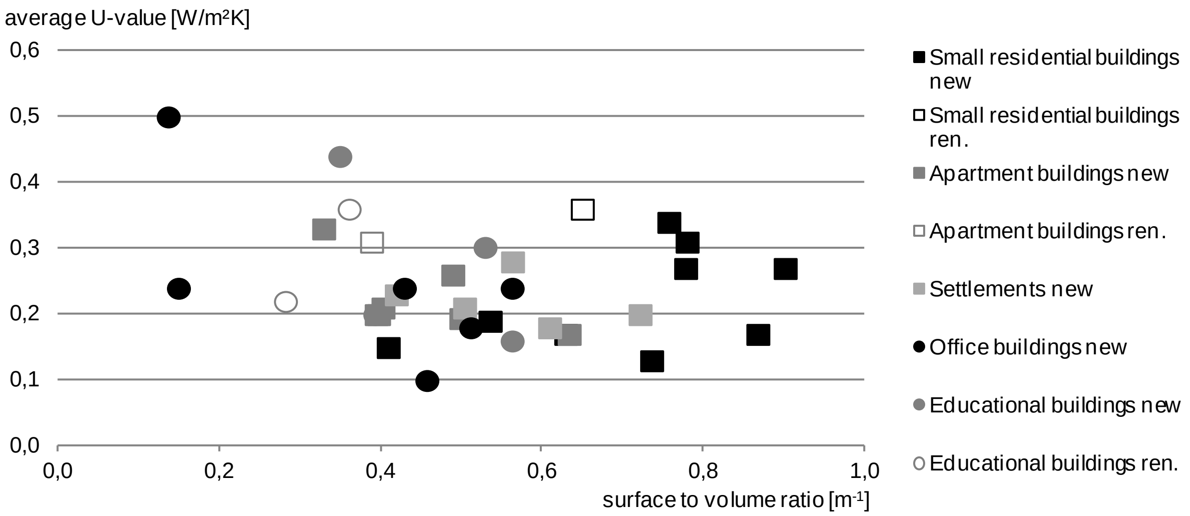

Fig. 3: Mean U-value of the total building envelope as compared to the compactness of the building (indicated by the A/V ratio) for zero-energy buildings in heating-dominated climates. University of Wuppertal, see [Voss Musall 2011]

With respect to the use-specific consumers, the use of household appliances in the highest efficiency classes, energy-saving lights and often washing machines and dishwashers with a warm water connection are the basis for planning an equated energy balance. These can be installed regardless of a new building or renovation. The practice, however, shows that the measures, with few exceptions, do not yet bring the desired success. In fact, the actual electricity consumption in Zero Energy building lies often close to the average general consumption. This means that there are large differences between the planning and operation [Voss Musall 2011].

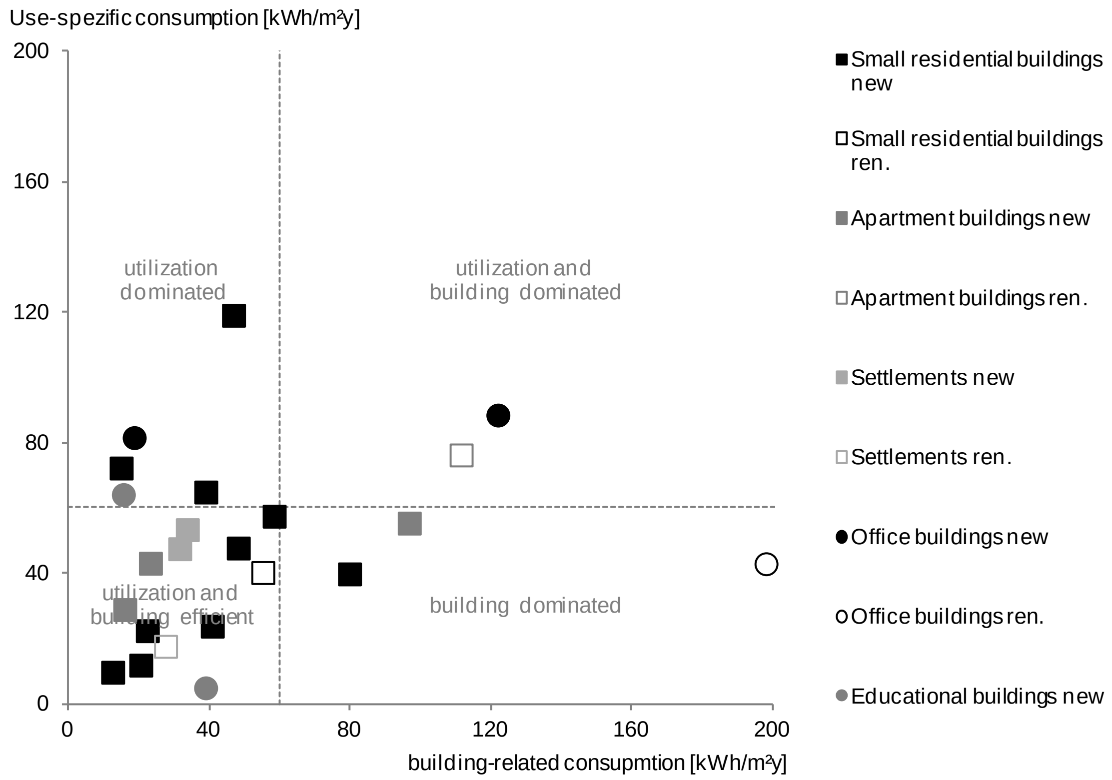

Fig. 4: Comparison of the primary energy consumption for the technical services and the use-specific consumption. Only those buildings are plotted for which both types of consumption are recorded separately (local primary energy factors, no climate adjustment). Optimal results are achieved for the buildings which show a high efficiency in both areas of consumption. University of Wuppertal

3 Energy Supply

By expanding the passive house concept by energy systems for energy export, the step to an equated energy balance is made. Almost all buildings with this claim have a solar power system for this purpose. For small buildings without additional power generating capacity, an installed PV capacity of 40 kW_p/m^2_{NFA} is sufficient to cover the whole energy consumption (Fig. 5). For projects with a larger energy demand (non-residential buildings or renovated buildings), this value is hardly greater. This is due to the fact that the useful roof area decreases in comparison to the net floor area. Especially in office buildings, further power systems like CHP plants or (external) wind turbines are used [Voss Musall 2011]. The choice of the systems for heat generation is clearly more differentiated than for power generation. Systems range from the compact ventilation device through to heat pumps using energy from the ground, the ground water or coupled with solar energy for ‘all electric buildings’, or rather biomass boilers and co-generation plants. The use of biomass drastically reduces the primary energy needed for heating and thus promotes a decrease in the credits for energy balancing. In only a few of the buildings investigated, the credits are based on the export of heat generated by solar thermal systems. However, more than 60 %

of the zero-energy buildings have solar thermal systems to assist in the hot water and space heating, unless other concepts, like CHP or local heating grids or a continuous PV systems (possibly for economic reasons), are preferred. In heating-dominated climates, all-electric buildings affect an asymmetry between supply and demand. High energy efficiency in several areas is key in making this asymmetry as low as possible; thus reducing the expenditure on the grid side. For buildings with CHP, electricity and heat are generated synchronously. Through suitable thermal storage, the use of electricity and heat can be decoupled over the course of the day [Musall 2009].

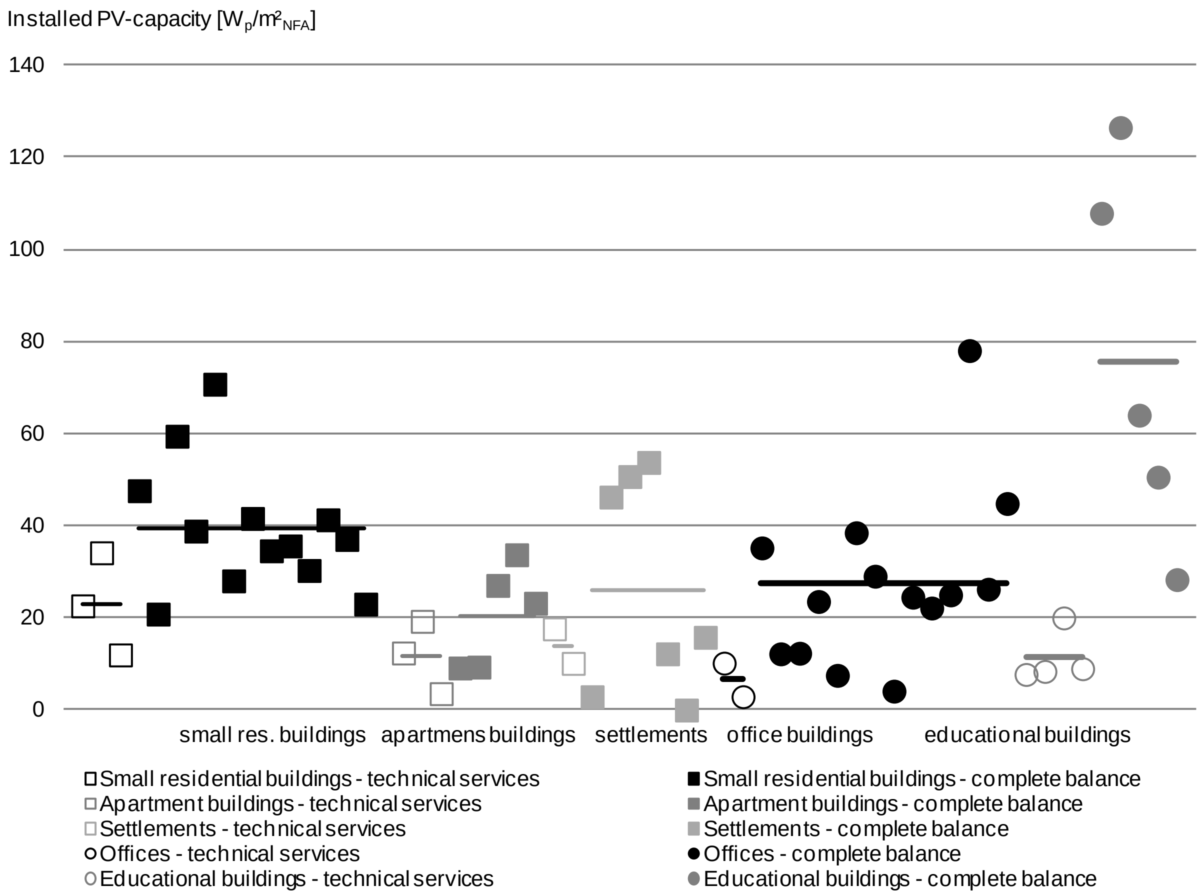

Fig. 5: Installed power of PV systems per m²$_{NFA}$ (Subdivisions in buildings which balance includes the technical building services or all energy consumers) University of Wuppertal, see [Voss Musall 2011]

4 Outlook

Based on the existing zero-energy buildings, strategies for energy efficiency and for using renewable energy can be drawn up, categorized and partly quantified. With regard to a future climate-neutral building stock, the application of these strategies is difficult, but at the same time imperative, for buildings with higher energy consumption (e.g. renovated buildings). PV systems are often not able to meet the higher energy demand of these buildings. Maximized efficiency and matching energy generation and load are necessary. Otherwise a large amount of storage capacity must be built up in the grid in order to match the seasonal energy demand and supply. The building-integrated co-generation (CHP) offers an option whereby credits are received for exporting self-generated electricity to the grid. This concept is suitable especially for (future) biomass systems.

5 References

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