From Experimental to Passive House Plus:

Some 4-Decade Insights

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Invited Presentation

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Summary/Abstract

The oil crisis 1973 triggered energy and first Passive House research some 4 decades ago. The author, one of the “Passive House Pioneers”, is still active in the field and will share his insights gained on the road from early Experimental to latest Passive House Plus projects in new and old buildings.

1. Introduction: The Philips Experimental House Project 1974ff – Passive Potentials & Priorities

Triggered by the oil crisis 1973 and the fact that heating and cooling constitute a major share of energy demand in industrial countries, the Philips Company – more than 40 years ago – started extensive research on the use of energy in buildings. **Experimental evidence, experimentally verified computer models**, thousands of year-round hourly computer runs as well as **systematic parameter studies** carried out by the author **showed how factor 5 to 20 savings can be achieved with appropriate “passive” measures** (cf. Bruno, Hörster, Steinmüller et al 1977-1982).

In fact, it turned out that in most climates, **measures that focus on the “passive” side** of the building - especially the largely “passive” building envelope and its heat losses or gains - tackle the problem at its root and **are much more effective than measures on the “active” side** (e.g. the heating and cooling system designed to iron out energy deficits) and they influence size, cost and effectiveness of active ones in a profound manner. Thus - for a company which had set out to look for business opportunities on the active side - the paradoxical result was that **passive measures should receive top priorities first of all.**

- Insulation < 0.16 W/m²K
- Efficient Window Systems: (coated double) + shutters
- Ventilation 90% h. recovery + soil heat exchanger
- Heating 20 - 30 kWh/(m²a)
- Renewable Energies
- Suite of Simulation Models
- Parameter Studies Europe & US ...

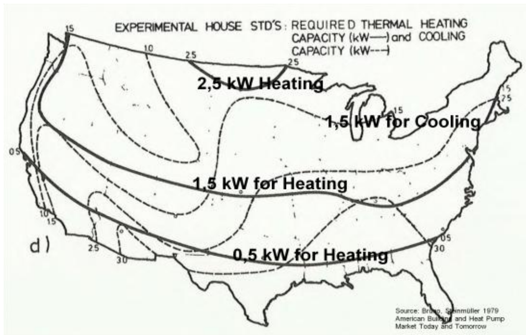

Figure 1: Philips Experimental House 1974 ff (left) Implied US Heating & Cooling Loads (right)

In the following, the author –who has been engaged in energy & buildings, digital industries and sustainability management since then - will outline subsequent developments and share **insights illustrated with examples** from his own professional environment.

2. The Passive House Standard for New Buildings 1985ff

Delays and Progress in Germany and Europe

While Philips researchers largely turned to other subjects, **Germany - instead of putting the knowledge gained into practise - followed the public solar hype** and started research on “passive **solar** buildings” at the beginning of the eighties. This strongly distracted from the proper passive targets to be followed and was bound to deliver poor results. On top of that, a “**brick lobby” misleadingly proclaimed “massive” instead of passive** measures and caused further delays in energy reduction. This was the more unfortunate, as it became increasingly clear that on top of energy usage the resulting CO_2-emissions have to be lowered drastically (cf. review Steinmüller 2008 for more details).

It was Wolfgang Feist, who – also encouraged by Scandinavian research and supported by the German State of Hessen at IWU (Institut Dwelling and Housing) - consequently refined the passive approach in an appropriate way (Feist 1988, 1993) resulting in the Passive House Standard, which defined a new optimum for efficiency and thermal comfort in new buildings - with a maximum heating load of 10 W/m^2 (equivalent to a maximum heating demand of 15 kWh/m^{2}a for south-oriented buildings in Mid-Europe). This was demonstrated by the first Passive House in Darmstadt-Kranichstein in 1991, while **whole Passive House settlements have proven the economy and sustainability of the approach since the mid-nineties** (Rasch 1997, Ebel et al 2001). 2003ff the capital of Hessen Frankfurt embarked on a Passive House Strategy for all buildings under public influence. More cities followed - as exemplified on the last Passive House conference in Heidelberg/Germany in May 2019. **On the national level, however, the insights gained still were not reflected:** the German building code admitted 150 kWh/m^{2}a in 1995 and 100 kWh/m^{2}a until 2002. Even at present the gap has not been closed - **creating a huge mismatch between available knowledge and necessary national implementation.**

Figure 2: First Passive House, Darmstadt/Germany 1991

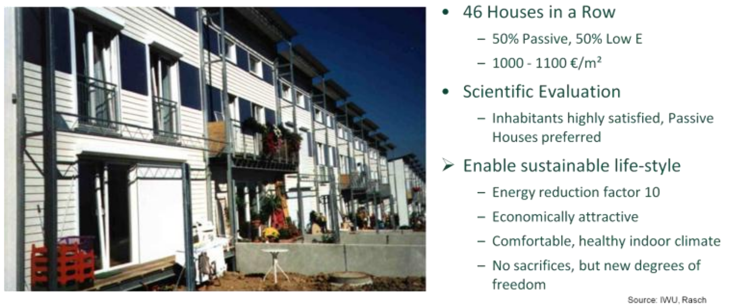

Figure 3: First Passive Settlement, Wiesbaden 1997 demonstrates economics & sustainability

In Europe Passive House research was promoted by the project **“Cost effective Passive Houses as European Standard” CEPHEUS** and follow-up projects. The **European Union recognized the need for Passive Houses** in its action plan 2006 and finally called for the implementation of national “near zero energy building” codes by 2019 for public and 2021 for private buildings - which, however, are **still waiting for proper national realization**.

Progress World-Wide – A glance at America, China taking the lead?

Beyond Europe the Passive House Standard gained increasing support, not least because it is freely available in a transparent, scientifically well-founded universal manner so that it can **be easily applied to a broad spectrum of climates** all over the world.

In the US, the first “new” Passive House was erected in 2003 in Illinois, the first certified one followed in 2006 in Minnesota, while campaigns for passive retrofits emerged shortly thereafter (see below).

Growing international interest has been reflected by the internationalization of the Passive House Project Planning Tool "PHPP", its application to global studies, the growing share of international visitors to Passive House conferences and finally **by the current international conference, which for the first time takes place outside of Europe: in China.** Here **new construction is booming** with new quarters and cities shooting out of the ground. Near the conference site **in Gaobeidian the world's largest district in Passive House standard currently is being erected.** Clearly, as each new building for a long period of time adds to the climate load of the future the need to construct it according to the most progressive housing standards is an absolute necessity. Thus, I am happy to see what is achieved and **hope that this will quickly spread over China and the world as a whole!**

3. Challenges in Old Buildings 2000ff

However, the large existing building stock adds an even higher load to the climate budget of our future. It requires deep and extensive energy reductions all over the world. The author - with insights gained at Philips and systematically extended at IWU - re-entered this endeavour in the nineties, where cooperative sustainable refurbishment campaigns in various parts of Germany and North America showed that **factor 5 to 10 savings are possible in the building stock too.** This is exemplified below and reflected in the Passive House **EnerPHIT Standard since 2010**.

Figure 4: Regional Forerunners Identified in Competitions

Figure 5: Optimizing Passive House Techniques in Old Buildings, Pilot Bielefeld, Germany, 2003- 2005

In Germany, on the **regional scale** various competitions were held in 2000ff to identify forerunners, to communicate best practise and spread well-founded knowledge about energy saving potentials as well as means to exploit them. **Pilot projects deepened the knowledge and confirmed that Passive House techniques can be successfully applied to refurbish residential as well as non-residential buildings in a sustainable way** (see e.g. Steinmueller 2005, 2012).

On the **national level**, the state-owned bank "KfW" operates funding programmes to complement regional ones. This is flanked by the newly founded German Energy Agency DENA since 2003. However, these programmes are scaled in terms of rather weak national building codes. While the author and others could motivate the KfW to open its funding scale to lower energy targets, funding of EnerPHIT/Passive House Standards is missing.

As far as **international activities** are concerned, the author helped the promotion of Passive Houses in cold as well as hot climates with focus on the US. Here, increased interest in European activities led to talks and a summit meeting 2007 in San Francisco, where the author kicked off the idea of the 1000 Homes Challenge on deep energy reductions in North America together with Linda Wigington (Steinmüller 2008, Mann 2009). While deep energy reductions and Passive House techniques have become part of American retrofit approaches, political support currently is far too low.

4. Passive House Plus 2015ff

Once energy demand is deeply reduced, **renewable energies and active measures have to be optimally incorporated.** In fact, as the delays of the past have dramatically overused our planet's carbon budget, "factor of 10 reductions" will not suffice any longer. Rather "zero" and even "negative" emissions have to be reached in the near future (IPCC 2018). While optimization depends on the specific boundary conditions met, **typical building measures have become apparent** in the last decade, whereby the Passive House/EnerPHIT-**"Plus" and "Premium" Standards** (2015) provide a framework for finding sustainable answers.

I will illustrate this by means of a fairly **challenging retrofit** recently applied to a 2-family east-west oriented attached building with a mediocre A/V-ratio reconstructed with old material after the 2nd world war on top of thick cellar walls rising from an old city wall in Germany. While coal had been replaced by gas firing and single pane windows by double ones, energy consumption still was unsustainably high. A fungus infection of the roof finally gave rise to a fundamental modernization **towards Passive House Plus in 2015/16: Passive steps** (insulation, triple pane windows, ventilation via refurbished chimneys) reduce Primary Energy Renewable Demand by a factor of 7 from about 500 to 70 kWh/m^{2}a, while **active steps** (heat pump, PV) save another 40 kWh/m^{2}a and produce 60 kWh/m$^2_{Ground}$a respectively. In combination the Passive-House-Plus-Standard has been reached in 2017 – well-confirmed by measurements after 2 heating periods (see Figure 7).

As far as the **passive side** is concerned insulation levels are in line with those typical and economic for new Passive Houses (e.g. walls 24, roof 44 cm). However, thermal bridges at walls rising from the cellar, connecting walls, roofs, ceilings towards the neighbour as well as the protruding bay window room need special attention. Unnecessary windows were closed, while required ones were optimized and moved forward into the new insulation layer. Thereby the latter operation also needs some extra effort. Finally, controlled ventilation poses a special challenge in old buildings. Here, however, often existing chimneys and open staircases can be used to minimize installation and operational cost (see also Steinmueller 2005 & 2017).

As far as the **active side** is concerned, the installation of PV is fairly straightforward, whereby the orientation of the house moderately reduces active as well as passive solar gains. Heat pumps require more attention and trade-offs between efficiency, cost, noise emissions and available out-/indoor spaces. Here a small earth-based system was chosen, which collects heat via 3 prefabricated collector rows buried in three 0.4m x 2m x 7m ditches in the garden and delivers it via an integrated 170l-tank into a reduced hot water distribution system or alternatively to the old radiator system. Thanks to passive measures the latter now can be operated very favourably at temperatures below 35C.

User feed-back after two summer and two heating periods is positive. Thermal comfort is high, while operational costs are extremely low.

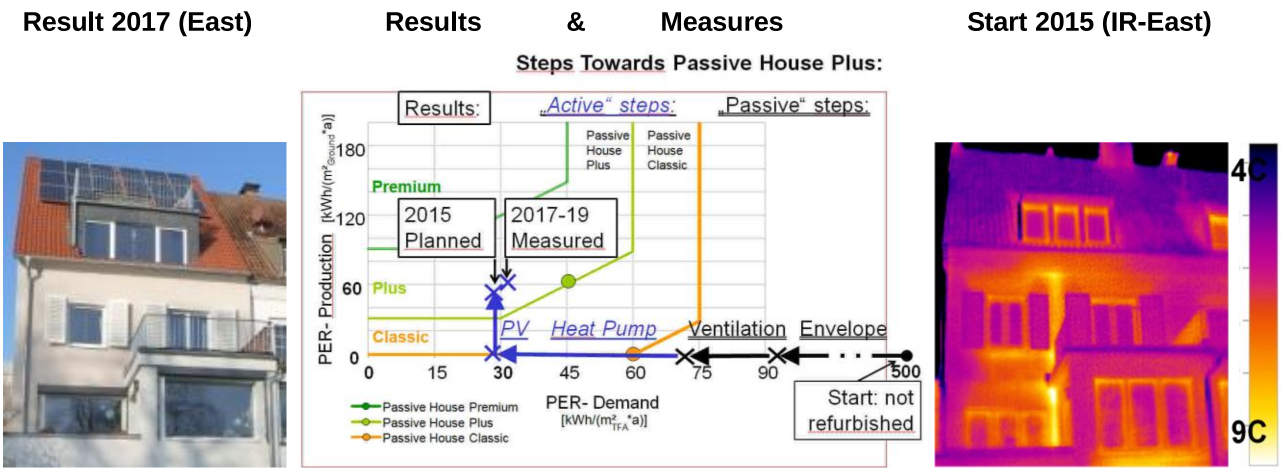

Figure 6: Passive-House-Plus in the Building Stock: result (left) & measures (middle), start (right)

Similar responses have been obtained from other projects including non-residential classic Passive Houses extended with “Plus”-Measures in the sequel. Thereby, scarcity of well-educated craftsmen has become an increasing problem over the years in Mid-Europe.

5. Conclusion and Outlook

While the oil crisis in 1973 triggered energy research more than 4 decades ago showing what measures can be taken, energy consumption has not been reduced due to sluggish proliferation of knowledge, counter-acting interest groups as well as lack of political and public support. Moreover, it has become clear since the nineties at the latest **that on top of energy usage the resulting CO_2-emissions have to be drastically lowered**. **Unfortunately, the opposite happened** so that the remaining carbon budget for keeping earth warming below 1.5C with a probability of 2/3 has shrunk to about 500 billion t CO_2, which - at a current consumption rate of about 50 billion t/a – means that **we have just a decade for most drastic changes** in order to become climate-neutral and - due to unavoidable overshoot **- even “emission negative” thereafter**.

As the building sector accounts for a major part of the problem, **we have to drastically accelerate** transformation, implementation, proliferation speed and depth of available knowledge**.** The **Passive House concept and its set of progressive standards provides a framework pointing the way to a carbon-free future and sustainable answers for new as well as old buildings**. Corresponding political support, strong sustainable building codes, education of decision makers, architects, planners, craftsmen forged into powerful targeted actions are needed to finally achieve a break-through. The conference in China can act as an important enabler.

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(See also https://passipedia.org/basics/the_passive_house_-_historical_review/passive_versus_active_measures_in_europe_america and https://www.bsmc.de/ for downloads and more details)

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