Case study of an NZEB (renovation) with 7 years measurement data – what can a designer learn from it?

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Abstract

A typical residential building from 1937 located near Wuerzburg in Germany, was deep retrofitted in 2013.

The simulations of energy balance and load profiles (in IDA ICE) match well with measurements. Self-consumption and export of electricity to the grid was monitored. The results show variations in self-consumption. Monthly self-consumption varied between 6% and 25.5%.

Key Innovations

- Monitoring data from 7 years performance of a NZEB. This represents a very comprehensive retrofitting towards plus energy level. Energy consumption and production as well as usage patterns and load profiles were monitored over a period of one year.
- Self-consumption and export of electricity to the grid show variations between 17% (2015) and 22% (2020).

Research Implications

The results have implications for energy load profiles which represent a new type of grid load that needs further recognition in planning of renovation work.

Introduction

Residential use of energy is responsible for 28% of EU energy consumption (EC 2012). The barriers to consumer energy saving are still present, lack of information, high initial investment in energy-efficient equipment and habits of energy users (BPIE 2013).

Likewise, while awareness of the existence of renewable energies has improved considerably in the last years, there is still a lack of understanding of how to use and optimize them in practice.

The EPBD requires nearly zero energy buildings from 2021. There are many approaches to this goal and several pilot buildings have been built and extensively measured (EPBD 2020). The theoretical approach is normally based on two pillars; first, energy saving measures have to be applied that ensure a massive reduction of heating energy. The second pillar is the production of renewable energy on-site. Both measures have been applied in a simulation model to identify the most valuable combination for this case.

A residential building from 1937 located near Wuerzburg in Germany, was deep retrofitted in 2013. The project received funding from the German Bank for Rebuilding (KfW) in the class kfW50 which uses 50% of the energy budget defined in the existing German building code (EneV) (KfW 2014; EneV 2014). With detailed modelling and building performance simulation (BPS), the best values for building envelope, appliances and energy supply have been identified. These simulation results were used to discuss the steps of realization with architect, engineers, suppliers and local authorities.

Key performance indicators (KPI)

Besides key performance indicators for energy production and energy use it is interesting to monitor different KPI for self-consumption. Energy costs is another useful KPI.

Self-consumption indicators

Load matching (1) and Grid interaction equation (2) have been identified as useful indicators (Salom et al. 2014):

$$f_{load} = \frac{1}{N} \cdot \sum_{year} \min\left[1, \frac{g(t)}{l(t)}\right] \quad (1);$$

$$f_{grid} = STD\left(\frac{ne(t)}{max(|ne(t)|)}\right) \quad (2)$$

where
g(t) is the energy generation at each time step
l(t) is the energy load at each time step
N is the number of samples in the evaluation period
ne(t) is the net export at each time step

NZEB renovation

Building envelope

Roof, façade and ceiling in the basement were highly insulated and thermal bridges were minimized. Windows were replaced with three-layered glazed windows with wood-aluminium windows.

Appliances

Residential appliances/white goods (Refrigeration, Laundry, Dishwashing) were installed/replaced by A+++ equipment. Cooking equipment was replaced by induction device. Lighting fittings were replaced with LED in the whole building.

Ventilation

A 6 kW compact unit (balanced ventilation system with integrated air-to-water heat pump) was installed. This

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delivers 220m3/h to all the rooms (except storage room in 2. floor; 35m2) with a supply and extract fan (with dampers). A cross-plate heat exchanger with 85% thermal efficiency is included in the compact unit. The ventilation ducts were integrated into the existing chimneys.

Energy supply

A compact unit (balanced ventilation system with integrated air-to-water heat pump) was installed. Exhaust air is used as heat source, for the electricity supply a special 'heat-pump' tariff was chosen (HT: 28,18 € cent/kWh; LT: 20,53 € cent/kWh). An underfloor heating system was installed in the kitchen.

Renewable energy sources

A 7.95 KW PV system with a south-west orientation and 50 degrees angle was installed. It was chosen to use a roof-integrated system consisting of 32 modules with 165 W each. A contract for a feed-in tariff of 14,25 €ct/kWh was signed with the local energy provider.

Results

This paper reports a case study of deep retrofitting of a residential building towards plus energy level. Energy consumption and production as well as usage patterns and load profiles were monitored over a period of seven years. The simulations of energy balance and load profiles match well with measurements as shown in Figure 1.

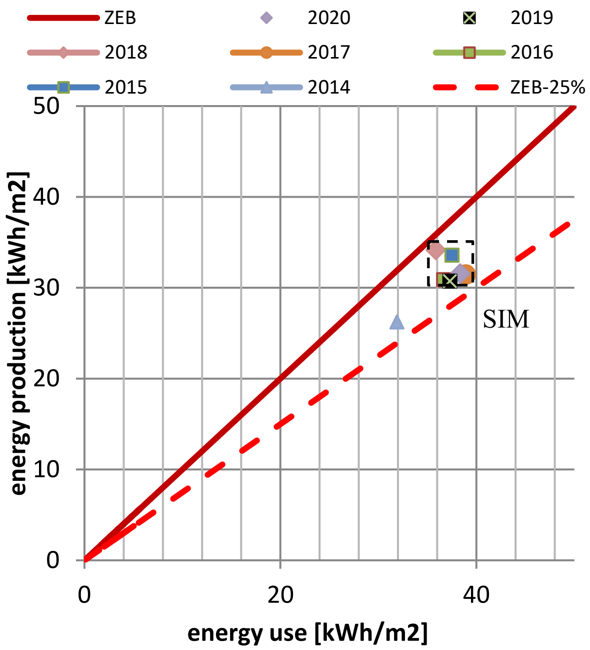

Figure 1: Annual energy use and production

Self-consumption

Self-consumption and export of electricity to the grid was monitored. The results show variations in self-consumption. Annual self-consumption varied between 17% (2015) and 22% (2020).

While self-consumption was larger during summer months in absolute figures, it dropped during the winter months. The annual self-consumption together with KPIs introduced in formulas (1) and (2) (Figure 2) as well as annual energy costs (Figure 3) were monitored for 7 years.

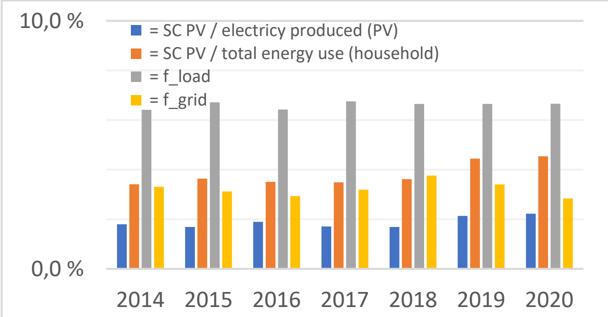

Figure 2: Self-consumption indicators.

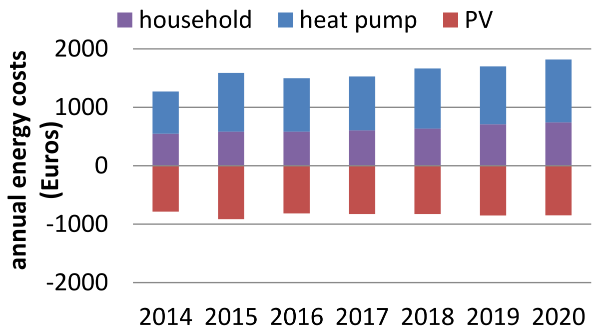

Figure 3: Annual energy costs.

The economic results in Figure 3 show variations in annual buying and selling of electricity. Annual energy costs vary between 785,54 (2014) and 913,40 Euros (2015).

Conclusion

Using BPS for NZEB renovation is an important element for success. Results from BPS were crucial in the design process to overcome barriers (like agreeing on the energy concept, technology choice, investment and life cycle costs) and helped to plan, execute and monitor the NZEB renovation.

Energy and load profiles represent a new type of grid load that needs further recognition. An optimization of the operation of the building should be done based on the following needs:

- Optimization of operation of the heat pump
- Careful check of heating demand, demand for DHW and saving potential
- Monitoring of PV system over a longer period (several years) and analysis with weather data
- Analysis of user pattern (dryer operation, lighting, other appliances)
- Optimize PV area (different orientations, size, costs)

Acknowledgement

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