Short report based on research project

Control Strategies for EnergyPLUS Buildings on the example of Berghalde

File number: SWD-10.08.18.7-13.33

Funding agency: Bundesinstitut für Bau-, Stadt- und Raumforschung

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit

Bundesinstitut für Bau-, Stadt- und Raumforschung im Bundesamt für Bauwesen und Raumordnung

FORSCHUNGSINITIATIVE Zukunft BAU

Recipient of fund: Technische Universität Braunschweig
Institut für Gebäude- und Solartechnik (IGS)

Project management: Univ. Prof. Dr. M. Norbert Fisch
Dipl.-Ing. Arch. Thomas Wilken

Development: Dipl.-Ing. F. Bockelmann
Ch. Kley M. Sc.

Term: 08.08.2013 – 10.08.2015

Status: October 2015

The research report was funded by the Federal Institute for Research on Building, Urban Affairs and Spatial Development in the context of the research initiative “future building” (file number: SWD-10.08.18.7-13.33). The responsibility for the content of this report lies with the authors. The authors are grateful for the support.

1. RISE AND STARTING POINT

Due to the turnaround in energy policy new challenges in the energy supply of Germany occur. Buildings, causing ~ 30 % of the energy consumption, turn from energy consumers to producers and, thus, become part of a decentralized supply system. In this context one solution is the concept of an EnergyPLUS-House. One key fact here is a high proportion of self-produced and self-used electric power. The building is mainly turning into a power plant.

2. PURPOSE OF THE RESEACH PROJECT

In the research project different optimizations for the increase of the self usage of PV generated power were investigated. For this purpose numerical simulations of the building and the building services of the single-family-house in Leonberg-Warmbronn (figure 1 and 2) were performed. By a parametric study the key factors for the design of decentralized energy supply and energy storage as well as the corresponding strategies for the control system were investigated. Different solutions were realized in the building and tested under real conditions. Then these measures can be evaluated by their relevance in praxis.

By the monitoring, an evaluation of a 4-year period and the measured building performance is possible to optimize the building's operation in terms of energy efficiency and user comfort.

Results of the monitoring

The primary goal to achieve the Netto-Plusenergy-Standard related to the annual primary and final energy balance with a good indoor climate and high user satisfaction was fully reached in all four years of operation.

The PV produced up to 80 % more electric power than the consumption of the building was in total. From 2012 to 2014 about 30 % each of the renewably produced energy was used directly in the building. Therefore about 70 % was fed into the public grid.

Referring to the building's energy consumption 30 to 50 % was covered directly by the self-usage of PV generated electric power (solar fraction) (figure 3).

The yearly energy consumption differs between 9.027 kWh/a and 12.244 kWh/a. This yields specific values related to the living area of 35 to 47 kWh/(m²a). The heat pump is by far the main consumer of the building, needing about 1/3 of the building's energy consumption to generate the heat for the floor heating and domestic hot water. In total 34 % of the energy consumption is caused by the conditioning (heating, hot water, cooling, ventilation) of the building. Household electricity (white goods, lighting, etc) causes about 37 % of the total consumption. The rest of the consumption can be assigned equally to e-mobility, the ICA and charging / discharging losses of the battery.

The heating consumption of the highly-insulated building lies between 43 and 66 kWh/(m²a),respectively weather adjusted between 50 to 65 kWh/(m²a).

Within all four years the consumption of useful energy (heat) for domestic hot water including distribution losses lies between 4 to 5 kWh/(m²a).
Except from 2013 the gain of the PV system was about 1.050 kWh/$kW_{p.}$
Due to a change of the heat pump system (2013) and adjustments in the control strategies and preferences of the heat pump and changes in operating times and the heating curve, the seasonal performance factor (SPF) raised from 3,0 (2011) to 4,62 (2014). For 2015 a SPF of 5,0 is expected.

Simulation study - increase of self-usage
Technical and economic potentials for increasing the self-usage of PV electricity are investigated in the project. The aim is to identify the key parameters on the increase of the self usage and energy efficiency in an EnergyPLUS-building. The adjustments of parameters of the building services as well as the adaption of the concept are described and evaluated.
The investigations consider the adjustments of control strategies, the enlargement of the buffer storage and the increase of the battery capacity. The evaluation is based on the investment costs related to the benefit in term of the increase of the self-usage.
As a low-investment measure night setback yields an increase of about 1 % of the self-usage. By the implementation of an adjusted control strategy (heat pump operation while PV-production) the solar fraction can be increased from 34 to 42 %. Combining all measures yields to an increase from 27 to 56 % in the self usage of PV power and from 34 to 62 % in the solar fraction (figure 4). The increase of battery capacity is not cost-efficient under current conditions und has amortization periods larger than 20 years.

3. CONCLUSION / OUTLOOK

The four years of monitoring and scientific support show that EnergyPLUS buildings can be realized successfully and can be operated efficiently at high comfort.
The realized prototypes in EffizienzhausPLUS Standard offer high potentials to do research on buildings under real conditions. Primarily, the focus lies on the increase of the self-usage, so that renewably generated power is consumed on-site within the balance limit.
Simulation studies showed that a huge increase is possible by the expansion and activation of thermal storages in the building. By the use of chemical storages a solar fraction of up to 80 % can be reached. On the hand there are still many obstacles – technical and economic - for battery systems to overcome. Furthermore, there is a need in research on the use of renewable energy in urban context, meaning that not just single buildings have a yearly surplus, but urban areas become decentralized power suppliers by a smart inter-linking. Synergies, especially by a holistic view and the consideration of different building types and different uses have to be investigated.

4. BASIC DATA

Lemma

EnergyPLUS - Aktivhouse

Research and Project Management:

Project management:	Univ. Prof. Dr. M. Norbert Fisch Dipl.-Ing. Arch. Thomas Wilken
Development:	Dipl.-Ing. F. Bockelmann Ch. Kley M. Sc.
Total costs	215.299,30 €
Rate federal government	130.584,30 €
Project duration	08.08.2013 – 10.08.2015

5. PICTURES AND GRAPHS

Figure 1: Net-surplus-energy building in Leonberg-Warmbronn

Name of the figure: Ansicht.jpg

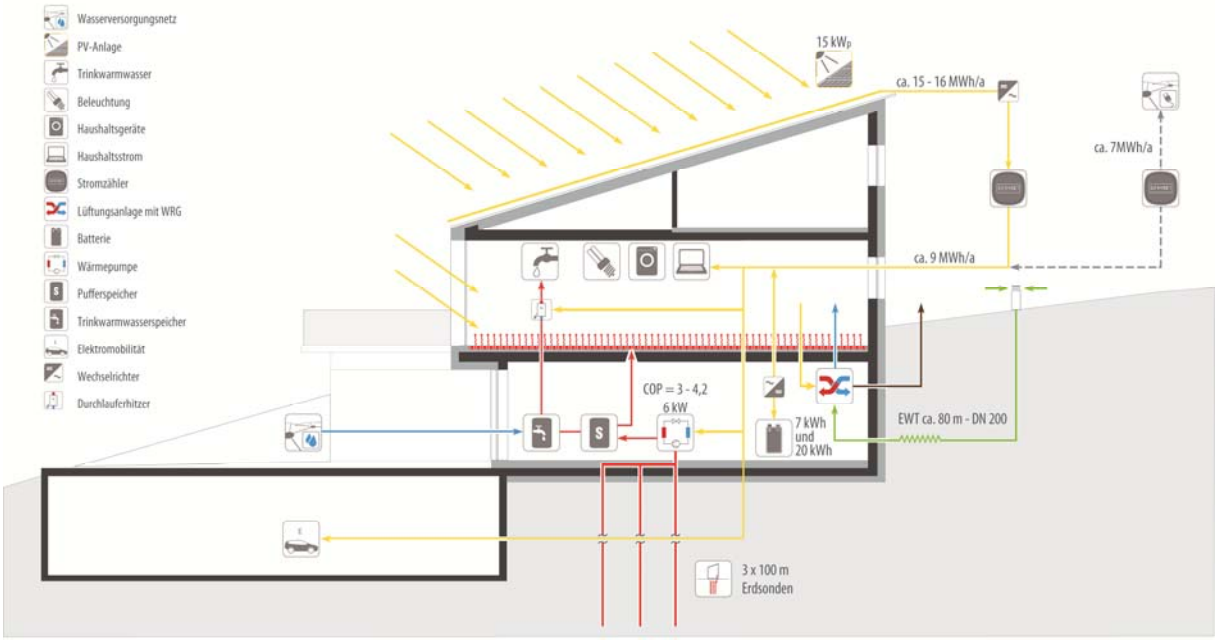

Figure 2: Energy Concept

Name of the figure: Energiekonzept.jpg

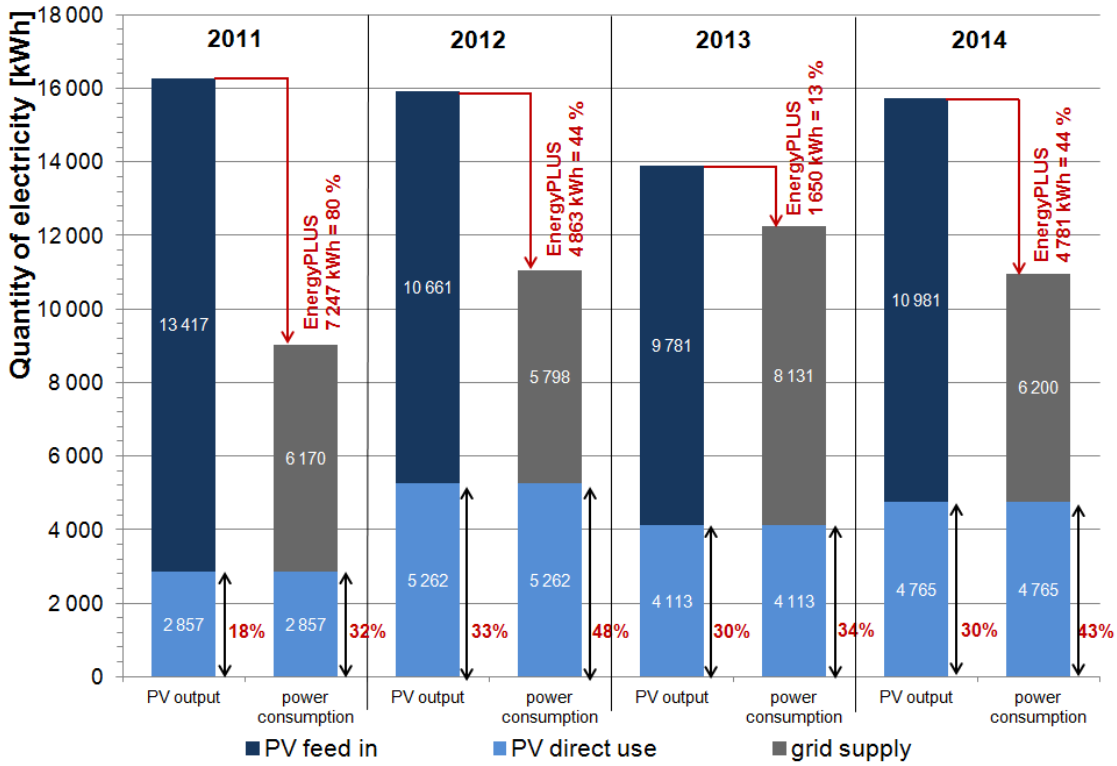

Figure 3: Annual balance of electricity / final energy and own shares in comparison (2011 - 2014)

Name of the figure: Jahresbilanz_Strom.jpg

Figure 4: Results Simulation to increase self usage – annual balance

Name of the figure: Steigerung_Eigenstrom.jpg