Plus Energy House Rupperswil, Switzerland

"Plus Energy House with Electromobility". The building produces more energy than needed for heating, hot water and household electricity. Part of the excess energy is used to operate an electric car.

Key facts

Building
Location *Obermatt 11, 5102 Rupperswil AG, Switzerland*
Construction 2013
Heat distribution *in building Floorheating*
Heated area 396 *m² living*
Level of insulation *Minergie-P-Eco (Zertifikat Nr. AG-005-P-ECO)*

Heat pump and source
Number of heat pumps 1
Installed capacity 8.9 *kW*
Operation mode *monoenergetic*
Heat source *geothermal probe 180 meters depth*
Brand and type Alpha-InnoTec, Typ SWC 80H/K
Refrigerant R410A
Sound level 45 *dB*

Heating system
Heat demand 27,8 kWh/(m2a)
Heating temperature *30°C*

Domestic hot water
Type of system *Double function heat pump*
Max. Temperature 50*°C*
Circulation system
Legionella measures *thermal*
Storage size 800 *litres*
Number of storage tanks 1
Storage losses
Temperature control

Other information
Electric energy
Consumption year *2,168 kWh space heating*
1,014 kWh water heating
Investments costs *unknown*
PV installation *102.7 m²*

Lessons learned
Hall, Monika & Geissler, Achim. (2015). Optimization of Concurrency of PV-Generation and Energy Demand by a Heat Pump - Comparison of a Monitored Building and Simulation Data. 10.5075/epfl-cisbat2015-573-578.

Photographs: © Setz Architektur

A two-storey multi-family house in Rupperswil in the canton of Aargau, with a basement has a heated living area of 320 m^2. On the ground and first floor there is an apartment with a heated area of 135 m^2. The balconies face west. In the basement there is an east-facing studio with a heated area of 50 m^2. The building is certified with Minergie-P-ECO (AG-005-P-ECO) and won the Swiss Solar Prize 2012 in the PlusEnergieBau category.

A heat pump type Alpha Innotec SWC 80 H/K with 8.9 kW (B0/W35) nominal output generates the heat for hot water and space heating. A 180 m deep geothermal probe is used by the heat pump as a heat source. The heat generated is temporarily stored in an integrated buffer storage with 200 liters for heating and a domestic water storage with 800 liters. The heat is transferred via a low-temperature underfloor heating. For passive cooling, the geothermal probe can be coupled directly to the floor circuit via a heat exchanger.

A mechanical ventilation system from Drexel & Weiss, type Topo with heat recovery in counterflow (heat recovery = 80%) and a flow rate of 120 m^3/h supplies the apartments with fresh air. The building is equipped with a photovoltaic system (PV system) with a 102.7 m^2 panel area, consisting of 63 monocrystalline modules of the Sunpower SPR-318-WHT-D type and three inverters, type SMA Sunny Mini Central 6000 A. The output of the PV system is 20 kWp and an annual yield of 18,000 kWh is expected. The facility faces south and the angle of inclination is 10°.

A weather station, type Spline P03 / 3, provided data on the outside temperature, the illuminance (east, west and south orientation) and the wind speed at the building site. The energy information system shows the household electricity consumption and heat consumption for each apartment and allows a comparison with stored daily, weekly, monthly and annual maximum values.

Monitoring and optimizing the system (source reports Mehrfamilienhaus mit Elektromobilität in Rupperswil, 3. Zwischenbericht)

The large photovoltaic system on the roof of the building provides more electricity than all consumers in the building need over the entire project period. 45% of the total electricity consumption is distributed over the household electricity supply. 23% are used to operate the heat pump (16% for heating the building, 7% for preparing hot water). 19% of the electricity purchases are used for the electric car, 6% each for the mechanical ventilation of the building and the general electricity supply.

The shifting and limiting the running times of the brine-water heat pump into the day is very suitable for increasing the self-consumption. This means that the amount of electricity used in the building itself can be increased by around 1,000 kWh. The self-coverage rate increases from 21% to 34%.

The energy information system is hardly used by the tenants and has only a minor influence on their energy consumption. For example, the heating energy consumption exceeds the orientation values of the energy information system by approx. 57%, since the room air temperatures in all three heating periods are significantly higher than the default values. Hot water consumption is around 10%, household electricity consumption is around 11% above the default values.

Planning and orientation values

When planning the building, a specific heating requirement of 10.8 kWh/(m^{2}a) was used in accordance with the Minergie application. According to SIA 380/1, 20.8 kWh was assumed for the hot water requirement. As already explained in the 2nd example, the planning estimated an EBF of 396 m^2. The real heated area of the building is 320 m^2. The mean measured room air temperature of 22°C is also significantly above the planning value of 20°C. Based on this, the specific heating demand at real EBF, 22°C room air temperature and assuming a thermally effective outside air volume flow of 0.21 m^3/(m^{2}h) to 26 kWh/(m^{2}a) is calculated. For orientation, the tenants can query their heat supply in an energy information system. A value of 17.5 kWh/(m^{2}a) is stored in this system for the area-weighted heating requirement.

The specific heating demand was converted with a distribution key into monthly amounts of heat depending on the outside climate and saved in the energy information system.

The annual hot water requirement (Q_{ww}) was adjusted to the hot water temperature reduced from 60°C to 50°C and to the number of tenants per apartment to 10.1 kWh/(m^{2}a). Based on this, 1,000 kWh/a hot water per tenant is set as a reference value in the energy information system.

Hot water consumption (entire project duration)

During the project 234 m^3 or 10,300 kWh are consumed. Based on the EBF, this value corresponds to a specific hot water consumption of 15 kWh/(m^{2}a). In September 2013, hot water consumption skyrocketed and reached a high level in the following months. In comparison of the monthly consumption values with the values stored in the energy information system, the exceeding of the monthly specification is the normal case. Only the hot water consumption of the ground floor apartment is close to the reference value. Compared to the planned value according to SIA 380/1 (20.8 kWh/(m^{2}a)) or 17,200 kWh for 31 months and 320 m^2 EBF), there is a reduction in consumption of around 7,000 kWh. This is due to the low tenant occupancy (80 m^2 per person) of the building.

The working figures for hot water and heating operation are calculated on the basis of one-day values for heating, hot water consumption and electricity for heating and hot water production. The values for heating and hot water consumption are adjusted to simplify and reduce the measurement error. All heating values less than 10 kWh$_{therm}$/d and all hot water consumption less than 1.4 kWht$_{herm}$/d (corresponds to 0.03 m^3) are not taken into account for the calculation of the working figures.

The operating modes of the heat pump are divided into "Demand-led" and "Optimized", characterized as:

- Demand-driven The return temperature of the underfloor heating or the temperature in the hot water tank determine the operating time of the heat pump

- Optimized The operating period for heating and hot water generation is limited to the hours of the day so that there is a high level of agreement with the PV yield times.

The operating modes and the selected initial useful energy quantities result in 309 value pairs for demand-driven heating and heating and 168 value pairs for demand-driven hot water operation. In optimized operation, 285 value pairs for heating and 664 value pairs for hot water can be used. It is checked whether the operating modes of the hot water and heating operation have an impact on the labor figures. For this purpose, the useful and operating energy quantities of the respective mode of operation are summed up over the number of value pairs and offset to an average labor figure.

	Demand driven		**Optimized**	
	Space heating	Water heating	Space heating	Water heating
SPF	3,8	3,6	4,9	3,9

The optimization of the operating times results in noticeably higher work figures compared to the demand-led operation in both heating and hot water operation. This is due to longer continuous operating times and the reduced number of compressor starts. As a result, the energy consumption of the heat pump decreases overall.

The runtime of the heat pump for hot water operation in the first heating period was not restricted. Then it was limited to 11 a.m. to 5 p.m. from May 9, 2012 and from 1 p.m. to 5 p.m. from July 21, 2012. It can be observed that a daily operating time between 30-120 minutes is sufficient to cover the hot water requirement of a day. On average, the heat pump runs for about an hour a day. During this operating time, the hot water tank (800 L) is heated to 50°C. To do this, an average of 3.2 kWh of electricity is used per day. The hot water supply is ensured despite the time limit.

The fact that the operating energy consumption of the auxiliary units (brine and distribution pumps) is very low shows that the system has been well balanced hydraulically. The exegetical level of heat generation is close to the level of low-temperature heating demanded by the tax authorities. Due to the routing of the heating and hot water distribution within the insulation perimeter of the building, the distribution losses of the heat balance of the house benefit as passive heat gains. For the production of hot water and heating energy, only the environmental heat of the geothermal probe and the operating energy of the heat pump compressor are used throughout the project period. The use of the direct electric heating element to generate heat was not necessary at any point in the investigation period.

Compared to similarly designed buildings all measures described in this project can be implemented by simple adjustments to the heat pump control. Design changes to the building technology were not necessary. The results of this project contradict the statement made in the literature that the coupling of photovoltaics and heat pumps is neither economically viable nor useful for the grid. Rather, it can be seen that simple optimization measures on the heat pump significantly improve the use of solar power and increase the amount of power that is used by around 1,000 kWh/a.

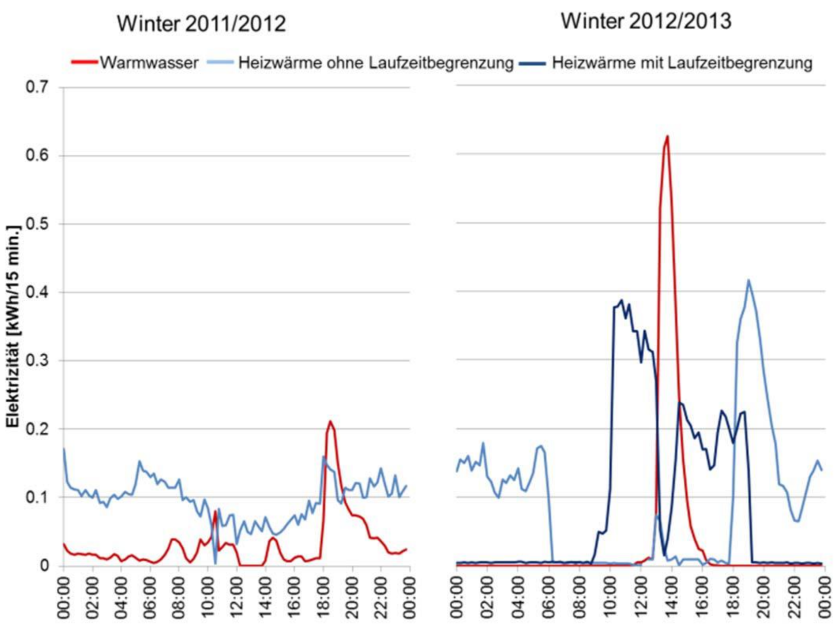
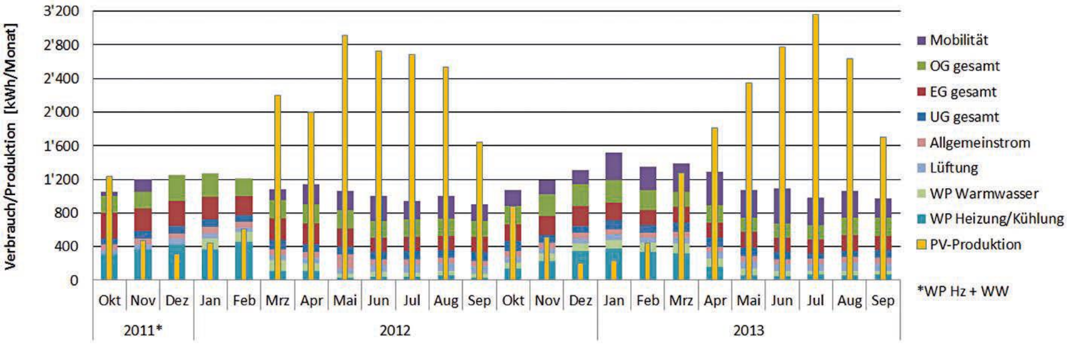


Figure: The average 15-min energy consumption of the heat pump in heating and hot water mode during the day with heat-controlled (left) and for a limited time (right)

Plus Energy House Rupperswil, Switzerland, Technical details

Technical room in the middle of the basement



Electric car

Detailed values for individual consumers, PV-generation and climate data for both years of operation

	1st Year	2nd Year	dev
Household electricity for 3 apartments	6.584 kWh (50 %)	6.013 kWh (42 %)	-9%
elec. Heat pump, heating / cooling	2.163 kWh (16 %)	2.168 kWh (15 %)	0%
elec. Heat pump, hot water	906 kWh (7 %)	1.014 kWh (7 %)	12%
Electric car	1.792 kWh (14 %)	3.476 kWh (25 %)	94%
ventilation	826 kWh (6 %)	887 kWh (6 %)	7%
General electricity	940 kWh (7 %)	776 kWh (5 %)	–17 %
Overall elec. use	13.210 kWh (100 %)	14.334 kWh (100 %)	9%
Overall elec. use without Electric car	11.354 kWh (86 %)	10.858 kWh (75 %)	–4 %
PV yield, forecast: 18.157 kWh/a	19.805 kWh (+9 %)	17.976 kWh (–1 %)	–9 %
Excess	6.659 kWh (50 %)	3.584 kWh (25 %)	–46 %
Mileage of the electric car	8.745 km	15.820 km	81%
Hours of sunshine, long time. Medium:2.649 h	2.552 h (–4 %)	2.466 h (–7 %)	–3 %
Global radiation: 1.050 kWh/(m2a)	1.149 kWh/(m2a) (+9 %)	1.029 kWh/(m2a) (–2 %)	–11 %
Outside temperature, long-term. Medium:9,2 °C	11,3 °C (+2,1 K)	10,6 °C (+1,4 K)	–0,7 K
Heating degree days, long years. medium: 3199 °Cd	3.243 °Cd (+1 %)	3.395 °Cd (+6 %)	5%
heating energy requirements*, 26 kWh/(m2a)	27,8 kWh/(m2a) (+7 %)	27,9 kWh/(m2a) (+7 %)	0%
Hot water demand, 20,8 kWh/(m2a)	12,2 kWh/(m2a) (–43 %)	17,5 kWh/(m2a) (–16 %)	43

*considering 22 ° C room temperature and comfort ventilation system with heat recovery

Description of the technical concept