Case Study IEA HPT Annex 49

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nZEB with mixed residential and office use and e-mobility

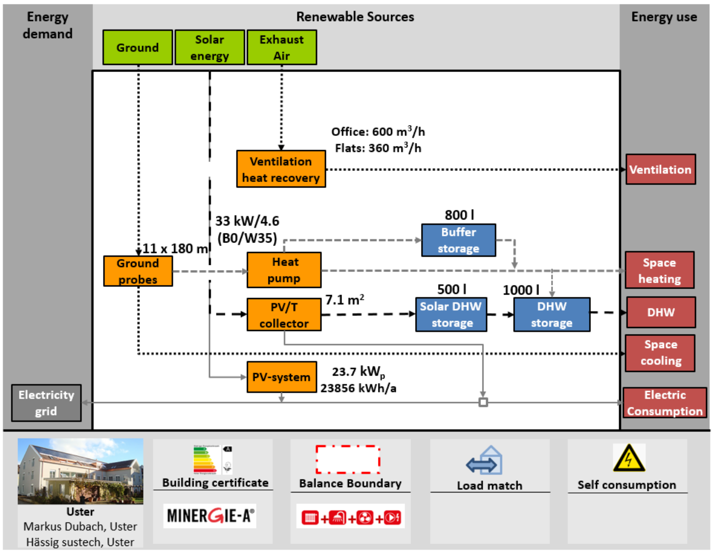
First MINERGIE-A®-building with office use in canton Zurich

Summary

The first MINERGIE-A® building with office use in canton ZH, located in Uster, has been monitored for two years from May 2014 - April 2016. The all-electric building is equipped with a 33.1 kW ground-source heat pump (B0/W35) a 24 kW_p solar PV-system and a 7.1 m² PV/T-collector for domestic hot water (DHW) preheating. Moreover, a mechanical ventilation system with 80% heat recovery is installed. The ground-source is used for free-cooling in summer operation.

The nZEB balance according to the MINERGIE-A® label of 2014 has been reached. The ground-coupled heat pump achieved an SPF_{HW} of 4.5 in space heating (SH) and DHW mode, while a SPF_C of 17 is reached in free-cooling. The solar fraction of the PV/T collector is 13%, with a thermal efficiency of the collector cycle of 27% in summer operation. Optimisation potentials were found in the consumption of the accompanying DHW pipe heating, which made-up 30% of the electricity consumption in the first year and could be reduced by 60% in the second year

Concept



Building Data

Location:	Uster, canton Zurich
Building Use:	office, 7 flats
Energy ref. area (office/total)	366 / 1206 m²
Walls (brick/concrete)	0.18 / 0.2 W/(m²K)
Roof	0.15 W/(m²K)
Ground floor	0.18 W/(m²K)
Windows (total/glass/frame)	0.97/0.7/1.3 W/(m²K) triple glazing, g=0.47
Space heating/DHW demand:	33.8/19 kWh/(m²a)
Design MINERGIE-A® balance	-5 kWh/(m²a)

July 2019

International Energy Agency

Heat Pumping Technologies

Background

In Switzerland, no uniform definition of a nZEB existed at the time of the field monitoring. However, in March 2011, the MINERGIE-A®-label has been introduced as an nZEB concept requiring a net zero energy balance in the boundary of the building technology. While initially only applied for residential buildings, an extension to offices has been introduced in May 2014. Therefore, not much experience existed and monitoring data were required for office application. Moreover, as innovative technology at the time, a PV/T collector for DHW preheating is installed and a publicly rentable electric car serves as local electricity storage for on-site generated PV-electricity to enhance local self-consumption on on-site PV electricity.

Technical concept

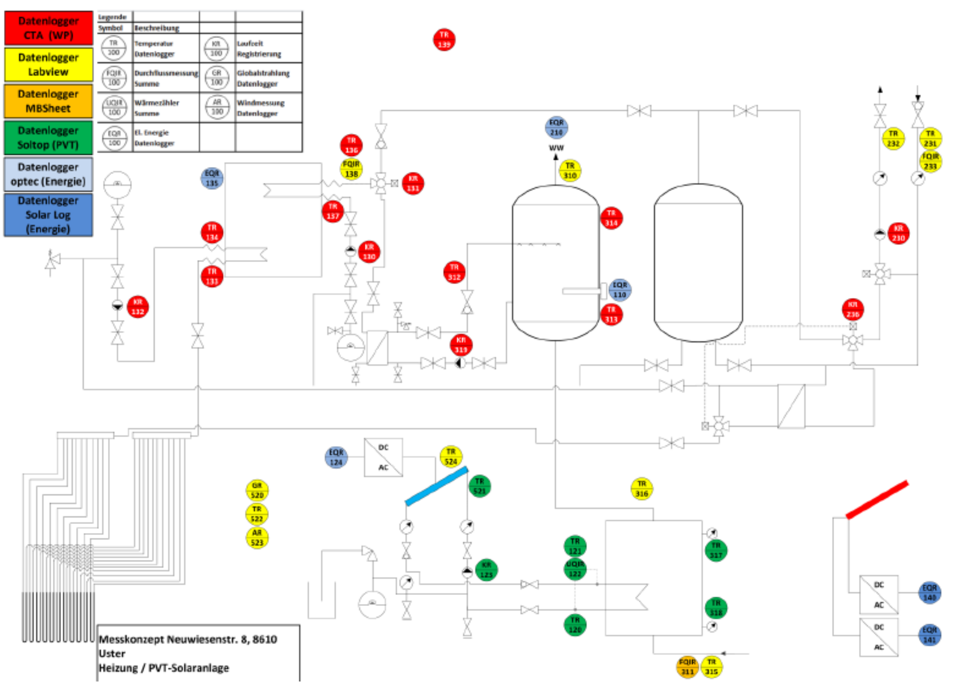
The building is equipped with a ground-coupled heat pump with a capacity/COP of 33.1 kW (30.5 kW)/4.6 (3.0) at B0/W35 (W50). 11 double-U-tube ground probes of 80 m depth each serve as heat source. The building has a floor heating with design temperatures of 35 °C/30 °C both for the offices and the 7 flats. In order to meet the nZEB balance a solar PV-system of 128 m² is installed on the roof. With a peak power of 23.7 $kW_{p.}$, an annual yield of 1007 kWh/kW_p has been calculated. Additionally, a PV/T collector of 7.1 m² of 180 $W_{el.p}/m^2$ and 310 $W_{th.}/m^2$ is coupled to a 500 l storage to preheat the DHW. The DHW is reheated by the heat pump in a 1000 l storage which also contains a direct electrical back-up for legionella protection. Additionally, an 800 l heating buffer storage is integrated in parallel and a balanced ventilation with 80% heat recovery efficiency is installed. In summer time, the borehole field is used for free-cooling operation. Since only electricity is used as energy carrier, the building can be characterized as all-electric building.

Current market state

The MINERGIE-A® label has been revised in 2017 to cover the whole energy balance incl. appliances, which has to be compensated with on-site PV electricity on an annual basis. Electricity is weighted with a factor of 2 for the balance. However, exported PV-electricity is weighted with a reduced factor of 0.8, so there is still an incentive for self-consumption.

Technical data of the unit

Heat pump	
CTA optiheat OH 32e	
Heating capacity/COP	**W35: 33.1 kW/4.6**
	W50: 30.5 kW/3.0
Solar PV system	
51 modules on the south-eastern roof	
52 modules on the south-western roof	
Total PV area:	**128 m²**
Peak power:	**23.7 kW**
Electrical efficiency	**18.6%**
PV/T collector	
Total PV/T area:	**7.1 m²**
Nominal capacity electric	**180 W_p/994 W_p**
Nominal capacity thermal	**430 W/2300 W**
Storages	
Heating buffer storage	**800 l**
DHW preheating	**500 l**
DHW reheating	**1000 l**
Ventilation systems	
Volume flow rate office	**700 m³/h**
Volume flow rate flat	**1200 m³/h**
(CO_2-control)	
Heat recovery	**80%**
Accompanying pipe heating	
2 heat tapes	**90 m /30 m**



Sensor	Symbol	Unit	Description
EQR 110	Electric heating element	kWh (Btu)	Electrical energy heating element
TR 120	TPVT-S	°C (°F)	Supply temperature to PV/T collector
TR 121	TPVT-R	°C (°F)	Return temperature to PV/T collector
UQIR 122	QPVT	kWh (Btu)	Heat energy PV/T collector
KR 123	tL-PVT-UWP	h	Status pump PV/T collector
EQR 124	EPVT	kWh (Btu)	Electrical energy PV/T collector
KR 130	tWP-UWP-WW	h	Status HP DHW pump
KR 131	tST-WP-H/WW	h	Status HP SH pump
KR 132	tWP-UWP-ground	h	Status HP source pump
TR 133	Tground-probe-VL	°C (°F)	Supply temperature borehole
TR 134	Tground-probe-RL	°C (°F)	Return temperature borehole
EQIR 135	EWP	kWh (Btu)	Electrical energy heat pump
TR 136	TWP-VL	°C (°F)	Supply temperature heat pump
TR 137	TWP-RL	°C (°F)	Return temperature heat pump
FQIR 138	VWP-circulation	L	Volume flow heat pump condenser
TR 139	T outdoor	°C (°F)	Outdoor air temperature
EQR 140	EPV_140	kWh (Btu)	Electrical energy solar PV field 1
EQR 141	EPV_141	kWh (Btu)	Electrical energy solar PV field 2
EQR 210	E_element	kWh (Btu)	Electrical energy heating element
KR 230	tWP-UWP-H	H	Status distribution pump
TR 231	TWP-VL-H	°C (°F)	Supply temperature heating
TR 232	TWP-RL-H	°C (°F)	Return temperature heating
FQIR 233	VWP-H	L	Volume flow heat pump heating
KR 236	tST-WP-H/C	H	Status heat pump heating/cooling
TR 310	TWW-outlet	°C (°F)	Temperature DHW outlet
FQIR 311	Vcold-water	L	Volume flow cold water
TR 312	TWW-storage-VL	°C (°F)	DHW storage supply temperature
TR 313	TWW-storage-bottom	°C (°F)	DHW storage temperature bottom
TR 314	TWW-Speicher-top	°C (°F)	DHW storage temperature top
TR 315	Tcold-water	°C (°F)	Temperature cold water inlet
TR 316	T outlet preheating	°C (°F)	Temperature outlet DHW preheating
TR 317	Tpreheating-top	°C (°F)	Temperature DHW preheating top
TR 318	Tpreheating-bottom	°C (°F)	Temperature DHW preheating bottom
KR 319	tWW-UWP	h	Status storage loading pump
GR 520	Global irradiation	W/m2 (Btu/ft²h)	Global solar irradiation
TR 521	Tcollector	°C (°F)	Surface temperature PV/T collector
TR 522	Troof	°C (°F)	Temperature on the roof below tiles
AR 523	Wind speed	m/s (ft/s)	Wind speed

Measurement concepts and data loggers

Field monitoring results

The objectives of the field monitoring is the evaluation of the net zero energy balance acc. to the MINERGIE-A®-label requirements. As further aspect the load match of office use and PV yield is investigated in terms of self-consumption. In this context, also the use and availability of the electric car is of interest as local electricity storage option. Moreover, the performance of the PV/T collector for preheating the DHW is evaluated.

The monitoring period lasts from May 2014 to April 2016. The heat pump reached a seasonal performance factor for SH and DHW of SPF_{hw} = 4.3 (4.5) in the first (second) year, with 4.6 (4.9) in SH and 3.5 (3.5) in DHW mode. Including the solar DHW preheating of the PV/T collector, the overall performance is SPF_{gen}=4.8 based on the generated heat. The ground-coupled free-cooling operation reached an SPF_c = 17, since only electricity for the pumps is used. According to the user statements, comfort is fulfilled by only using the passive cooling. By the free-cooling operation, the SPF of the DHW mode is increased by 5% to the warmer source temperatures is summer.

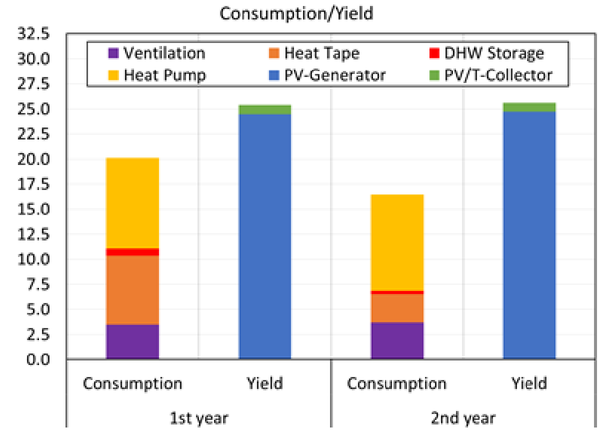
The heat pump is with 45% (58%) the largest electricity consumer of the building technology. Based on the used energy, however, the SPF decreases significantly to SPF_{sys}=1.3, which is mainly caused by the accompanying DHW distribution pipe heat tapes, which consumed more than 30% of the balanced electricity in the first year. Despite this large consumption, the MINERGIE-A® requirements could be already reached in the first year with a balance of -8.6 kWh/(m²a), i.e. a PV surplus of 8.6 kWh/(m²a) regarding the consumption of the building technology.

The PV/T collector reached a thermal collector efficiency of 27% and a solar fraction of 13% of the DHW in the second year with a thermal production of 1400 kWh_{th}/a similar in both years. By rejecting the heat from the PV-cells, an increase of electrical efficiency by 1.3% to 10.8% could be reached, which was evaluated by the performance with and without thermal collector operation on single days with similar irradiation and temperature conditions. The electrical yield of the PV/T is 900 $kWh_{el.}$/a, also similar in both years.

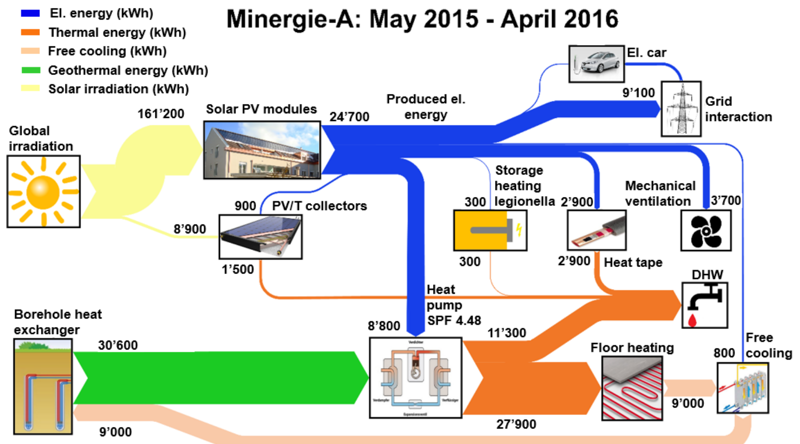
The yield of the solar PV was in total in both years about 24,500 $kWh_{el.}$/a which is with 1030 (1040) $kWh_{el.}/kW_p$ slightly above the calculated value.

Performance in Field monitoring

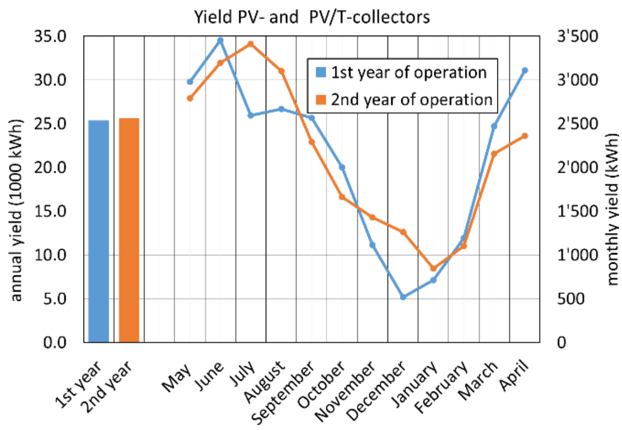
Seasonal performance factors	
SPF heat pump (boundary COP)	4.3 (4.5)
SPF generators (HP and PV/T thermal)	4.6 (4.8)
SPF ground-coupled free-cooling	17 (17)
SPF system (all system components)	1.3 (1.9)
Solar PV yield	
Solar PV system	24,500 kWh (1,035 $kWh_{el.}/kW_p$)
Solar PV/T yield el.	900 kWh_{el}
Solar PV/T yield th.	1400 $kWh_{th.}$
nZEB balance (acc. MINERGIE-A® of 2014)	
MINERGIE-A characteristic	-8.6 kWh/(m²a)
MINERGIE-A characteristic	-15 kWh/(m²a)
Temporal characteristic (annual on 5 min step basis)	
Demand cover factor (self-consumption)	30%
Supply cover factor (self-generation)	37%



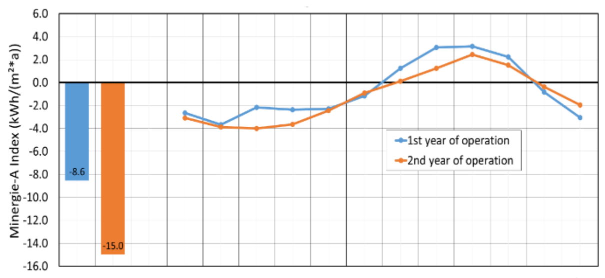
Annual Comparison of the consumption and production



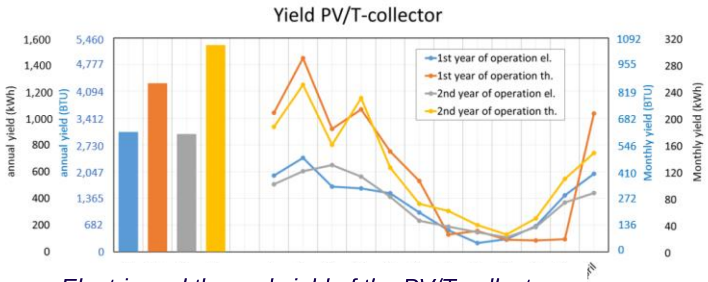
Energy flow diagram for second year from May 1, 2015 – April 30, 2016



Electric yield of the solar PV system in the two years



Monthly and annual nZEB balance for the two years



Electric and thermal yield of the PV/T collector





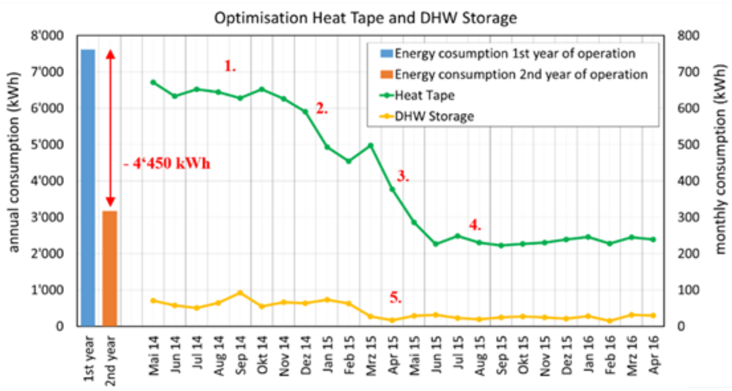
System performance and optimization

The overall system performance of the system is with 4.5 in a good range for ground-source heat pumps. By the solar preheating with the PV/T collector the heat pump tends to work at higher DHW temperature for the storage reheating, and therefore, the SPF_W of 3.5 is limited.

Based on the monitoring results of the first year optimisation measures have been implemented and approved by the performance in the second year.

The very poor system performance of 1.3 could be improved by the accompanying DHW pipe heating which is operated for DHW comfort reasons. However, by the change of control strategy of the direct electric heating to a scheduled operation, the electric consumption could be reduced by 60% without complaints of the users. Thereby, the MINERGIE-A® balance could be increased from -8.6 to -15 kWh/(m²a).

The electric car was not so frequently used and could thereby contribute to self-consumption of the PV-electricity, which was limited by the charging capacity, though. In the future, a smart charging control shall be applied, where the charging power and time can be adapted to the instantaneous PV surplus. But this would hard- and software update of the charging station and the car, which, however, are now available.



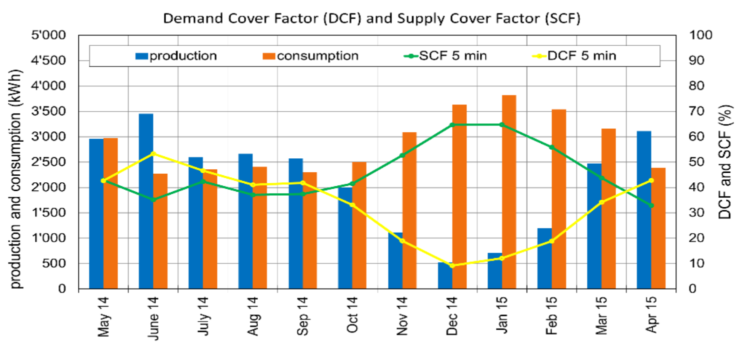
Different optimization steps of accompanying DHW heating

Economy, ecology, costs and self-consumption

At the time of monitoring, the PV-tariff with cost equivalent feed-in tariff called “KEV” was high, so there is no financial incentive to enhance the self-consumption of the on-site generated PV-electricity.

The PV-electricity necessary to meet the MINERGIE-A® nZEB balance, though, could not be sold under the KEV, but only the surplus of the balance, since the so-called “ecological added value” of renewable energy generation had to remain at the building site to fulfill MINERGIE-A® requirements. Thereby, for a MINERGIE-A® certification, self-consumption was beneficial. In 2017, though, this was changed, so presently, all PV electricity is taken into account. However, weighting factor of 0.8 instead of 2 for the balance still are an incentive for self-consumption.

Moreover, KEV has been replaced by a 30% subsidy of the PV investment cost for systems of 2 to 30 kW_p. But, at current PV system prices, it is possible to reach generating cost of PV electricity of 0.15-0.2 CHF/kWh, which corresponds to the electricity price for private consumers in daytime tariff. Common feed-in tariffs of PV electricity without KEV are around 0.04-0.1 CHF/kWh, so there is an incentive for enhanced self-consumption for smaller system. The heat pump operation and the electric car have been investigated in this context.



Demand/supply cover factor of first year for the boundary building technology

Imprint

Building owner
Markus Dubach, Überseeische Missionsgemeinschaft

Design
hässig sustech gmbh, Uster

Field monitoring
hässig sustech gmbh in collaboration with
HSR University of Applied Sciences Rapperswil

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