



13<sup>th</sup> IEA  
**HEAT  
PUMP**  
CONFERENCE



13th IEA Heat Pump Conference  
May 11-14, 2020 Jeju, Korea



TECHNISCHE HOCHSCHULE NÜRNBERG  
GEORG SIMON OHM

# Herzo Opt – Group of eight buildings with low temperature heating grid

## Speaker:

Christina Betzold  
Technische Hochschule Nürnberg  
Georg Simon Ohm

## Authors:

Workshop IEA HPT Annex 49  
Design and integration of heat pumps for nZEB

26. April 2021

# Herzo Opt - Project presentation

- Funded by the BMWi from 2016 until 2022
- Eight terraced houses were built as nearly Passive House (KfW Efficiency House 40 Plus) in 2017
- Plus energy building
- Monitoring since April 2018



Supported by:



Federal Ministry  
for Economic Affairs  
and Energy

on the basis of a decision  
by the German Bundestag



Herzo Opt – Group of eight buildings with low temperature heating grid

Christina Betzold, Technische Hochschule Nürnberg Georg Simon Ohm

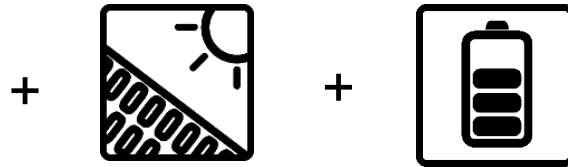
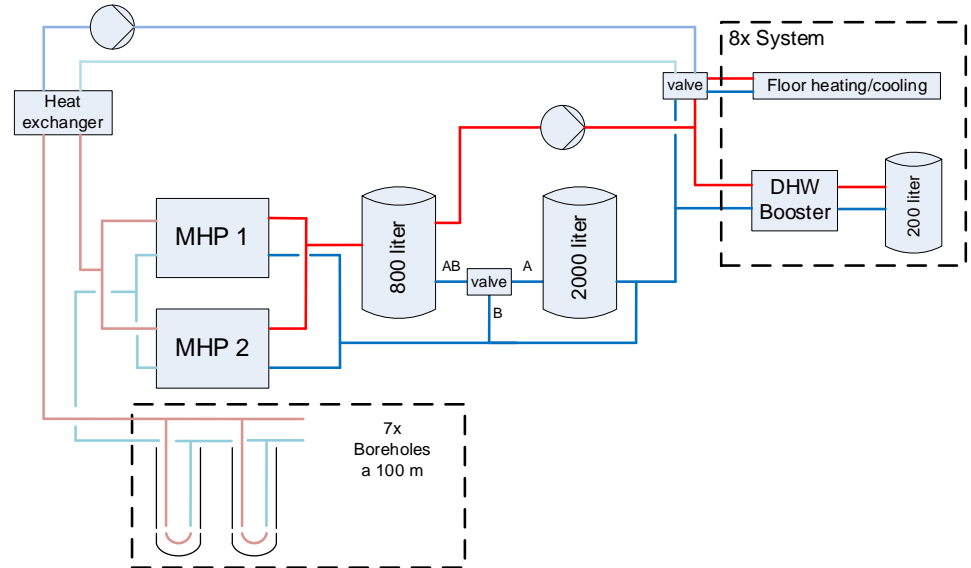


# Energy system

- 2 geothermal heat pumps
- 7 geothermal probes with free cooling
- 8 decentralised domestic hot water heat pumps (boosters)
- Thermal storage cascade
- PV power (shared use)
- Battery (shared use)

## Advantages:

- Shifting electrical load peaks
- Hygiene and hot water temperature
- Use of PV power surplus



89 kWp

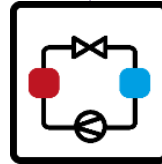
40 kWh

# Simulation and control strategies

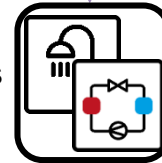
PV-optimized control (PVC)

- Rule based control
- High PV use
- Less grid feed (profit)

2x MHPs



8x DHW-HPs



Model predictive control (MPC)

- Proactive operation
- Cost optimized
- Target: cost saving by 10%

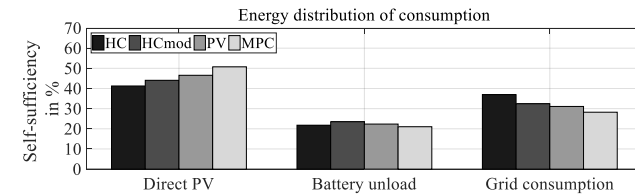
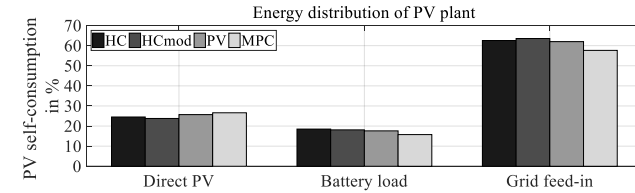
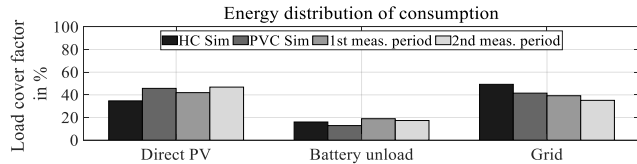
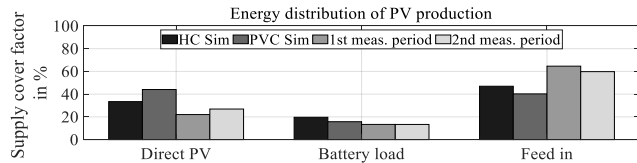
# Simulation and control strategies

## PVC-Simulation

- Simulation in TRNSYS
- Design and definition of parameters
- Start since October 2019 for MHPs
- Start since January 2020 for Boosters

## MPC-Simulation

- Simulation in MATLAB
- Comparison of heat-control and PVC
- Test operation phases since February 2020
- Long-time operation phases since December 2020



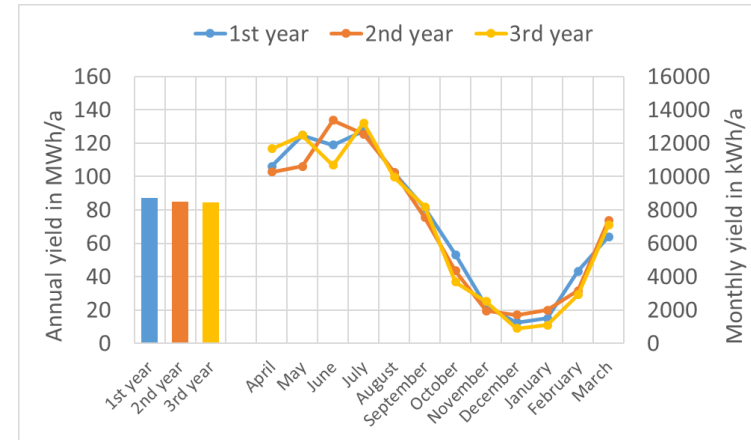
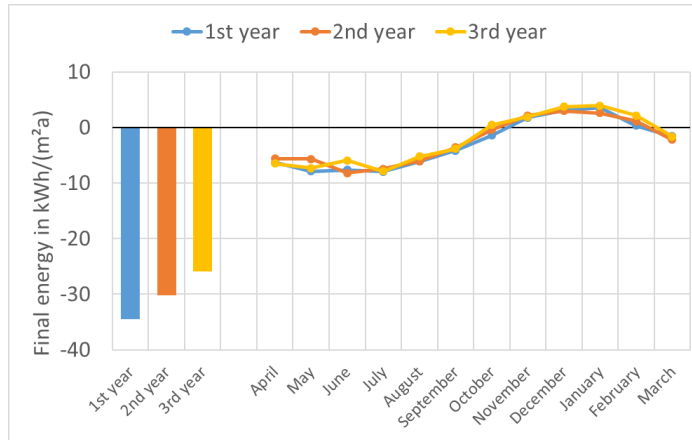
# Monitoring

## Final energy and annual PV yield



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
▶ 73 W/m<sup>2</sup><sub>NFA</sub>  
▶ 983 kWh/kWp



- FE: -34/-30/-26 kWh/m<sup>2</sup>y
- PV: 87/85/84 MWh/y

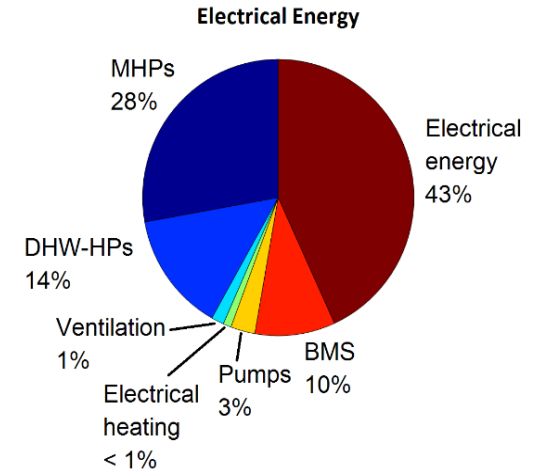
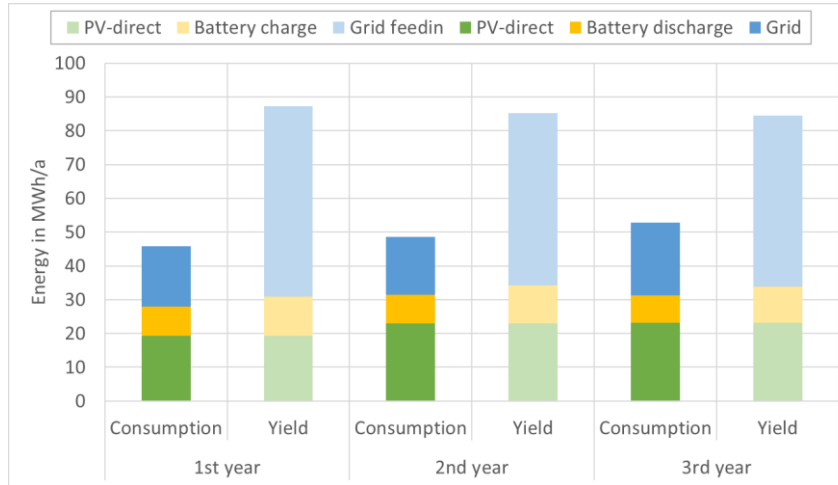
# Monitoring

## Final energy and annual PV yield



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
▶ 73 W/m<sup>2</sup><sub>NFA</sub>



- El. household: ~ 20 kWh/m<sup>2</sup>y
- Total consumption: ~ 41 kWh/m<sup>2</sup>y
- PV yield: ~ 71 kWh/m<sup>2</sup>y

Herzo Opt – Group of eight buildings with low temperature heating grid

Christina Betzold, Technische Hochschule Nürnberg Georg Simon Ohm

# Monitoring

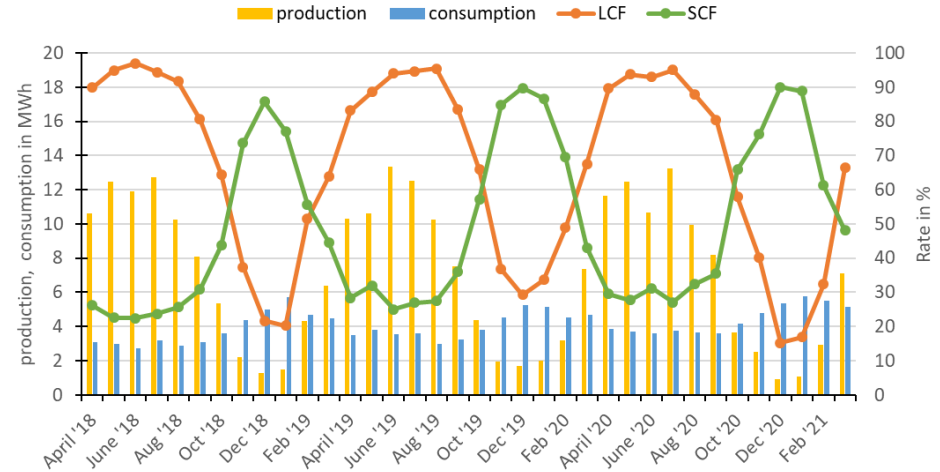
## Load cover factor (LCF) and supply cover factor (SCF)



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
► 73 W/m<sup>2</sup><sub>NFA</sub>

Year	LCF	SCF
1st	61 %	32 %
2nd	65 %	37 %
3rd	59 %	37 %



- LCF decrease through higher consumption (Electrical vehicles)
- SCF increase through PVC

$$LCF = \frac{\text{PV direct consumption}}{\text{Total consumption}}$$

$$SCF = \frac{\text{PV direct consumption}}{\text{PV yield}}$$

# Monitoring

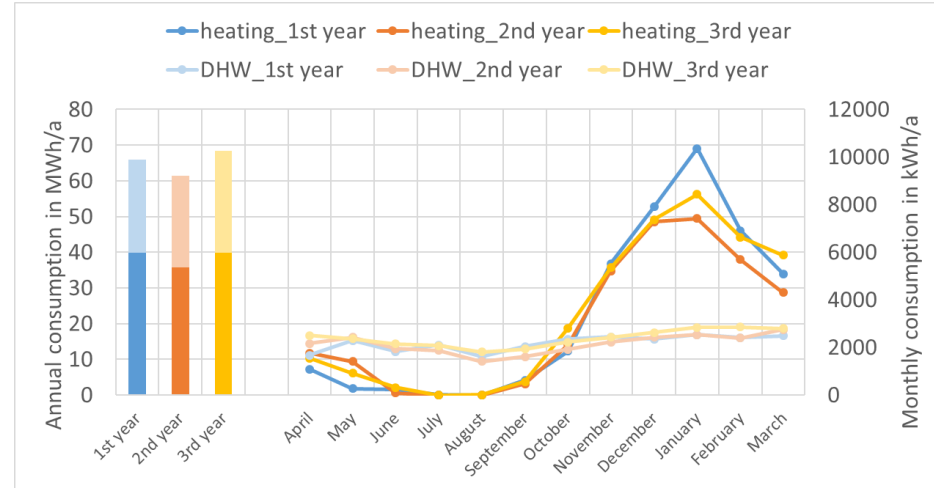
## Heating and DHW consumption



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
▶ 73 W/m<sup>2</sup><sub>NFA</sub>

Year	Heating kWh/m <sup>2</sup>	DHW kWh/m <sup>2</sup>
1st	33.2	21.8
2nd	29.8	21.4
3rd	33.2	23.9
Simulation	23.4	18.5



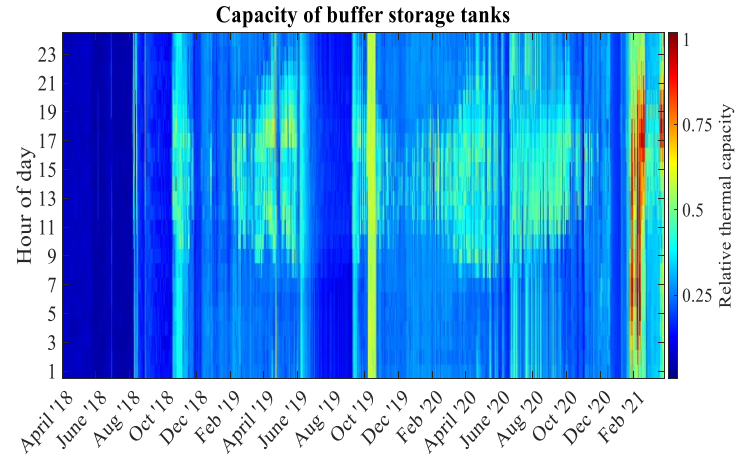
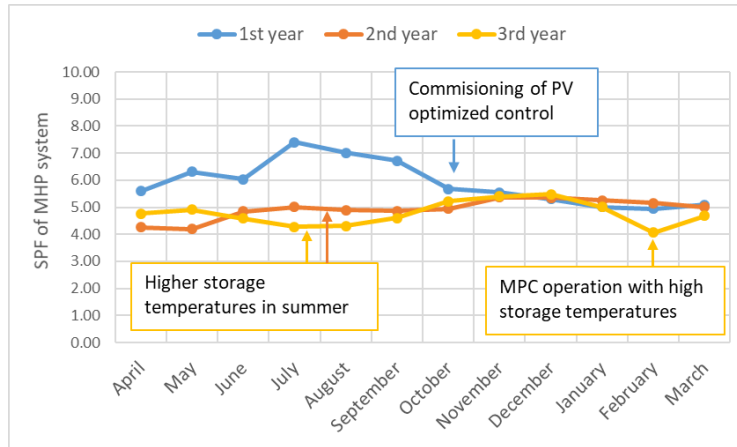
# Monitoring

## Seasonal performance factor (SPF) of MHPs



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
▶ 73 W/m<sup>2</sup><sub>NFA</sub>



### Annual SPF

- SPFMHPs between 4.8 and 5.6
- SPFBoosters between 4.0 and 4.3

Herzo Opt – Group of eight buildings with low temperature heating grid

Christina Betzold, Technische Hochschule Nürnberg Georg Simon Ohm

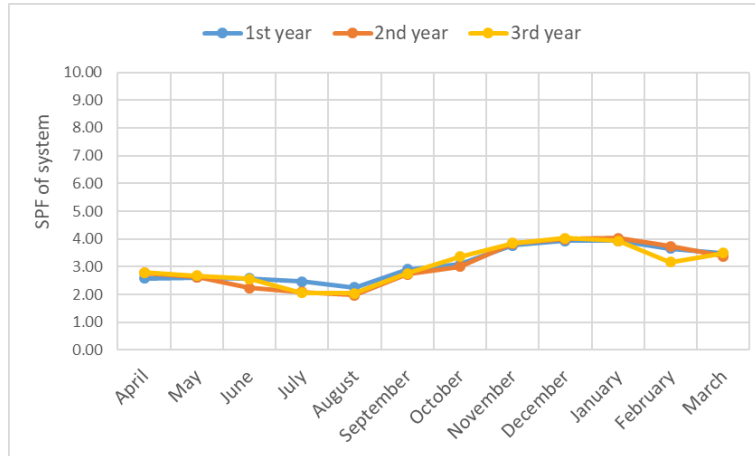
# Monitoring

## Seasonal performance factor (SPF) of system (incl. auxiliary energy)



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
▶ 73 W/m<sup>2</sup><sub>NFA</sub>



### Annual SPF

- SPF<sub>system</sub> between 3.3 and 3.4
- Auxiliary energy of pumps counts up to 13 % in summer and 5 % in winter

# Conclusion



8 houses  
NFA 1200 m<sup>2</sup>

87 kWp PV  
▶ 73 W/m<sup>2</sup><sub>NFA</sub>

## PV yield and self-consumption

- Plus energy building on annual balance
- Design of PV field under higher assumptions
- Increase of SCF by PVC
- High LCF of 59 % to 65 %

## System performance

- High SPF of MHPs and Boosters
- PVC and higher temperature decrease SPF
- Auxiliary energy (pumps) decrease system SPF in summer

## Economic

- Reduction of electricity price of 75 % to 85 %



13<sup>th</sup> IEA  
**HEAT  
PUMP**  
CONFERENCE



13th IEA Heat Pump Conference  
May 11-14, 2020 Jeju, Korea



TECHNISCHE HOCHSCHULE NÜRNBERG  
GEORG SIMON OHM

## Herzo Opt – Group of eight buildings with low temperature heating grid

### Questions and Comments

#### Speaker:

Christina Betzold  
Technische Hochschule Nürnberg  
Georg Simon Ohm

#### Contact:

Christina Betzold  
Technische Hochschule Nürnberg Georg Simon Ohm  
Fürther Straße 250, 90429 Nürnberg  
[christina.betzold@th-nuernberg.de](mailto:christina.betzold@th-nuernberg.de)  
+49 (0)911 5880-3123