Heat pump integration and application in nearly Zero Energy Buildings (nZEB)

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IET INSTITUT FÜR ENERGIETECHNIK

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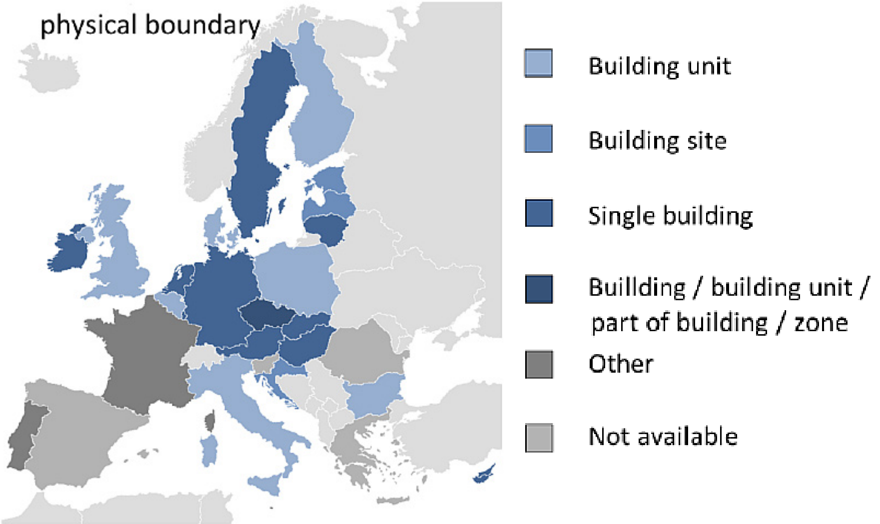
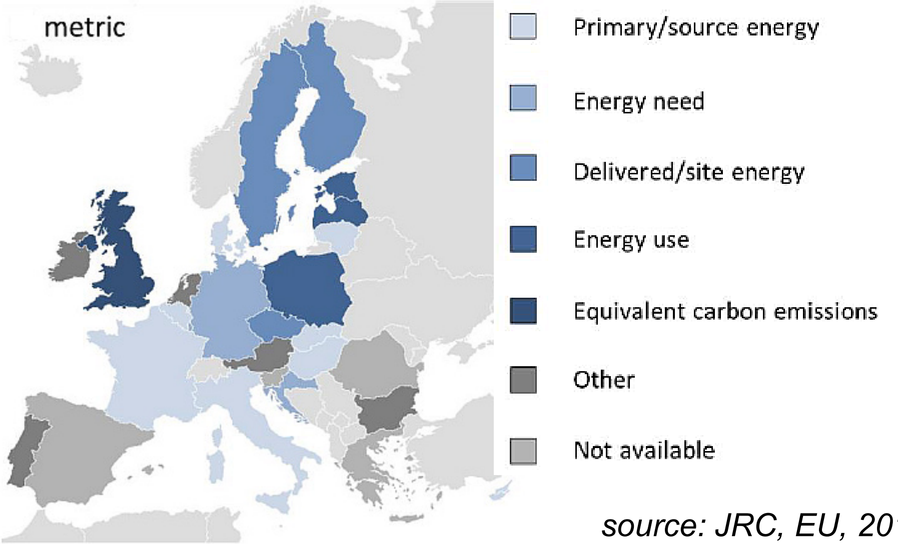
Motivation

- **Nearly Zero Energy Buildings (nZEB) are the global future building standard**
- **In the USA and Canada as well as in China and Japan nZEB will be introduced between 2020 - 2030**
- **Since Jan 1, 2021, all new buildings in the EU have to comply with nZEB requirements**
  - Despite different harmonisation initiatives, different national implementations in the member states leading to different ambition levels
  - In Switzerland implemented by MuKEn 2014
- **Building technology to reach nZEB is of particular interest**
  - Heat pumps are already well established as building technology for nZEB
  - nZEB can become a market driver for heat pumps





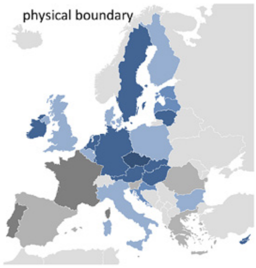
source: JRC, EU, 2016

Research in IEA HPT Annex 49

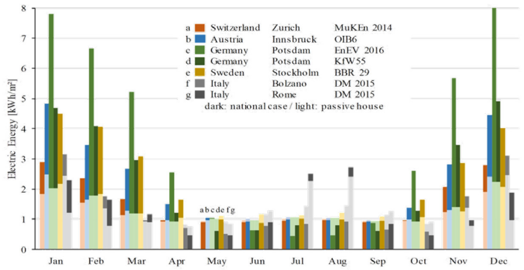
- **8 participating countries, 16 institutions**

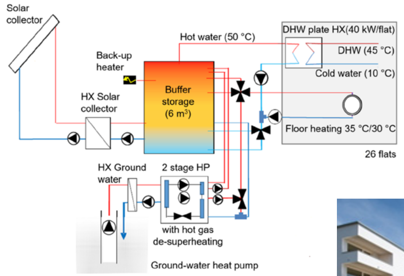
  AT BE CH DE NO SE UK US

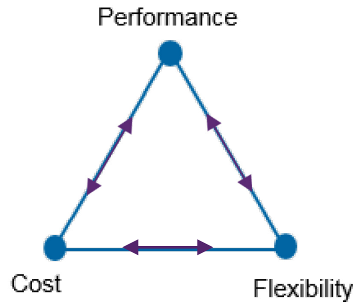
- **State of the art of nZEB in participating countries**
  - Definition and ambition level of nZEB
- **Integration of multi-functional heat pumps in nZEB**
  - Integration with storages, solar components and the ground
- **Monitoring of marketable/prototype heat pumps in nZEB**
  - Focus on larger residential and non-residential nZEB with heat pump
- **Design and control of heat pump systems for nZEB**
  - Increase of self-consumption and energy flexibility



source: JRC







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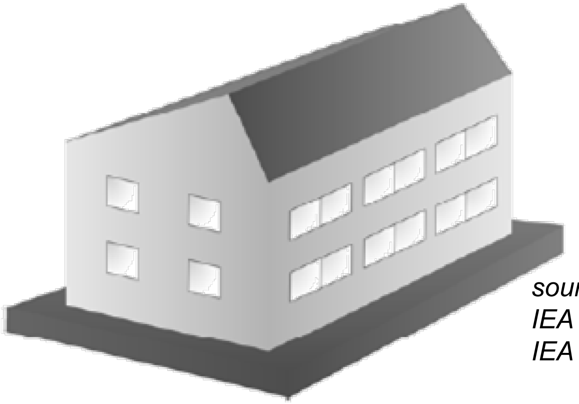
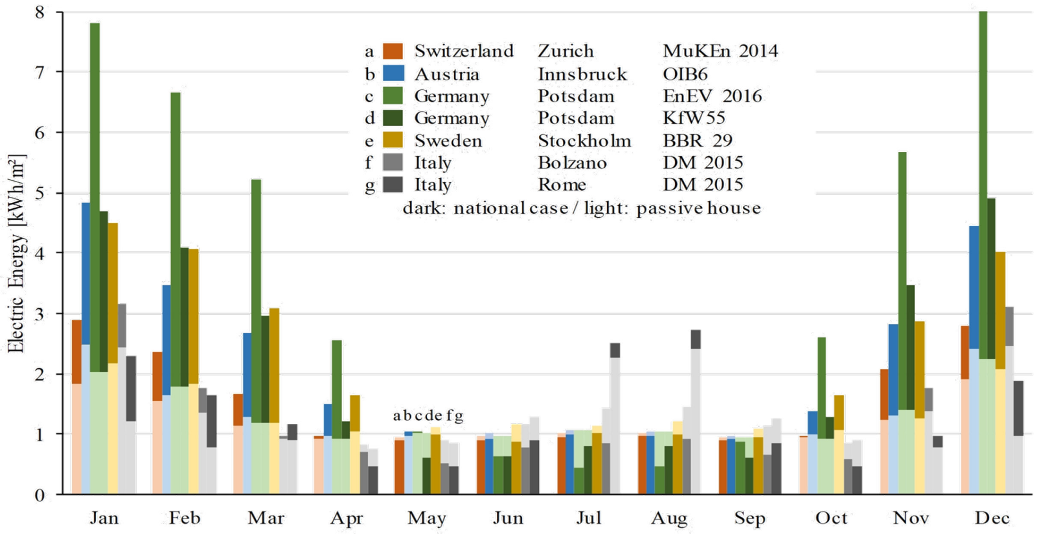
State of nZEB implementation

- **Methodology to compare nZEB ambition level**
  - Elaborated by AT, CH and DE
  - Method based on building and system simulation
  - Test for a single family house (based on Reference framework of IEA HPT Annex 38/SHC Task 44)
  - Implementation of building based on national nZEB rating and transformation to common boundary conditions
  - Relative comparison of ambition levels possible
  - Current limitations
    - limited countries tested (AT, CH, DE, IT, SE)
    - Single family building use
    - A-W heat pump heating and DHW system



source: IEA SHC Task 44/ IEA HPT Annex 38



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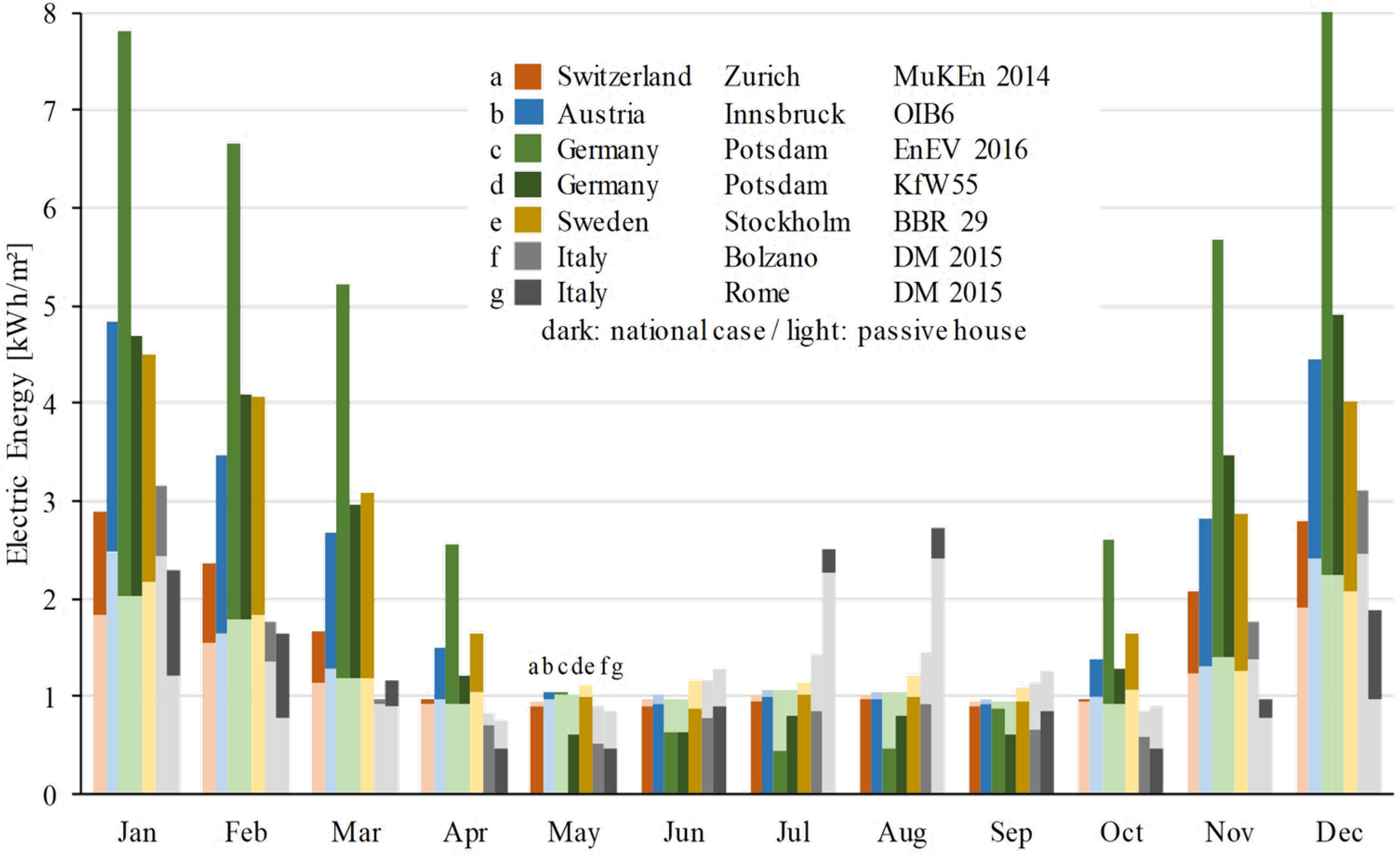
State of nZEB implementation

- Results for monthly electric energy consumption with air-to-water HP
- Comparison to a passive house in the same location and same boundary conditions (DHW demand, internal loads etc.)
- In IT Rome, cooling demand in summer



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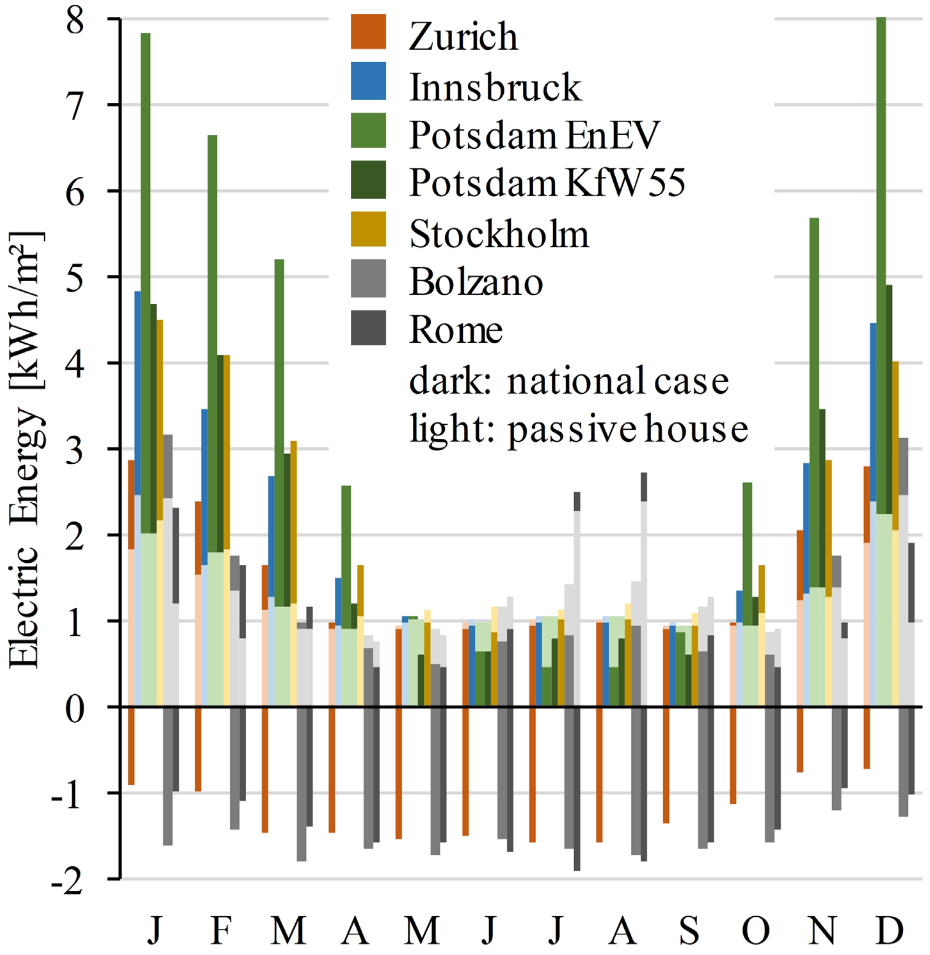
State of nZEB implementation

- **Results for net electric energy consumption**
  - IT and CH set additional requirements for on-site renewable energy production

Energies [kWh/m²/yr] / Country/ regulation	National nZEB	On-site PV yield	Net balance
AT OIB 6 Innsbruck	26.0	0	26.0
CH MuKEn Zurich	18.3	14.9	3.4
DE EnEV Potsdam	42.0	0	42.0
DE KfW55 Potsdam	26.1	0	26.1
SE BBR Stockholm	26.7	0	26.7
IT DM 2015 Bolzano	15.8	18.8	-3.0
IT DM 2015 Rome	16.3	17.0	-0.7



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State of nZEB implementation - Conclusions

- **Methodology to compare nZEB ambition level**
  - Different nZEB implementations and ambition levels among EU member states
  - EU cost optimality guideline (2012) and recommendation (2016) set reasonably ambitious nZEB targets for the new built sector
  - Some national nZEB implementations do not meet EU recommendations and cost optimal levels
  - Developed methodology enables a relative comparison based on building/system simulation to enhance transparency
  - Results can be used to further develop requirements and enhance ambition levels

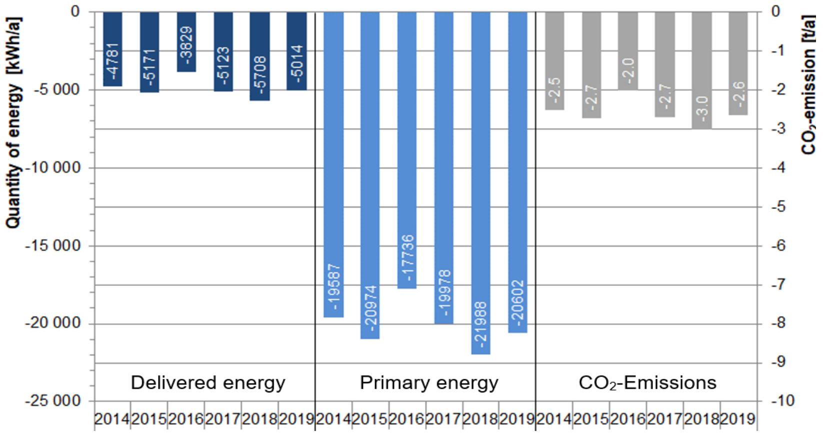
Site	nZEB	EU	Δ [%]	Net	EU	Δ [%]
AT	70	57.5	122	70	22.5	311
CH	51	57.5	89	13.5	22.5	60
DE E	110	57.5	191	110	22.5	489
DE K	70	57.5	122	70	22.5	311
SE	72	77.5	93	72	52.5	137
IT B	45	60	75	-2.5	30	-108
IT R	46	57.5	80	3.2	7.5	43

Legend: DE E – DE EnEV, DE K – DE KfW55, IT B Italy Bolzano, IT R – Italy Rome, Δ - percent deviation, nZEB – energy demand national nZEB, net – Net balance national nZEB, EU – EU recommandation benchmark

Steinbeis-Innovationszentrum energie+

nZEB Monitoring and Simulation

- **Single family building Berghalde, Stuttgart-Leonberg**
  - 260 m², 4 inhabitants, Plus-energy house of initiative "Effizienzhaus Plus"
  - Building envelope on passive house level
  - 10 kW ground-coupled heat pump, 3 boreholes of 100 m each
  - Mechanical ventilation with 85% heat recovery efficiency and 80 m ground-to-air heat exchanger
  - Whole roof covered with 15.3 kW_p solar PV system
  - 825 l thermal buffer storage and 7 – 27 kWh electric battery
- **6 years of Monitoring**



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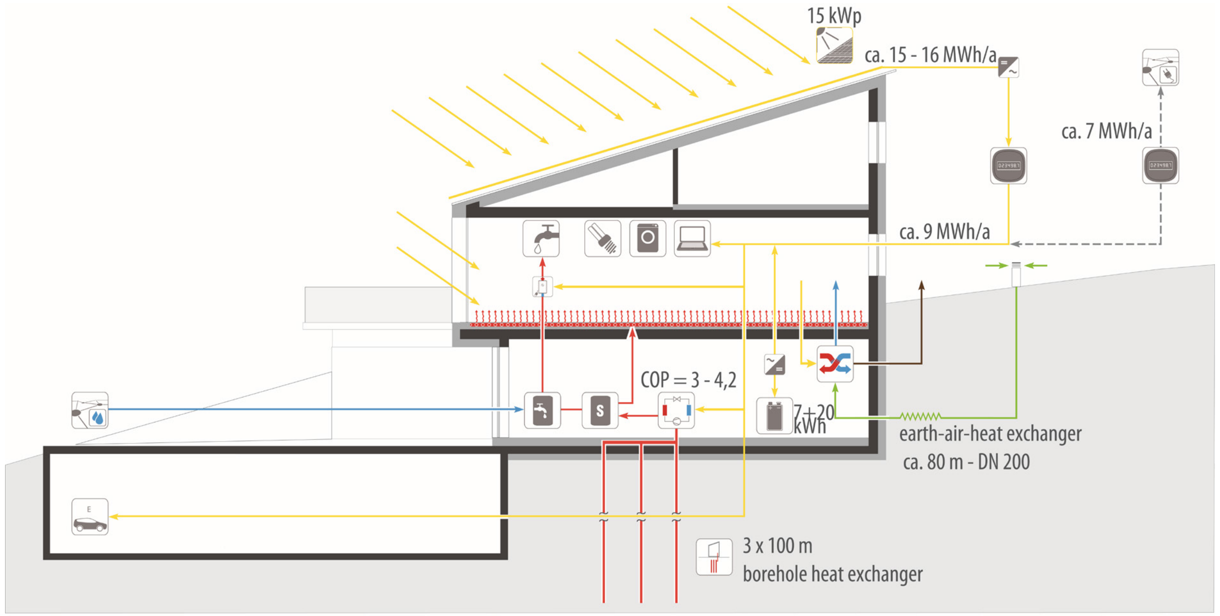
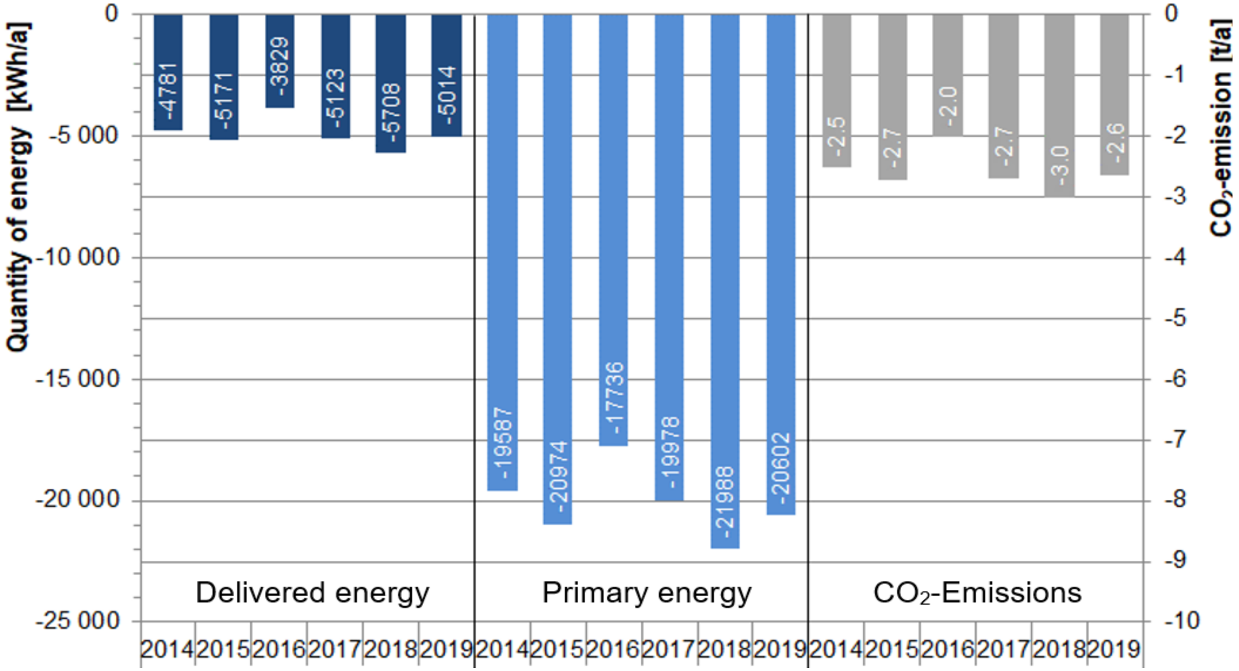
nZEB Monitoring and Simulation

- **Plus energy balance could be confirmed for each year of the measurements**
  - High heat pump performance in the range of an SPF of 5
  - Additional investigations for load management options with control and storage integration

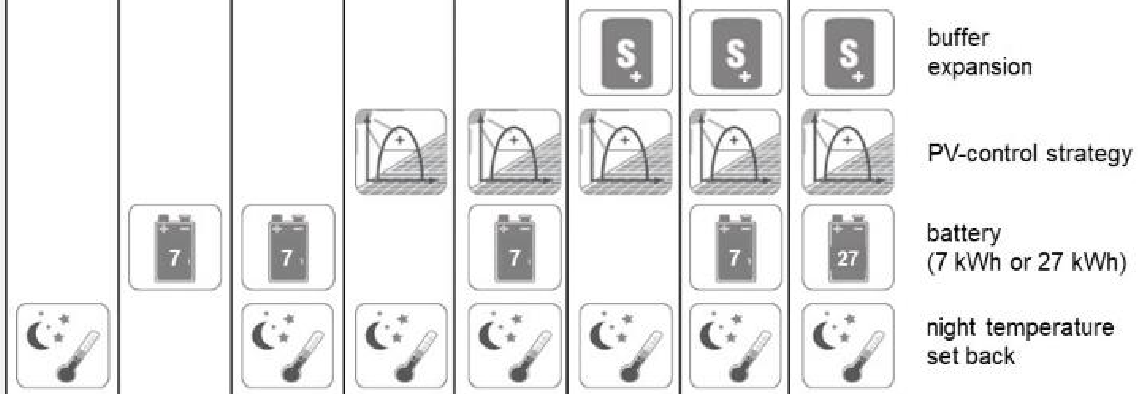




source: TU Braunschweig

nZEB Monitoring and Simulation

- **Load management by**
  - Night-time setback control
  - PV control strategy
  - Buffer storage expansion
  - Electric battery
- **Results**
  - Energy consumption may increase (e.g. buffer expansion)
  - Already simple control strategies can increase PV-self consumption
  - Electric battery storage can be replaced by thermal storage
  - Both PV-self-consumption and grid support can be notably increased



Simulation combination	Basis								
total power consumption	11.227 kWh	- 2,4 %	0 %	- 2,4 %	+ 1,3%	+ 1,3%	+ 4,5%	+ 4,5%	+ 4,5%
direct use of PV-output	27 %	28 %	31 %	31 %	34 %	37 %	38 %	41 %	48 %
fraction on power consumption	34 %	36 %	37 %	39 %	42 %	45%	45 %	48 %	54 %
grid power	7.420 kWh	- 5,4%	- 4,6%	- 9,9%	- 11,2%	- 15,5%	- 13,3%	- 17,0%	- 28,0%

source: TU Braunschweig

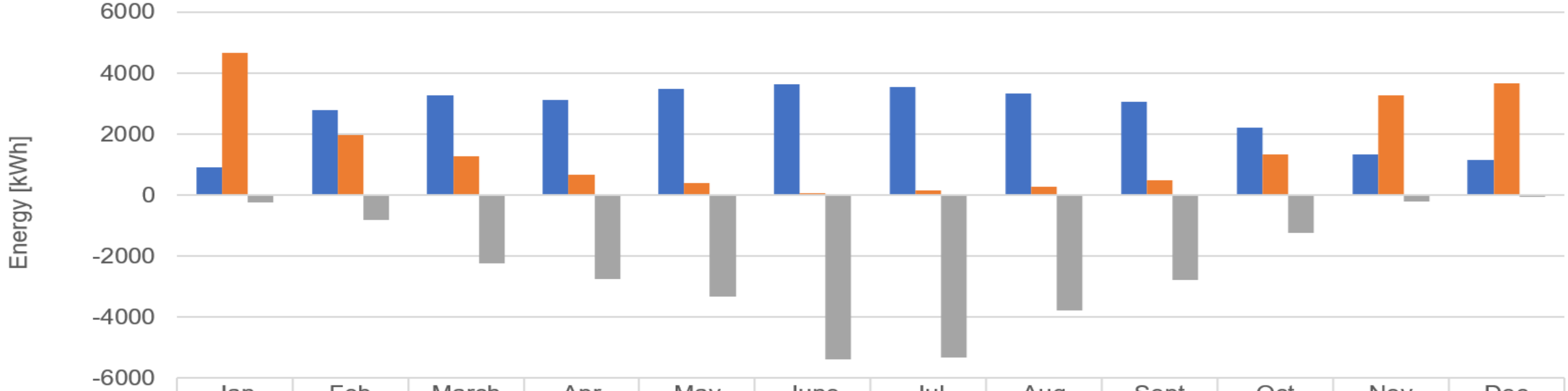
nZEB Monitoring and Simulation

- **Five storey multi-family passive house nZEB**
  - 1700 m^2 ERA, 10 flats, built in 2018
  - Monitoring in 2019
- **Building and system technology**
  - Building envelope on passive house level
  - 23 kW ground-source heat pump with free-cooling, 2 borehole ground probes of 200 m each
  - Mechanical ventilation with heat recovery
  - 81.3 kW_p PV, 44.5 kW_p on the roof and 36.8 kW_p façade-integrated (SW and SE)
  - 78 kWh electric battery, shared battery electric vehicle

source: arento

nZEB Monitoring and Simulation

- **Monitoring results 2019**
  - Surplus in annual PV-production of about 40%, SPF HP in the range of 4.5
  - In 6 summer month about 90% autarky, during 9 month PV-surplus
  - **However, occupancy of the building was rather low in 2019 (26 persons)**
  - With higher occupancy, PV surplus is reduced



	Jan	Feb	March	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
PV Self-consumption	899	2778	3253	3129	3478	3637	3537	3332	3067	2202	1325	1157
Grid supply	4663	1968	1278	670	395	72	144	273	479	1332	3263	3658
PV Surplus	-246	-807	-2235	-2761	-3343	-5393	-5331	-3778	-2786	-1239	-228	-65

Summary monitoring results of nZEB with HP

- **15 partly long-term monitorings in larger nZEB**
  - High SPF of the heat pump up to 5.5 for all building services approved
  - Ambitious nZEB targets may remain a challenge in larger buildings
- **Conclusions**
  - High performance building envelope and high heat pump performance are a prerequisite to reach ambitious nZEB targets in larger buildings
  - Large solar PV installation in the building envelope required, but building envelope may be a limitation in larger buildings
  - System integration of different building functions can further increase the heat pump performance







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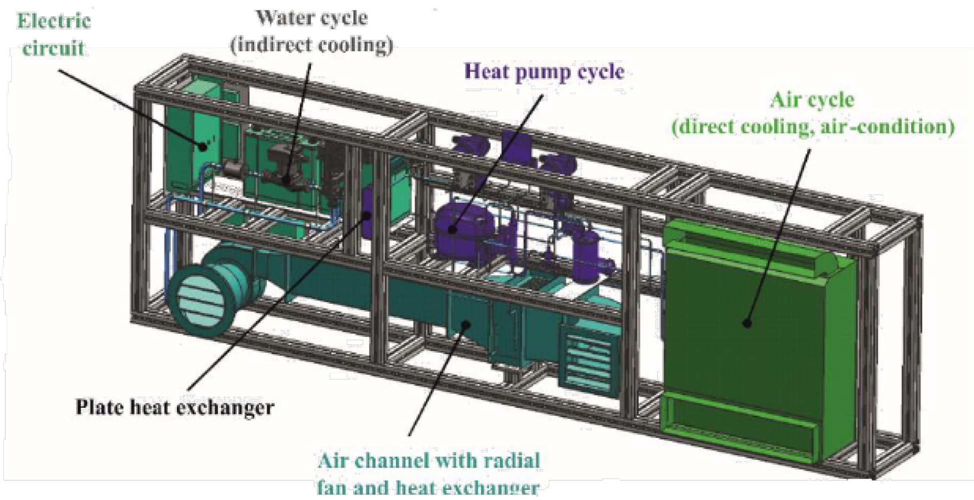
Prototype developments

- **Prototype developments in Annex 49 refer to integrations of multiple functions in one packaged unit, e.g.**
- **Prototype development of façade integrated heat pump**
  - PV installed in the façade
  - Heat pump integrated behind PV panel
  - Cooling operation of adjacent office room shall enable an autarkic cooling operation driven by the PV modules
- **Integrated façade module**
  - Heat pump with connection to water circuit (cooling ceiling, TABS) and air cooling by fan coil
  - Integrated electric battery
- **Investigation of prototypes**
  - Simulations of prototypes for different boundary conditions (e.g. Façade, location, grid coupled, climate)
  - Monitoring in Test cells on the Campus of TU Graz



Prototype developments

- **Simulations results**
  - At site Graz the typical cooling demand of an office room can be almost entirely covered by PV
  - In heating operation about 60% of the demand can be covered
- **Monitoring results**
  - Both heating and cooling operation could be successfully operated in the test cells
  - Cooled cells are about 3-6 K colder than an uncooled room
  - Max. temperatures of 27 °C could be kept
- **Development**
  - Integration of an electric battery is to question
  - Facade integration of multiple modules will be analysed

IEA HPT Annex 49 - Conclusions







- **State of nZEB**
  - Different nZEB implementations and ambition levels which are hard to compare
  - Developed methodology enables relative comparison and transparency of implementation
  - More harmonised implementation enables more standardised HP system solutions

- **Results IEA HPT Annex 49**
  - High performance of the investigated heat pumps in nZEB application in larger buildings
  - Integration of different buildings services increases heat pump performance and cost-efficiency
  - In larger buildings reaching the nZEB balance can be a challenge despite high HP performance
  - In turn ambitious nZEB requirements can become a market driver for heat pumps

- **Integration of nZEB**
  - Integration of groups of buildings can further increase load balancing and flexibility
  - Demand response has higher importance in nZEB as active component in future energy grids

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Results of IEA HPT Annex 49

- **Results of IEA HPT Annex 49 are documented in the following final documents**
  - Executive summary (2 page and 7 page)
  - Final report and parts
  - Part 1: State-of-the-art of heat pumps in nZEB
  - Part 2: Monitoring in nZEB with heat pumps
  - Part 3: Integration/Design/Control for heat pumps in nZEB
  - Part 4: Prototype developments of integrated heat pumps
  - 4-page Best practice sheets of monitored systems
- **For download of IEA HPT Annex 49 deliverables please visit**

  https://heatpumpingtechnologies.org/annex49/deliverables


49 IEA HPT Annex 49
Design and Integration of heat pumps for nearly Zero Energy Buildings
Final Report IEA HPT Annex 49
Final Report IEA HPT Annex 49
Project outline and main results
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International Energy Agency
Heat Pumping Technologies

New Annex on Heat Pumps in positive energy districts

- New upcoming Annex for
  Heat pump in Positive energy districts (PED) with the topics
- State of heat pumps in positive energy neighbourhoods
- Techno-economic concept analysis by modelling and simulation of HP system integration, design and control
  - For clusters of buildings and neighbourhoods
  - For new built and retrofit
- Accompanying field monitoring of heat pumps in cluster of buildings and neighbourhoods
- State: Online Kick-off meeting,
  next meeting in presence planned for July, 4-5, Univ. of Innsbruck

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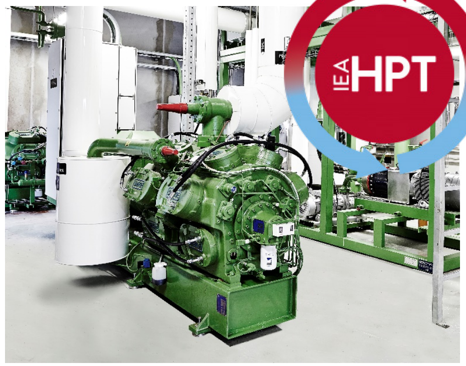
IEA HPT Annex 58: High-Temperature Heat Pumps (HTHP)

08 Feb 2022: Switzerland has joined Annex 58



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Project Partners

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Industrial Partners

supporting with Case Studies

Cremo DEPUIS 1927

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Spiess Wurst für Feinschmecker.

- **Operating Agent:** Benjamin Zühlsdorf, PhD, bez@dti.dk, Danish Technological Institute
- **Participating Countries:** Austria, Belgium, Canada, Denmark, France, Germany, Japan, Netherlands, Norway, Switzerland
- **Duration:** 01/2021 to 12/2023
- **Homepage:** https://heatpumpingtechnologies.org/annex58
- **Objectives:** Overview of HTHP technologies, potentials, perspectives, concepts and strategies for process heat with supply temperatures above 100 °C
- **Overview of Activities:**

Technologies
- Available and close-to market supplier technologies
- Demonstration cases
- Development perspectives

Concepts
- Best-practice solutions for HP-based process heat supply
- Various industrial processes and sectors

Applications
- Transition strategies towards HP-based solutions
- Energy integration
- Level of integration
- Non-technical aspects

HP Specifications
- Definition and testing of HP specifications
- Baseline for performance comparisons
- Project handling

Dissemination
- Increasing awareness
- Various target groups
- Dedicated dissemination activities

Multi-disciplinary and cross sectoral activities

Thank you for your attention