Heat pumps for nearly Zero Energy Buildings – Design and integration

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DEFINITION “nearly Zero Energy Building” (nZEB)

- Means a building that has a **very high energy performance**
- **Nearly zero or very low energy amount** should be covered to a **very significant extent** by energy from renewable sources, including renewable energy **produced on-site or nearby**
- Currently no uniform definition of nZEB, neither in politics nor in the market
- Nevertheless ambitious time schedule for the introduction of nZEB in the EU

![Time Schedule Diagram](image-url)
State of definition nZEB in EU member states

- **nZEB Definition in the EU**
  - EU member states have a definition of nZEB
  - But current definitions vary regarding criteria and metrics as well as limits
  - Some EU MS aim at more ambitious target than nZEB
    - NL: Net-Zero Energy Buildings
    - UK: Zero Carbon Buildings
    - DK and FR: Plus Energy Buildings
    - DE: Climate Neutral Buildings

Source: JRC, EU, 2016
Project structure IEA HPT Annex 49

- **Task 1: Update on definitions and heat pump applications**
  - Definition of nZEB in participating countries
  - Conclusions for system configurations and design

- **Task 2: System integration**
  - Evaluation of integration options (storage, ground, building envelope)
  - Integration of nZEB with heat pumps into neighbourhoods, energy systems and grids

- **Task 3: Prototype development and field monitoring**
  - Development of integrated heat pump prototypes
  - Field monitoring of new and existing nZEB with heat pump

- **Task 4: Design and control of heat pumps for nZEB**
  - Design criteria regarding performance, cost and demand response
  - Controls for improved self-consumption and grid-supportive operation

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*Source: Viridén, 2sol, ORNL, IGS, FhG-ISE*
Participating countries and institutions Annex 49

- **AT:** Unit Energy efficient building Uni Innsbruck, AIT, IWT of TU Graz
- **BE:** Aero Thermo Mechanics, Free Univ. of Brussels
- **CH:** IET of the UAS Rapperswil (Operating Agent)
- **DE:** TH Nürnberg, TEB GmbH, IGS/TU Braunschweig
- **EE:** Tallinn Univ. of Technology
- **NO:** SINTEF Building Research, NTNU, COWI, Enova SF
- **SE:** RISE, Swedish manufacturers
- **UK:** Glen Dimplex
- **US:** ORNL, CEEE Uni Maryland, NIST
Contribution to Task 2 – Integration options for heat pumps in nZEB

- **Contributions to Task 2: Integration of heat pumps**
  - **AT:** Simulation of two passive MFH with heat pump, solar PV and solar thermal collectors
  - **BE:** *Evaluation of waste water as heat source for large nZEB*
  - **CH:** Integration of heat pumps and solar technologies
  - **DE:** *Storage integration and control for group of terraced NZEB dwellings*
  - **EE:** Integration of heat pumps and ground
  - **SE:** Comparison of system configurations acc. to Swedish definitions
  - **UK:** Investigation of building technology for nZEB with building company
  - **US:** Simulation of Net Zero Energy Residential Testing Facility (NZERTF)
Annex 49 Task 2 – Integration of waste water as heat source

- **Contribution of Belgium to Task 2**
  - Integration of waste water as heat source for heat pumps in larger nZEB
  - Retrofitting of sewers with heat exchangers for heat source application
  - Evaluation of temperature levels
  - Evaluation of volume flow rates
  - Evaluation of the technology in large demonstrator in Uccle

![Image of a tunnel and building](image)

![Graph showing sewer flow vs. time of day](image)
Annex 49 Task 2/3/4 – Design and integration of NZEB

- **Project HerzoBase**
  - 8 terraced houses
    - SH: 8.9 kWh/(m²a), 22.7 kW
    - SC: 25.6 kWh/(m²a), 52 kW
    - DHW: 16.9 kWh/(m²a)
  - Two modulating GS-HP with storage
  - Distribution grid at low temperature level
  - Decentralised DHW storages (200 l) with 8 booster HP
  - Solar PV installation (98 kW_p, 66 MWh/a) and batteries designed for plus energy
  - Control concept of heat pumps and storage to increase self-consumption and reduce grid interaction by grid-supportive operation
Annex 49 Task 2/3/4 – Design and integration of NZEB

- Interim evaluation of PV self-consumption and grid interaction

**PV self-consumption**

<table>
<thead>
<tr>
<th>Direct consumption</th>
<th>Battery feed</th>
<th>Grid feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy in MWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ 21 %</td>
<td>- 10 %</td>
</tr>
<tr>
<td></td>
<td>- 11 %</td>
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</tr>
</tbody>
</table>

**Grid consumption**

- Grid consumption without DMS
- Grid consumption with DMS

Load peak reduction of 24 %
Contribution to Task 3 – Monitoring of NZEB

Contributions to Task 3: Prototype developments and field monitoring

- **AT**: Field monitoring of two passive MFH with heat pump and solar PV
- **BE**: Field monitoring of Belgian nZEB
- **CH**: Field monitoring of plus energy office with ground-source HP and PV on roof and façade
- **DE**: Monitoring of 3 nZEB (SFH, MFH, educational building)
- **NO**: Monitoring of residential and non-residential buildings
- **SE**: Prototype development and testing in twin houses
- **UK**: Monitoring of building technology for nZEB
- **US**: Monitoring of IHP prototypes in different applications
Annex 49 Task 3 – Monitoring of nZEB

- Monitoring of NZEB with mixed use
  - 617 m² commercial (beauty salon, pharmacy)
  - 616 m² office and
  - 1521 m² multi-family residential use

- Building envelope
  - U values wall 0.16 /roof 0.12/window 0.92 W/(m²K)
  - Solar PV system 74 kW_p (roof 26 kW_p façade 48 kW_p)

- Ground-source heat pump
  - for space heating, cooling and DHW production

- Evaluations
  - Yield of roof- and façade solar PV system
  - Performance of HP for operation modes
  - Free-cooling fraction and performance
  - Load match of produced/used electricity
  - Seasonal balance of ground-source HP
Annex 49 Task 3 – Monitoring of nZEB

- **Results heat pump**
  - High heat pump performance
  - SH 4.9 / DHW 3.1 / SC 5.9; overall 5.2
  - High free cooling fraction
  - All recooling energy is recovered for DHW and regeneration of the ground, no recooler installed

- **Results solar PV-system**
  - Roof yield as expected 928 kWh/kW_p
  - Façade yield below expectation
    - 490/262/137 kWh/kW_p at south/west/east facade

- **nZEB Balance**
  - Balance for SH, DHW and SC met
  - Balance including ventilation slightly missed
  - Balance building technology could be kept with higher PV yield in the façade
Contribution to Task 4 – Design and control

- **Contributions to Task 4: Design and control for heat pumps for nZEB**
  - **BE**: Design for modular nZEB dwelling
  - **CH**: Design for heat pumps, ground and integrated solar components
  - **DE**: Heat pump control for smart grid, *design recommendations for storage integration*
  - **EE**: Design guidelines for heat pumps in nZEB
  - **NO**: Design/control for smart heat pumps
  - **SE**: Design and operation of capacity controlled heat pumps
  - **UK**: Design and control of building technology for nZEB
  - **US**: Design evaluation based on testing in NZERTF
Conclusion

- **Introduction of nZEB**
  - Tight time schedule for the introduction of nZEB in the EU
  - Different definitions in the EU member countries
  - North-America and Japan also declared nZEB as future building requirement

- **All electric buildings are an archetype solution for nZEB**
  - Buildings with heat pump and solar PV are a standard system to reach nZEB

- **Heat pumps for the application in nZEB**
  - Heat pumps are high performance generators in nZEB operating conditions
  - High performance of heat pumps reduces necessary energy production on-site to keep the balance
  - Heat pumps can cover different buildings services with one generator
  - Heat pumps are among the main electricity consumers and enable load management for optimised self consumption of on-site electricity
Acknowledgement

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