

# Workshop 3.1

## Heat Pumps in Positive Energy Districts

Outline Annex 61, Joint WS HPT A61, EBC A83; SHC T66,  
Carsten Wemhoener, IET, OST, IEA HPC 2023, Chicago, May 15, 2023



The HPT TCP is part of a network of autonomous collaborative partnerships focused on a wide range of energy technologies known as Technology Collaboration Programmes or TCPs. The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Views, findings and publications of the HPT TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

# Introduction

- **Joint workshop of three IEA Technology Collaboration Programmes TCPs**  
**"Heat pumps in positive energy districts – opportunities, challenges and perspectives"**
- **Heat Pumping Technologies HPT**  
<https://heatpumpingtechnologies.org>
- **Energy in Building and Communities EBC**  
<https://iea-ebc.org>
- **Solar Heating and Cooling SHC**  
<https://iea-shc.org/>



# Workshop programme

- **First part: Introduction to the IEA Projects**

## **Introduction to IEA projects**

9:00 – 9:05	Welcoming and Workshop overview	(C. Wemhoener, OST)
9:05 – 9:20	IEA HPT Annex 61 Heat pump in Positive Energy Districts	(C. Wemhoener, OST)
9:20 – 9:35	IEA EBC Annex 83 Positive Energy Districts	(U. Eicker, Concordia University)
9:35 – 9:50	IEA SHC Task 66 Solar Energy Buildings	(L. Oppelt, TU Freiberg)

# Workshop programme

- **Second part: Presentation of research contributions in the IEA-Projects**

## **Outline and interim results of research projects**

9:50 – 10:30      Short presentations of research projects in the IEA Projects      (IEA project attendees)

Fabian Ochs (Energy efficient building, Univ. Innsbruck): Campagne district - Innsbruck

Wim Boydens (boydens engineering part of sweco, Univ. Ghent): Gare Maritime

Ursula Eicker (Concordia Univ.): EBC Annex 83 research

Lukas Oppelt (TU Freiberg): Task 66: Multi-family building with supply of surrounding buildings

Franziska Bockelmann (SIZ energieplus): Quarree100 district

**10.30 – 10.45      Coffee break**

# Workshop programme

- **Third part: Interactive panel discussion**

10:45 – 11:00      EU DUT Partnership, Mission Innovation      (E. Pasic, Swedish Energy Agency)

**State Positive Energy Districts, Opportunities, challenges and perspectives for Heat Pumps**

11:00 – 11:45      Panel discussion with involvement of the audience      (panel, all)

Moderator: Carsten Wemhoener

Panel:

HPT Annex 61: Fabian Ochs, Wim Boydens

EBC Annex 83: Ursula Eicker

SHC Task 66: Lukas Oppelt, Franziska Bockelmann

**Conclusion and outlook**

11:45 – 12:00      Summary, perspectives, Q & A      (C. Wemhoener, all)



# IEA HPT Annex 61

## Heat Pumps in Positive Energy Districts

Outline Annex 61, Joint WS HPT A61, EBC A83; SHC T66,  
Carsten Wemhoener, IET, OST, IEA HPC 2023, Chicago, May 15, 2023

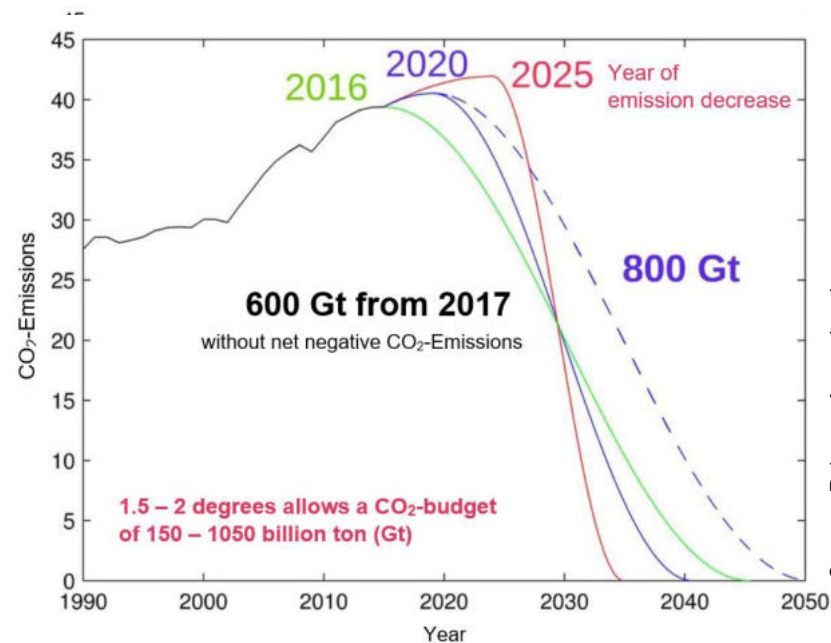


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# Motivation



- Ambitious CO<sub>2</sub>-reduction is needed to Net Zero Emissions until 2050 (or sooner)
- Building sector of key importance in many countries holding large potentials
- Building energy assessment is extended from individual buildings to clusters of buildings/districts
- Potential for high heat pump (HP) performance can be unlocked by heat/electric integration in districts of different load structures
- Integration of HP in buildings and districts considering load balancing among buildings for thermal and electric energy



Source: Rahmsdorf, translated

# Objectives and Scope



- The **role/positioning** of HP in positive energy districts (PED)
- **Generic concepts** for HP integration in new built and existing districts for positive energy/net zero emission balance
- **Modelling** of decentralised and centralised HP for integration in districts
- **Real performance/case studies** of HP concepts in districts
- **Roadmap/Guidelines** to positive energy/net zero emission districts by HP

## SCOPE

- Districts of new and existing buildings
- Individual/cluster of buildings, districts of different building uses (residential, office)

# Annex Tasks

## 1 State-of-the-art analysis

- Definition and Framework for HP in PED
- Technologies and HP-concepts in existing PED
- Legal & policy regulations/barriers
- Boundary conditions for system analysis
- Cross-country comparison of HP in PED

## 2 Generic HP systems

- Generic HP system from individual building to district level
- Top-level integration categories & detailed system concepts
- Archetype PED for new built, mixed use and retrofit context
- Technology evaluation and description

## 3 Techno-economic analysis

- Detailed analysis of favourable integration concepts
- System modelling and validation
- Design and control studies of larger centralised HP
- Storage integration and energy flexibility potentials

## 4 Case studies and Monitoring

- Case studies for HP integration in clusters and districts
- Evaluation of HP performance in real operation
- Identification and application of optimisation potentials
- Validation data for simulation models

# Expected Annex results



- **State-of-the-art and cross-country comparison** of HP in PED
- **Generic concepts of decentralised vs. centralised** HP integration in PED
- **System modelling for HP design and control** optimisation
- **Retrofit concepts** with HP on individual buildings/district level
- **Evaluation of real performance** of HP in districts, **Best Practice Systems**
- **Dissemination** of Annex (interim) results (website/workshops/publications)

# Annex Task 1 – State-of-the-art

- Objective of JPI Urban Europe  
100 PED in Europe until 2025
- 61 projects evaluated and differentiated into
  - 29 PED ambition
  - 32 towards PED (interesting features)
- Common baseline set as PED framework  
with some flexibility for local conditions
- Balance evaluated by primary energy  
including building operation and  
user-related energy

URBAN EUROPE



## EUROPE TOWARDS POSITIVE ENERGY DISTRICTS

FIRST UPDATE  
February 2020

A compilation of projects towards sustainable urbanization  
and the energy transition

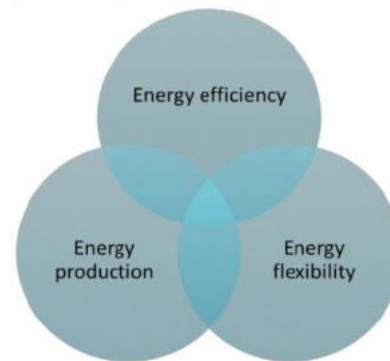


# Annex Task 1 – State-of-the-art

- EU-Definition/Framework of PED

“Positive Energy Districts *are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net zero greenhouse gas emissions and actively manage an annual local or regional surplus production of renewable energy.*”

They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while *securing the energy supply and a good life for all in line with social, economic and environmental sustainability.*”



source: JPI Urban Europe

## PEDs: Framework, Methods, Certifications and Labels Three Level Approach

### I. PED Programme

**PED/PEN Framework Definition** (European)  
(national stakeholder processes with problem owners)

### II. National PED Communities






**Refinement and application of the PED Framework in the local and national context**

Examples: 2,000 Watt sites (Switzerland) | Eco-Districts (France) | Zukunftsquartiere (Austria) | Viable Cities (Sweden) | Zero Emissions Neighbourhoods (Norway) | .....

(as starting point for further (national) developments)

### III. Standardisation/Certification Bodies (National, Regional, European)



**Certifications and Labels for PEDs**

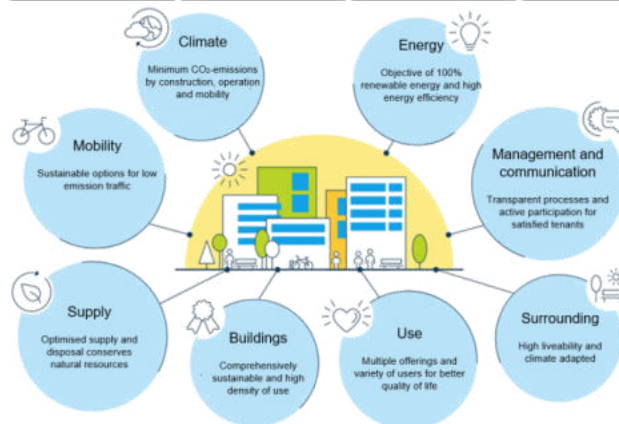
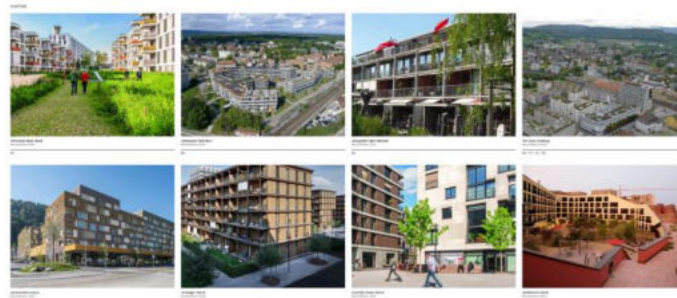
Examples:       
(to be further developed)



# Annex Task 1 – State-of-the-art



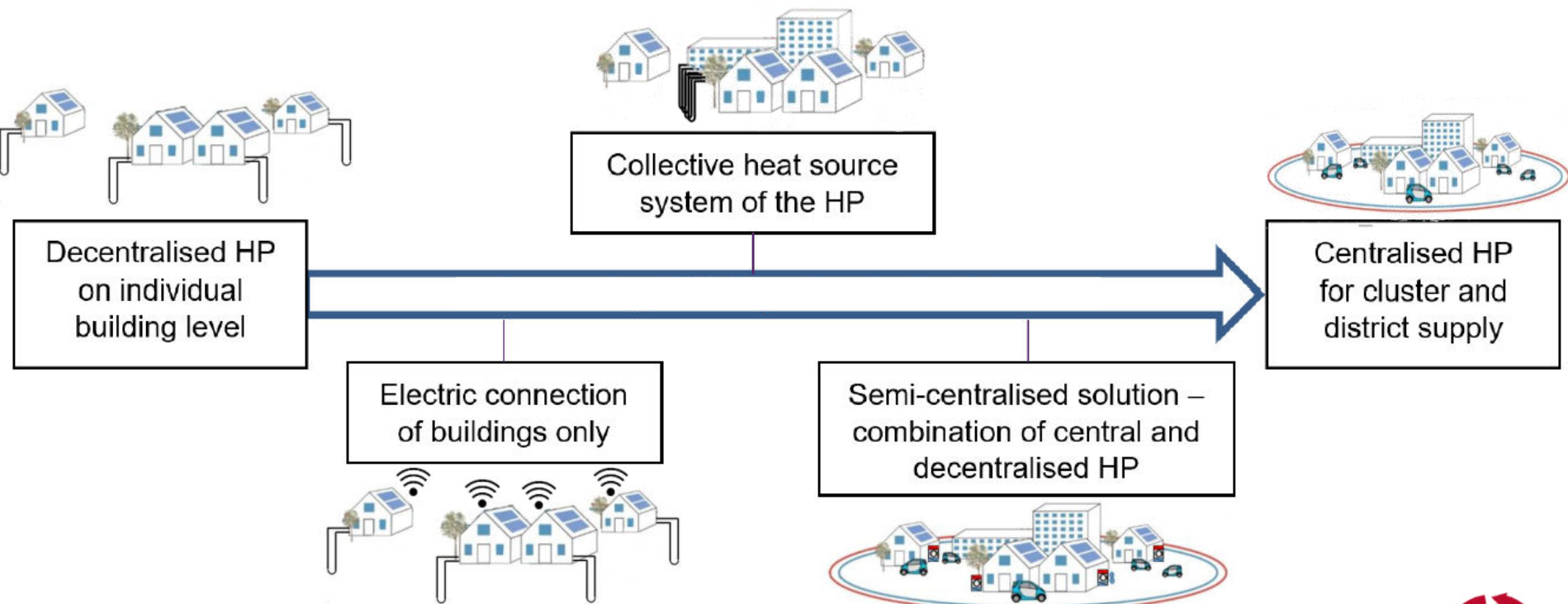
-  • Swiss implementation of PED: 2000-W-sites
- Currently 48 districts certified:  
31 planning, 12 operation, 5 transformation
- Additional criteria to be fulfilled
- 66% HP, 33% DH and 91% PV
-  • In Germany: 24 EnergiePlus districts
- 12 planning, 12 in operation
- 45% HP, 50% CHP, 100% PV, 42% thermal grid



source: 2000-W-sites



# Annex Task 2 – Generic system concepts



# Annex Task 2 – Generic system concepts

- **Technology description of generic concepts**
  - Outline of system configuration
  - Typical KPIs like performance indices, specific cost, etc.
  - Design recommendations
  - Comparison with pros and cons
  - Field of application
  - Input for more detailed techno-economic analysis in Task 3
  - Later link to field monitoring results

61 IEA HPT Annex 61  
Heat pumps in Positive Energy Districts



61 Generic system concepts

### Low temperature heating grid



**Summary**

Low temperature heating grids or 5<sup>th</sup> generation district heating is a newer grid concept, where grid fluid temperature is on the ambient or heat source temperature level, typically in the range of 5-15 °C and provide a heat source/sink for decentralized heat pumps/circuits. Due to the low temperature level, uninsulated pipes can be used and grid losses are notably reduced. On the other hand, higher volume flows and larger pipe diameters are required to transport the capacity and frost protection may be required. In typical bidirectional operation the grid configuration enables to connect different low temperature remote heat sources, simultaneous heating and cooling operation and recovery of waste heat from cooling or other sources. Depending on the temperature level, direct cooling from the grid is possible or active cooling at low recirculating temperatures can increase cooling performance, while the waste heat can be recovered for simultaneous heating applications. (Seasonal) load mismatch can be overcome by integration of low temperature heat storage as BTES or ATEs at different points of the grid. Favourable applications fields are districts with heating and cooling demand. Low temperature grids can also be a means to overcome source limitation in densely built districts.

**Technical values**

Performance	
SFP space heating	6 - 8
SFP space cooling	> 15
Primary energy factor	0.2 - 0.4 (waste heat 0)
GHG-Emission	20-40 g/kWh

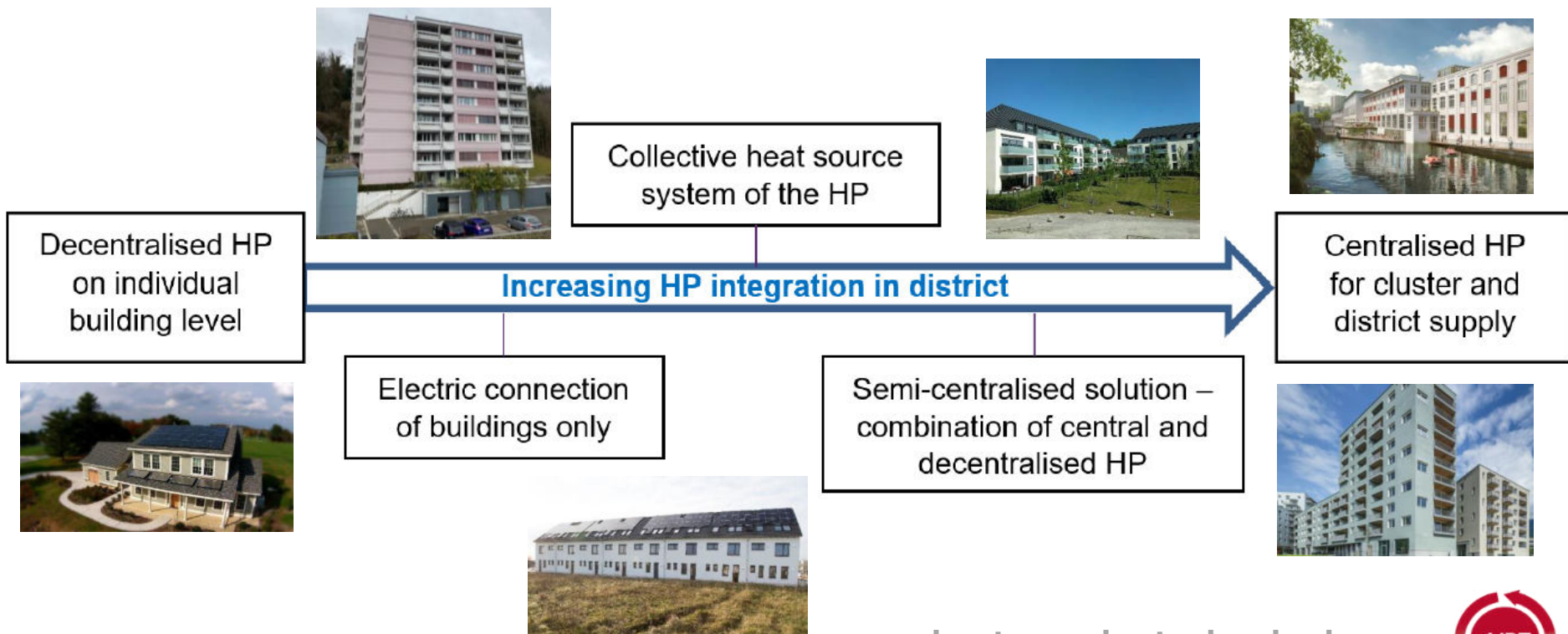
**Design**

Heat density	3 MW/ha
System pressure	PN 10 - 16

May 2023

International Energy Agency  
Heat Pumping Technologies

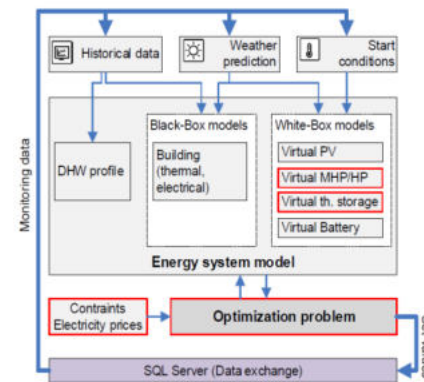
# Annex Task 4 – Field monitoring of HP in districts





# Contributions (selection) – DE

- **sEnSys – concept development for climate neutral retrofit**
  - Retrofit concept for MFH (32 flats) with the objective of climate neutrality
  - Smart control for increased PV-self consumption
  - Integration e-mobility and second life batteries
  - Transfer stations in the flats
  - Concept development and monitoring
- **Extension of the concept to similar neighbouring buildings by simulation**
  - Assessment of the concept on district level



## Contributions (selection) – DE

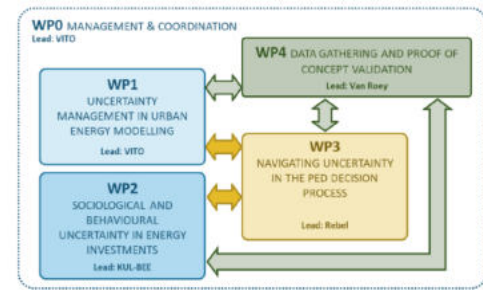
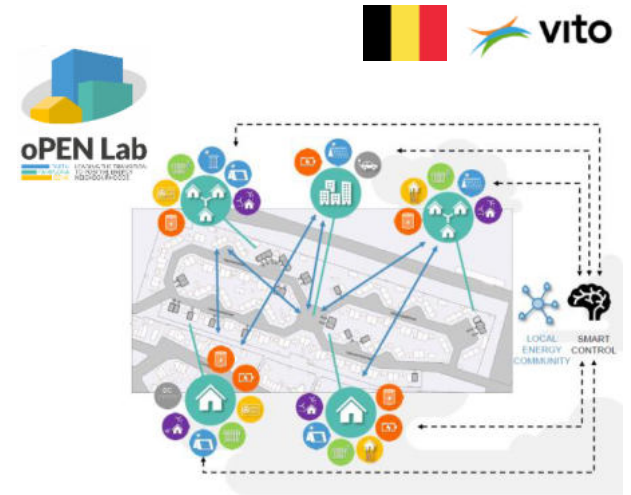


- **Monitoring of clusters of buildings**
  - Monitoring of MFH-clusters
  - in Konstanz (2 MFH) and
  - Wolfsburg (4 MFH)
  - Technical and economic characterisation of Performance, design and control
  
  - Plusenergy balance is not reached due to too low PV-generation
  - Partly due to legal barriers (Use of PV-electricity in neighbouring buildings)



## Contributions (selection) – BE

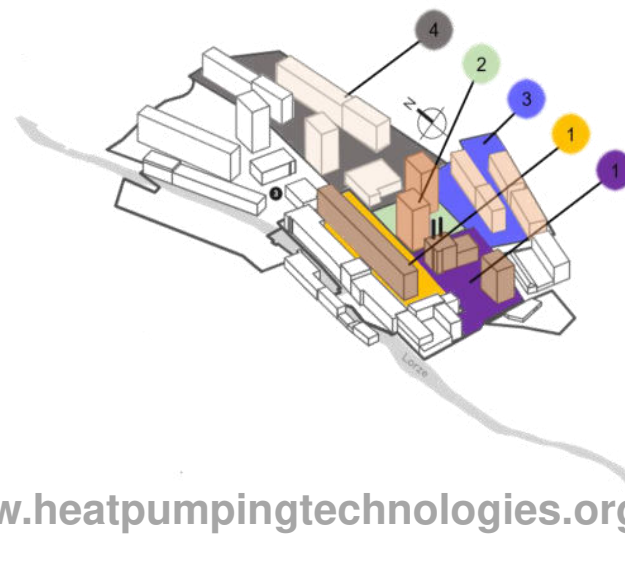
- **Project open lab**
  - Living lab for retrofitting district in Genk with 33 residential buildings to plus energy with different concepts (individual buildings, clusters)
  - Further projects in Tartu and Pamplona
- **Project MUPEDD**
  - Management of uncertainties in the frame of PED design
  - Assessment of PED-concepts in the early planning phase
  - Framework for scenario analyses



## Contributions (selection) – CH



- **New built/retrofitting of industrial neighbourhood of residential and office use**
  - First phase with  $\approx 270$  flats and commercial and office use (ground floor)
  - Collective dual heat source of borehole field and river water heat source
  - Centralised integrated HP for space heating, DHW and space cooling
- System modelling and simulation
- Concept comparison of HP integration
- Monitoring of optimization of the central HP and dual source ground and river water



# Contributions of participating countries



- **Contributions**
  - New built
  - Retrofit applications
- **Buildings**
  - Clusters
  - Districts
- **Heat pumps**
  - Centralised
  - Decentralised

Country	Institutions	Contributions
AT	UIBK, AIT, AEE-INTEC	<ul style="list-style-type: none"> <li>• Concept analysis in 7 equal multi-family houses (MFH) by simulation/monitoring</li> <li>• Evaluation of HP in clusters of buildings (decentral, semi-central, central)</li> <li>• Investigation of new built district regarding integration option by simulation/monitoring</li> </ul>
BE	ULB, KU Leuven, Swecobelgium, vito	<ul style="list-style-type: none"> <li>• Design and monitoring of clusters of offices/neighbourhoods with sewage water heat source</li> <li>• Development of models and a testing framework for district concepts</li> <li>• Test of different HP technology options in a living lab of a district retrofitted to PED</li> </ul>
CA	Concordia	<ul style="list-style-type: none"> <li>• Model development and case studies of PED by simulation</li> </ul>
CH	IET OST	<ul style="list-style-type: none"> <li>• Simulation and monitoring of PED with centrally integrated heat pumps</li> <li>• Design of larger heat pumps for MFH and clusters of buildings</li> </ul>
DE	THN, SIZ energieplus	<ul style="list-style-type: none"> <li>• Model predictive control of a cluster 8 single family plus energy houses for energy flexibility</li> <li>• (Retrofit) concepts for MFHs/neighborhood by simulation and monitoring</li> </ul>
IT	Univ. Firenze	<ul style="list-style-type: none"> <li>• Monitoring and simulation of neighborhood with seasonal thermal storage, HP and solar collectors/troughs</li> </ul>
JP	Univ. Nagoya	<ul style="list-style-type: none"> <li>• Evaluation of contribution of HP in positive energy district to reach climate protection targets</li> <li>• Case studies of simulation and monitoring of HP in districts</li> </ul>
NL	RVO	<ul style="list-style-type: none"> <li>• Investigation of decentralized and centralized system concepts for HP in new built and retrofit application</li> </ul>
NO	SINTEF, NTNU, COWI AS	<ul style="list-style-type: none"> <li>• Case studies of heat pump application in clusters of buildings by monitoring</li> <li>• Integration of heat sources for clusters of residential buildings and districts</li> </ul>
SE	RISE	<ul style="list-style-type: none"> <li>• HP modelling and development for the use in thermal grids</li> <li>• Control of HP flexibility in thermal grids and large-scale control of HP</li> </ul>
US	NIST, ORNL, EPRI	<ul style="list-style-type: none"> <li>• Simulation, testing and monitoring of high performance ground source integrated HP with different ground-source systems (horizontal/borehole)</li> </ul>

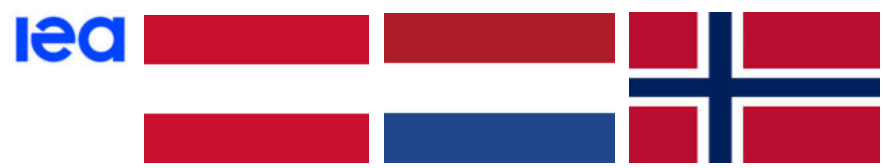


# Links

- **HPT Annexes**
  - Annex 57 on flexibility in grids, Annex 62 on multi-family houses
- **Other IEA TCP**
  - IEA EBC Annex 83: Positive Energy Districts
  - IEA SHC Task 66 Solar Energy Buildings
  - ECES, DHC
  - Cities
- **Upcoming projects DUT partnership**



# IEA Cities TCP



Decarbonisation of cities and communities

## Vision

Cities TCP's vision is that by 2050, cities have transformed their current building stock, energy supply and mobility into CO2 neutral systems through knowledge-based and ambitious action, while simultaneously **ensuring a high quality of life for and broad acceptance by citizens.**

Cities TCP aims to provide

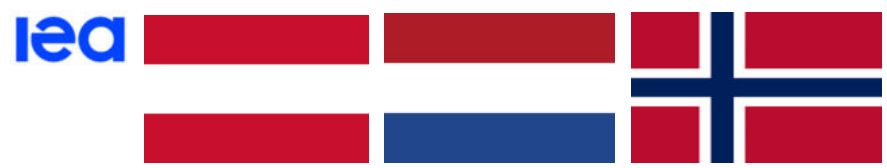
- Scientific and evidence-based information, tools, and recommendations to support urban decarbonisation efforts.
- IEA TCP network for research and innovation-related projects on urban energy and mobility system transformation
- Exchange between TCPs to share innovation in each field as well as between TCPs and practitioners to share best practices and to pool resources.

[www.cities-tcp.org](http://www.cities-tcp.org)



**Cities TCP**  
Decarbonising Cities & Communities

# IEA Cities TCP and PED



- Relevance of PED concept for achieving carbon neutral cities / decarbonized cities, optimization of the local energy system through energy efficiency, flexibility and local energy generation at district level.
- Instruments of urban planning to implement PED concepts, improvement of planning processes.
- Strategies for stakeholder cooperation (cooperation of key stakeholder groups like public administrations, real estate developers and utilities).
- Implementation of PED concept in inner urban areas / existing building stock - what does this mean (adapted technological concepts, boundary definitions (requirements on mixed use, load profiles, specific social aspects ...)).
- Improvement of legal framework conditions for implementation of PED.

In general

- We'd like to have experts from EBC Annex 83, HPT Task on PED and others to present their (interim) results and to discuss necessary next steps for implementation, including cities' needs.

More information:

[www.cities-tcp.org](http://www.cities-tcp.org)



**Cities TCP**  
Decarbonising Cities & Communities

Thank you for your attention

