H-DisNet

Technology for next generation district heating networks

H-DisNet Webinar
18th November 2019

Co-funded by the Horizon 2020 programme of the European Union, Grant No. 695780

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Agenda

	Introduction	
14:00	Thermo-chemical networks (Technology and Simulation)	Philipp Geyer (KU Leuven)
14:15	Questions	
	Humidity Control	
14:25	Greenhouse Demonstrator	Serena Danesi (ZHAW)
14:35	Case Study Automotive Manufacturing	Andrew Smallbone (UNEW)
14:40	Discussion	
	Heating and Cooling	
14:50	Building Demonstrator	Martin Buchholz (Watergy)
15:00	Case Study Hasselt	Philipp Geyer (KU Leuven)
15:05	Discussion	

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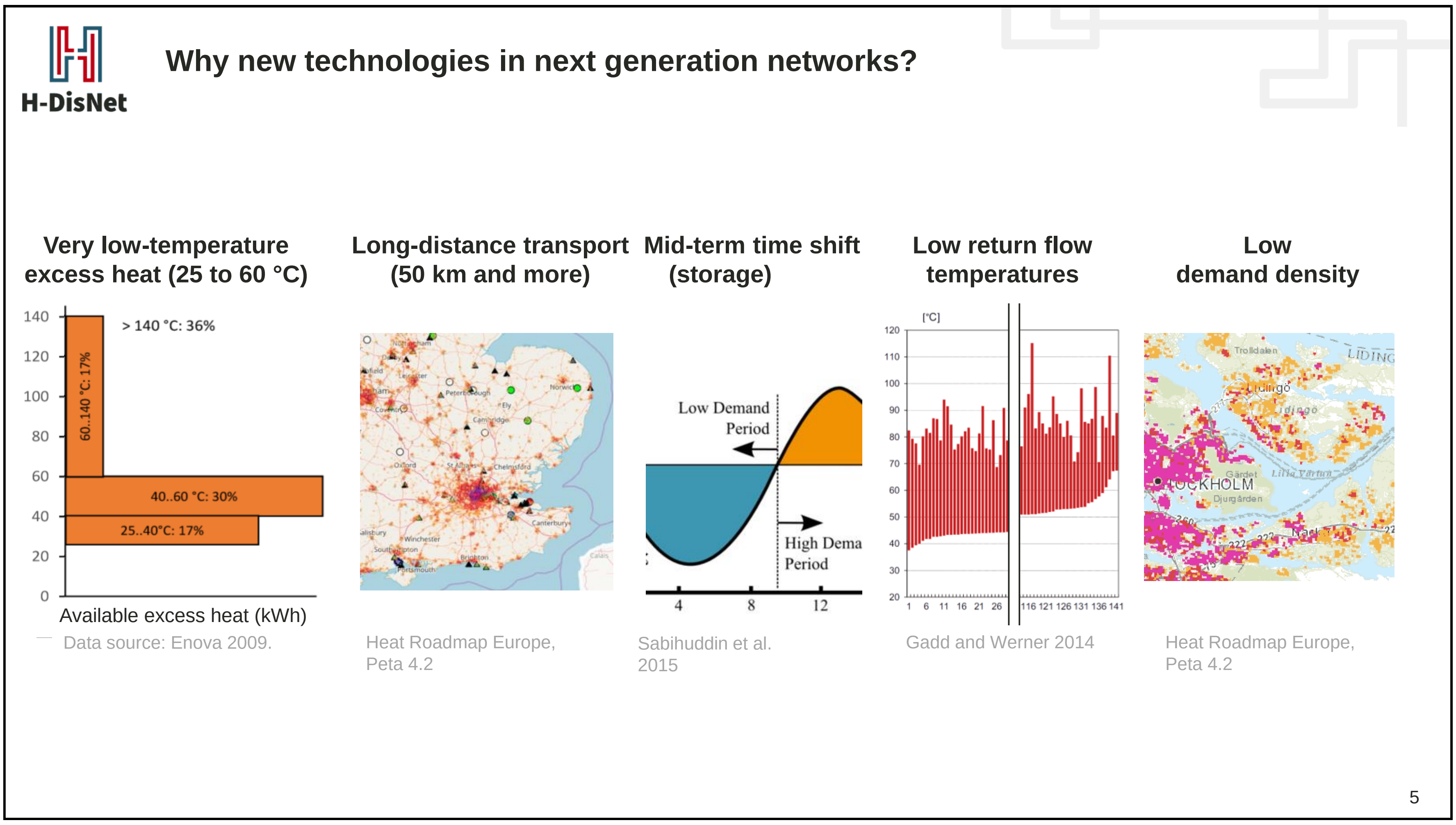
Agenda

	Smart Grid and Power Applications	
15:15	Smart Grid Demonstrator – Network Integration	Andrew Smallbone (UNEW)
15:25	Case study Moyle Interconnector	Andrew Smallbone (UNEW)
15:30	Discussion	
	Market and Stakeholders	
15:40	Surplus heat in energy-intensive Industries	Mukund Bhagwat (Aurubis)
15:45	Trends in District Heating and Cooling	Markus Thürnbeck (Thermaflex)
15:50	Stakeholder perspectives	Damian Werli (Accelopment)
15:55	Discussion	
16:05	**Wrap up**	

Introduction

14:00	Thermo-chemical networks (Technology and Simulation)	Philipp Geyer (KU Leuven)
14:15	Questions	



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Why new technologies in next generation networks?

Very low-temperature excess heat (25 to 60 °C)

Available excess heat (kWh)

Data source: Enova 2009.

Long-distance transport (50 km and more)

Heat Roadmap Europe, Peta 4.2

Mid-term time shift (storage)

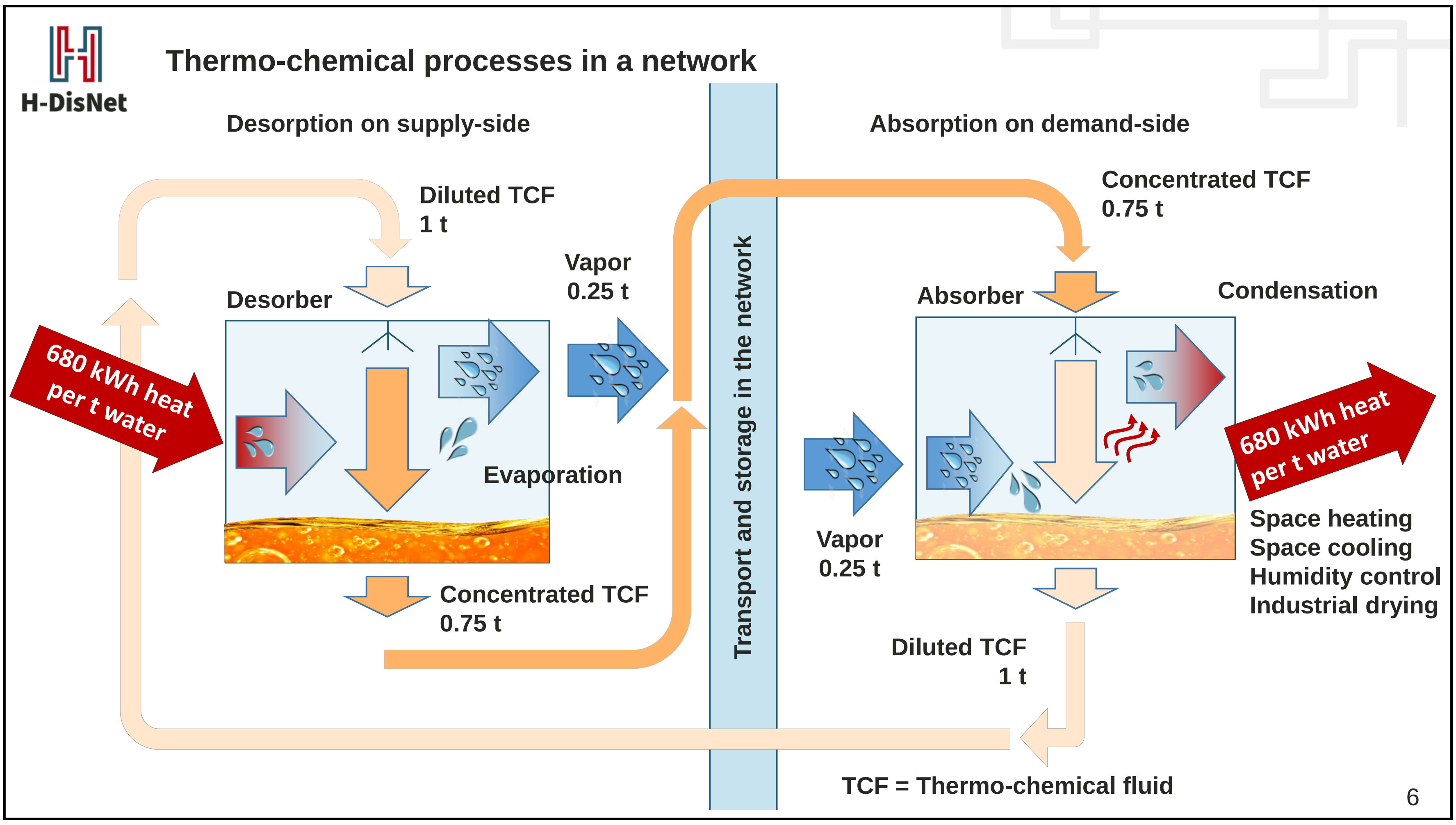
Sabihuddin et al. 2015

Low return flow temperatures

Gadd and Werner 2014

Low demand density

Heat Roadmap Europe, Peta 4.2



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Thermo-chemical processes in a network

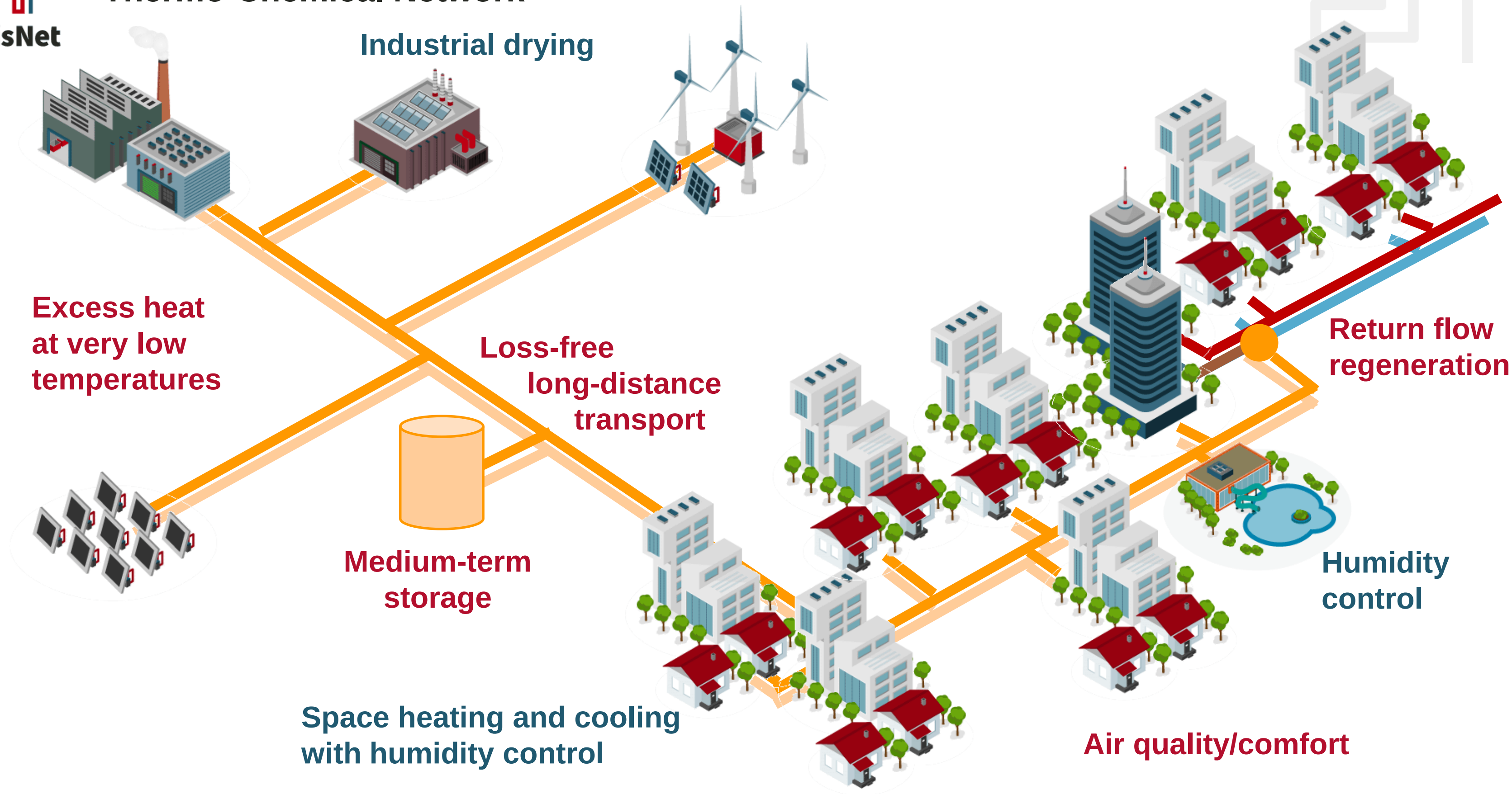
Desorption on supply-side

Absorption on demand-side

Space heating
Space cooling
Humidity control
Industrial drying

TCF = Thermo-chemical fluid

Thermo-Chemical Network



Industrial drying

Excess heat
at very low
temperatures

Loss-free
long-distance
transport

Return flow
regeneration

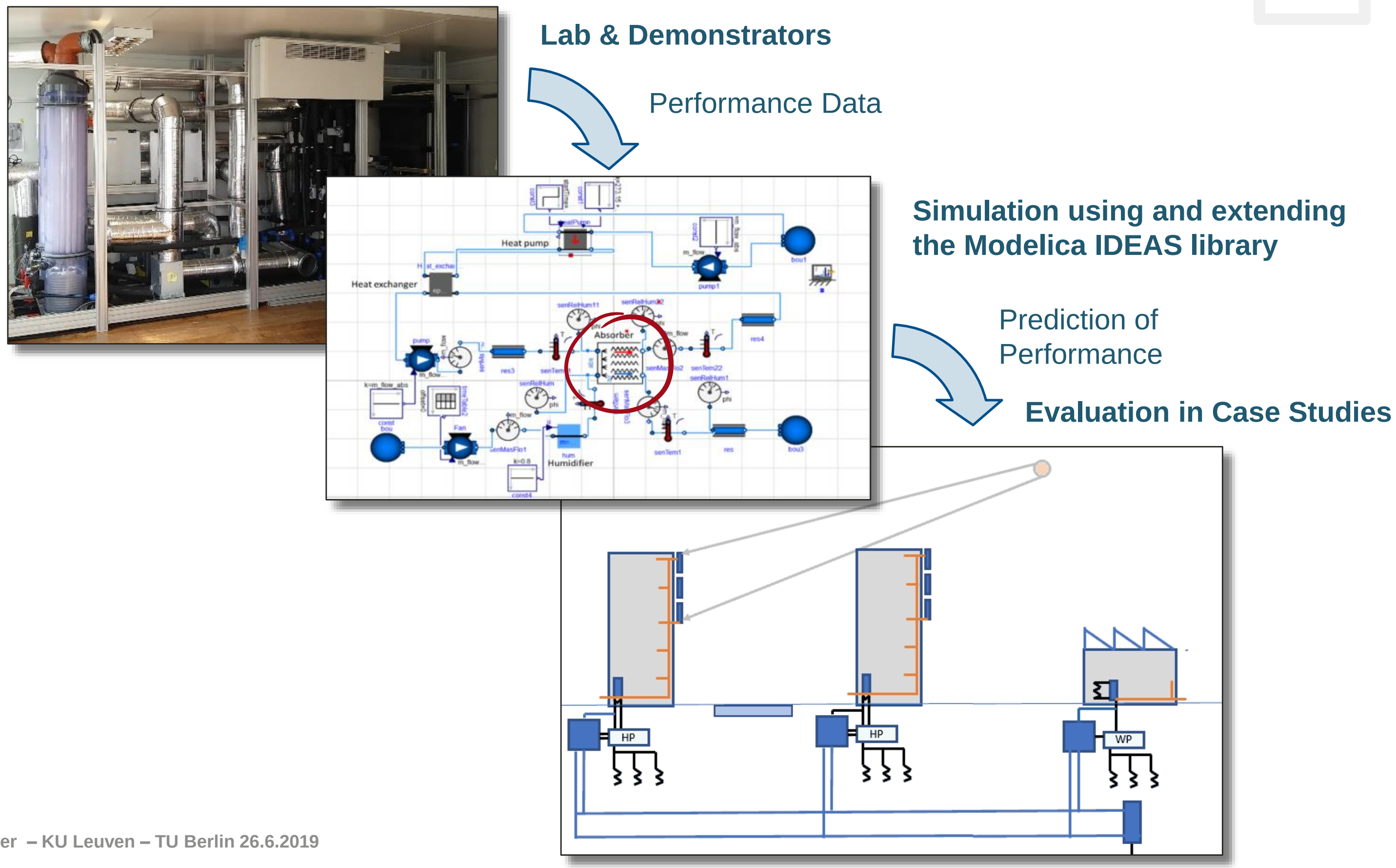
Medium-term
storage

Humidity
control

Space heating and cooling
with humidity control

Air quality/comfort

Data-driven simulation approach



Lab & Demonstrators

Performance Data

Simulation using and extending
the Modelica IDEAS library

Prediction of
Performance

Evaluation in Case Studies

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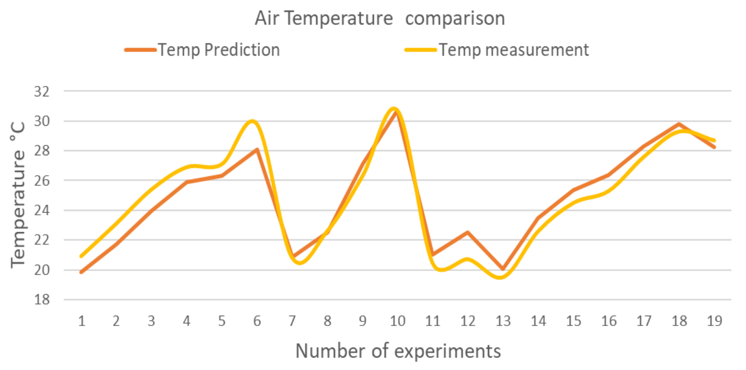
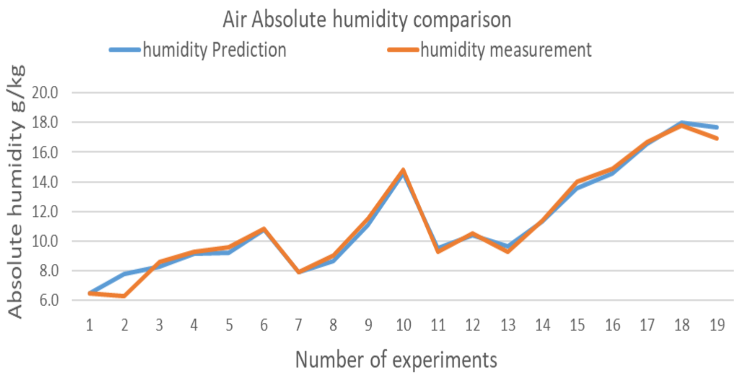
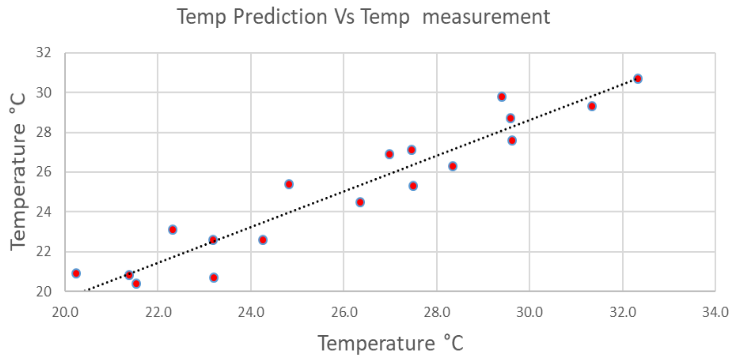
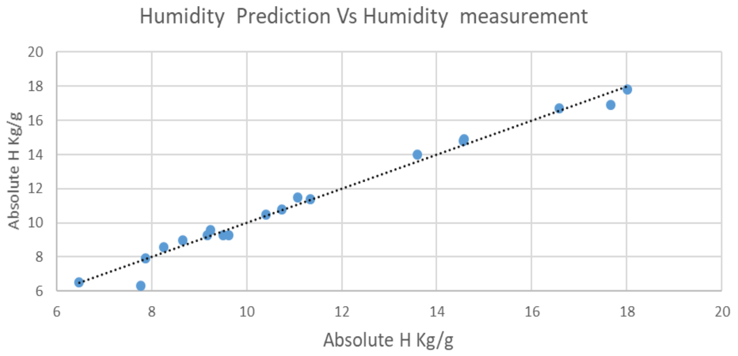
ZHAW demonstrator calibration and validation results









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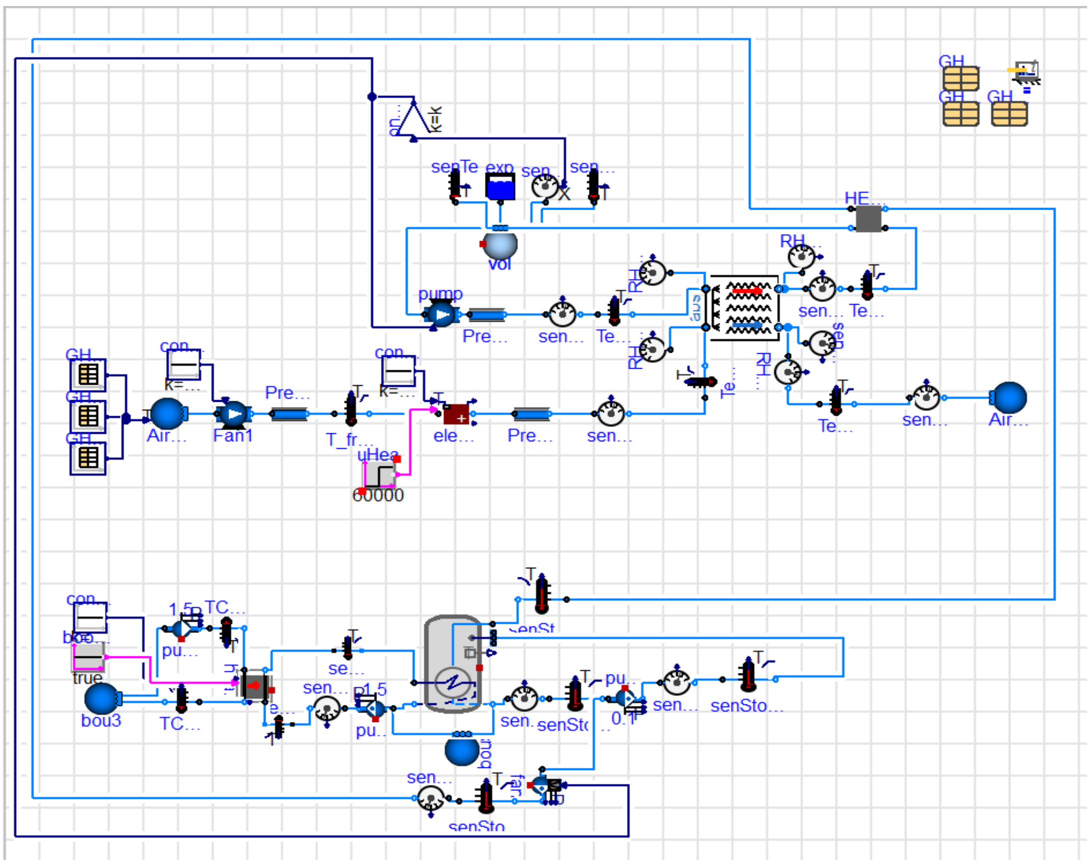
Modelica model based on Adlershof demonstrator



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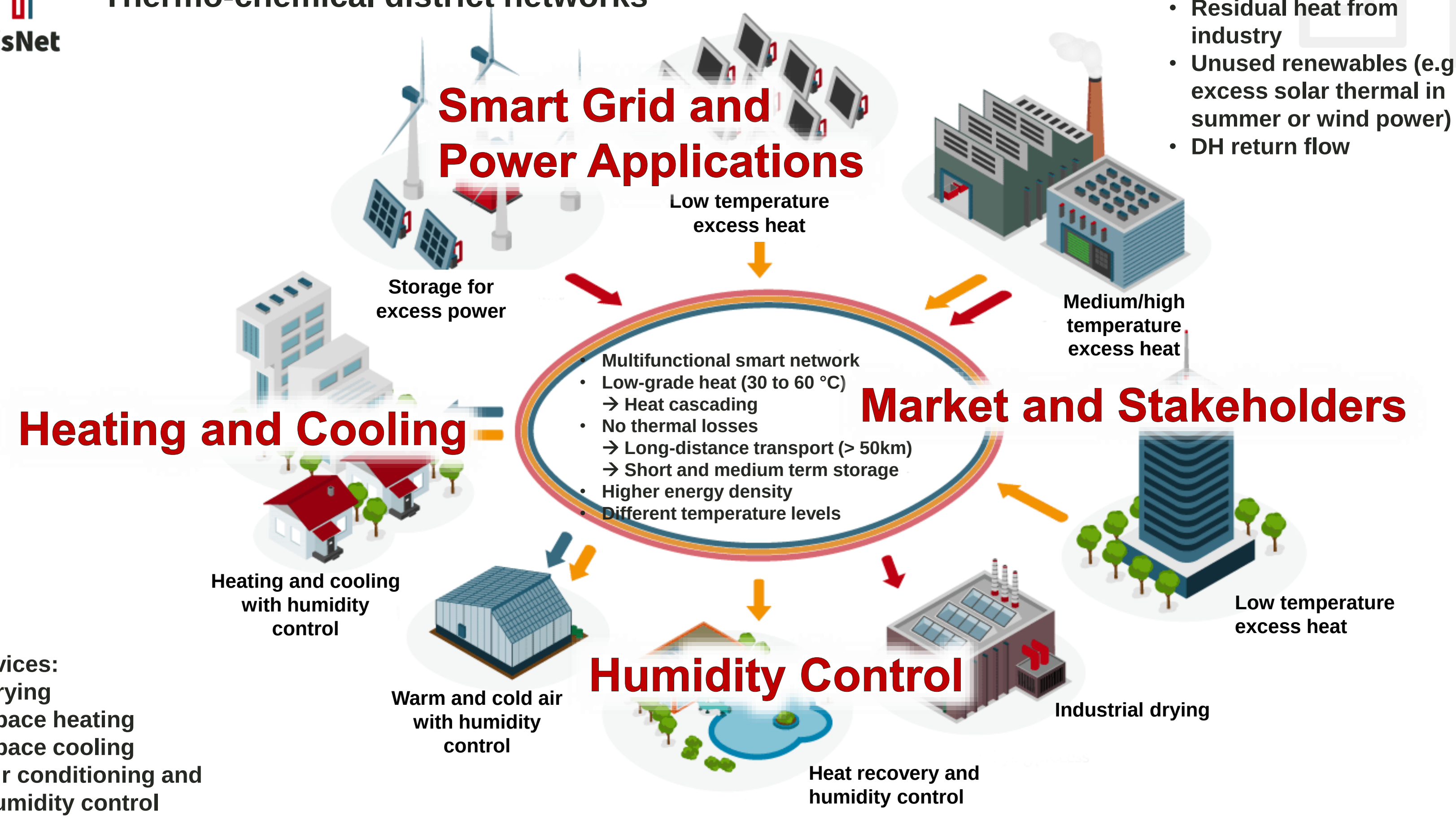
Thermo-chemical district networks

Heat sources:
- Residual heat from industry
- Unused renewables (e.g. excess solar thermal in summer or wind power)
- DH return flow



Smart Grid and Power Applications

Storage for excess power

Low temperature excess heat

Medium/high temperature excess heat

Market and Stakeholders

Low temperature excess heat

- Multifunctional smart network
- Low-grade heat (30 to 60 °C)
  → Heat cascading
- No thermal losses
  → Long-distance transport (> 50km)
  → Short and medium term storage
- Higher energy density
- Different temperature levels

Heating and Cooling

Heating and cooling with humidity control

Warm and cold air with humidity control

Humidity Control

Heat recovery and humidity control

Industrial drying

Services:
- Drying
- Space heating
- Space cooling
- Air conditioning and humidity control

Humidity Control

14:25	Greenhouse Demonstrator	Serena Danesi (ZHAW)
14:35	Case Study Automotive Manufacturing	Andrew Smallbone (UNEW)
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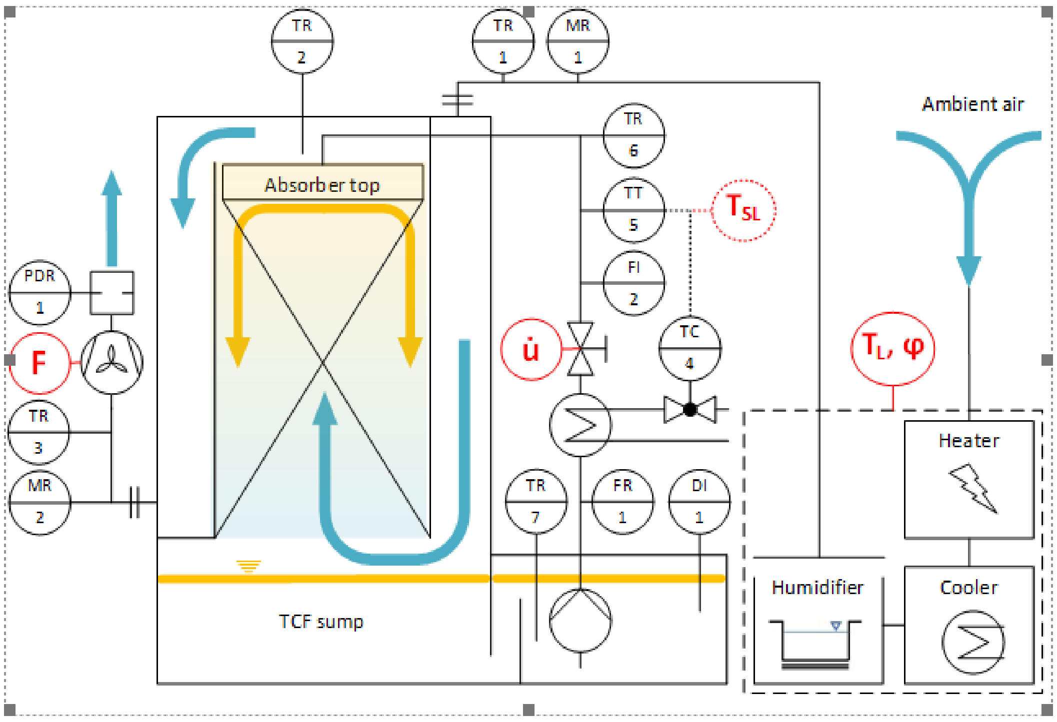
Humidity and Temperature Control: demonstrator

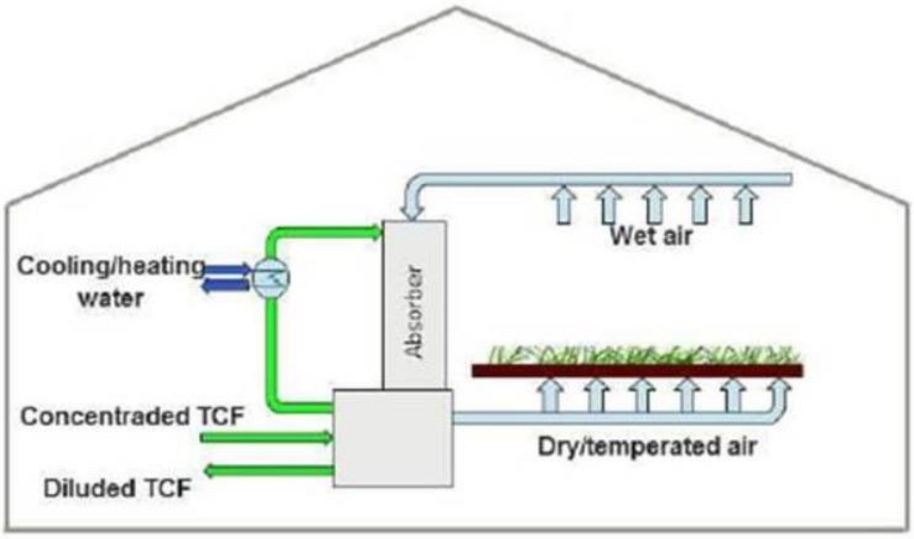
Swiss Demonstrator

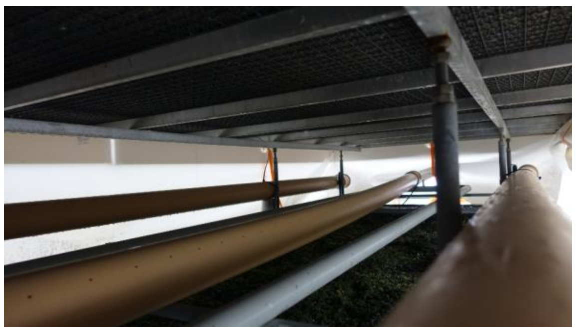
- 600m^2 commercial greenhouse closed to Zurich
- Heating, cooling and humidity control
- 9 absorbers (incl. 1 absorber with special design of Watergy)
- Conditioned air injected directly to the crop
- Test run in winter 2018/2019 and in summer 2019

Humidity and Temperature Control: absorber

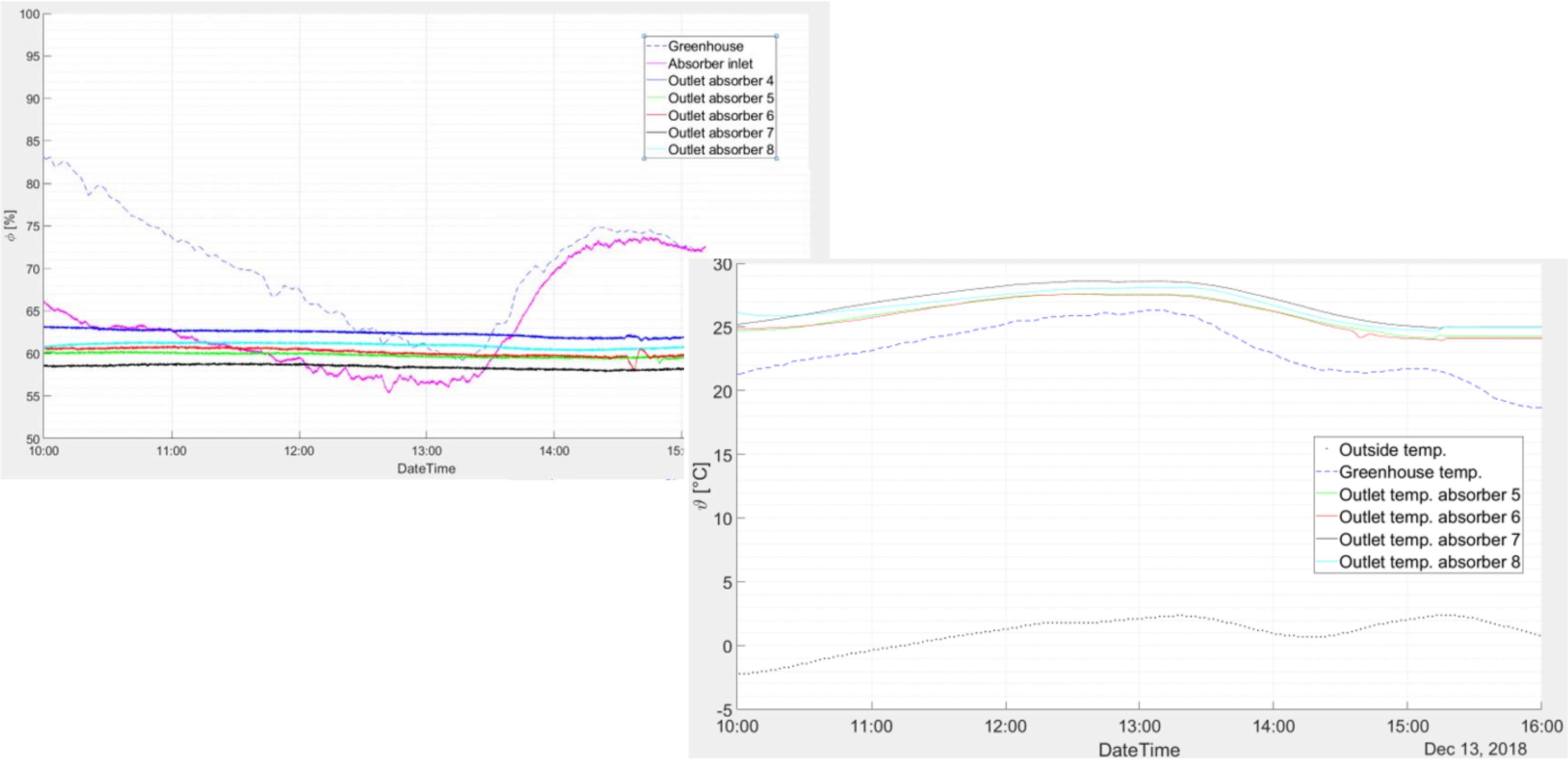


Humidity and Temperature Control: air injection system

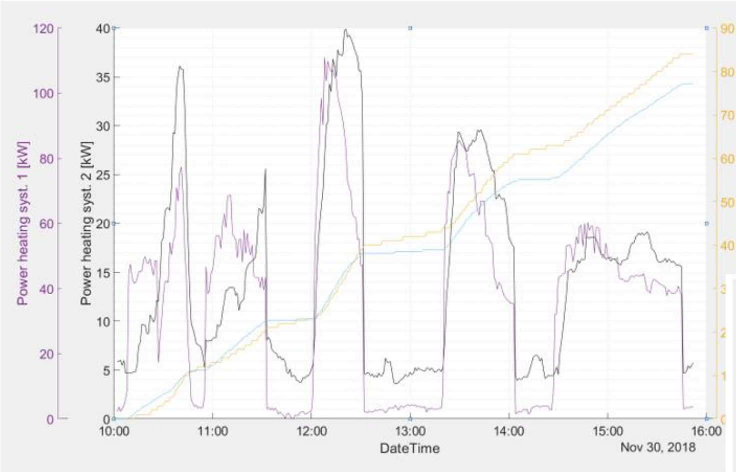




Humidity and Temperature Control : winter operation



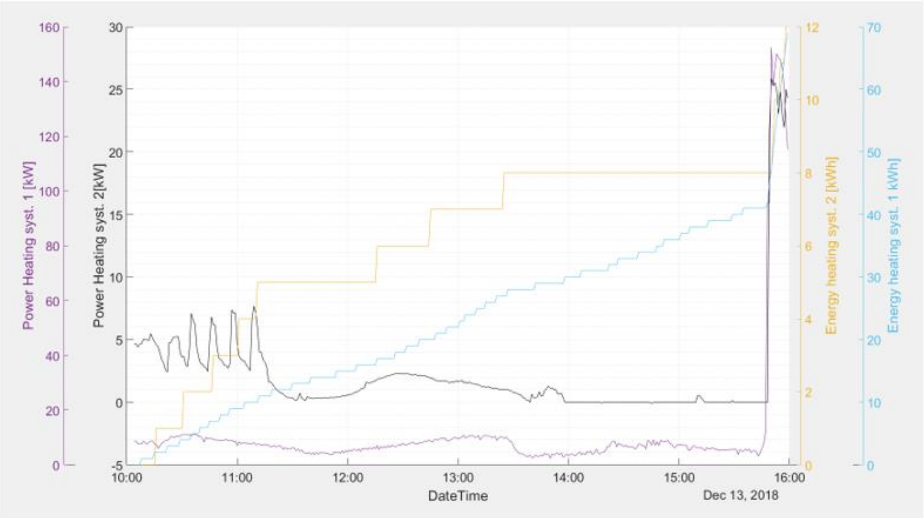
Humidity and Temperature Control : winter operation



Energy consumption of average winter day (outside temperature 0°C-5°C)

On the left: absorbers not in operation

On the right: absorbers in operation between 10:00 and 15:30

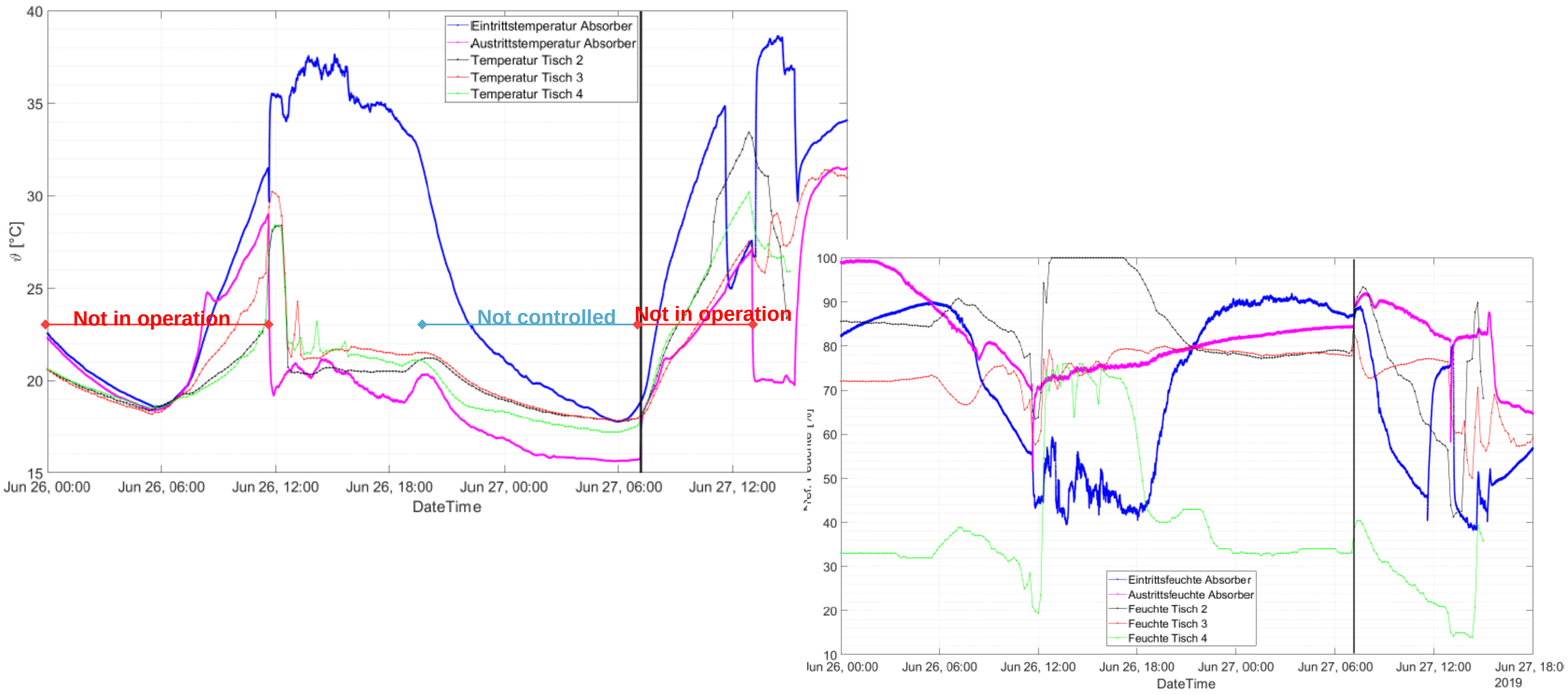


Energy consumption:

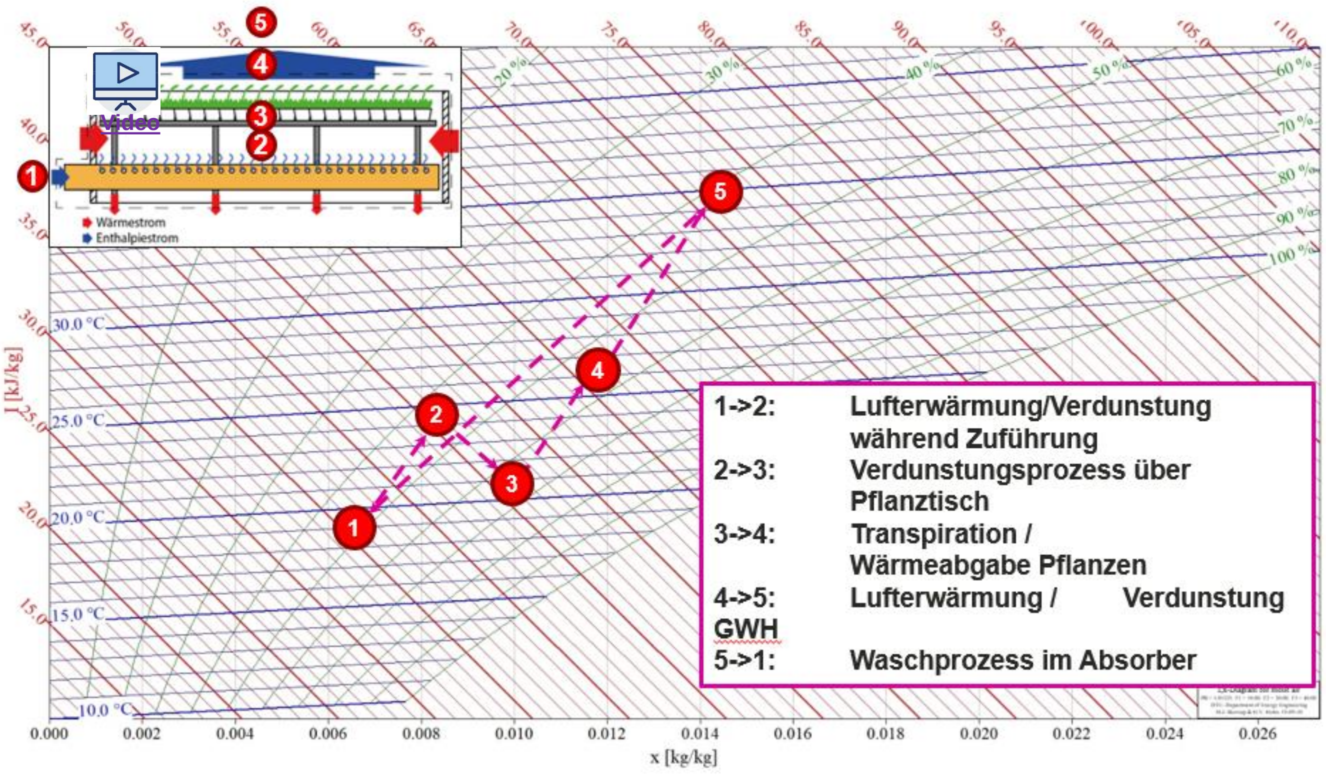
W/o absorbers: appr. 300 kWh

With absorbers: appr. 50 kWh

Humidity and Temperature Control : summer operation



Humidity and Temperature Control : summer operation



1->2:	Lufterwärmung/Verdunstung während Zuführung
2->3:	Verdunstungsprozess über Pflanztisch
3->4:	Transpiration / Wärmeabgabe Pflanzen
4->5:	Lufterwärmung / Verdunstung GWH
5->1:	Waschprozess im Absorber

Humidity and Temperature Control: Video

Video

Humidity Control

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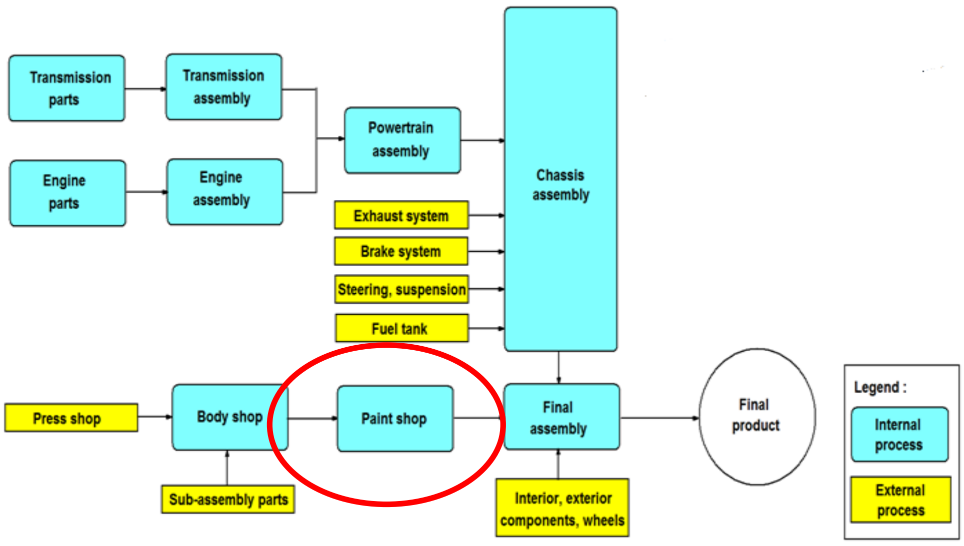
Automotive manufacturing: Opportunity



Sector	Energy consumption
Paint system	27-50 %
Heating, ventilation and air-conditioning	11-20 %
Lighting	14-15 %
Compressed air	9-14 %
Welding	9-11 %
Materials handling/tools	7-8 %

Hildreth AJ, Oh SC. Analytics for Smart Energy Management: Tools and Applications for Smart Energy Management, 2016.

Implementation of Energy management standards (ISO) and waste heat recovery are the strategies currently most employed by automotive manufacturers for reduction of the energy consumption (resulting in economic savings).

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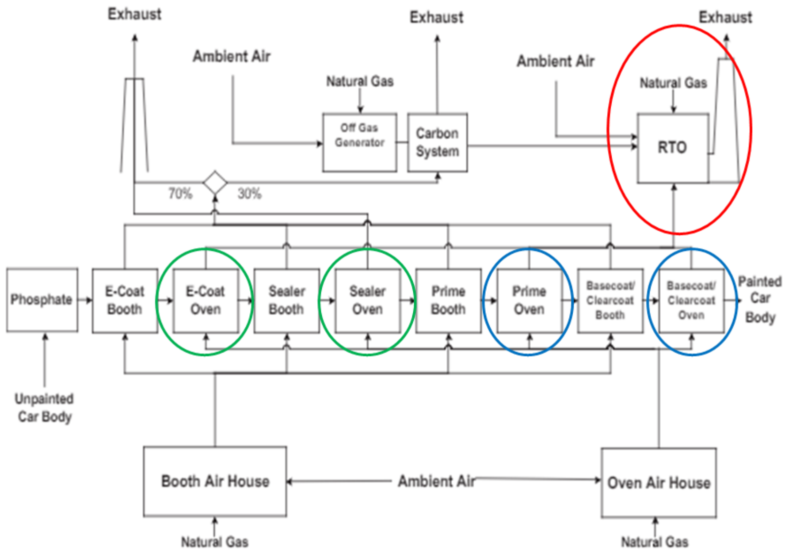
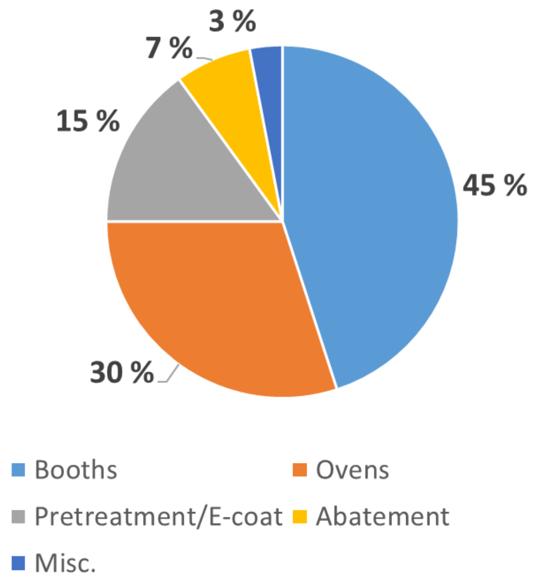
Automotive manufacturing: Opportunity



Roelant GJ, Kemppainen AJ, and Shonnard DR. Assessment of the Automobile Assembly Paint Process for Energy, Environmental, and Economic Improvement. Journal of Industrial Ecology 2004; 8: 1-2.

The conditioning of the air for paint booth and ovens are highly energy consuming.



Implementation of Energy management standards (ISO) and waste heat recovery are the strategies currently most employed by automotive manufacturers for reduction of the energy consumption (resulting in economic savings).

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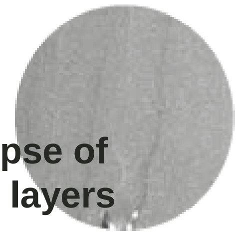
Automotive manufacturing: Challenge – get the humidity right!

Checking

Too low relative humidity of the air supplied to paint booth: it involves a series of cracks and lesions on the painted surface, with a loss of gloss on the substrate. Consequences are a reduction in product viscosity and low hiding power of the coating.

Blistering

Too high relative humidity of the air supplied to paint booth: the droplets of water trapped inside the coating explode during drying, creating bulges on the surface of the paint film of varying size and frequency.



Collapse of inner layers

Too high relative humidity of the air supplied to paint booth: the water never completely evaporates, meaning the paint remains highly viscous even after the application of subsequent coats. This defect appears in the form of irregular localised and well-defined accumulation of paint, with rounded edges.

CAREL. Air humidity in paint booth. Report 2017.

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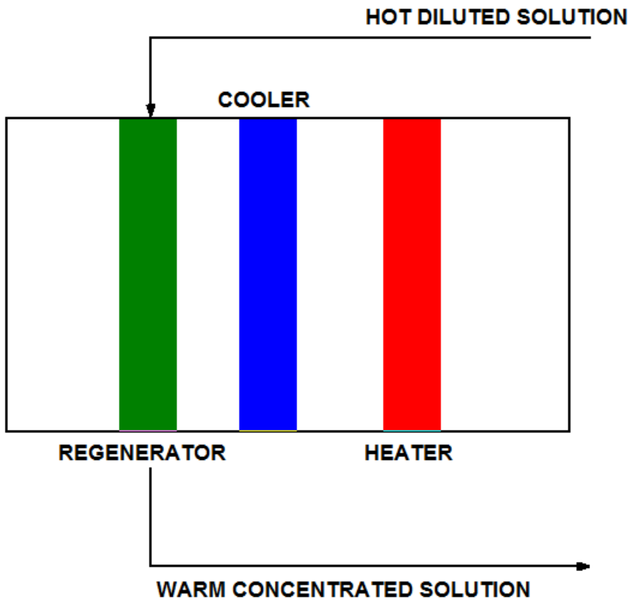
Automotive manufacturing: Solution



- Conventional AHU systems are unable to deliver a narrow window of temperature and humidity for the supply air. In addition, they are unable to promptly respond to variations in outdoor air conditions.

- The temperature and humidity of the supply air required in the paint booth with water-based paint is usually T=23 ± 1 °C, RH=70 ± 1 %.

- For climates where the outdoor temperature is lower than 23 °C most of the time, the main problem handling the outdoor air is the <u>heating and humidification process.</u>

- Moreover, the plant operates 22.5/24 h, working during most time of the night (lower temperature).

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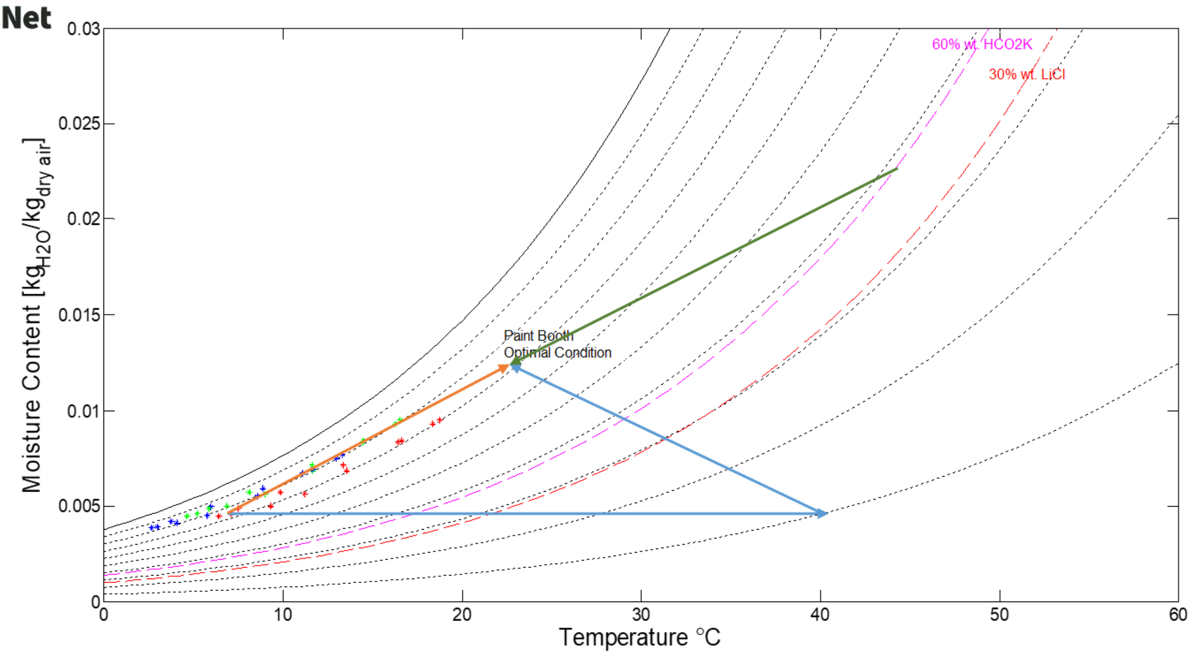
Automotive manufacturing: Solution



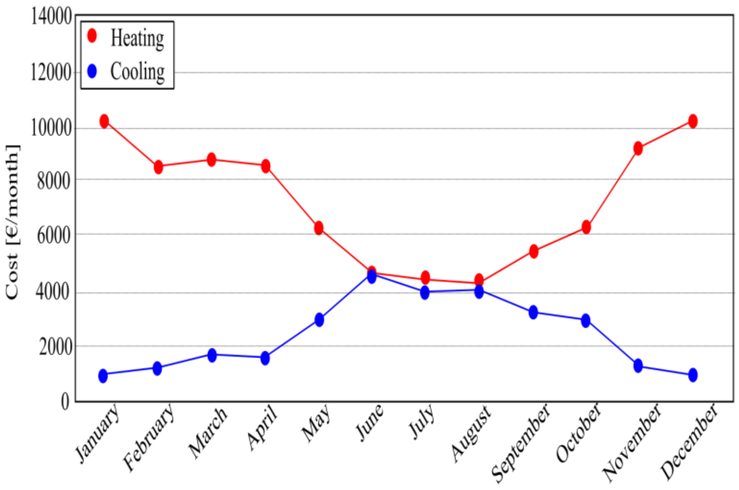
Weather conditions
Washington NZ3157
manufacturing
Period: 01/2009 – 07/2017

* Minimum Temperature
* Average Temperature
* Maximum Temperature

Paint booth optimal:
T_{air} = 23 °C, RH = 70%

- The liquid desiccant ASU could supply warmer and more humid air.
- This process could be highly efficient from an energetic point of view, exploiting the chemical ability of desiccant solutions and the paint shop waste heat.
- <u>The air compressor heat recovery (45-50 °C) seems particularly feasible.</u>

Automotive manufacturing: Result



Parameter	Value
Volume flow rate of an ASU/ARU	100,000 m^3/h
Paint booth temperature	23 C
Paint booth RH	70 %
Working hours	5962.5 h/y
Savings in heating for ASU	€ 87,113.6 y^{-1}
Savings in humidification for ASU	€ 21,778.4 y^{-1}
Savings in cooling for	€ 29,133.6 y^{-1}
Capital cost of the H-DisNet technology system	€ 283,580
O&M cost of the H-DisNet technology system	€ 19,850 y^{-1}
Payback period for the H-DisNet technology	Lower than 3 years

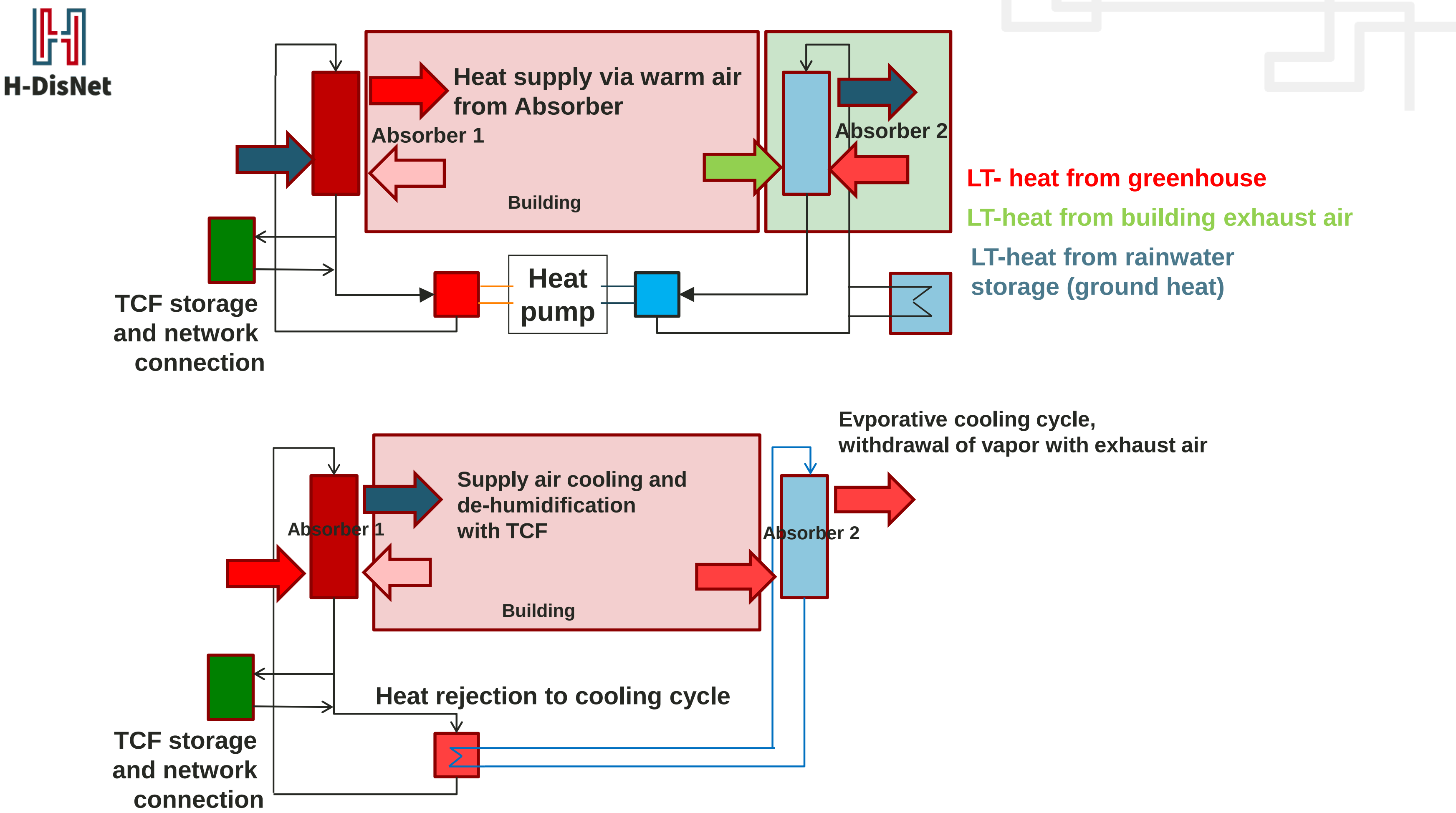
- **Techno-viability of the system was evaluated and costed**
- **System had a return on investment slightly under 3 years. Much of it realised through lower gas and electricity utilisation**

Heating and Cooling

14:50	Building Demonstrator	Martin Buchholz (Watergy)
15:00	Case Study Hasselt	Philipp Geyer (KU Leuven)
15:05	Discussion	

H-DisNet Building Demonstrator in Berlin-Adlershof

- Heat supply and humidity control
- Space cooling and humidity control
- Water recovery from greenhouse air



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Heat supply via warm air from Absorber

Absorber 1

Absorber 2

Building

Heat pump

TCF storage and network connection

LT- heat from greenhouse

LT-heat from building exhaust air

LT-heat from rainwater storage (ground heat)

Evporative cooling cycle, withdrawal of vapor with exhaust air

Supply air cooling and de-humidification with TCF

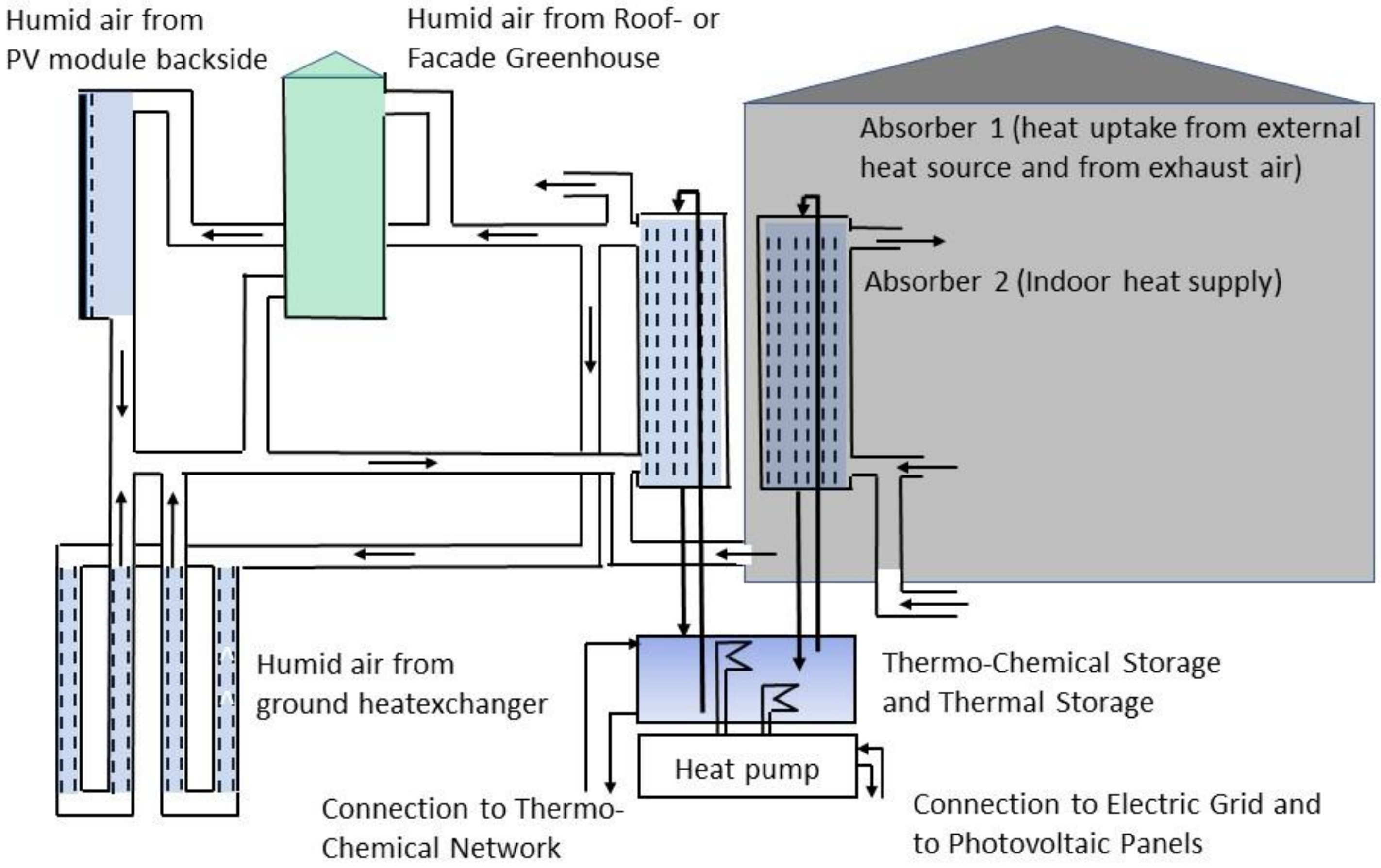
Absorber 1

Absorber 2

Building

Heat rejection to cooling cycle

TCF storage and network connection



Humid air from
PV module backside

Humid air from Roof- or
Facade Greenhouse

Absorber 1 (heat uptake from external
heat source and from exhaust air)

Absorber 2 (Indoor heat supply)

Humid air from
ground heatexchanger

Thermo-Chemical Storage
and Thermal Storage

Heat pump

Connection to Thermo-
Chemical Network

Connection to Electric Grid and
to Photovoltaic Panels

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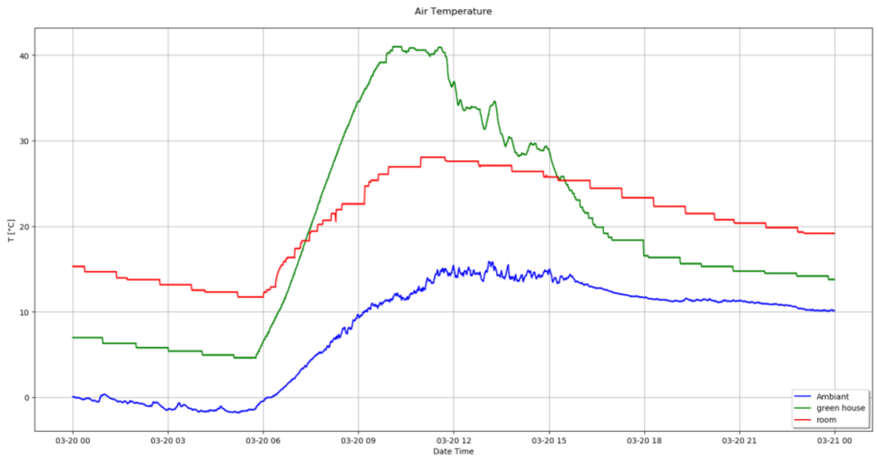
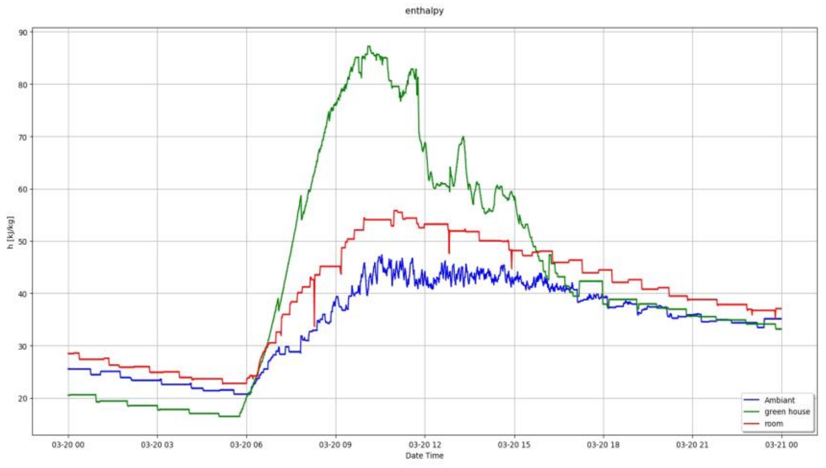
Humidity and Temperature Control: Video

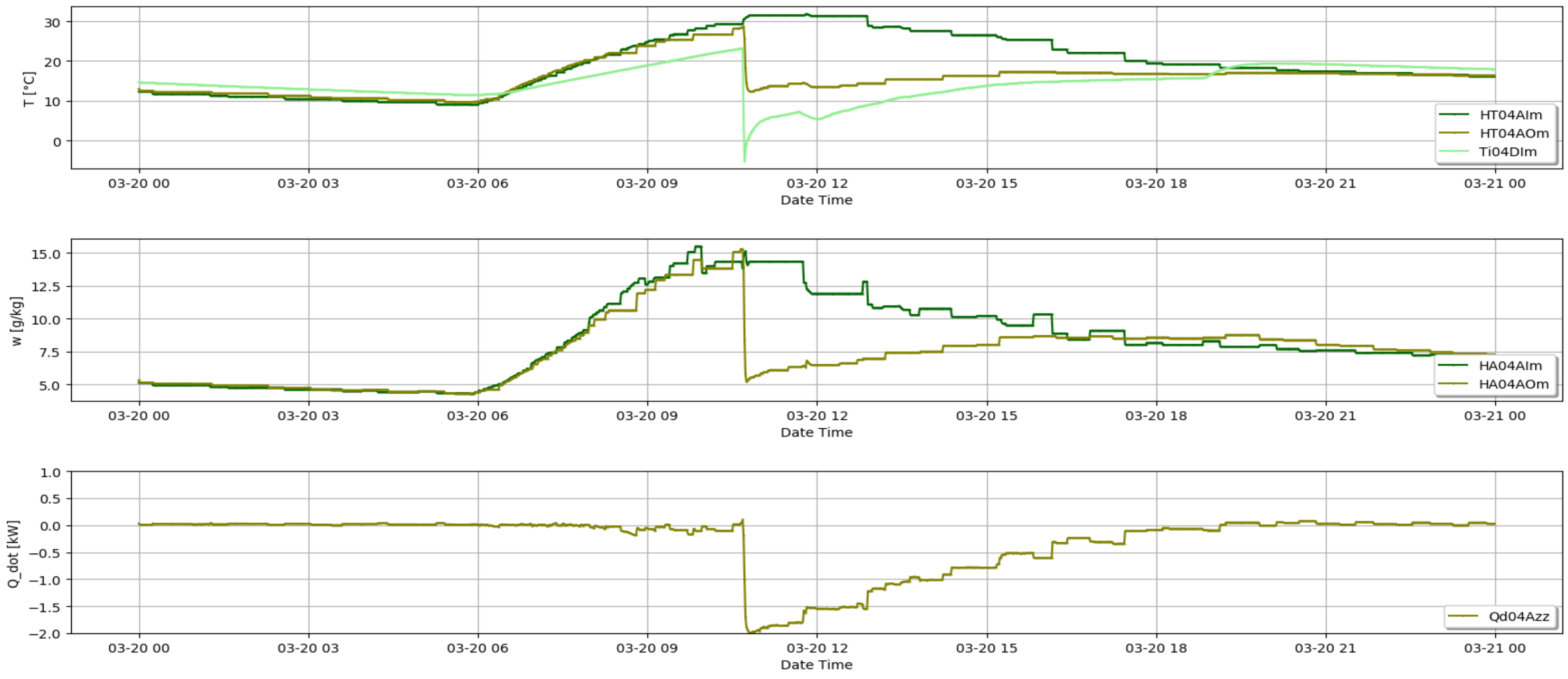
Video

Greenhouse temperature (°C) and air enthalpy (kJ/kg)

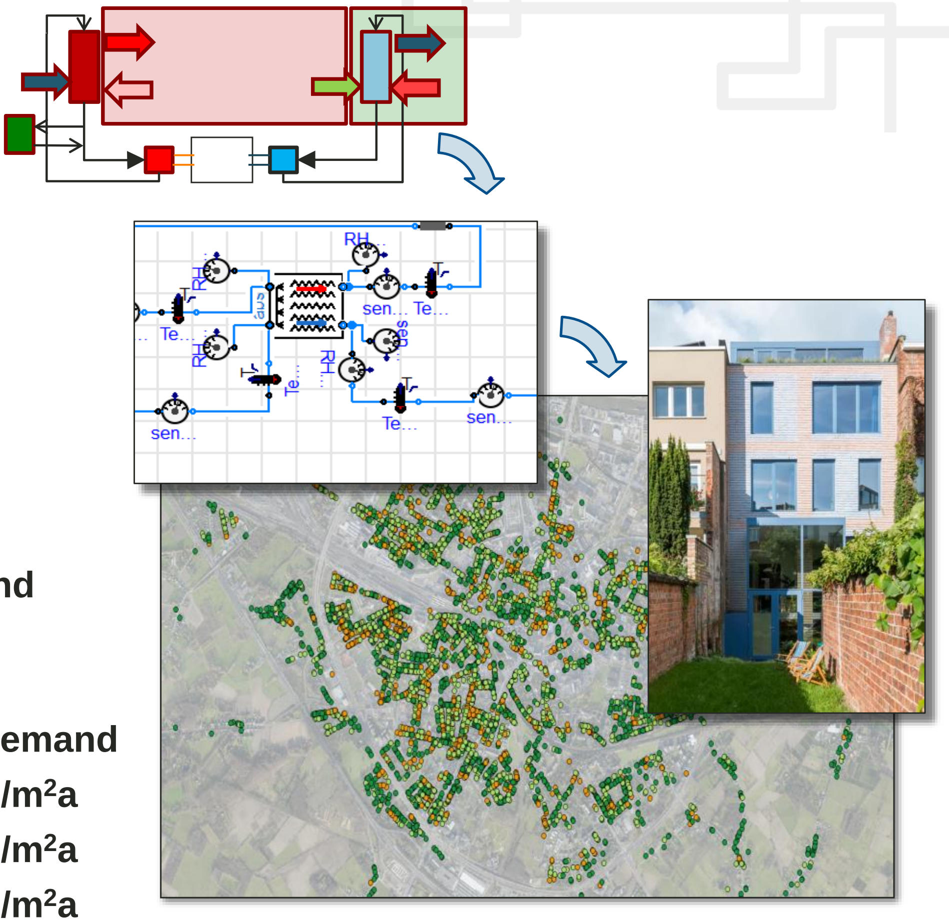




Input and Output values of Absorber (temperature and water content, Energy uptake (kW)



Case Study Hasselt, Belgium



Case study: What if the technology is applied to selected areas of city?

- **TC Systems**
- **Gas Boilers**
- **Standalone Heat Pumps**
- **Conv. DH**

Network serving 155 GWh/a of Heat Demand (42% City Coverage)

3 Building Clusters acc. to Specific Heat Demand

a.	**Low**	**< 110**	**kWh/m²a**
b.	**Medium**	**110 : 235**	**kWh/m²a**
c.	**High**	**> 235**	**kWh/m²a**

Hasselt Case Study: Results

	CO_2 Emissions (tCO_2/a)	Primary Energy Use (GWh/a)	Annualized Project Costs (M€/a)
Gas Boilers	48,366	242	45
Standalone Heat Pumps	11,406	156	68
TC Systems	2,332	32	57
Conv. DH	581	6.3	43.7

Conv. DH: Water-base conventional District Heating
Lifetime of the project: 25 years. Several components have lower lifetime. Exchange considered.

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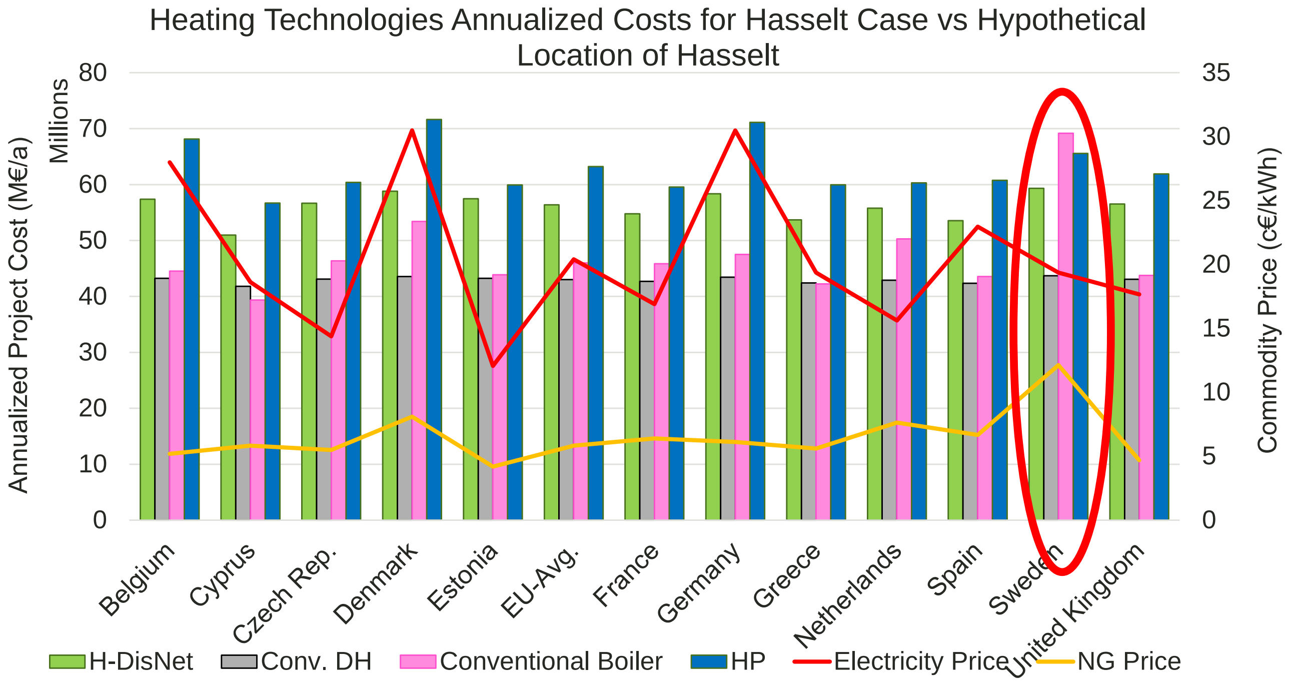
Is H-DisNet A Solution for Europe?

- High Natural Gas Price
- Low CO_2 emissions in Power Mix



Data for Commodity Prices obtained from European Comission, EUROSTAT Data Statistics

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Smart Grid and Power Applications

15:15	Smart Grid Demonstrator – Network Integration	Andrew Smallbone (UNEW)
15:25	Case study Moyle Interconnector	Andrew Smallbone (UNEW)
15:30	Discussion	

Smart Grid Demonstrator – Network Integration

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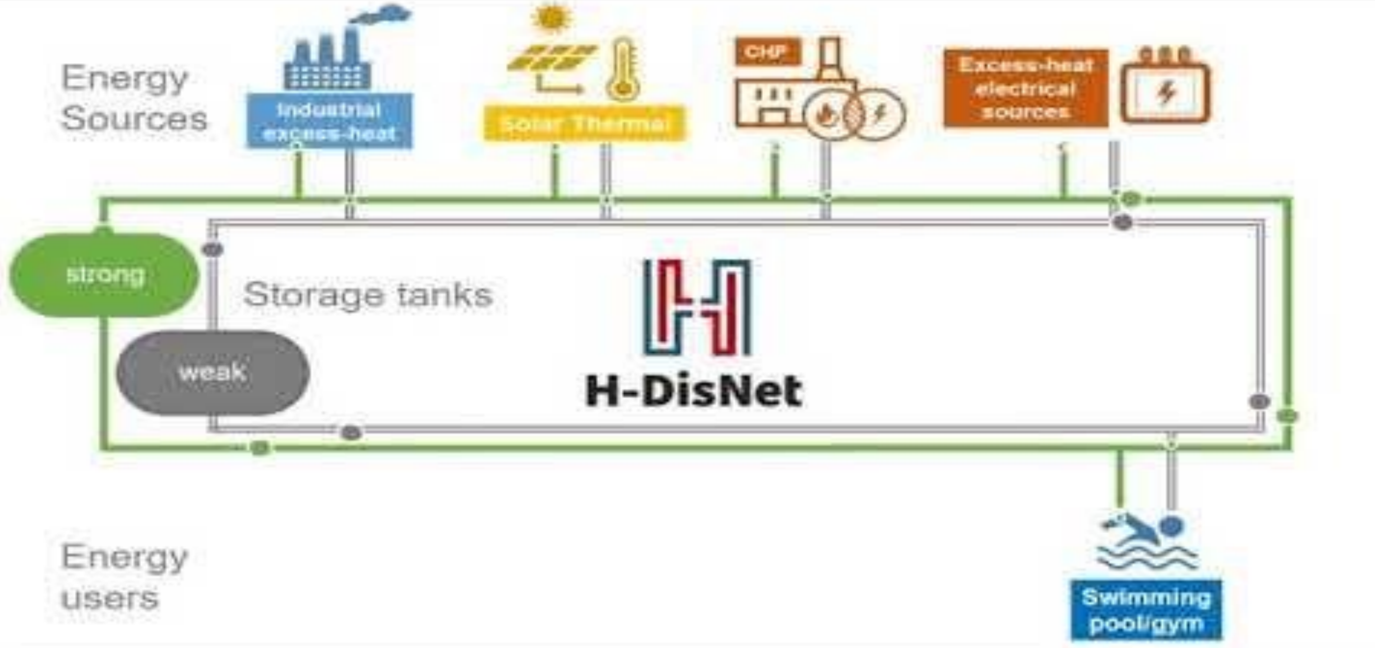

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Smart Grid Demonstrator – Network Integration

Challenge

H-DisNet has lots of potential applications

- different energy sources
- different energy demands
- what size does the storage need to be?
- how might they couple together as a network?
- how would this system be controlled?

These need to be tested, characterised and explored.

What we did

We designed, built and developed a flexible test platform to:

- Emulate multiple thermal sources (up to 90ºC)
- Emulate multiple thermal demands
- Store heat and TCF
- Control these systems and measure performance
- Try out alternatives

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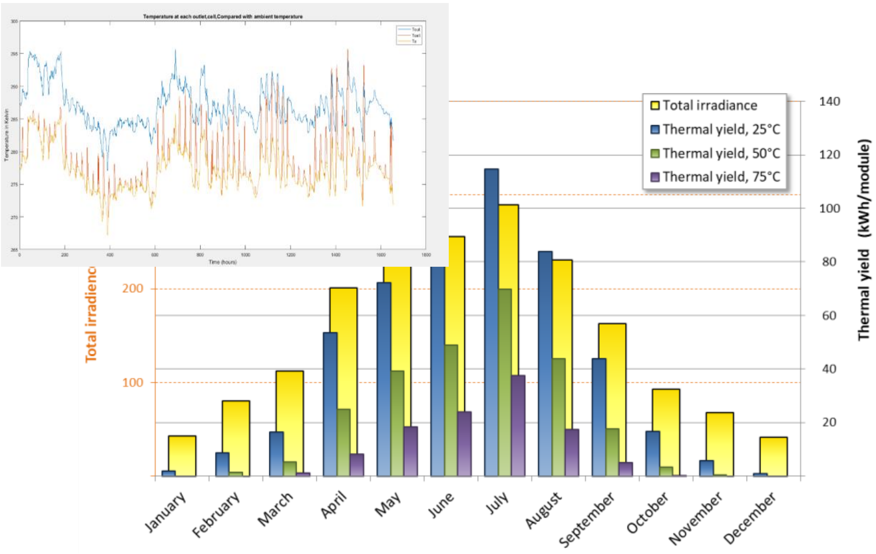
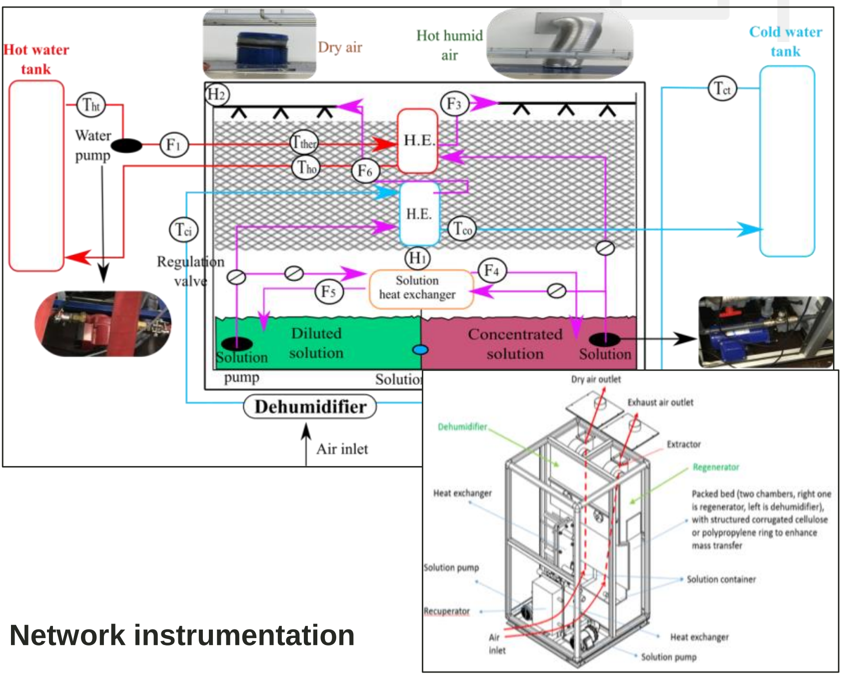
Smart Grid Demonstrator – Network Integration





Component level characterisation

PV-T system
Thermal collectors
Electrical heaters
Efficiency, inputs, outputs *etc.*

TCF Network instrumentation

All gas and TCF flows instrumented
All temperatures and concentrations measured
Humidity and energy all measured

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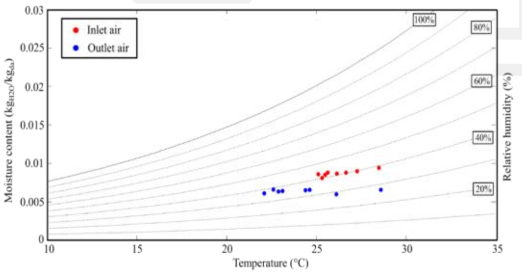
Smart Grid Demonstrator – Network Integration



Two-node network testing

Renewable energy to air-conditioning demonstration

Fluctuating solar energy

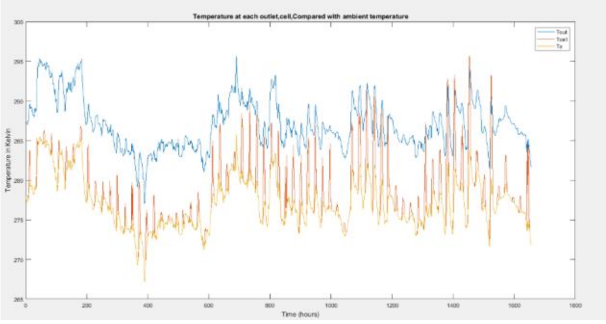
Up to 50ºC of heat was provided by the PVT system

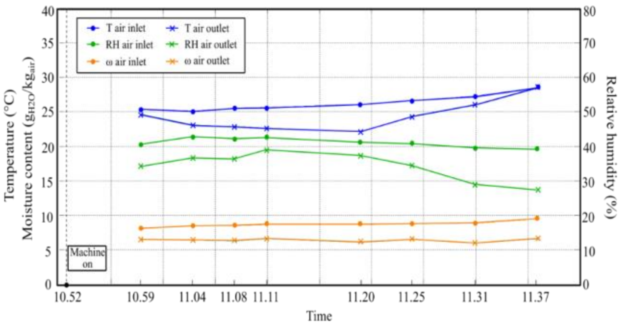
H-DisNet technology

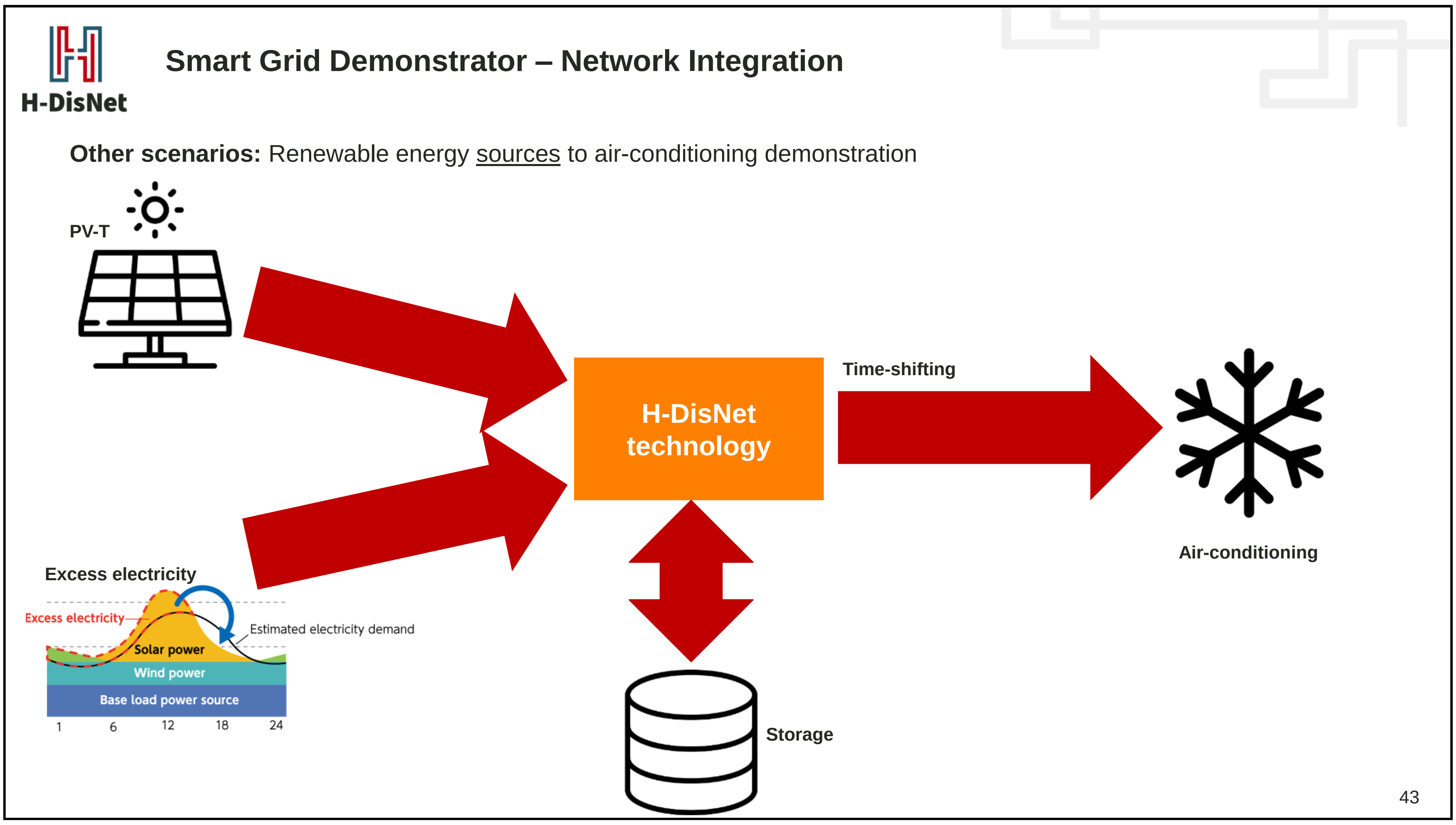
4ºC cooling and 10%RH reduction

PVT

Air-conditioning







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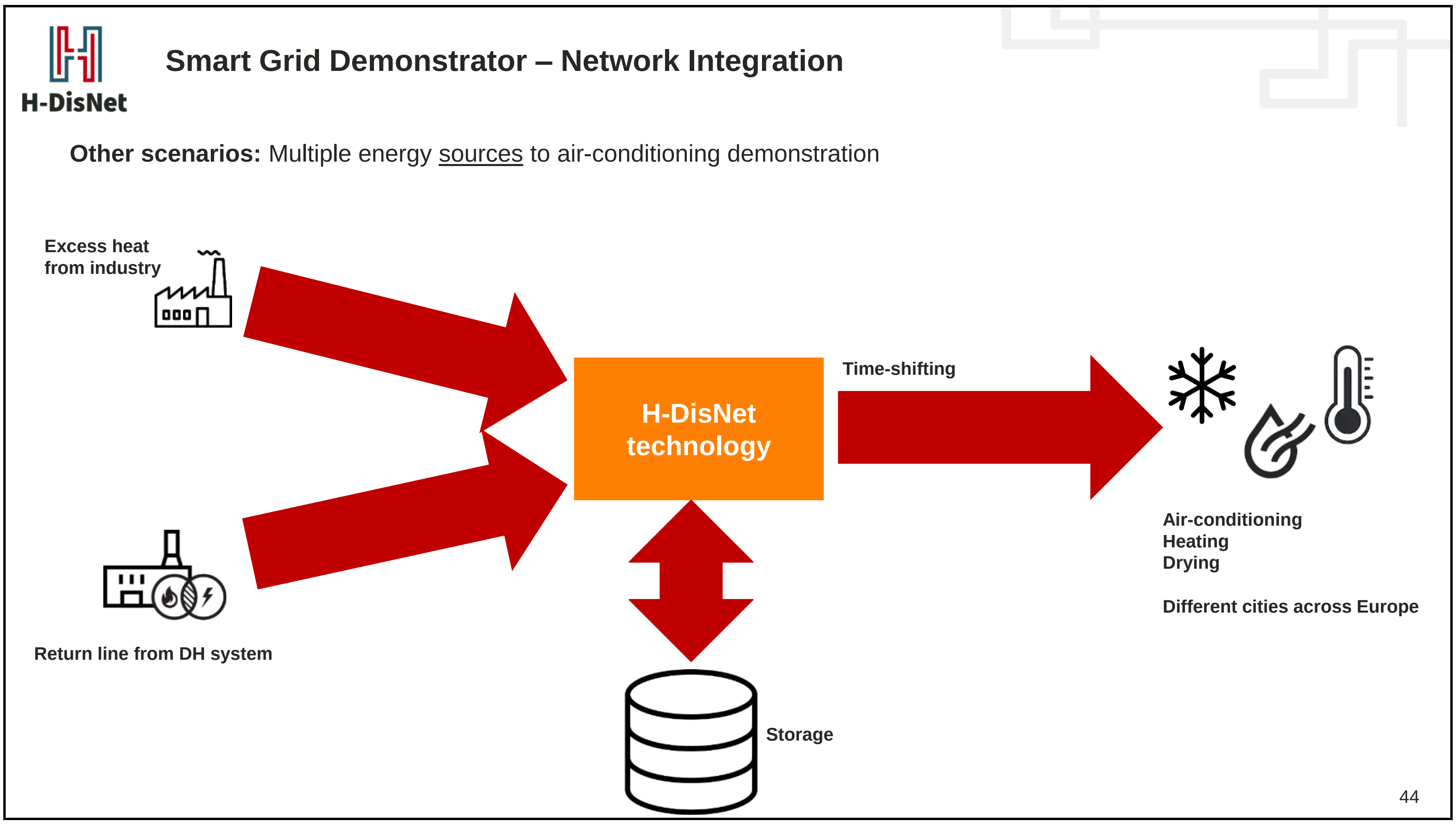
Smart Grid Demonstrator – Network Integration

Other scenarios: Renewable energy sources to air-conditioning demonstration



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Smart Grid Demonstrator – Network Integration

Other scenarios: Multiple energy sources to air-conditioning demonstration

Smart Grid Demonstrator – Network Integration

Summary

Flexible H-DisNet test platform has been developed at Newcastle University

Different configurations of networks can be tested

Alternative energy sources and demands can be emulated and control strategies determined

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Smart Grid and Power Applications

15:15	Smart Grid Demonstrator – Network Integration	Andrew Smallbone (UNEW)
15:25	Case study Moyle Interconnector	Andrew Smallbone (UNEW)
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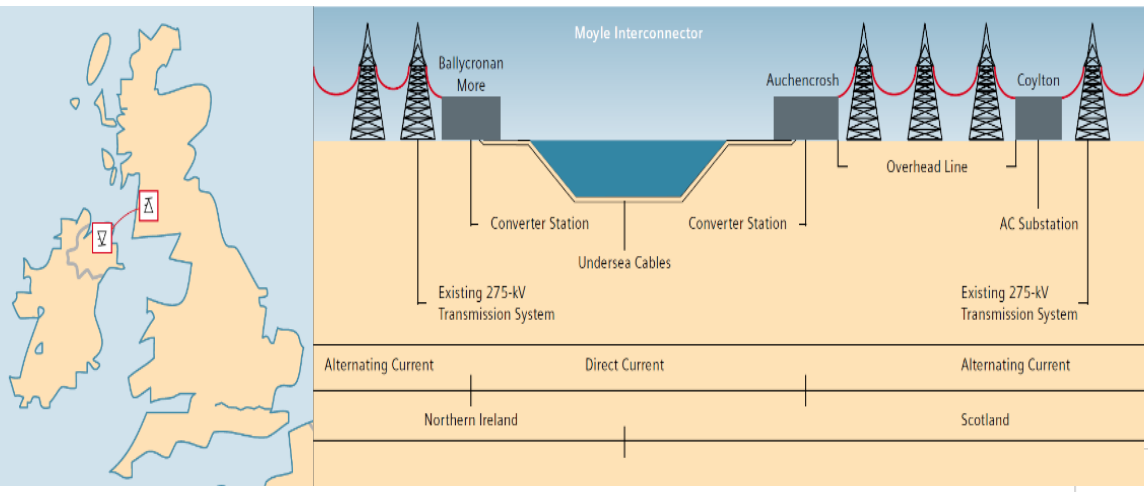
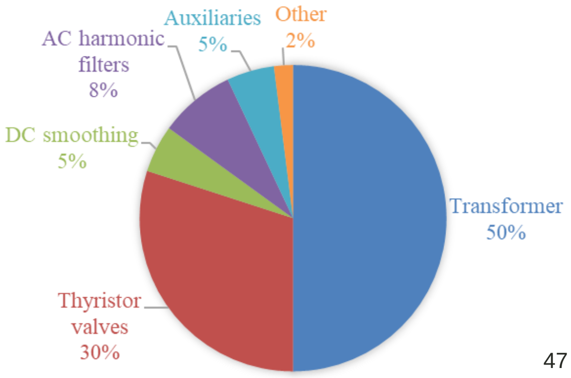
High-voltage interconnector - opportunity



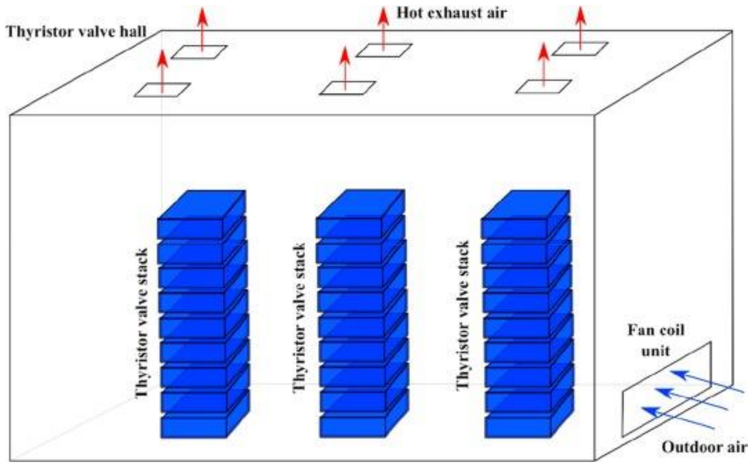
Characteristic	Quantity
Transmission capacity (MW)	250 x 2
System voltages (kV)	Direct current: 250 Alternate current: 275
Rated current (A)	1000
Transmission distance (km)	63.5

Around 1% of total transmission power is lost to low grade heat

However this is 5MW – vented to atmosphere!



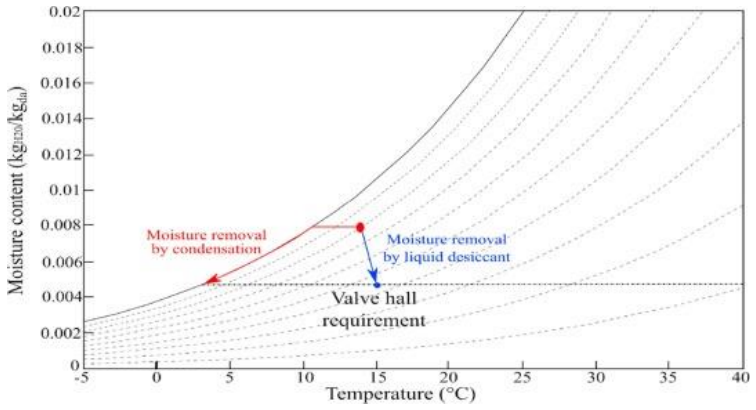
High-voltage interconnector - opportunity



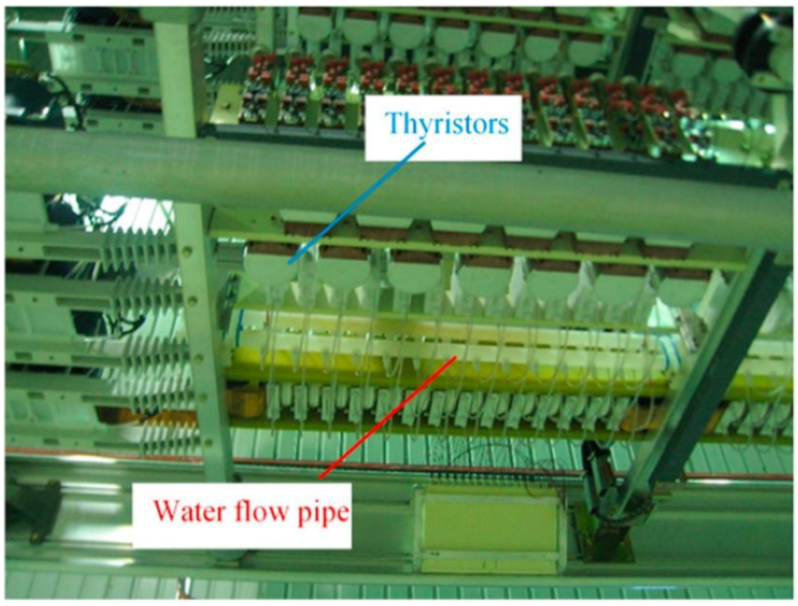
The thyristor valves hall uses a significant amount of air-conditioning

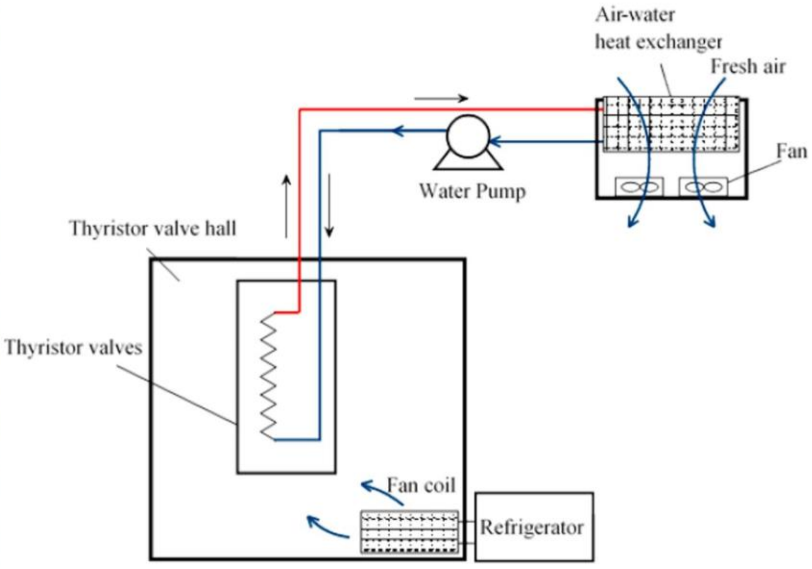
The room is maintained at 15ºC and low humidity

Avoid corona discharges



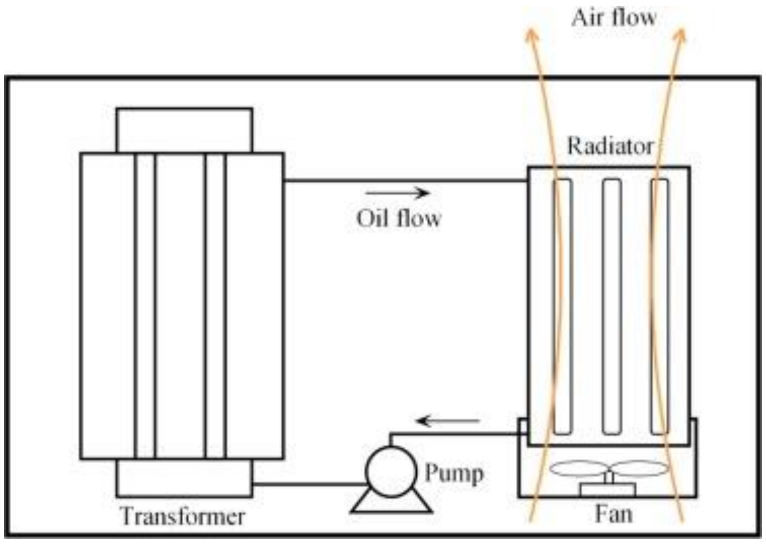
High-voltage interconnector – excess heat sources





- Cooling water within the thyristor valves system
- 385-443kW per pole
- 39-43°C

High-voltage interconnector – excess heat sources



- OFAF transformer
- 99+% efficiency but losses are heat

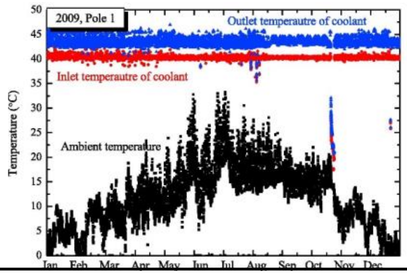
- 300-378kW heat per pole
- 55 - 85°C

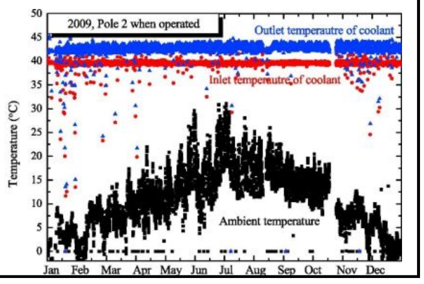
High-voltage interconnector – excess heat sources

	2009 Pole 1	2009 Pole 2		2014 Pole 1	
	Whole year	Whole year	When operated	Whole year	When operated
Cooling based on thyristor waste heat (kW)	77	53.6	77	–[a]	88.6
Cooling based on transformer waste heat (kW)	120	108	151.2	–[a]	146
Total cooling (kW)	197	163.6	228.2	–[a]	234.6

a. Temperature sensors failed in October.

- Cooling offset the air-conditioning costs for the Thyrister Hall
- Calculation made more complex by weather and HVDC use





High-voltage interconnector - results

Alternative modes for energy recovery were also considered

Organic Rankine Cycle (ORC) – no ROI

Absorption heat transformer + ORC – no ROI

H-DisNet technology – 5-8.7 years ROI

	Retro fit	New project 1	New project 1
Flow rate (m^3/h)	12,610	12,610	12,610
LD capital cost (€)	81,350	81,350	81,350
DEC capital cost (€)	/	/	2470
VC capital cost savings (€)	/	29,400	44,400
Maintenance cost LD (€/year)	1627	1627	1676.4
Maintenance cost VC (€/year)	1332	432	/
Operation cost (€/year)	4067.45	4067.45	4191
Savings (€/year)	13,725.93	13,725.93	13,725.93
Payback period (years)	8.7	6.1	5
LCOSE (€/kWh)	0.305	0.2	0.155

All results are presented in detailed in

Alessandro Giampieri, Zhiwei Ma, Janie Ling Chin, Andrew Smallbone, Padraig Lyons, Imad Khan, Stephen Hemphill, Anthony Paul Roskilly,
Techno-economic analysis of the thermal energy saving options for high-voltage direct current interconnectors,
Applied Energy, Volume 247, 2019, Pages 60-77,
https://doi.org/10.1016/j.apenergy.2019.04.003.

Market and Stakeholders

15:40	Surplus heat in energy-intensive Industries	Mukund Bhagwat (Aurubis)
15:45	Trends in District Heating and Cooling	Markus Thürnbeck (Thermaflex)
15:50	Stakeholder perspectives	Damian Werli (Accelopment)
15:55	Discussion	

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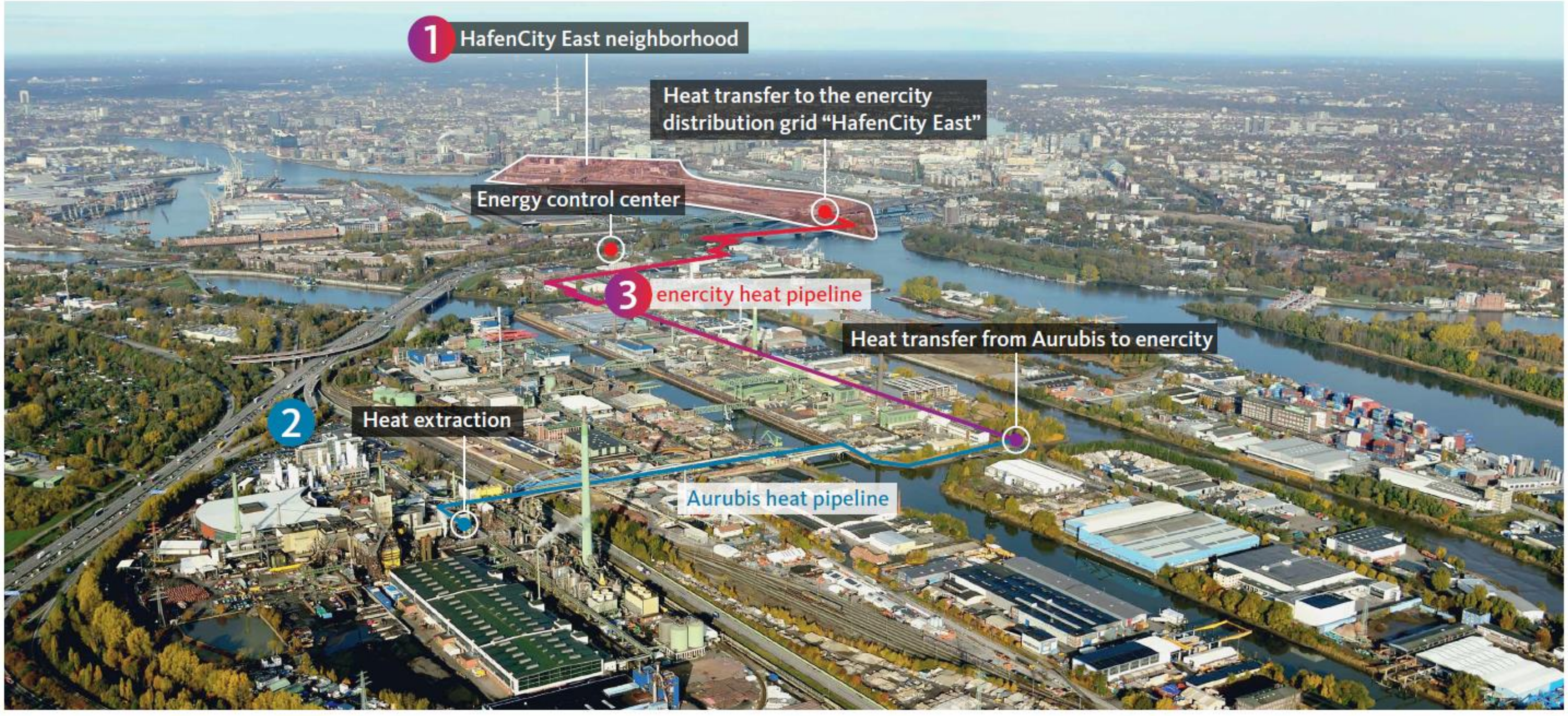
Germany’s largest industrial heat project

- Hamburg wants to reduce its CO_2 emissions by 80% by 2050 compared to 1990 levels. For the first time, an entire district of Hamburg is almost completely supplied with CO_2 free industrial heat.



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What’s behind it?

- Project scope and complexity are unique and show the potential for the heat change.

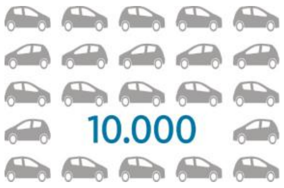
1. Large

- The hamburger **Köhlbrandbrücke** extends almost the same length.

2. Heat giving

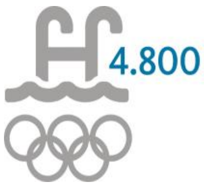
- The total available potential is sufficient for **25,000 households.**

3. Climate protect



- If the full potential were exploited, CO2 emissions could even be reduced by about **140,000 t CO2.**

4. Water saving



- **12 million m³ of cooling and Elbe water** per year saves the conversion of acid cooling

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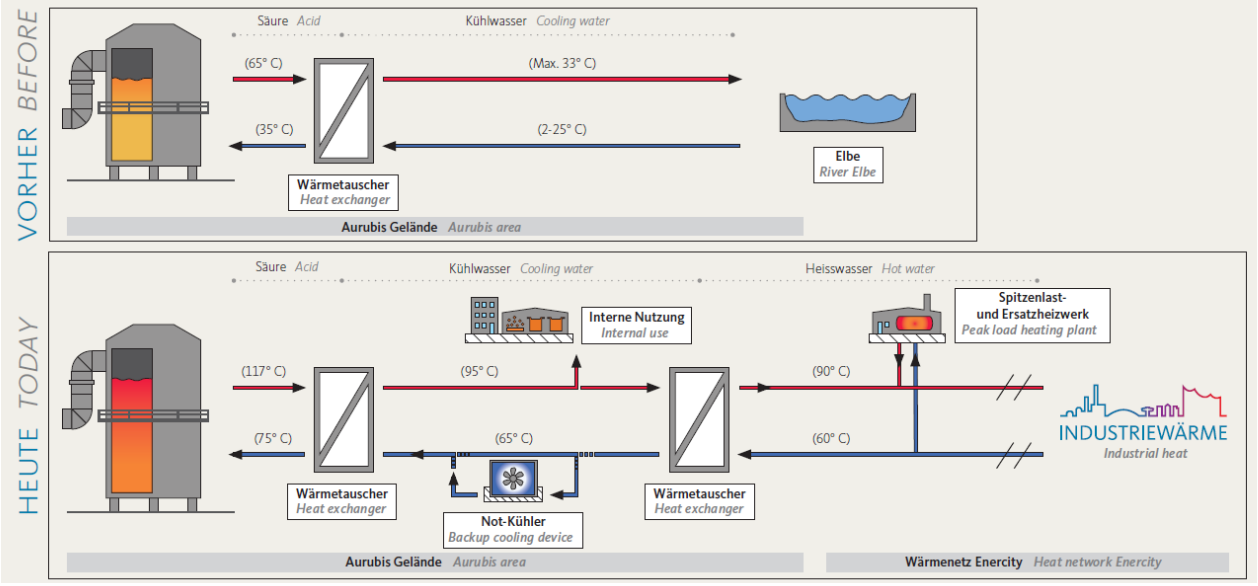
How does it work?

- Already today the Hamburg plant covers 87 % of its heat needs from its own production processes. It is possible to extract more heat that forms in a sub-process of copper production.



The heat forms in an exothermal process when gaseous sulphur dioxide transforms into sulphuric acid. This process is free of CO_2 and does not require any fossil fuels. Aurubis extracts this heat for district heating.

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Enablers and supporters

Excellence

... awarded and certified by:

LEUCHTTÜRME ENERGIEEFFIZIENTE ABWÄRMENUTZUNG

GERMAN RENEWABLES 2018 AWARD

ENERGY EFFICIENCY AWARD *)

ener.CON AWARD

Forward-looking

The pipeline capacity is already designed to carry the full industrial heat potential that Aurubis could provide.

Supported

... in all project phases by:

Bundesministerium für Wirtschaft und Technologie

KFW

EUROPÄISCHE UNION
Investition in unsere Zukunft
Europäischer Fonds für regionale Entwicklung

Hamburg | Behörde für Umwelt und Energie

Committed

Both partners – Aurubis and enercity – each invested more than 40 Mio. € during the planning and implementation phase.

*) Thorsten Herdan, head of section II „Energy Policy – Heat and Efficiency“ (Federal Ministry for Energy and Economy) when awarding the Energy Efficiency Award: **“The external use of the industrial heat makes a significant contribution to the city of Hamburg’s climate protection goals […] With the help of industrial heat, the emission level in HafenCity East even falls below the demanding emission threshold stipulated for the heat supply of this new development area.”**

However: the EU-ETS recognizes only to a very limited extent the efforts of Aurubis to enable CO_2-savings through heat-delivery to third parties

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District Heating & Cooling

THERMAL ENERGY Distribution Local / district heating and cooling	**WATER Distribution** Hot and cold drinking and potable water
	
Energy saving Condensation prevention	Energy saving Frost protection

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PG11

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Development of District Heating

	1G	2G	3G	4G
	STEAM	**IN-SITU**	**PREFABRICATED**	**4th GENERATION**
Period of best available technology	1880-1930	1930-1980	1980-2020	2020-2050
Heat source	Coal waste	- CHP coal & oil - Coal waste	- Solar - Biomass & CHP Biomass - Industry surplus - CHP waste (oil, Coal) - Waste (Gas, Waste, Oil, Coal)	-Solar - **Georthermal** - **PV, Wave Wind surplus Electicity** - Industry surplus - CHP waste incineration - CHP biomass - **Centralized Heat pump** - **Centralized District cooling plant** - 2-way District Heating - Biomass conversion --- future energy sources?
Storage	Steam Storage	Heat storage	Heat storage	**Seasonal heat storage** Heat storage
Heat carrier	Steam <200°C	Pressurized hot water >100°C	Pressurized hot water <100°C	**Pressurized hot water <50-60°C (70°C)**
Labels	STEAM	A. Soviet DH Technology B. Market-Based DH Systems	Scandinavian DH Technology	-----
Typical Components	- Steam pipes in concrete ducts - Often no condensate return - Steam traps - Compensators	- Pipes in concrete ducts - Large shell- and tube heat exchangers - Extensive substations - Heavy, material intensive components	- Prefabricated, pre-insulated pipes directly buried into the ground. - Compact substations using brazed plate heat exchangers (also with insulation) - Material lean components - Metering and monitoring	- Highly pre-insulated pipes - Low energy demands - **Smart Energy** (optimum interaction of energy source, distribution and consumption) - 2-way DH
Quality	Outdated technology	Low quality for the Soviet DH technology and high to medium quality for other systems	High quality	High quality & Smart
Current use	New York and Paris. Replacement in Hamburg and Munich.	Older parts of all early district heating systems	All replacements in CEE and former USSR countries and all extensions and new systems in China, Korea, Europe, USA and Canada	Benelux, Nordic countries, ….

Next Generation: Utilization of even lower temperature sources

Low Temperature DH networks <30-40°C (DH 5G?)

- Low temperature energy sources like geothermal water or waste heat
  - Low temperature for underfloor heating 30°C
  - Local booster heat pumps for hotwater 55°C

“neutral” temperature levels

- Geothermal energy at a level 15-20°C or even lower
- Local Heat pump solutions and local storage

H-DisNet Thermal Chemical Networks – Future technology

Thermal chemical network vs. traditional thermal network

Benefits:

- No thermal losses during transport
- No thermal insulation required = cheaper network
- Material lean components
- Storage possible, simpler network management
- Humidity control inclusive

Barriers:

- Corrosion-resistant components required
- Exchange of technology required (new technology for network, demand and supply side)
- Technology readiness

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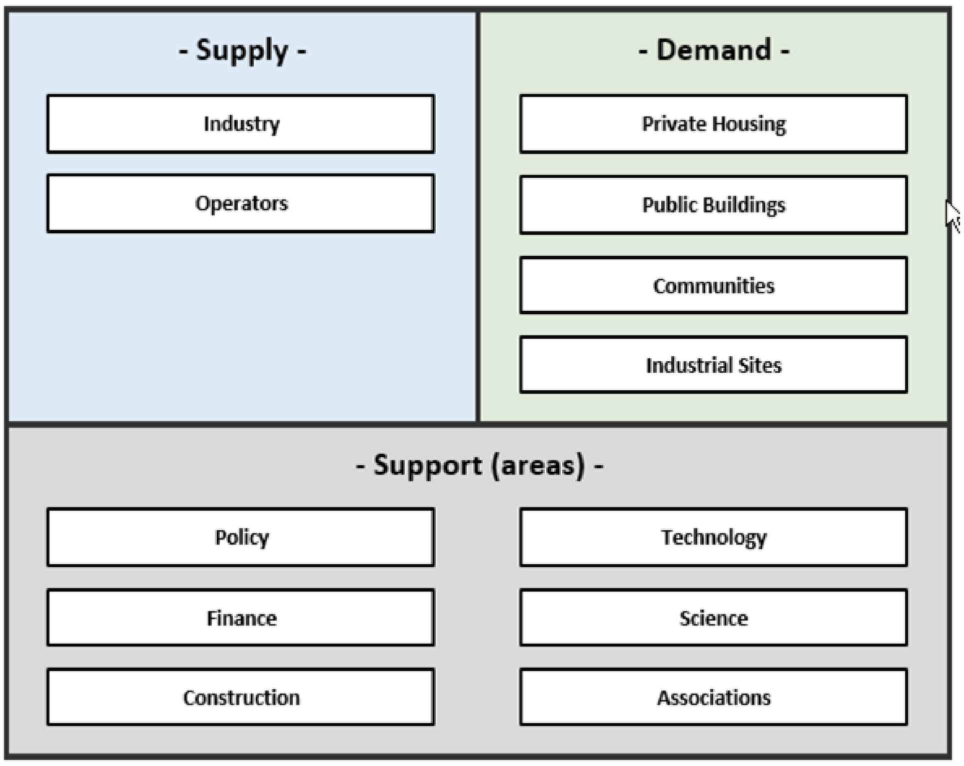
Stakeholder Mapping



- Supply -
- Industry
- Operators

- Demand -
- Private Housing
- Public Buildings
- Communities
- Industrial Sites

- Support (areas) -
- Policy
- Technology
- Finance
- Science
- Construction
- Associations

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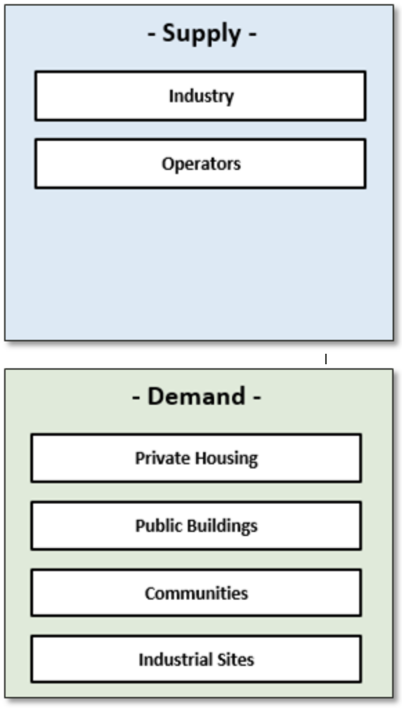
Supply- and demand-side perspectives



District heating networks

- Traditional, slow adaption of new technologies
- Focus on small-scale networks

Industry

- Interest exists, however low Technology Readiness Level is a key barrier
- Focus on collection of data and improvement of technology

Private Housing and Public Buildings

- Rising importance of climate control in buildings with no satisfying current solutions
- Main application should focus on humidity control
- Approach niche markets first. Think about smaller, cheaper solutions for mass market
- Development should be aligned with manufacturers of ventilation systems and heat pumps

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Wrap up

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Thank you for your attention! http://www.h-disnet.eu/

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