# Perspectives on implementing district heating in the built environment

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**Research Team Leader**

# Topics for today

- A short introduction on VTT Technical Research Centre of Finland
- District heating and cooling research; our scope, topics and ambitions
  - Integration of renewables & excess heat sources
  - Interaction with the surrounding energy system (i.e. sector-coupling)
  - Low-temperature distribution
- Project examples
  - IEA DHC Annex programme (XII, XIII, XIV)
  - INTERSTORES and the world’s largest thermal storage
  - TRANSCEND: Merging energy systems modelling and company-level economics

# Short introduction

## VTT Technical Research Centre of Finland

**VTT is a visionary research, development and innovation partner for companies and society, and one of the leading technical research organisations in Europe.**

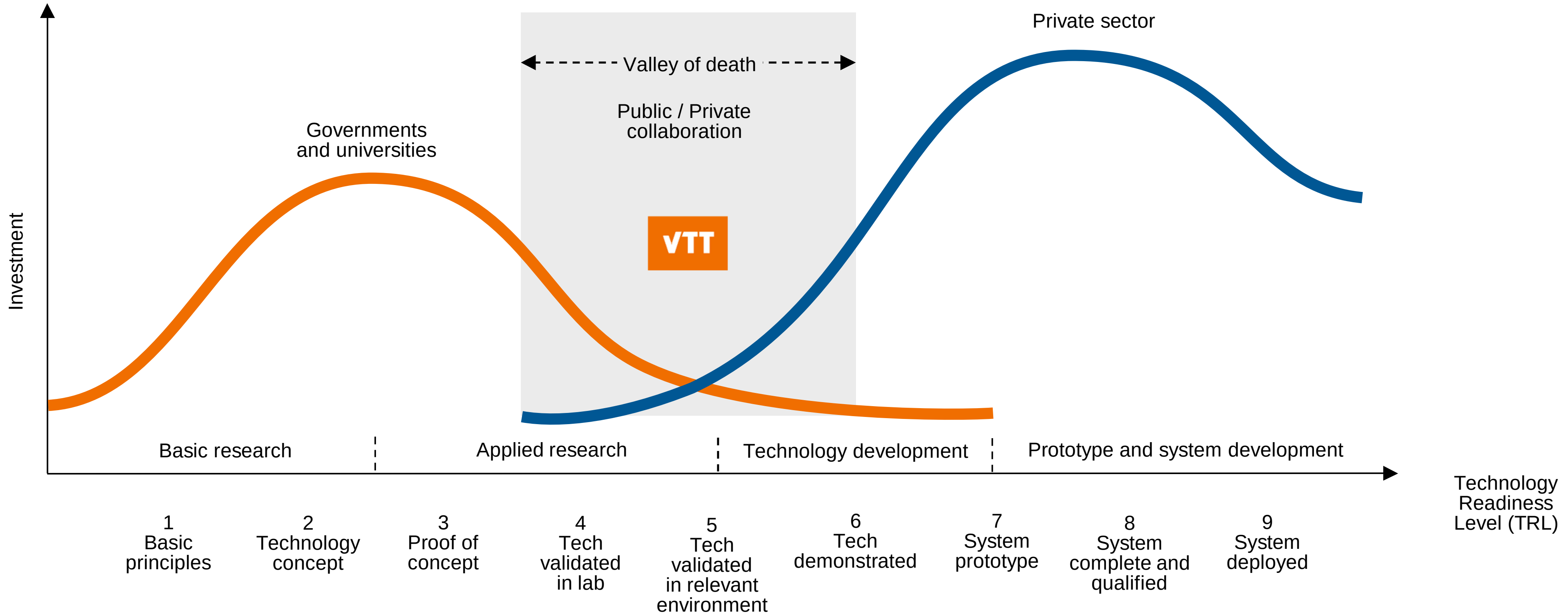
**We bring together people, business, science and technology, to solve the world's biggest challenges, creating sustainable growth, jobs and wellbeing.**

**We promise to always think beyond the obvious.**

| 2,355 | 1,135 | 284 M€ |
|---|---|---|
| employees | customers | operating income |

VTT Group (2023)

# We help our customers turn science into practical innovations



# Innovations emerge through cooperation in our partner network

**Public funding** ← **Customer** → **Commercial projects**

| SUOMEN AKATEMIA | EU | | BUSINESS FINLAND | VTT | Customer |
|---|---|---|---|---|---|
| **Academic research** | **EU funded projects** | **Other public research projects** | **Joint projects** | **Shared benefit projects** | **Direct customer agreement** |
| Progressive and high-quality scientific research, decision-making and training | Promote financial growth and create European jobs | Sector-specific funding, ministries, foundations, scholarships, investment funds | Accelerate the global growth of Finnish businesses | Overall investment divided among precommercial procurements | Company-specific R&D&I projects |
| **VTT** | **Research organisations + companies (EU)** | **Research organisations + companies (EU)** | **Enterprises + research organisations (FI)** | **VTT + 3+ companies** | **1+ companies + VTT** |

# We create solutions in three business areas

We help our customers and partners to build new business and find sustainable solutions to global challenges through science and technology. Our role is to promote the utilisation and commercialisation of research and technology in business and society.

Smart Energy and Built environment
**District heating and cooling**

**Carbon neutral solutions**

**Digital technologies**


**Sustainable products and materials**

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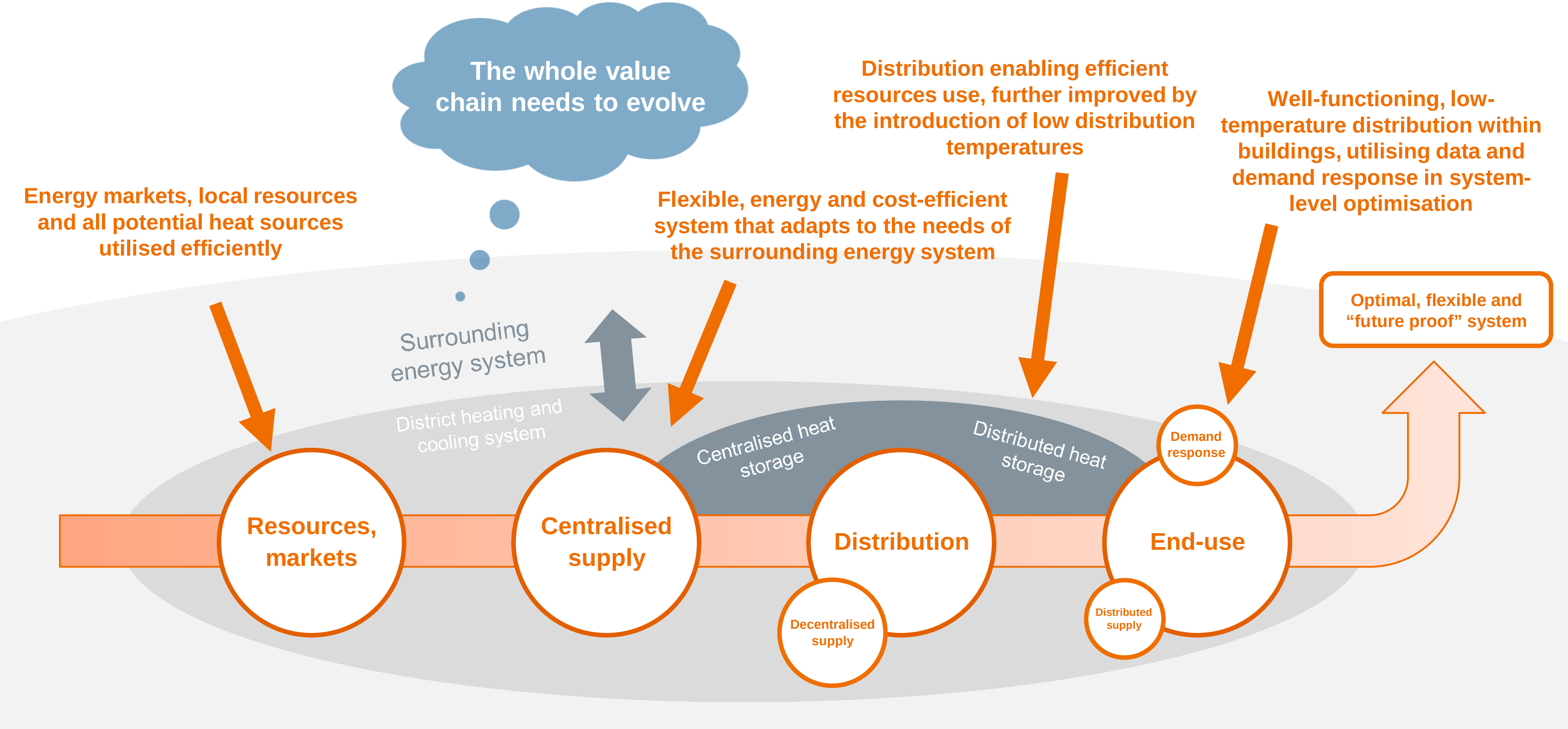
Our team

# District heating and cooling

# Developing DH throughout its value chain



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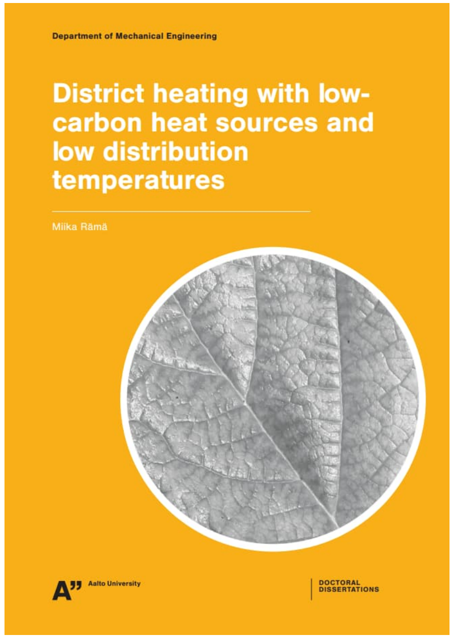
# Main research activities of our team

- Conceptual design on systemic solutions for developing DHC
- Tools for evaluating the benefits and costs of implementing low-temperature distribution
- Role of heating and cooling sector within the whole energy system
- Heat pumps and storage technologies
- Systematic method for mapping heat sources available within urban areas
- Stakeholder interaction, partnership networks and market structure

All topics and themes are very much interlinked and advanced in parallel

Quantitative support for decision-making is our core competence (simulation, optimisation-based research)

# Three (relatively) recent dissertations

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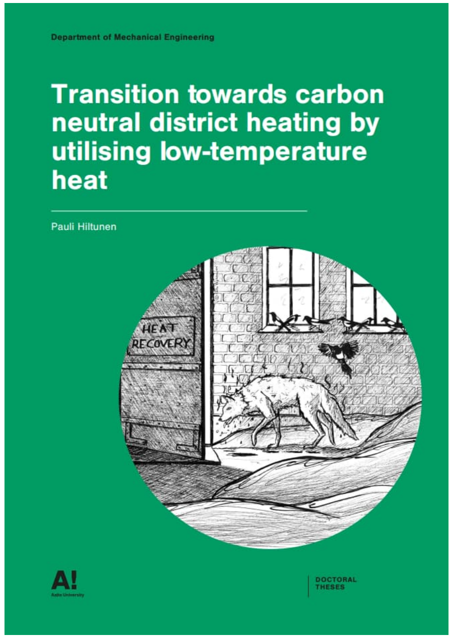


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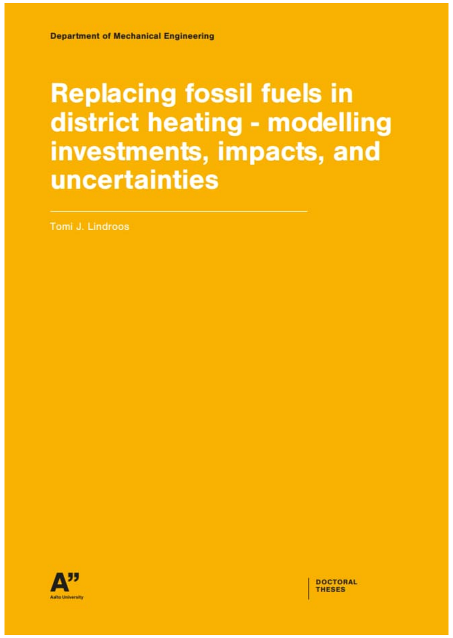


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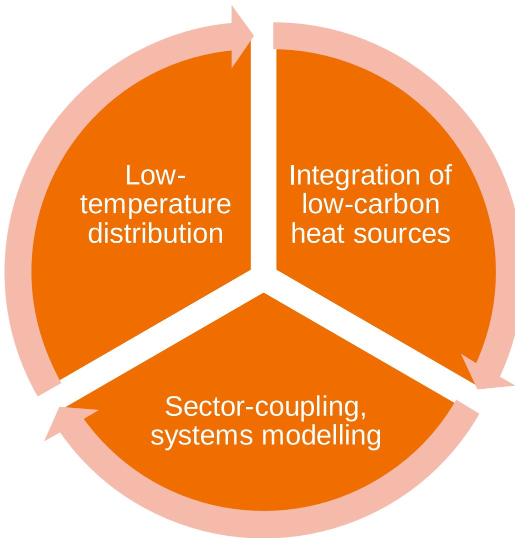
# Developing district heating systems

- Building specific measures (heat distribution systems, energy efficiency)
- Balancing costs and benefits
- Network simulation and management




- Available resources and existing markets
- Excess and natural heat source mapping
- Technology evaluation (e.g. biomass and the variety of heat pump-based solutions)
- Existing heat supply

- Impact and interaction with the surrounding energy system (energy systems modelling)
- Value for flexibility (e.g. thermal storages)

Aiming to a "moving target"? Many aspects of the system are in transition.

# Project examples

## IEA DHC Annex programme (XII, XIII, XIV)
## INTERSTORES (EU-funded)
## iBex TRASCEND (own-funded)

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# IEA District Heating and Cooling TCP

## Annex (XII, XIII, XIV) programme projects

- Annex XII (2017-2020): Stepwise transition strategy and impact assessment for future district heating systems (STEP)
- **Annex XIII (2020-2023): Optimized transition towards low-temperature and low-carbon DH systems (OPTiTRANS)**
- Annex XIV (2023-2026): Flexibility and district heating value chain (FlexVal)

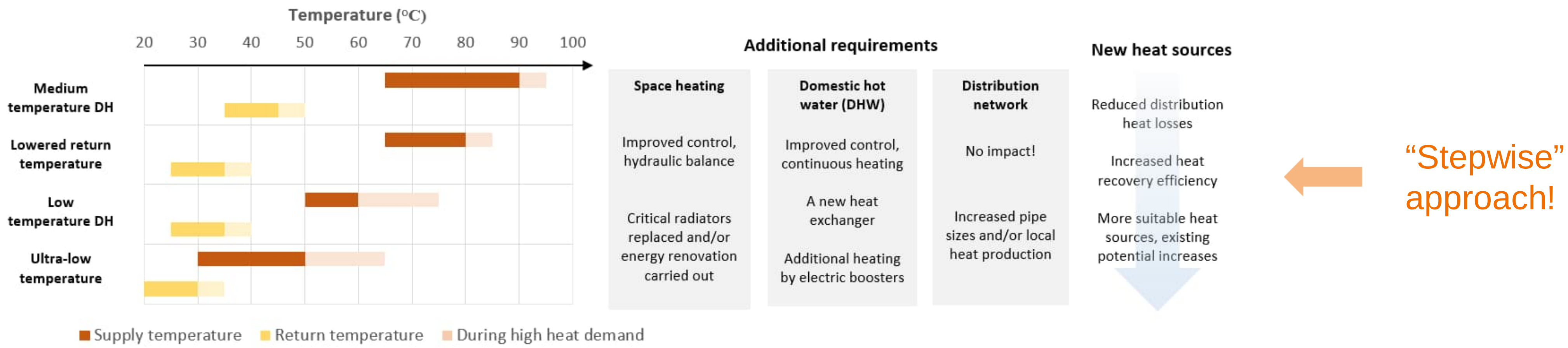
- All the work aims includes very different perspectives (main topic, methodology, part of the system, operational environment, etc.)
- Reports can be accessed and downloaded here:
  - https://www.iea-dhc.org/the-research/annexes/

Our partners:

# Annex XII: STEP

## Stepwise transition strategy and impact assessment for future district heating systems

- There is potential within the existing systems to enable lower distribution levels, and that there are mature options/measures to choose from
- Heat sources for 4GDH are there, but the potential is very system-specific
- The energy system impact of lower temperatures was evaluated (TIMES-VTT)



# Annex XIII: OPTiTRANS

## Optimized transition towards low-temperature and low-carbon DH systems

- Scenario-based long-term analysis in developing DH systems can be a powerful tool for decision-making *(TIMES –based approach)*
- Combining heat supply optimisation and network simulation necessary to assess benefits of LT transition *(methodological development, a case study)*
- Efficient and well-functioning building heating systems a cornerstone of improving the DH systems *(focus on building-level measures, substations)*
- Proper maintenance and control of heating systems in older buildings even with outdated equipment has a clear impact *(practical experiences in refurbishing an old office building, aiming for lower temperature levels)*

# Combining heat supply optimisation & network simulation

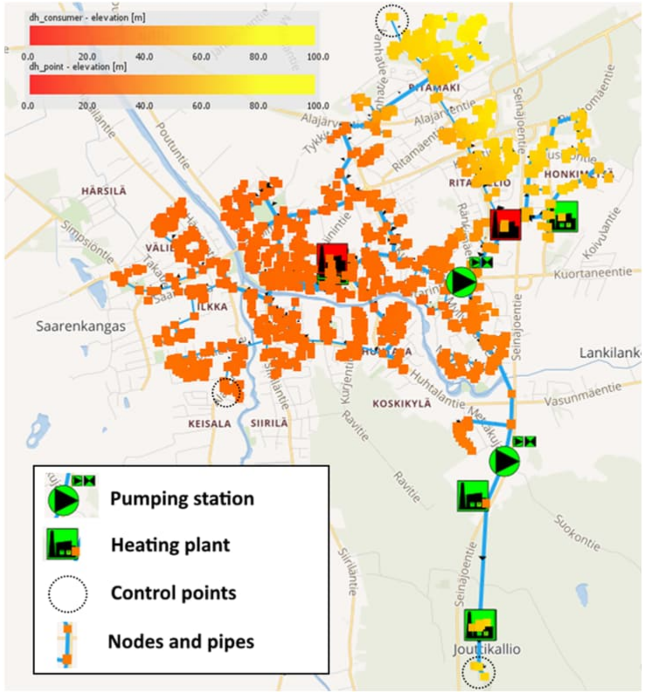
**Main objective:** to combine heat supply optimization and network simulation, an to carry out a DH system level case study on the impact of distribution temperatures and new decentralized heat supply based on utilisation of renewable/excess heat sources in an urban area.

**Motivation for the work:**

- Temperature level has an impact on the efficiency of heat supply (e.g. heat pumps, flue gas condensers) and managing a certain temperature level can represent a constraint for the heat supply of a specific unit
- Lower temperature levels can have an impact on the transmission capacity between different areas of the network

Lapua (Finland) DH system case study

- System divided into 21 areas
- Each area as a specified demand
- Transport capacity between areas limited (based on temperatures and pipe dimensions)
- Existing system (normal temperature) and low temperature configurations studied
    - Additional heat pump capacity included, except for the reference case representing the system as it is
    - Estimated low temperature setup (65/30 °C)
- Efficiencies of CHP unit, flue gas condenser and heat pumps tied to distribution temperature levels (based on results of the network simulation model)



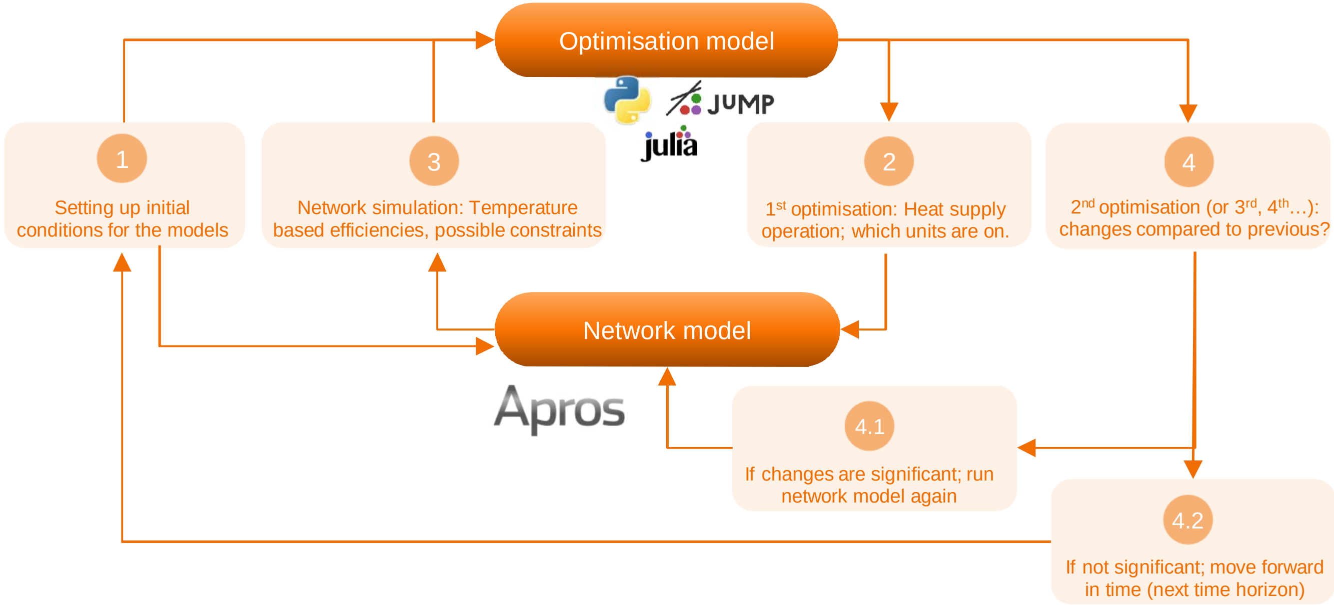

Key parameters describing the Lapua DH system.

| Key indicator | Value | Units | Capacity | Fuel |
|---|---|---|---|---|
| Heat demand | 70 GWh | Main CHP unit | 4 $MW_e$, 18+2 $MW_{th}$ | Biomass/peat |
| Peak demand | 30 MW | Sawmill | 6 MW | Biomass |
| Network length | 72 km | Industrial site | 1.5 MW | Biomass |
| Yearly heat losses | 15 % | Main boiler | 7 MW | Peat (not in use) |
| Heat demand density | 0.98 MWh/m | Backup boilers | 28.5 MW | Oil |

# Combining heat supply optimisation & network simulation

**Description of the model(s):**

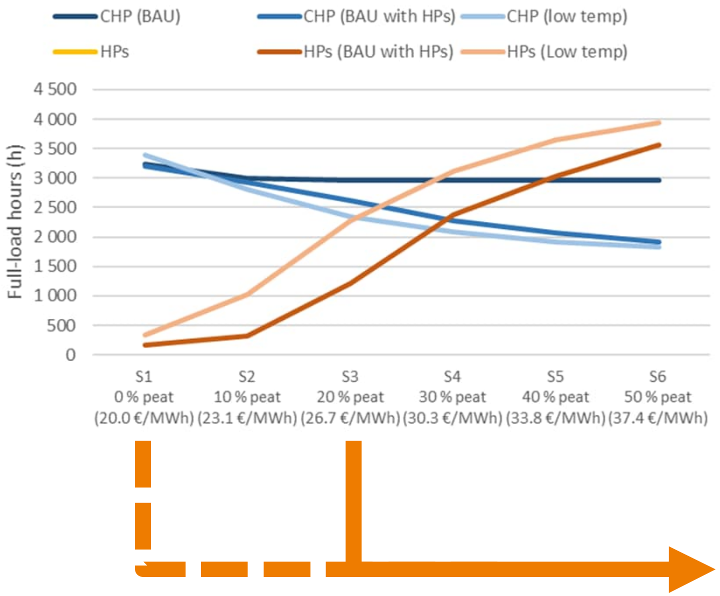
- The optimisation model implemented in the Julia programming language by using the JuMP modelling package and is run by Python
- The distribution network model implemented using Apros® modelling software with the District add-on. Apros District is a simulation modelling platform for dynamic investigation of district heating and cooling systems, with a comprehensive selection of predefined components.

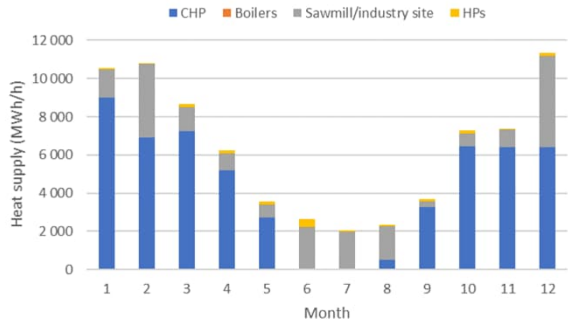


# Combining heat supply optimisation & network simulation

**Main results**

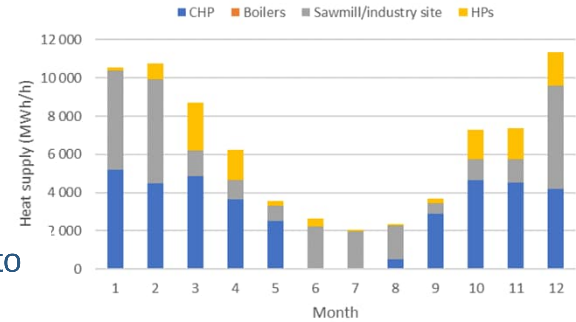
- Efforts to combine the models successful
- Main CHP unit and its flue gas condenser benefited greatly from the lower distribution temperature while the heat pumps were mainly used for maintaining the temperature levels on the outskirts of the network (resulting in minimal share in total heat supply)
- Results are highly sensitive to e.g. fuel price assumptions; a modest raise in price levels can result in significantly increased heat pump utilization




Impact of low increased fuel price (20 to 26.7 €/MWh)

Case studied: Low-temp (S1 → S3)

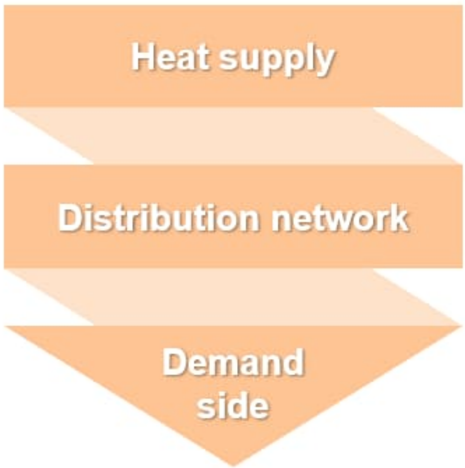



A more detailed look into especially the network simulation results indicated that there may be a need to add pressure management as a constraint for the optimization, and that (in the case system) there might be motivation to disconnected some areas from the main network and operate them independently.

# IEA DHC Annex XIV (2023-2026)

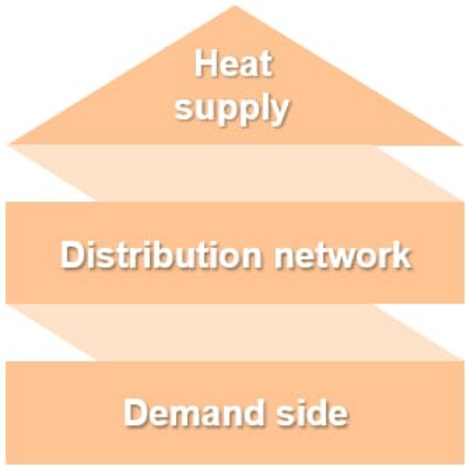
## Flexibility and DH value chain (FlexVal) – advanced analysis & compatible pricing

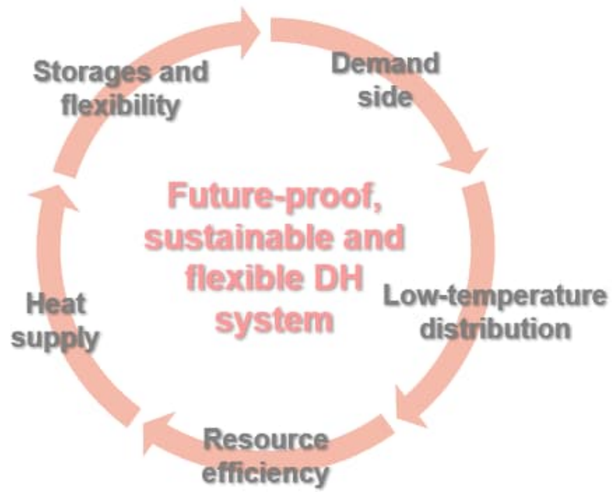
- The objective is to study flexibility both from operation and system development perspective in different time horizons in context of future 4GDH systems




**Top-down approach:** The conventional DH industry control/operation of the systems and planning the investments heat supply.

**Bottom-up approach:** Prioritizing improved operation on the demand side in planning the investments in low-carbon heat supply.

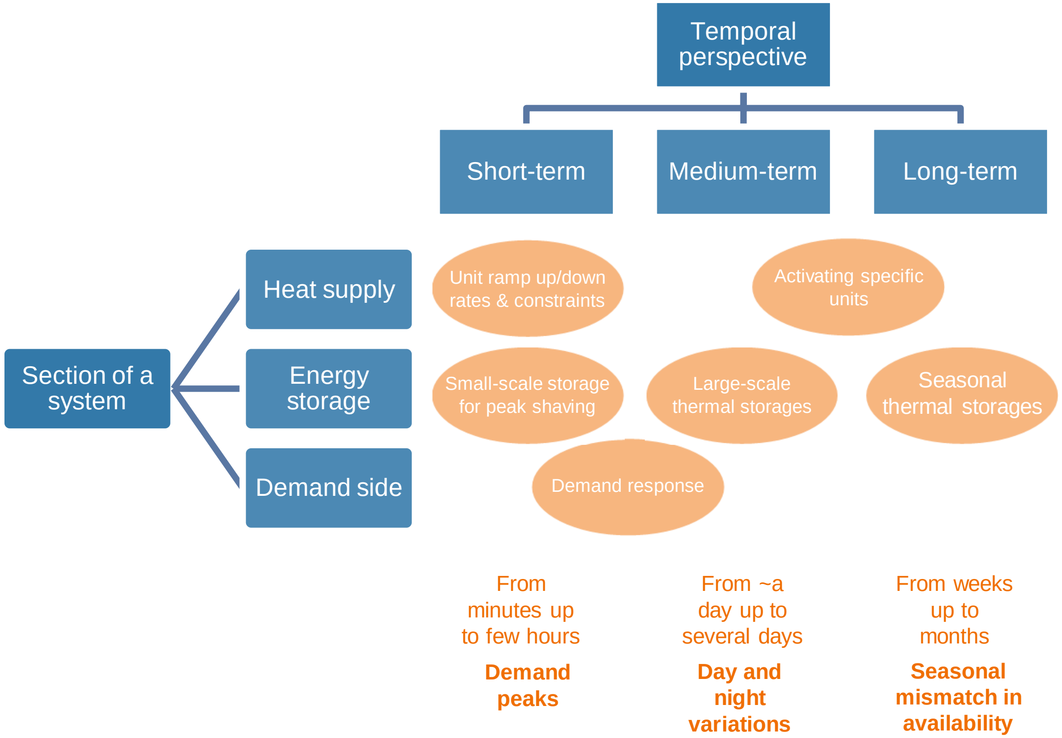



**Systemic approach:** Combining the bottom-up and top-down principles in long-term planning suited to a specific DH system and changes in the surrounding energy system.

# Mapping measures providing flexibility

**A systemic ability to control the heat supply to accommodate the heat demand in short-, medium- and long-term**




**Examples of the measures:**

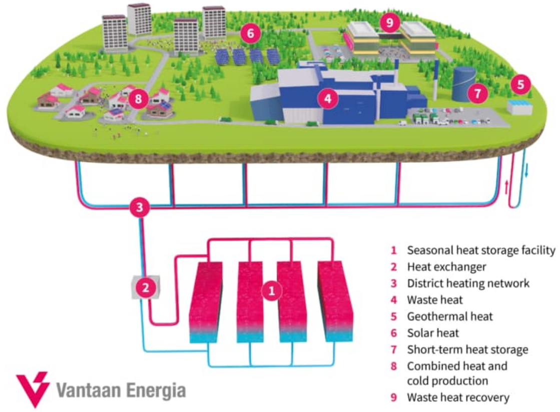
- Thermal storages (sensible heat)
- Heat pumps
- Electric boilers
- DSM measures for heating
- Flexible CHP design

- Low-temperature distribution to increase the feasibility of the measures?

# INTESTORES

## International Innovation Network for the Development of Cost- and Environmentally Efficient Seasonal Thermal Energy Storages

- An EU –funded project on large-scale seasonal thermal storages
- VTT focusing on technical design, materials and energy system integration (the DH system in context of the Nordic energy system) and on evaluation of the market potential of thermal storages in Europe
- Demonstration site is the 90 GWh storage project by Vantaan Energia (DH company)
- [Varanto - The World's Largest Cavern Thermal Energy Storage | Vantaan Energia]




INTER STORES

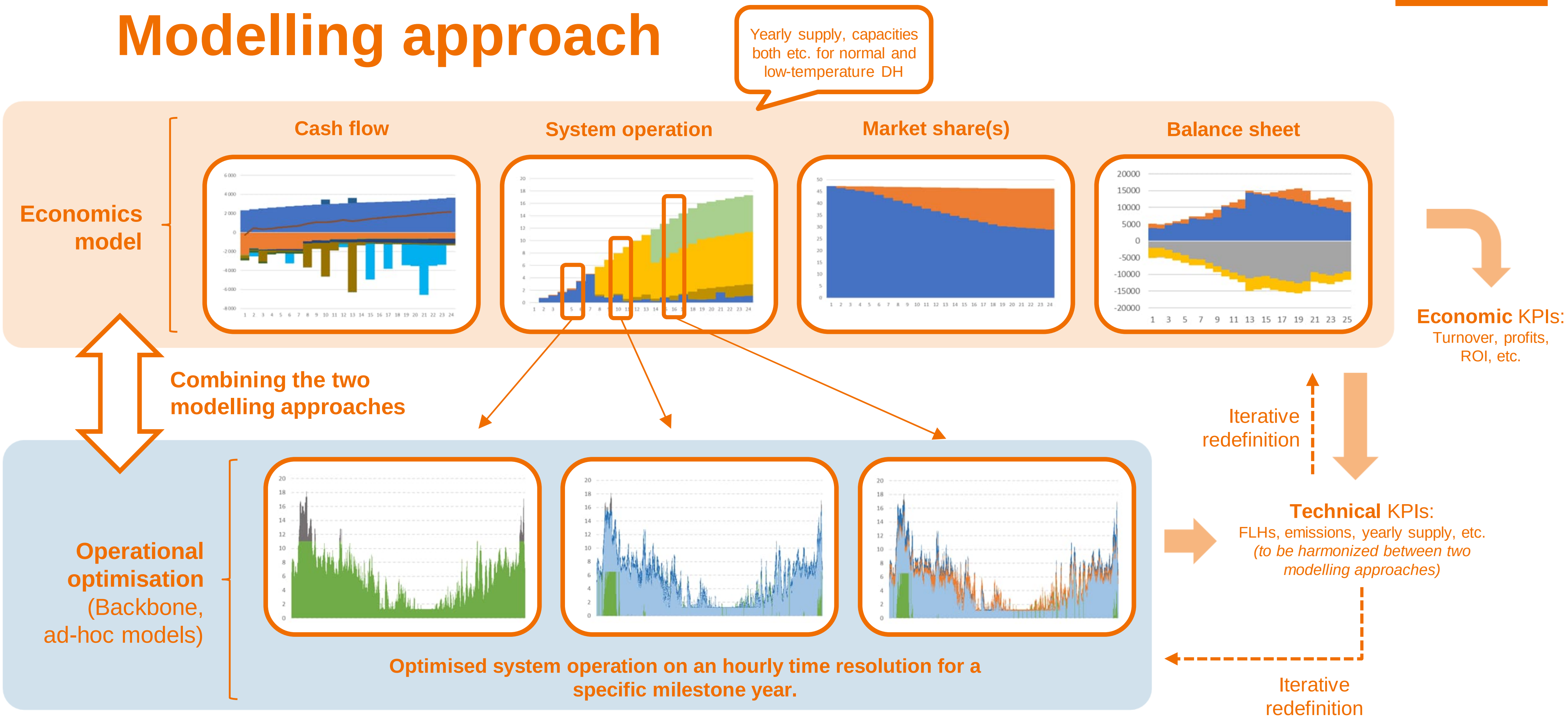
https://interstores.eu/

# VTT's iBex program and TRANSCEND

## Internal project on systemic challenges related to energy

- Part of a larger, VTT-level research programme that focuses on finding systemic solutions related to energy, materials and food
  - https://www.vttresearch.com/en/vtts-learning-lab-where-innovation-meets-complexity
- TRANSCEND builds upon considerable modelling expertise with a new perspective to support the practical implementation of the energy transition (within the heating sector)
- Concrete outcome is a modelling approach combining:
  - an energy system modelling based ”traditional” techno-economic assessment
  - a realistic, company-level economic perspective
- Evaluation of the development pathways with very realistic constraints AND an detailed view on how a specific system operates now and in the future

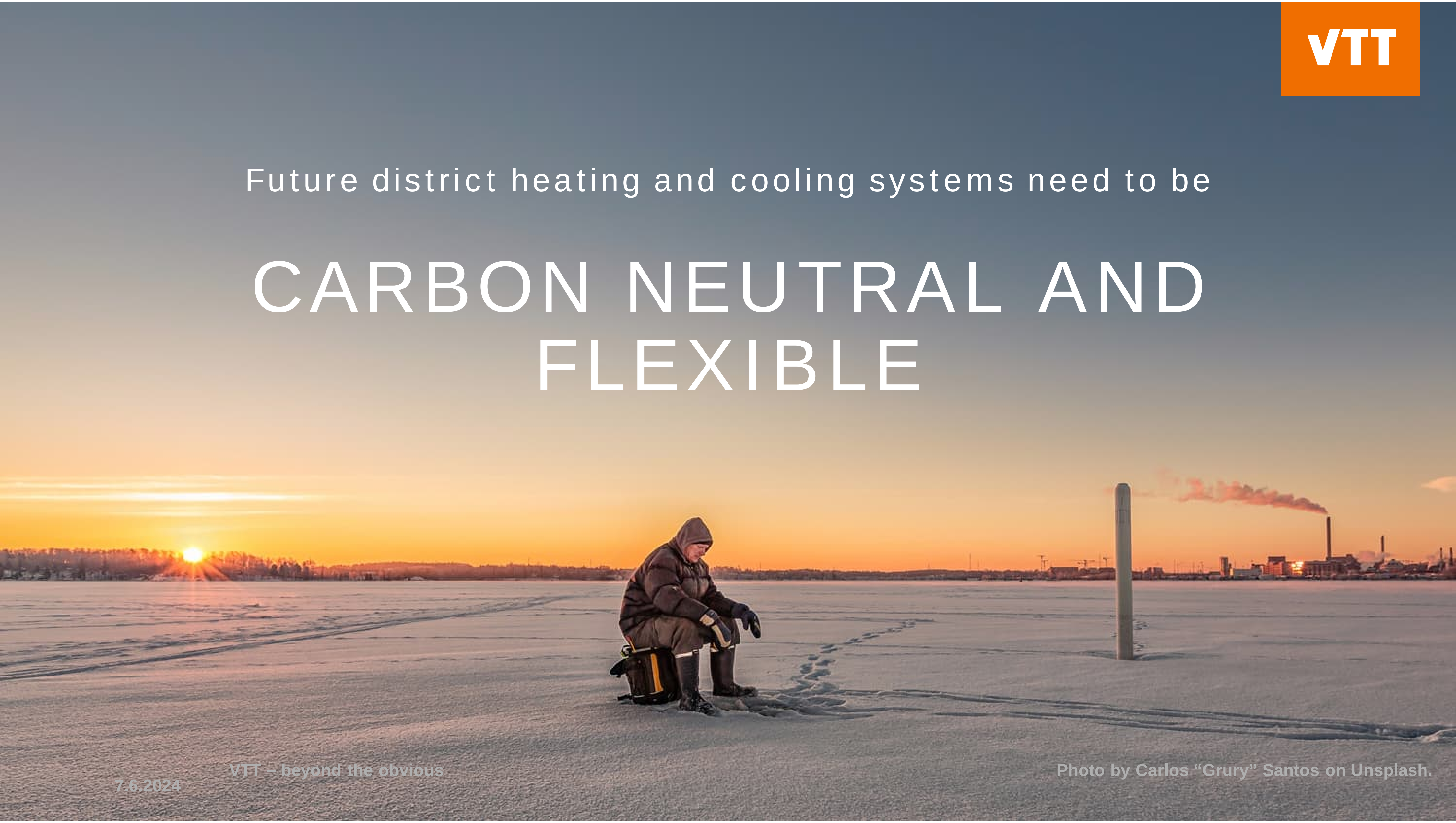
# Modelling approach



# Summarising thoughts on implementing DHC

# Summary

- Whole value chain of DHC needs to be considered, including the impact and interactions with the surrounding energy system (“a moving target”)
- Systems can potentially become more distributed, but the core benefits of centralized solution remain
- Low-temperature distribution makes the system more efficient, and more importantly, improves the feasibility of renewable and excess heat
- Buildings are in a key role, it is not (only) about the choices in heat supply!
- Choices and solutions very system-specific, the operation environment plays a crucial role (resources, markets, regulation, existing building stock, etc.)
- Shifting focus from technical design to facilitating the actual implementation? (stakeholder involvement and roles)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Future district heating and cooling systems need to be
CARBON NEUTRAL AND FLEXIBLE
VTT – beyond the obvious
7.6.2024
Photo by Carlos “Grury” Santos on Unsplash.

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# beyond

## the obvious

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