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FLEXIBLE DISTRICT HEATING NETWORK MODEL DEVELOPMENT FOR MASS FLOW, PRESSURE AND HEAT LOSS PREDICTION

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Agenda

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- Challenges
- DH Model:
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  - Current state
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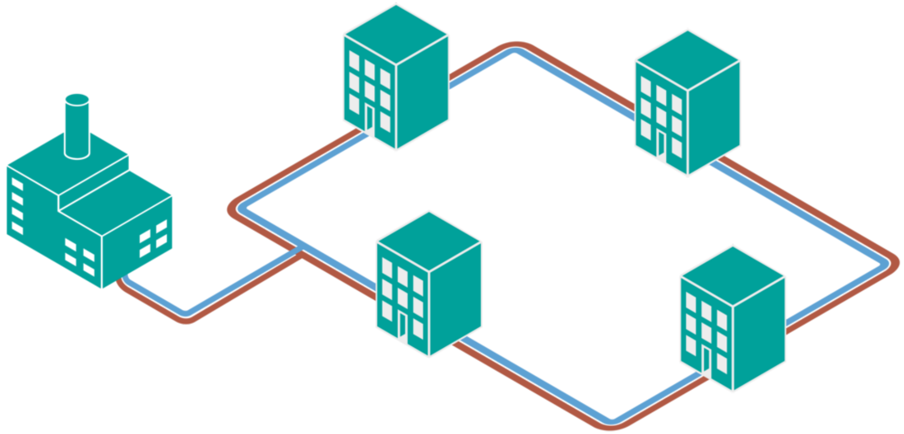
  - Practical example
  - Validation
- Conclusions
- Future work



Objective

- Reach a future **renewable** non-fossil heat supply as part of the implementation of overall sustainable energy systems.
- The present generation of **district heating** and **cooling** technologies have to be developed further into a new generation.

4TH Generation of District Heating

Challenges

- **Increasing urbanization** leads to urban densification and dispersion:
  - Structure of heat production changes from centralized to **decentralized** into smaller and more geographically distributed plants.
- Ability to supply **low-temperature** district heating for space heating and domestic hot water (DHW):
  - More energy efficient buildings (zero emission or plus energy houses).
  - Ability to distribute heat in networks with low grid losses.
- Ability to **recycle heat** from low-temperature sources and integrate **renewable** heat sources such as solar and geothermal heat.
- Increasing need for mobilizing **power balancing services** utilizing district heating systems.

Smart-grid → Balance Supply and Demand

DH Model: Requirements

- Software: **Matlab**
- **Flexible** and easy to add: topology, thermal loads and units.
- Able to **dynamically predict**: temperature, pressure mass flow, time-delay
- Able to be integrated with **electrical systems** and various hybrid assets e.g. Heat Pumps, electric boilers, etc.
- **Validated** against dedicated tools: experimental data.
- Able to run both long **off-line** but also **Real-Time simulations.**

DH Model: Current State

- One supply/return pipe is considered between two nodes
- Suitable for **time-domain simulations** during a steady state (time delay is not perceived)
- Currently limited to **tree topologies** but no limitation in the number of nodes
- Able to **dynamically predict**:
  - Temperature propagation (losses) between consumption nodes
  - Pressure losses
  - Total mass flow
  - Mass flow at each consumption

DH Model: Calculations

INPUTS

Topology Matrix

$$\begin{bmatrix} 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & -1 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

RUN

<u>Hydraulic Model</u>
Steady state approach

Pseudo-Dynamic Approach

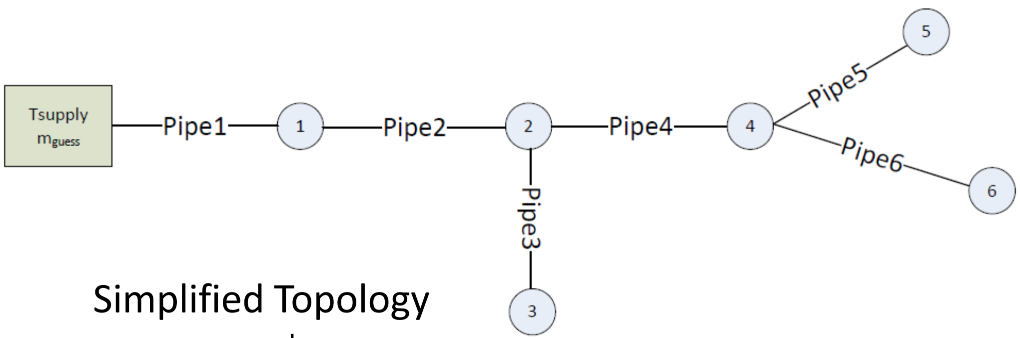
<u>Thermal Model</u>
Dynamic approach→ FEM

**Both for supply and return pipes*

DH Model: Inputs

Pipe Characteristics	Length of the pipes from node to node	L_n
	Internal Diameter (each pipe)	D_1
	External Diameter (each pipe)	D_2
	Insulation Diameter (each pipe)	D_3
	Depth from the ground to the centre of the pipe	H
	Density, heat capacity and conductivity of the insulation	ρ_{ins}, cp_{ins}, k_{ins}
	Conductivity of the ground	k_g
Time dependent parameters	Nodes consumption (changes with time)	Q_n
	Supply temperature (changes with time)	Ts
	Return temperature from the nodes (changes with time)	Tr
	Soil temperature (changes with time)	Tg
	Minimum mass flow in the pipes	m_{min}

DH Model: Practical Example



Simplified Topology

Matrix

Pipe

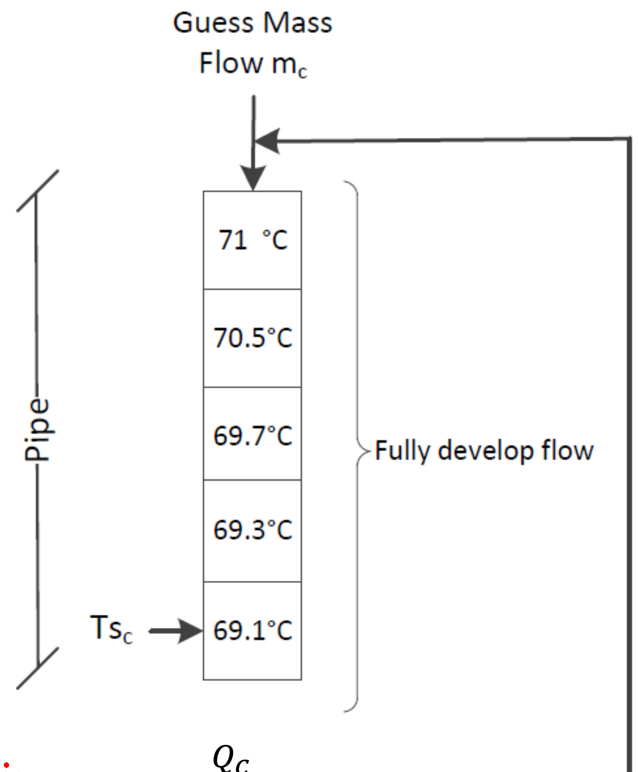
Node

$$\begin{bmatrix} 1 & -1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & -1 & -1 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

DH Model: Practical Example

During the calculation, there are 2 iterative process happening at the same time:

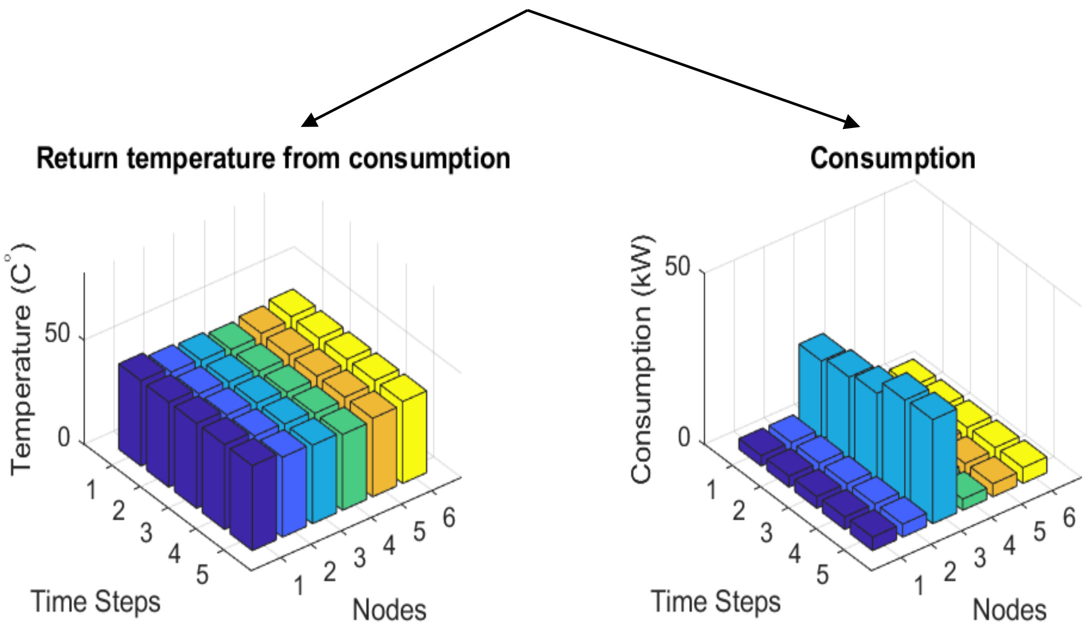
1. To assure fully develop flow
2. To assure final mass flow



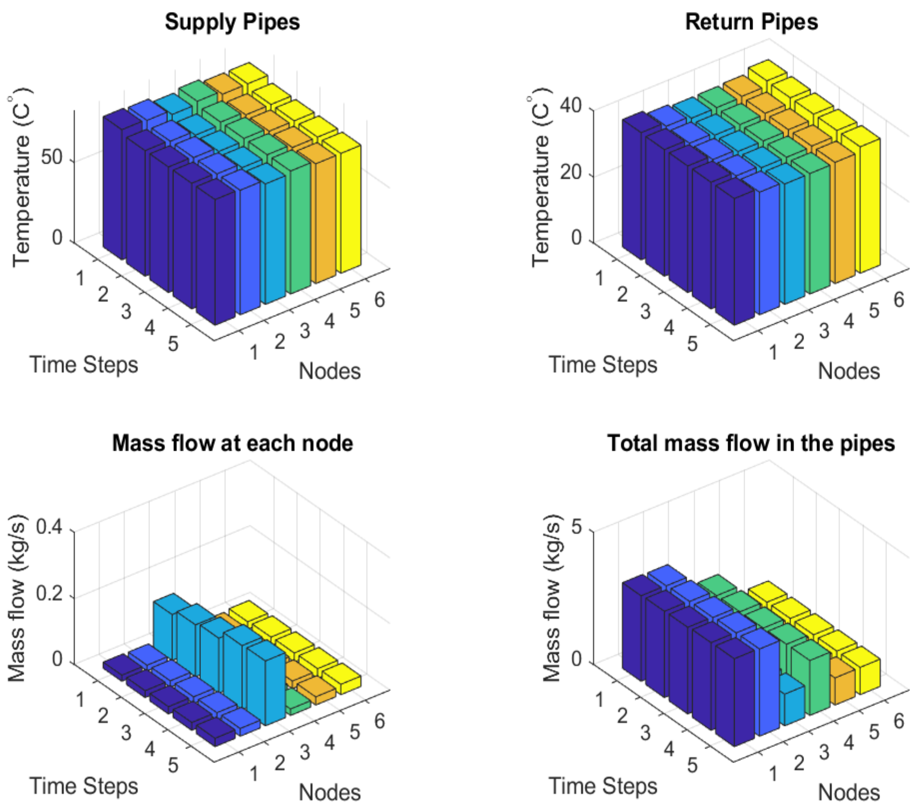
$$\dot{m}_c = \frac{Q_c}{cp_w \cdot (Ts_c - Tr_c)}$$

DH Model: Practical Example

Time dependent Inputs:

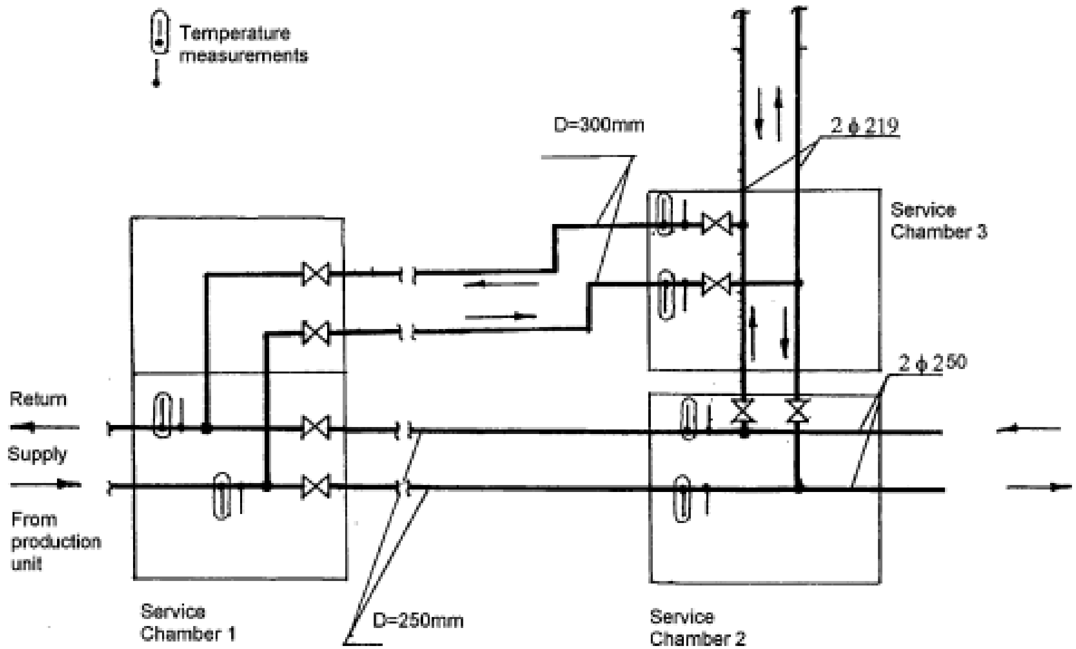


DH Model: Practical Example



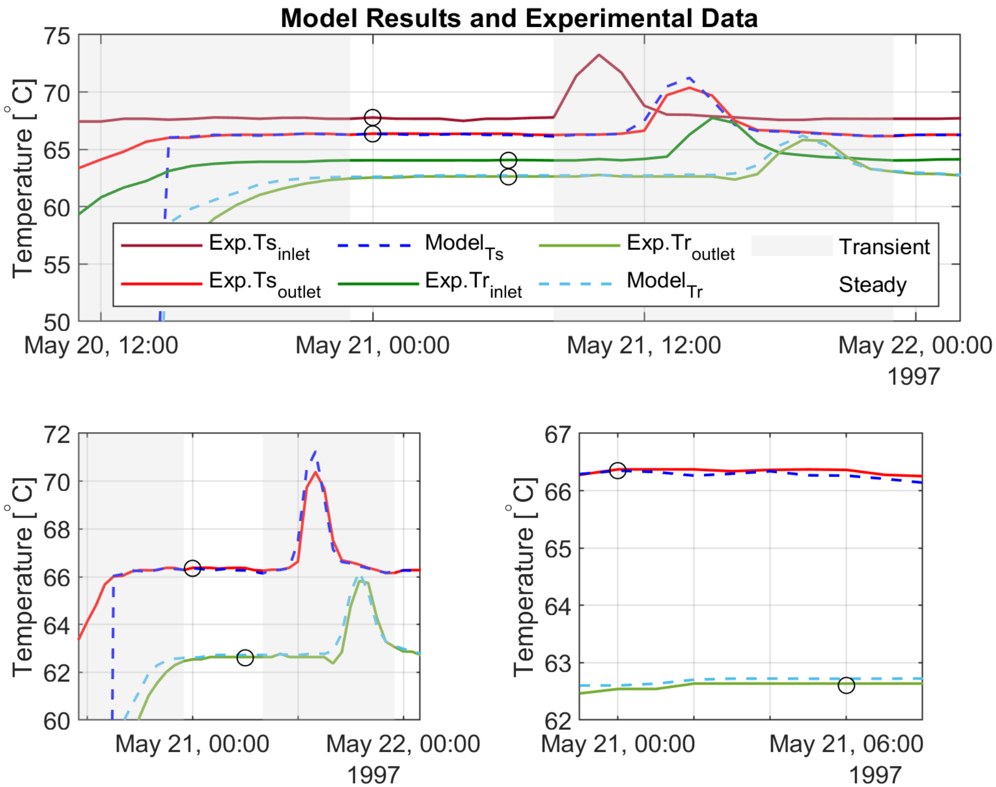
DH Model: Validation

'Experiments on Heat Losses from District Heating Pipelines, *Energetika*, vol 2, pages 35-40'



https://www.lmaleidykla.lt/ojs/index.php/energetika/index

DH Model: Validation



Deviation< 5%

DH Model: Conclusions

- A simple tool for DH parameter prediction
- From simple to complex
- Is developed in Matlab environment
- It is flexible to read different topologies
- It can be used for:
  - Studying interactions with electrical distribution grids (Smart-grid)
  - Assessment of system level control and optimization
  - Real-Time simulations with industrial controllers In-the-Loop

DH Model: Future Work

- Implementation in Opal-RT tools for Real-Time system integration studies (in progress)
- Inclusion of pressure differences due to terrain height
- Implementation of dedicated district heating elements such as bypass valves, heat exchangers, other energy generation substations…
- Validation against a real small DH network

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