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The role and potential of distributed thermal energy storage systems for active control of district heating networks

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4DH
4th Generation District Heating
Technologies and Systems

Contents

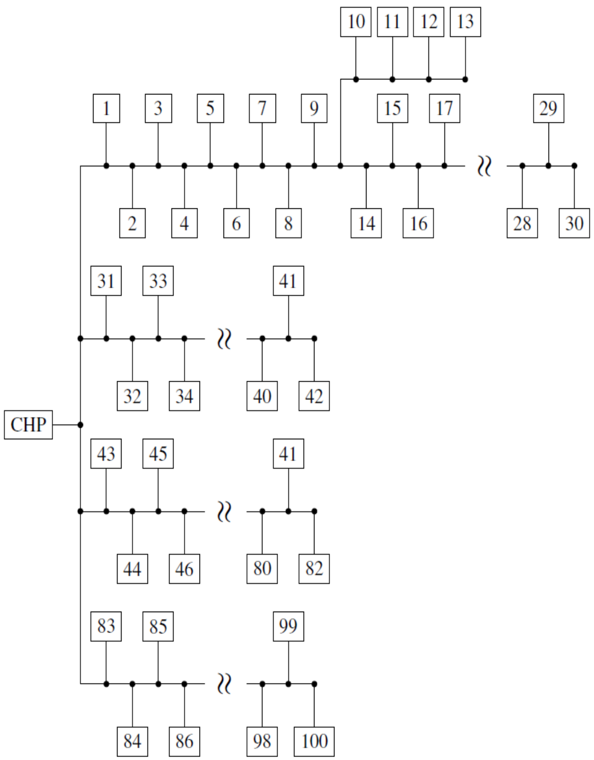
- Thermal energy storage systems in DH networks
- Results of lab test on distributed energy storage
- Conclusions and future research work

Thermal energy storage in DH networks

- Short and long term energy storage systems
  - Sensible, latent, sorption, thermochemical storage
- Short-term TES in district heating systems:
  - hot water storage tanks
  - phase change materials (PCM)
  - varying temperature in the DH network
  - utilizing building thermal inertia
- Peak heat load reduction measures
  - Demand side measures
  - Tariff model measures
  - Supply side measures

Research question

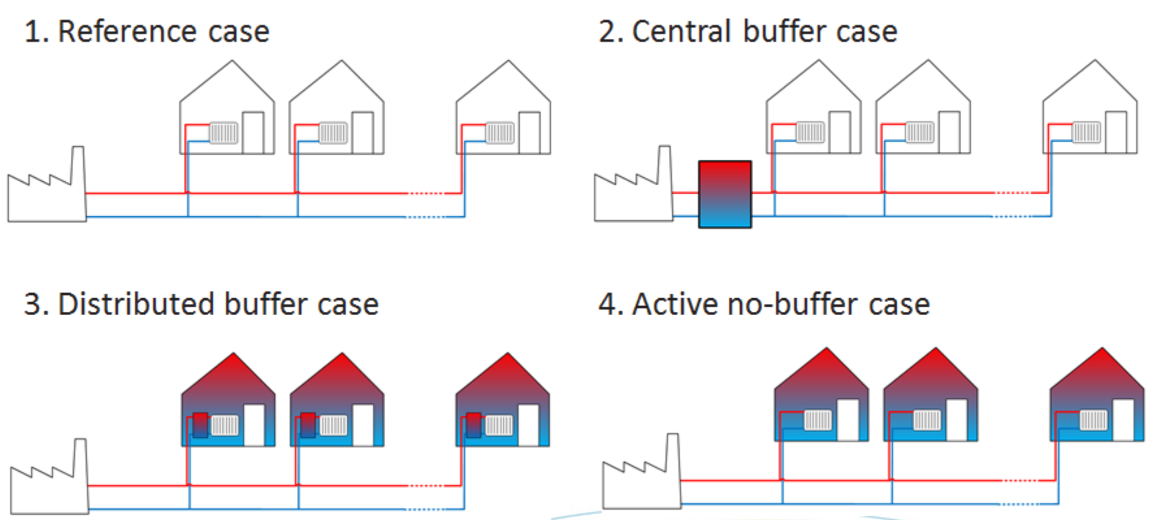
- The situation:
  - DH network, connecting 100 houses
  - Heat supply by a gas fired CHP, selling electricity (gas boiler for peaks)
- Combination of smart control of the system and integration of storage.
- Which system performs best, i.e. when is the profit of the CHP the highest?
  - No storage
  - Central buffer tank next to the CHP
  - Distributed buffers in the individual houses
  - Thermal mass of the individual houses



Methodology -1

- Tested configurations:

Configuration	Storage tank type?	Smart CHP control?	Smart demand control?
1. Reference	No	No	No
2. SC, central	Central	Yes	No
3. SC, distributed	Distributed	Yes	Yes
4. SC, no buffer	No	Yes	Yes



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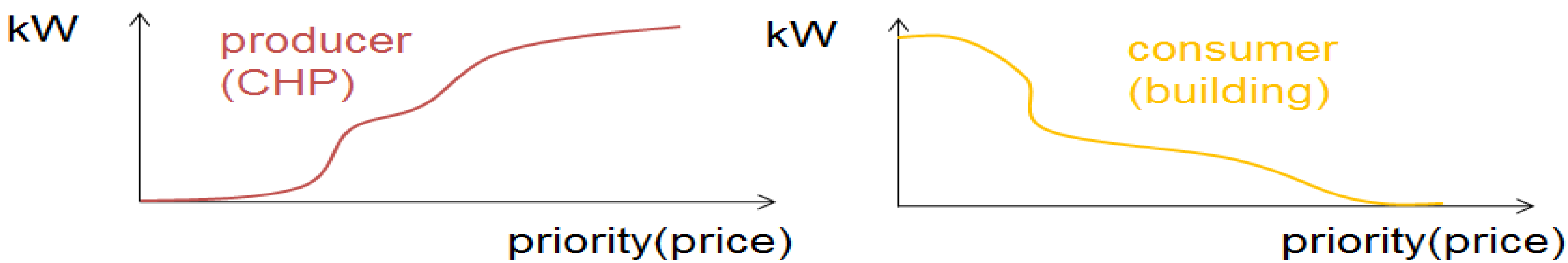
Methodology - 2

- Necessary components of the simulation
  - District heating pipe model: pseudo-dynamic
    - Flow rate calculation
    - Temperature propagation
  - Building model
    - Lumped capacitance model (3C,5R)
  - Buffer tank model
    - Multinode model
  - CHP and gas boiler model
    - Quasi-static black-box models

Smart control system

- Market-based multi-agent system (MAS)
  - The buildings and the CHP are represented by software agents
  - Every timestep, each agent communicates the supply or demand needs of the device to the market by means of a bid function
  - Then an equilibrium is calculated for priority and power, and communicated to the agents
  - The agents switch the CHP and opens the DH valves



Hardware in the loop simulation

- Lab tests:
  - 96 buildings simulated, 4 present in the lab
  - To validate the simulation models
  - Determination of state of charge storage vessels
  - To check the practical feasibilty

Results – 1 - operational behaviour DHN

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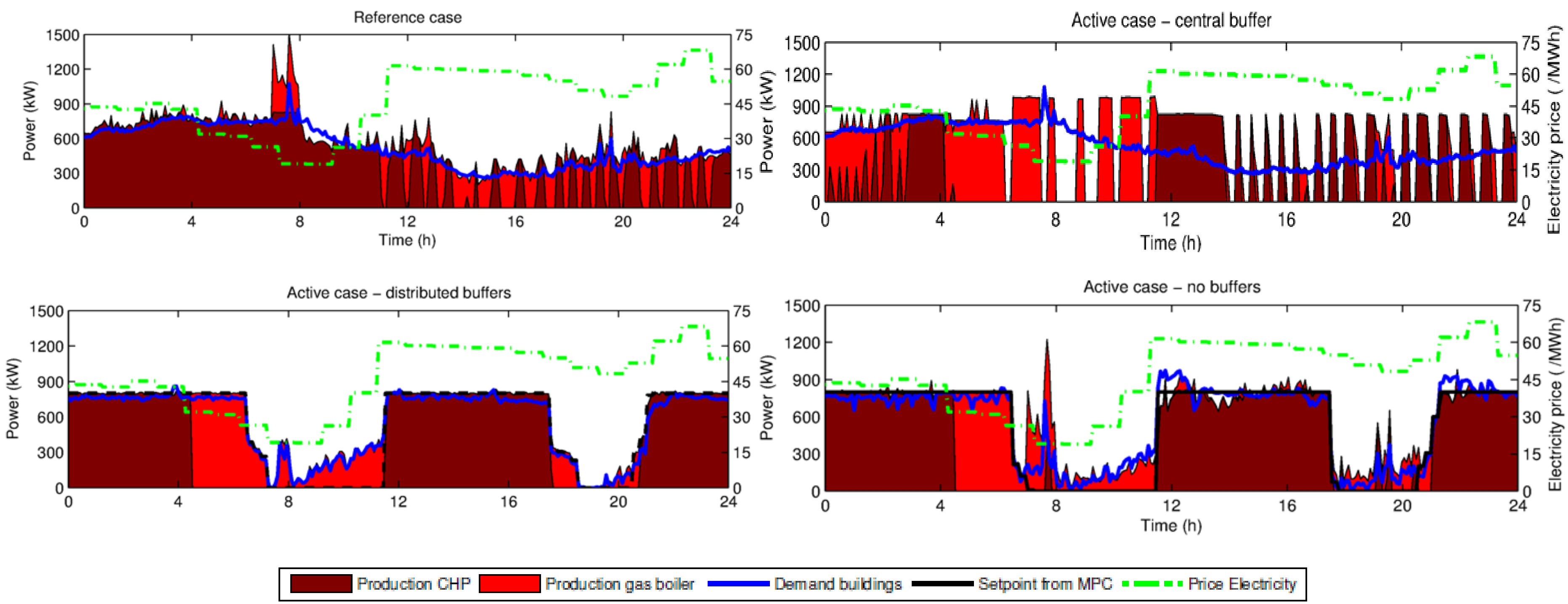

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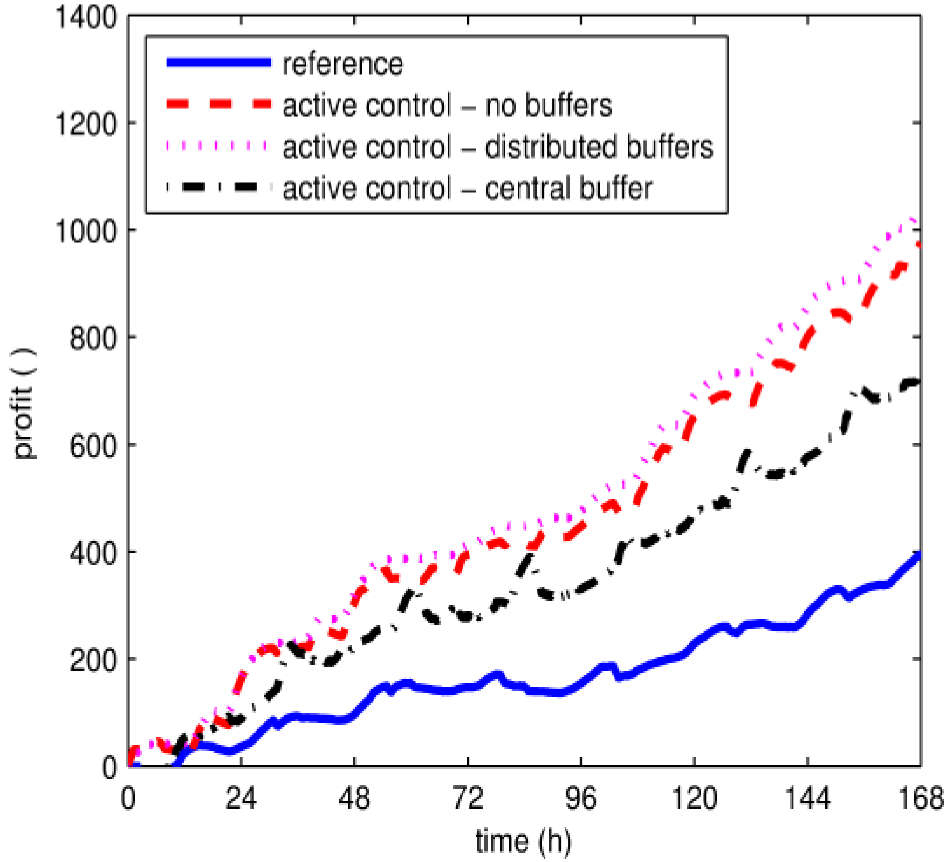
Results – 2 - energy consumption

configuration	energy consumed		energy produced total		energy produced CHP		energy produced gas boiler	
no buffers, regular control (reference)	70649		79447		58714		20651	
no buffers, active control	73562	(+4.1%)	79600	(+1.9%)	52100	(−11.3%)	27985	(+35.5%)
distributed buffers, active control	73594	(+4.2%)	80965	(−0.2%)	59177	(+0.8%)	21900	(+6.0%)
central buffer, active control	70577	(−0.1%)	78741	(−0.9%)	43750	(−25.6%)	35804	(+73.4%)

- Energy consumption higher for DSM cases: more switches DH valves
- Energy production comparable: a bit higher network efficiencies for DSM cases
- Large difference in CHP and gas boiler production: resulting from the choices of the MAS control system

Results – 3 - costs and revenues

- ‘Operational profit’ = revenues of heat + electricity sales – costs for gas
- Smart control: increase of the profit
- ‘Distributed’ and ‘no-buffer’ case perform better than central buffer case: activation of thermal mass buildings
- Hardly any difference between distributed case and no-buffer case: thermal mass of the buildings is way larger than that of the buffers (4165 kWh/K v.s. 39.5 kWh/K)



Assumptions:

- gas price: € 39.9/MWh (mean 2013 in Belgium for small industrial customers)
- heat price: € 54.5/MWh (mean natural gas price for reidential customers in 2013 in Belgium)

FP7 E-hub project – overview

- Results achieved in the framework of the FP7 E-hub project (2010 -2014)
- Energy-Hub for residential and commercial districts
  - Ambition: covering **up to 100%** of the energy demand **on district level** with **renewable energy** by overcoming it's fluctuating character through:
    - conversion and storage of energy
    - load shifting
  - All types of energy flow are considered: **heating and cooling, electricity**… Connecting **houses** but also **EV, commercial buildings** or **industry**
  - **e-hub** = *"a physical cross point, similar to an energy station, in which energy and information streams are interconnected, and where the different forms of energy can be converted into each other and/or can be stored"*
- Objective:
  - **develop** the **e-hub** as a **system**,
  - to **develop technologies** that are necessary to realize the system,
  - to **develop business models** in order to overcome institutional and financial barriers,
  - and to **demonstrate an e-hub** in feasibility cases.
- More details: www.e-hub.org

Conclusions and future work

- A controller framework was developed to compare the performance of central and distributed storage in a smart district heating grid.
- The controller is able to shift the demand and the production of heat.
- As a result, the controller is able to increase the profit of a CHP.
- The configuration with distributed buffers performs best, however the difference with the configuration without buffers is very small.
- Using building thermal mass as short-term TES in DH networks :
  - great potential as a cost-effective method for storing heat but …
  - important is the control of such storage , the type of business model with the DH supplier and the consumers acceptance (indoor temperature) .
- Future work:
  - Need for an integrated control of the DH network and the installations.
  - Impact of building thermal mass on system efficiency.
  - Extension to larger non-residential buildings and cooling applications.
- There is potential for thermal energy storage systems in DH network (control!).

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