

2<sup>nd</sup> International Conference on Smart Energy Systems and 4th Generation District Heating  
Aalborg, 27-28 September 2016

# Marginal price control of buildings utilised as thermal energy storage

Jens Carlsson



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



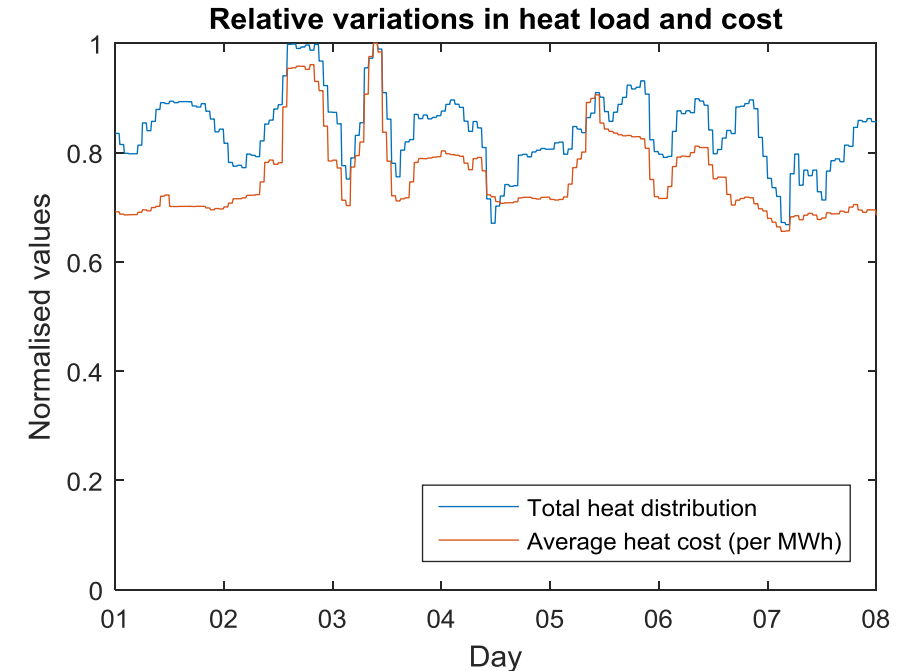
**AALBORG UNIVERSITY**  
DENMARK

**4DH**

4th Generation District Heating  
Technologies and Systems

# Background

- Heat load variations reduce energy mix quality
  - Solution: Load shifting by use of thermal storage
- Buildings as thermal storage alternative
  - Feasible without reducing thermal comfort
  - Requires no new constructions
  - Can be evenly distributed through a network
- New considerations
  - What incentives to give end-users?
  - Implemented by supplier or users?
  - What control metrics should be used?

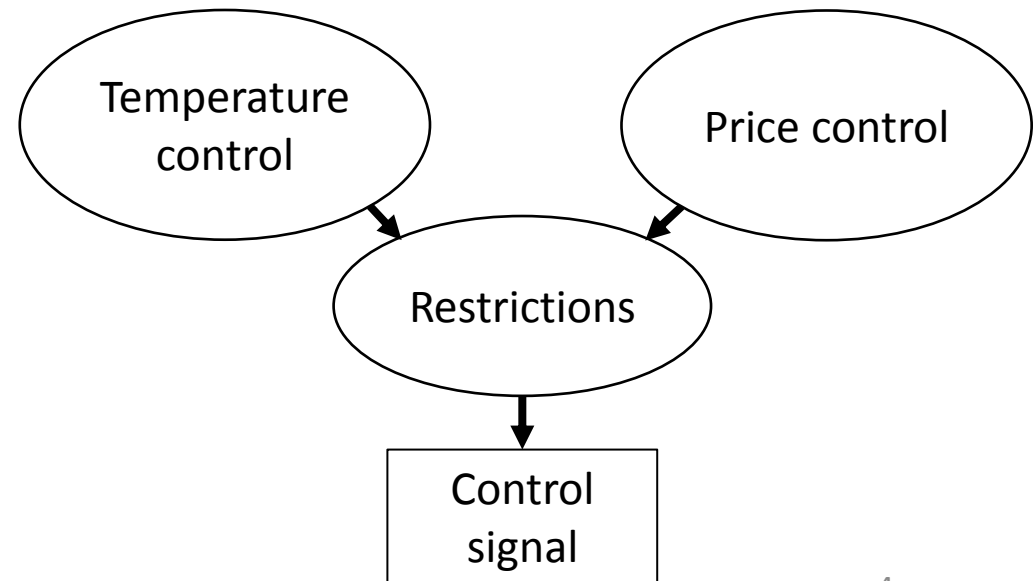
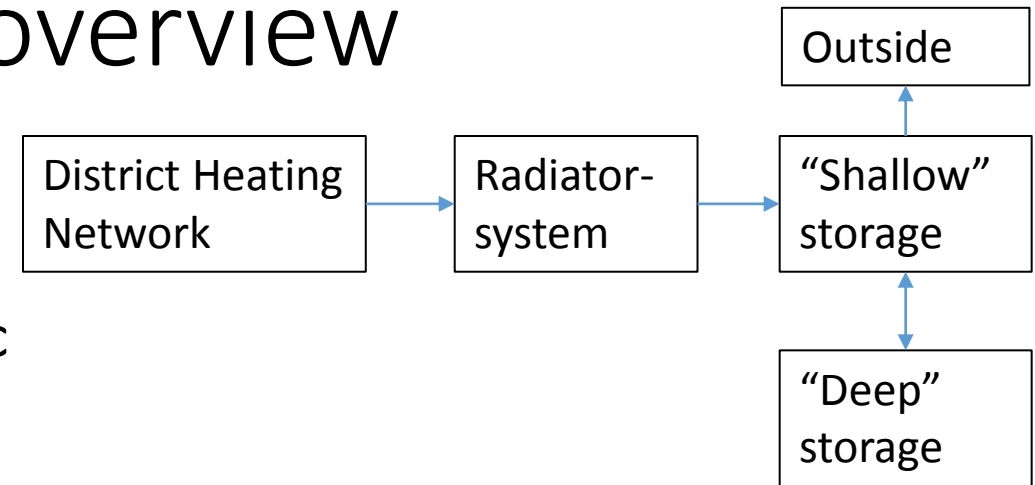


# Marginal cost optimisation

- Method: Minimise overall heating costs, assuming heat is purchased at the current marginal generation cost
  - Forecast available
  - Good proxy for unwanted behavior and environmental impact
  - Can be implemented either by user or supplier
- Conclusions: Significant savings possible
  - Heat use minimisation increases generation cost per supplied MWh
  - Storage dynamics non-trivial

# Model and control system overview

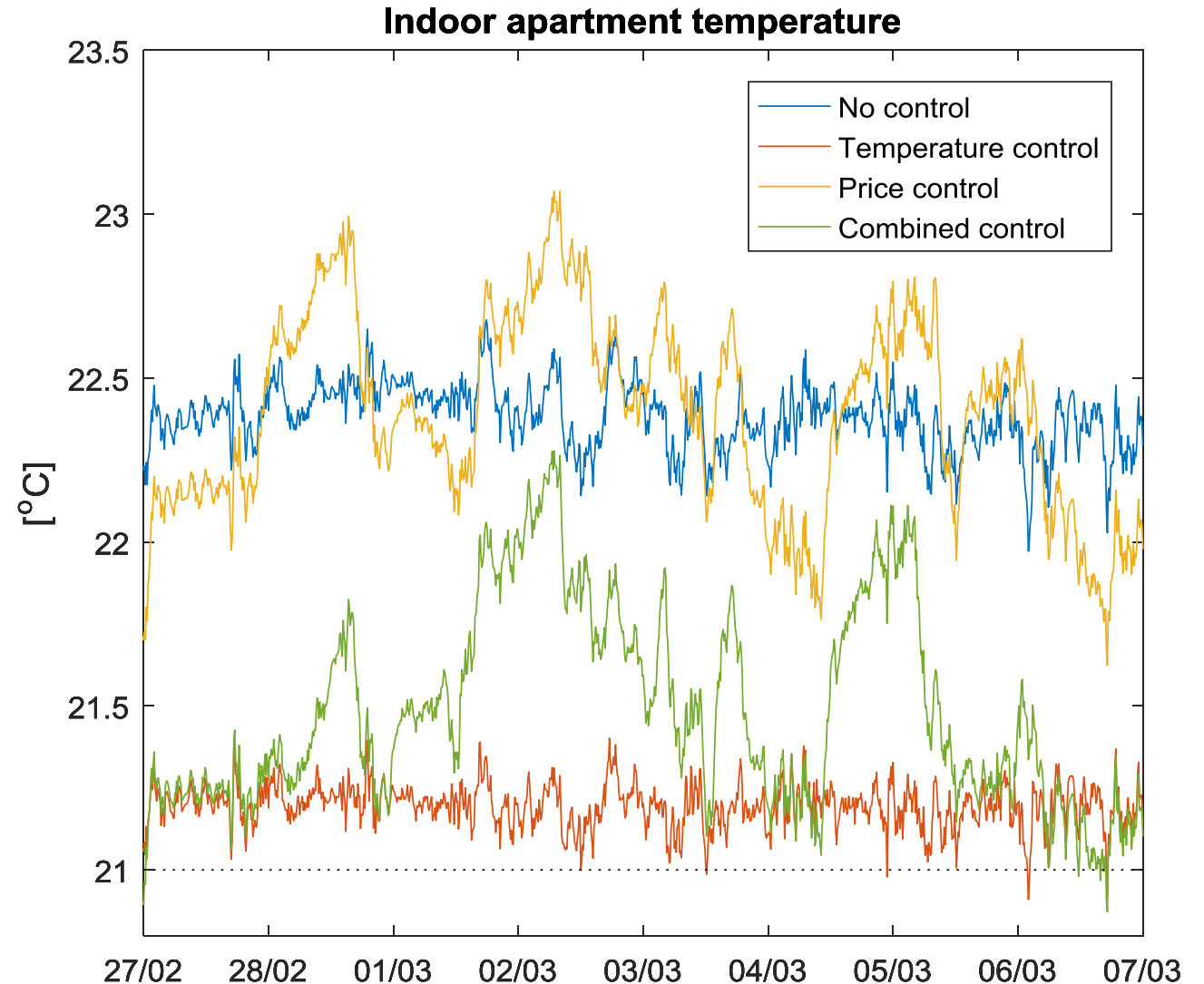
- Building model: Simple dynamical system
  - Shallow storage = apartment air + gypsum etc
  - Deep storage = structural core
  - Behaviour optimised to data collected by Göteborg Energi
- Control system: Two competing goal-oriented modules
  - Temperature control maintains stable 21°C
  - Price control does load shifting
  - No simulations performed by control system



# Results – Load shifting Potential

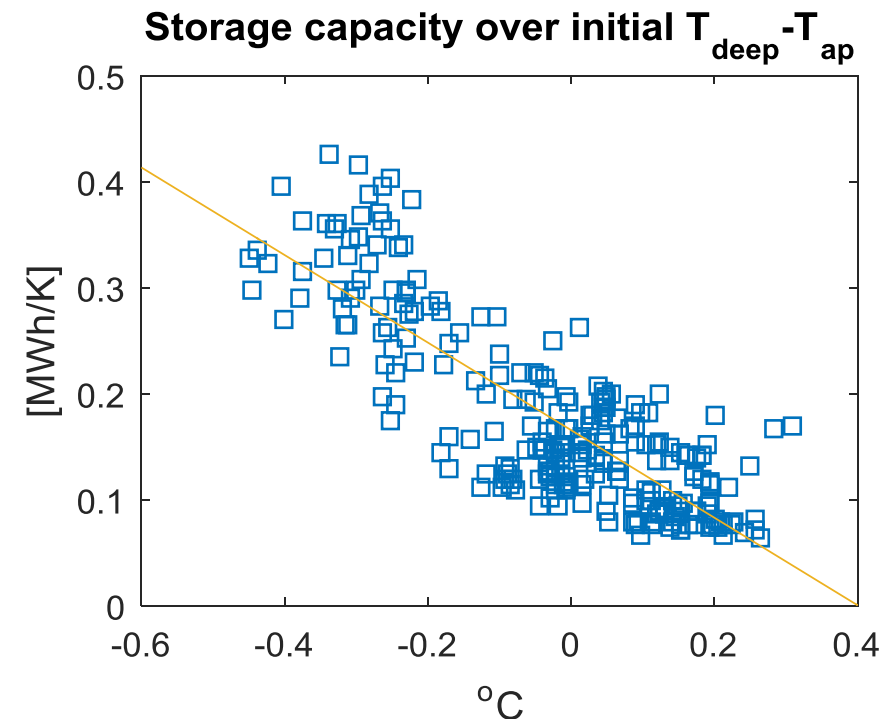
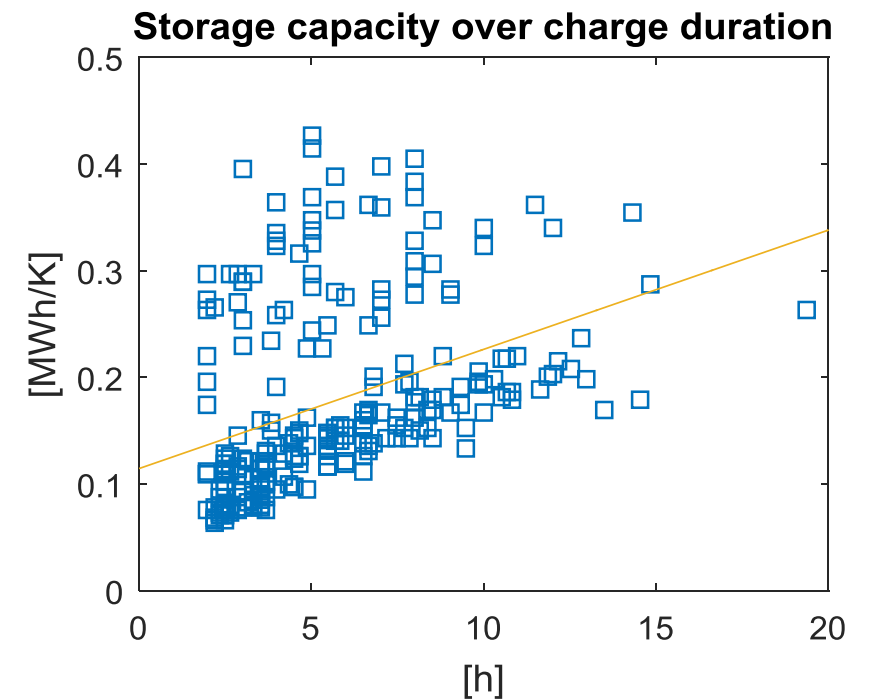
Case	% Energy Saved	% Cost Saved	Cost/MWh
No control	0	0	1.00

- Load shifting viable concept
- Temperature stabilisation on its own reduces energy mix quality



# Results – Storage Properties

- Effective heat capacity
  - $\frac{\Delta Energy}{\Delta Temperature}$
  - Limited by thermal comfort requirements
- Charge span = charging continuously > 2h
  - Capacity increases with cycle duration → Planning control system rewarding
  - Internal energy difference important when estimating available storage capacity



# Summary, Recommendations

- Load shifting demonstrably advantageous to heat use minimisation
  - Heat saving control with constant customer price not beneficial for supplier
  - Either control centrally or allow variable price contracts
  - Diminishing returns on large scale implementation
- Building dynamics are important
  - Long-term planning can increase effective heat capacity
- For maximum utility, use specialised control system
  - Self-learning or model-supported
  - Reprogrammable and on-line

# Thank you for your attention

Jens.Love.Carlsson@gmail.com

- Acknowledgements

- Johan Kensby
- Anders Trüschel
- Jan-Olof Dalenbäck
- Peter Hultén
- Christian Johansson
- Torbjörn Lindholm
- Astrid Ahlinder
- And all other thesis students, researchers and staff at and around Building Services Engineering and Göteborg Energi

