

IEA EBC Annex 84

Demand Management of Buildings in Thermal Networks

Webinar on

*Local Strategies for Demand Management of
Buildings in Thermal Networks*

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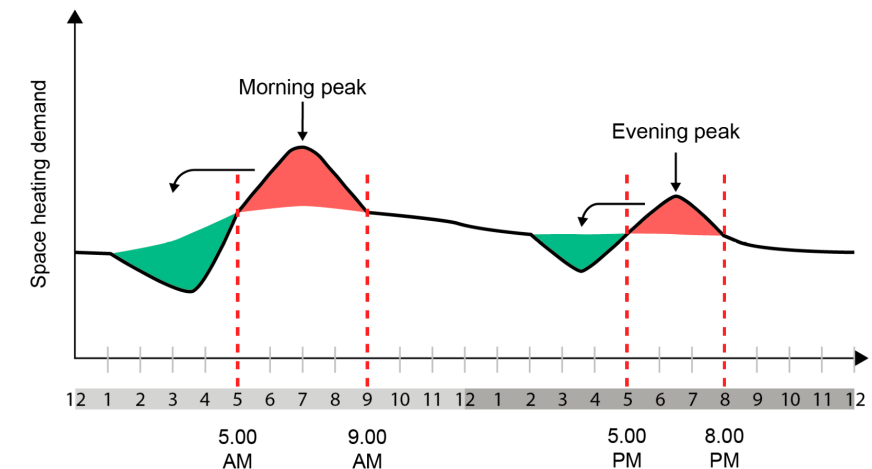


Agenda

1. Danish context
2. Local Initiatives
 1. Aalborg Forsyning: Watts app and Varme+ project
 2. InterHUB project, AAU
 3. Dynamic smart meters data potential
 4. READY+
 5. Flexible Energy Denmark
 6. Heat 4.0
 7. PreHeat

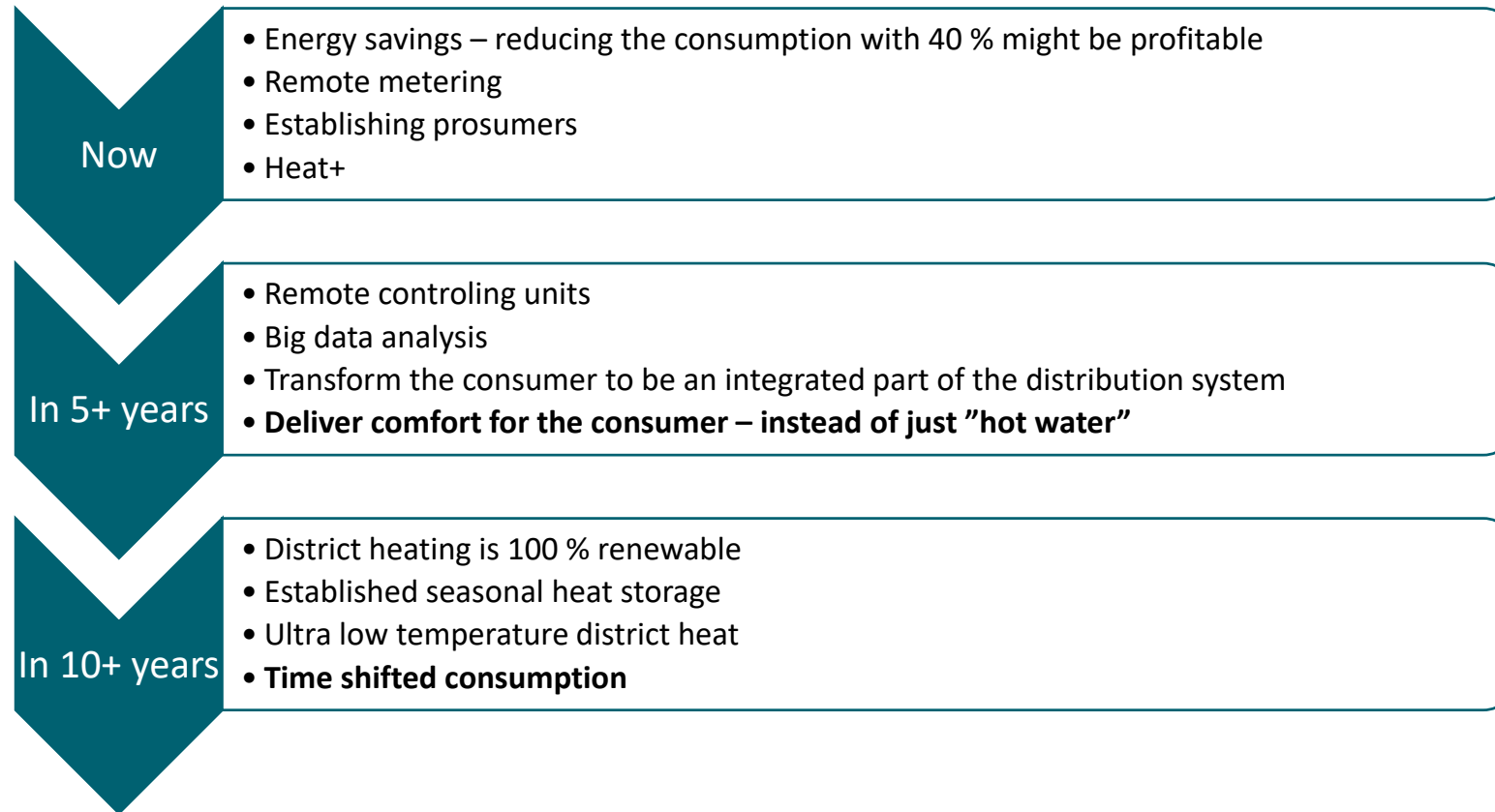
Danish context

- DH in Denmark is expected to play an important role in reaching the energy policy goals, i.e. 2030 - 50 % gross energy consumption from RES, 2050 - fossil fuels free energy system, by
- 64% of all Danish homes are connected to district heating grid (DH)
- > 400 DH companies of different sizes with various billing methods:
 - Monthly fee depending on building size or customer type
 - Fixed tariff per kWh or m³
 - Punishment fee for high return temperature
 - Dynamic tariffs (in many DH under preparation)
- Challenges of DH to be solved before 2050
 - Night/weekend setback and thereby peak periods **➔ Flexible DH systems**
 - Coupling with EL grid (intermittent RES)
 - High return temperature
 - High temperature demand of DHW **➔ Low-temperature DH-systems**



Source Larsen and Gram-Hanssen doi.org/10.3390/su12156031

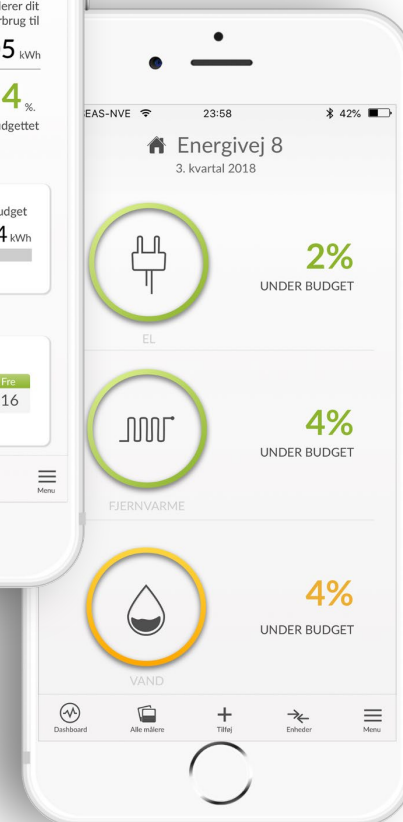
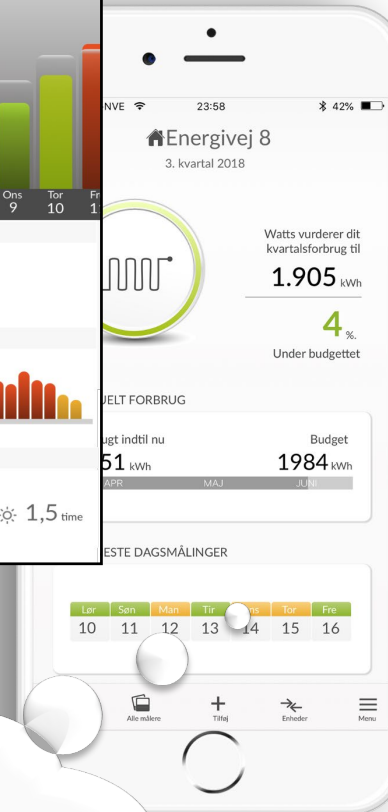
Perspective towards smart energy



Introducing 'Watts'

Få overblik over dit energiforbrug med appen Watts

I samarbejde med
KALUNDBORG FORSYNING
Aalborg Forsyning



Notifications & alarms
Individual prices
Benchmarking

All utilities in one app

Personal energy advices
Intelligent budgets

Introducing Heat+ (Varme+)



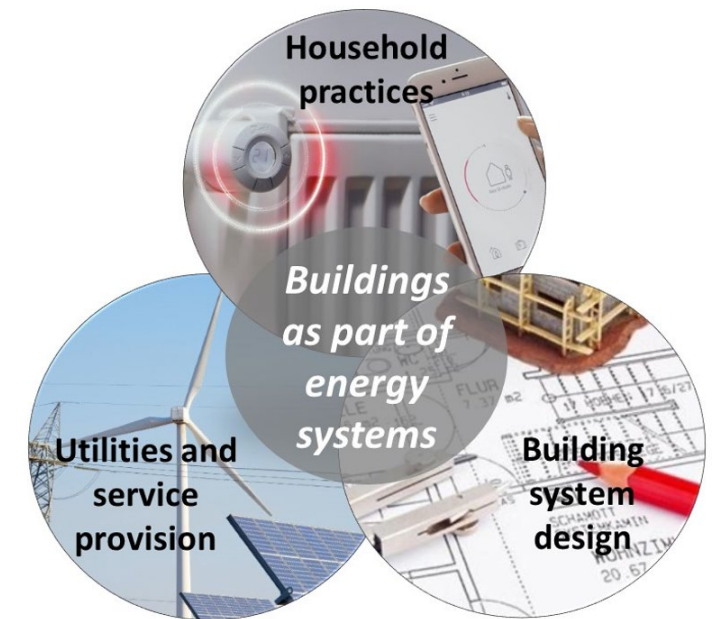
- 'Varme+' is launched as a new product the 1st of October 2018
- The consumer and the utility company is integrated. Aalborg Forsyning offers to own, operate and maintain the district heating unit
- The consumer is offered a maintenance scheme for the buildings heating system (50% of the heating systems has errors today)
- The benefit for the consumer is, that the utility company takes the investment, maintenance and operation. The consumer avoids risks and trouble regarding to the unit
- The benefit for the utility company is a competitive product, benefits in including the consumers heating installation in the district heating system as well as access to energy optimizations

InterHUB: Intermittent energy - Integrating Households, Utilities and Buildings

The purpose of InterHUB is to deepen our understanding of the challenges involved in realising an integration of buildings and households in a future integrated and flexible energy system.

PARTNERS:

Research Group on Sustainable Cities and everyday practices
Architectural Engineering, Department of Civil Engineering
The Sustainable Transitions research group
Department of Communication



<https://www.interhub.aau.dk/>



Investigation 1: 16 interviews (age 21-58 years old) in 4 case study buildings

Results:

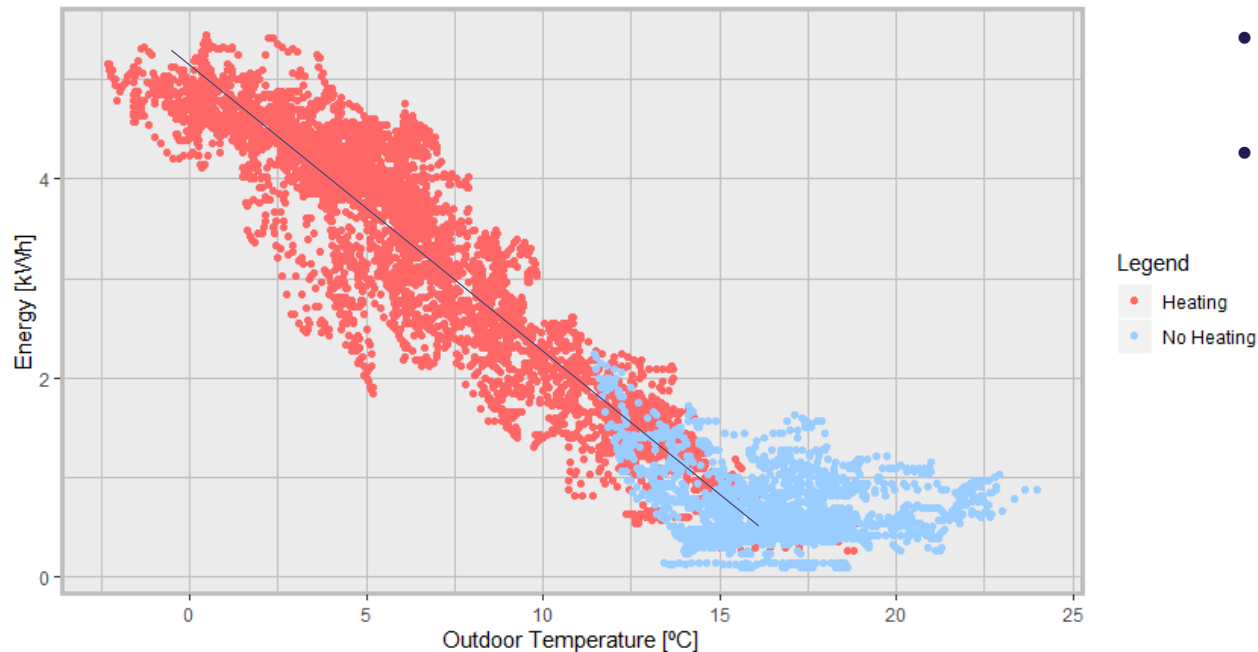
- ▶ It is necessary to take broader and more holistic perspectives on everyday life and understand why occupants consume energy (or heat their homes) in the way that they do.
- ▶ The limited scope of the flexibility scenario, which only highlights the technical possibilities for enabling flexibility, is not enough, and, as previous research has shown, smart home technology implies a number of collective structures, such as increased notions of convenience and comfort. Interventions aimed at enabling flexibility must consider the fact that most occupants do not consider energy to be a commodity in and of itself.
- ▶ Scenarios of energy flexibility should to be translated into something meaningful for occupants in their everyday lives, taking into consideration the fact that they come with different competencies and that the way in which they approach new technologies will be very dependent on such ways of doing.

Source Larsen and Gram-Hanssen doi.org/10.3390/su12156031

Dynamic smart meters data potential (1000 customers; 1 year data of 1h readings)

Temperature slope indication of transmission losses (temperature regression m_{temp})

Energy vs. Outdoor Temp. - SMA, k = 33



- Infiltration/Ventilation regression - m_{inf}
Solar radiation = 0 & wind speed > 1m/s;
- Radiation regression - m_{rad}
Solar radiation \neq 0 & wind speed < 1m/s

$$R_{inf} = \frac{m_{inf}}{m_{temp}} \quad \begin{cases} R_{inf} < 1, \text{ Low dependency of wind} \\ R_{inf} \geq 1, \text{ High dependency of wind} \end{cases}$$

$$R_{rad} = \frac{m_{rad}}{m_{temp}} \quad \begin{cases} R_{rad} < 1, \text{ High dependency of radiation} \\ R_{rad} \geq 1, \text{ Low dependency of radiation} \end{cases}$$

Pereira, D. H. L. E., Marszal-Pomianowska, A., Heiselberg, P., Johra, H& Tvedebrink, T.
To be published

AARHUS UNIVERSITY

DATA-DRIVEN DEMAND SIDE MANAGEMENT IN DISTRICT HEATING SYSTEMS

PREVIOUS PROJECTS – SIMULATION-BASED STUDIES

Funded projects

2013-2016: Virtual Power Plant for Smart Grid Ready Buildings and Customers
One PhD + 1 year post doc

2014-2020: Resource Efficient Cities Implementing Advanced Smart City Solutions (READY) Two PhDs + 2 year post doc

2015-2018: READY.DK – Method for identifying DR potentials of existing buildings facing a retrofit.
One PhD

2017-2020: Local Heating concepts for power balancing Two year post doc

Journal publications (11)

Knudsen M.D., Petersen S. Economic Model Predictive Control of Space Heating and Dynamic Solar Shading. <i>Energy and Buildings</i> (2020) 209, 109661
Hedegaard R.E., Kristensen M.H., Petersen S. Bottom-up modelling methodology for urban scale analysis of residential space heating demand response. <i>Applied Energy</i> (2019) 242, 181-204
Pedersen T.H., Hedegaard R.E., Kristensen K.F., Gadgaard B., Petersen S. The effect of including hydronic radiator dynamics in model predictive control of space heating. <i>Energy and Buildings</i> (2019) 183, 772-784
Kristensen, M.H., Hedegaard R.E., Petersen S. Hierarchical calibration of archetypes for urban building energy modeling. <i>Energy and Buildings</i> (2018) 175, 219-234
Kristensen M.H., Brun A. and Petersen S. Predicting Danish residential heating energy use from publicly available building characteristics. <i>Energy and Buildings</i> (2018) 173, 28-37
Hedegaard R.E., Pedersen T.H., Knudsen M.D. and Petersen S. Towards practical model predictive control of residential space heating: Eliminating the need for weather measurements. <i>Energy and Buildings</i> (2018) 170, 206-216
Pedersen T., Petersen S. Investigating the Performance of Scenario-based Model Predictive Control of Space Heating in Residential Buildings. <i>Journal of Building Performance Simulation</i> 11 (2018), 485–498
Hedegaard R.E., Pedersen T.H., Petersen S. Multi-market demand response using economic model predictive control of space heating in residential buildings. <i>Energy and Buildings</i> 150 (2017) 253–261
Knudsen M.D. and Petersen S. Model Predictive Control of Domestic Hot Water Preparation in Ultra-Low Temperature District Heating Systems. <i>Energy and Buildings</i> 141 (2017) 158–166
Pedersen T.H., Hedegaard R.E., Petersen S. Space Heating Demand Response Potential for Retrofitted Residential Apartment Blocks. <i>Energy and Buildings</i> 141 (2017) 158–166
Knudsen M.D. and Petersen S. Demand Response Potential of Model Predictive Control of Space Heating based on Price and Carbon Dioxide Intensity Signals. <i>Energy and Buildings</i> 145 (2016) 196–204

Conference papers (13)

Kim O., Knudsen M.D., Petersen S. Peak load reduction of district heating by control of indoor public swimming pool. <i>Building Performance Analysis Conference and SimBuild</i> . Chicago, USA. 2018.
Kristensen M.H., Hedegaard R.E., Petersen S. Urban-scale dynamic building energy modeling and prediction using hierarchical archetypes: A case study of two Danish towns. <i>4th IBPSA-England Conference</i> . Cambridge, England. 2018 (extended abstract and poster)
Knudsen M.D., Pedersen T.H., Hedegaard R.E., Petersen S. System identification of thermal building models for demand response – A practical approach. <i>Energy Procedia</i> 122 (2017) 937–942
Pedersen T.H., Hedegaard R.E., Knudsen M.D., Petersen S. Comparison of centralized and decentralized model predictive control in a building retrofit scenario. <i>Energy Procedia</i> 122 (2017) 979–984
Pedersen T.H., Knudsen M.D., Hedegaard R.E., Petersen S. Handling thermal comfort in predictive control schemes for demand response. <i>Energy Procedia</i> 122 (2017) 985-990
Kristensen M.H., Choudhary R., Petersen S. Bayesian calibration of building energy models: Comparison of predictive accuracy using different time scales of metered utility data. <i>Energy Procedia</i> 122 (2017) 277-282
Kristensen M.H., Petersen S. Bayesian calibration of residential building clusters using a single geometric building representation. In: <i>Proceedings of Building Simulation, International Building Performance Simulation Association</i> , San Francisco, CA, August 7-9, 2017
Hedegaard R.E., Petersen S. Evaluation of Grey-Box Model Parameter Estimates Intended for Thermal Characterization of Buildings. <i>12th symposium on building physics in Nordic countries</i> . Trondheim, Norway. 2017
Kristensen M.H., Petersen S. Explaining variability in metered energy use for similar buildings using Bayesian inference. <i>12th symposium on building physics in Nordic countries</i> . Trondheim, Norway. 2017
Pedersen R., Kristensen M.H., Petersen S., Brun A., Andresen, G. B. Direct and indirect heating network energy savings from building retrofit. <i>2nd International Conference on Smart Energy Systems and 4th Generation District Heating</i> , Aalborg University, Denmark. 2016
Knudsen M.D., Hedegaard R.E., Pedersen T.H., Petersen S. Model Predictive Control of Space Heating and the Impact of Taxes on Demand Response: A Simulation Study. <i>12th REHVA World Conference CLIMA</i> . Aalborg, Denmark. 2016
Hedegaard R.E., Pedersen T.H., Knudsen M.D., Petersen S. Identifying a Comfortable Excitation Signal for Generating Building Models for Model Predictive Control: A Simulation Study. <i>12th REHVA World Conference CLIMA</i> . Aalborg, Denmark. 2016
Pedersen T.H., Knudsen M.D., Hedegaard R.E., Petersen S. Handling Stochastic Occupancy in an Economic Model Predictive Control Framework for Heating System Operation in Dwellings. <i>12th REHVA World Conference CLIMA</i> . Aalborg, Denmark. 2016

CURRENT PROJECTS – SIM+EXP STUDIES

Funded projects

2019-2021: READY+
2 year post doc

*2019-2022: Flexible
Energy Denmark*

One PhD

2019-2022: Heat 4.0
One PhD

2019-2022: PreHeat
One PhD + 1 year post doc

Journal publications (2)

Kristensen, M.H, Petersen S. District heating energy efficiency of Danish building typologies. Energy and Buildings (submitted)

Kristensen, M.H, Hedegaard R.E., Petersen S. Long-term forecasting of hourly district heating loads in urban areas using hierarchical archetype modelling. Energy (2020) 201, 117687

Conference papers (5)

Hedegaard R.E., Kristensen, M.H, Petersen S. Including building energy flexibility as an asset in a system-wide district heating optimization model. uSim 2020

Hedegaard R.E., Kristensen, M.H, Petersen S. Investigating the impact of construction year on the urban-scale energy flexibility potential of single-family houses. uSim 2020.

Broholt T.H, Christensen L.R.L, Knudsen M.D, Hedegaard R.E., Petersen S. Comparison of robustness of black-box and grey-box models of thermodynamic behaviour of buildings when exposed to seasonal weather changes. 13th symposium on building physics in Nordic countries. Tallinn, Estland. 2020

Christensen L.R.L, Broholt T.H, Knudsen M.D, Hedegaard R.E., Petersen S. The influence of unmeasured occupancy disturbances on the performance of black-box thermal building models. 13th symposium on building physics in Nordic countries. Tallinn, Estland. 2020

Hedegaard R.E., Kristensen, M.H, Petersen S. Experimental validation of a model-based method for separating the space heating and domestic hot water components from smart-meter consumption data. 13th symposium on building physics in Nordic countries. Tallinn, Estland. 2020

Flexibility experiments in single family houses over the next 2-3 heating seasons to investigate:

- Is it possible to realise the theoretical potential identified in earlier studies?
- What DH planning and operation issues can heating-flexible operation of buildings help mitigate?
- Develop robust and cost-competitive technologies (hardware and software) for DR operation of hydronic heating systems in dwellings.
- Is thermal comfort compromised (or improved) due to heating-flexible operation of buildings?



Thank you