INVESTIGATION OF THE ENERGY FLEXIBILITY POTENTIAL OF DANISH RESIDENTIAL BUILDING ARCHETYPES

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PROJECT: LOCAL HEATING CONCEPTS
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REQUIRED CAPACITY IN DH NETWORKS

Consumption composed of:
- Space heating
- Domestic hot water usage
- Heat losses in the distribution network

*Data generously provided by district heating supplier AffaldVarme Aarhus*
REQUIRED CAPACITY IN DH-NETWORKS

Consumption composed of:

• Space heating
• Domestic hot water usage
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+ Redundancy requirements (often n-1 criteria)
= Oversized components for majority of year

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REQUIRED CAPACITY IN DH NETWORKS

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= Oversized components for majority of year

Removing the **50 hours** with highest consumption for each year yields significant capacity reductions.

Production: 14.3% - 17.7%
Demand: 13.5% - 16.5%

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ENERGY FLEXIBLE BUILDINGS

Objective:
Shift consumption to lower peak demand.
ENERGY FLEXIBLE BUILDINGS

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Principle:
Utilize the inherent thermal capacity of buildings to shift consumption without impacting comfort.
CASE STUDY: CITY EXPANSION SCENARIO

Archetype 1
Constructed 1951-1960

Archetype 2
Constructed 1979-1998

Archetype 3
Constructed 2011-2015

Potential Bottleneck
CASE STUDY: CITY EXPANSION SCENARIO

Questions:
1. To what extent can energy flexibility lower the required capacity of the neighborhood?
2. Should efforts be focused on making a given type of building flexible?
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Questions:
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Method:
1. Establish dynamic models of buildings
2. Perform multiple simulations of the area with different groups of buildings being flexible.
ARCHETYPE MODELLING

Archetype modelled:
- Archetype 1: 1951-1960

Building archetype model

Physics-based second-order RC-Model
ARCHETYPE MODELLING

Archetype modelled:
- Archetype 1: 1951-1960

Calibration of dynamic archetype models
1. Smart-meter consumption measurements
   Sample: Six months worth of data from 100 buildings
2. Weather data (Temperature and solar radiation)
3. Prior knowledge (our best beliefs)
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   Sample: Six months worth of data from 100 buildings
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MODELS VS REALITY

Prediction of Archetype 1
No. of buildings: 1000
Time resolution of visualization: 1h
No. of stochastic simulations per building: 1

Measured \( y_{1:1000} \)
Simulated \( y_{1:1000} \), Mean
Simulated \( y_{1:1000} \), 95% interval

Prediction of Archetype 2
No. of buildings: 1000
Time resolution of visualization: 1h
No. of stochastic simulations per building: 1

Measured \( y_{1:1000} \)
Simulated \( y_{1:1000} \), Mean
Simulated \( y_{1:1000} \), 95% interval

Prediction of Archetype 3
No. of buildings: 496
Time resolution of visualization: 1h
No. of stochastic simulations per building: 1

Measured \( y_{1:496} \)
Simulated \( y_{1:496} \), Mean
Simulated \( y_{1:496} \), 95% interval
MODELS VS REALITY

- Prediction of Archetype 1
  - No. of buildings: 1000
  - Time resolution of visualization: 1h
  - No. of stochastic simulations per building: 1

- Prediction of Archetype 2
  - No. of buildings: 1000
  - Time resolution of visualization: 1h
  - No. of stochastic simulations per building: 1

- Prediction of Archetype 3
  - No. of buildings: 496
  - Time resolution of visualization: 1h
  - No. of stochastic simulations per building: 1
MODELS VS REALITY

Prediction of Archetype 1
No. of buildings: 1000
Time resolution of visualization: 1h
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Prediction of Archetype 2
No. of buildings: 1000
Time resolution of visualization: 1h
No. of stochastic simulations per building: 1

Prediction of Archetype 3
No. of buildings: 496
Time resolution of visualization: 1h
No. of stochastic simulations per building: 1
MODELS VS REALITY

Prediction of Archetype 2
- No. of buildings: 1000
- Time resolution of visualization: 1h
- No. of stochastic simulations per building: 1

Prediction of Archetype 3
- No. of buildings: 496
- Time resolution of visualization: 1h
- No. of stochastic simulations per building: 1
MODELS VS REALITY
SIMULATION OF DEMAND RESPONSE
SIMULATION OF DEMAND RESPONSE

![Graph showing demand response simulation results]

- Refinement
- Archetype 1 Flexible
- Archetype 3 Flexible
- Max consumption

Average season deviation [\%]
- Archetype 1
- Archetype 2

Consumption [kWh]

Average season deviation [°C]

0 0.5 1 1.5 2
Jan 15 Jan 22 Jan 29 Feb 05 Feb 12

0 500 1000 1500
Jan 15 Jan 22 Jan 29 Feb 05 Feb 12

0 1000 1500
Jan 15 Jan 22 Jan 29 Feb 05 Feb 12

0 1050 1100 1150 1200 1250 1300 1350 1400 1450 1500
0 100 200 300 400 500

Hours
SIMULATION OF DEMAND RESPONSE
SIMULATION OF DEMAND RESPONSE
RESULTS BREAKDOWN
RESULTS BREAKDOWN

Preheating by 4°C allowed.
Preheating by 4°C allowed.

Preheating by 2°C allowed.
MAIN FINDINGS

Results indicated:

1. Significant capacity reductions may be achieved with only a modest increase in overall consumption.

2. Performance affected by:
   - Comfort preferences of occupants
   - Building energy efficiency
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Energy retrofitting may benefit both energy conservation and energy flexibility.