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Aggregation of building energy demands – Sønderborg case

WP3: Intelligent Energy System Integration

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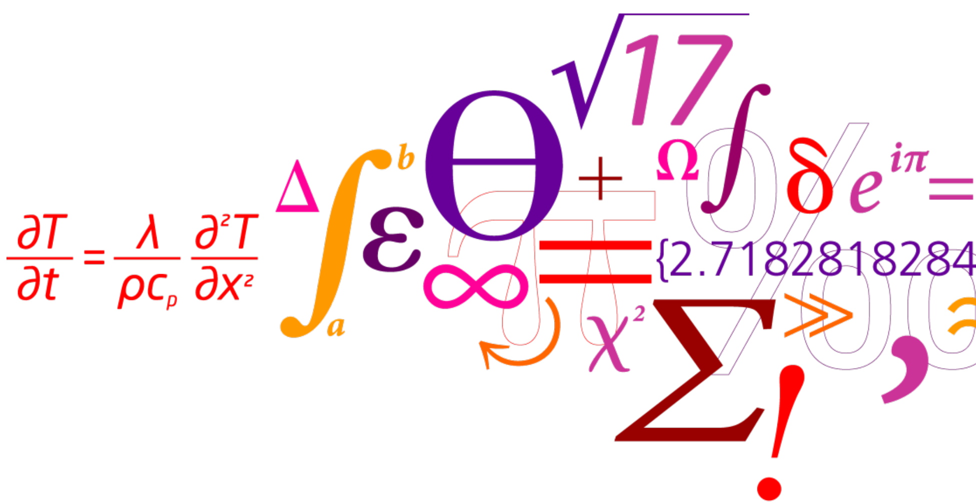


DTU Civil Engineering
Department of Civil Engineering

Main objectives

- Investigate the existing ways of **aggregating** building energy demands by implementing them on real case-studies
- Propose a **methodology** for estimating realistic energy demand models for districts or cities
- Investigate different energy simulation **tools**
- Study domestic **flexibility** – heat demand shifting to contribute to the overall stabilization of the energy grid

Implementation of city energy model

(First case-study)

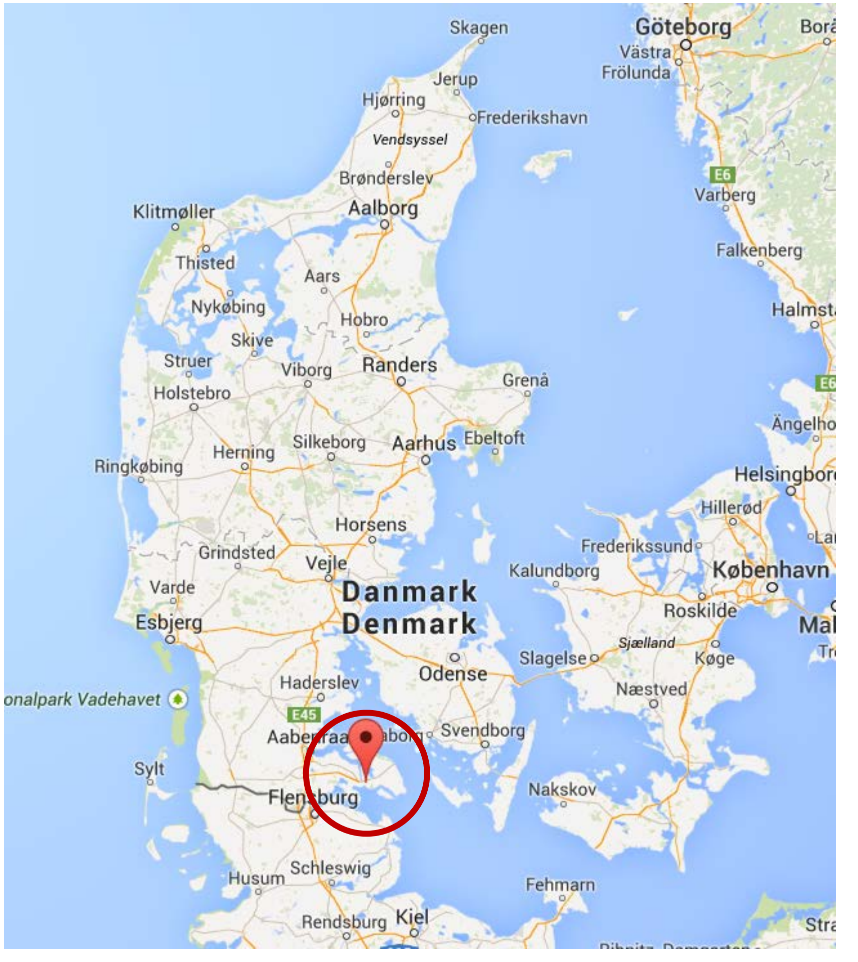
First case - Sønderborg

Population: 27,434

Bright Green Business
ProjectZero

- Ambitious environmental-energy **goals**:
  - ✓ Become carbon neutral by 2029
  - ✓ Half its current energy consumption
  - ✓ Increase local RES penetration

- **Building** sector (3rd most carbon intensive)
  - ✓ New buildings: low energy class I
  - ✓ Sustainable district heating (solar, geothermal/biogas plants, heat pumps)

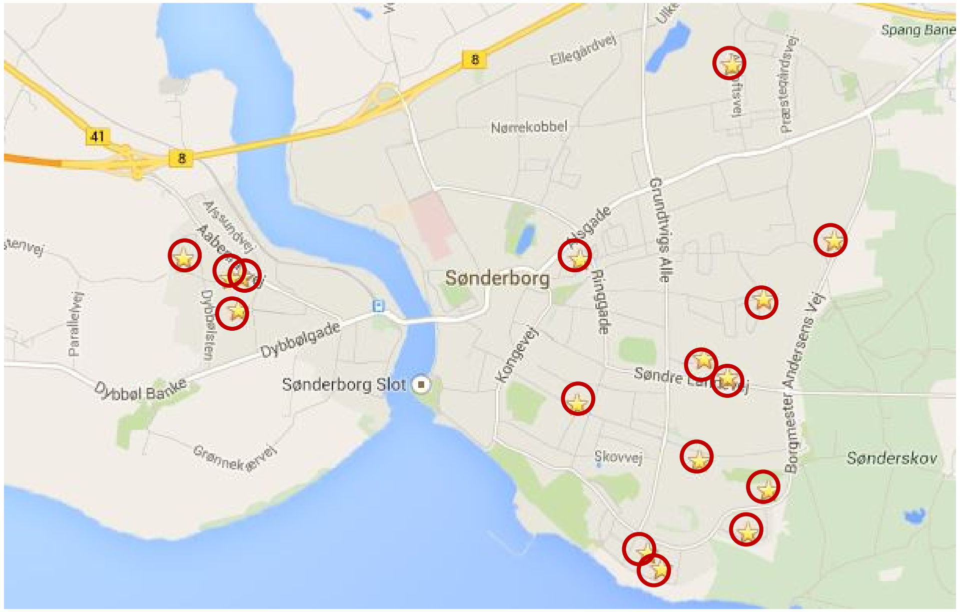


Implementation of city energy model

➢ **Description of the case study**

- **16** one-floor **single-family houses**
- Located in Sønderborg, Denmark
- Constructed mainly in 1960s
- Floor areas: 85 - 175 m^2
- Connected to local district heating network

Figure 1. Typical design of the single-family house



Implementation of city energy model

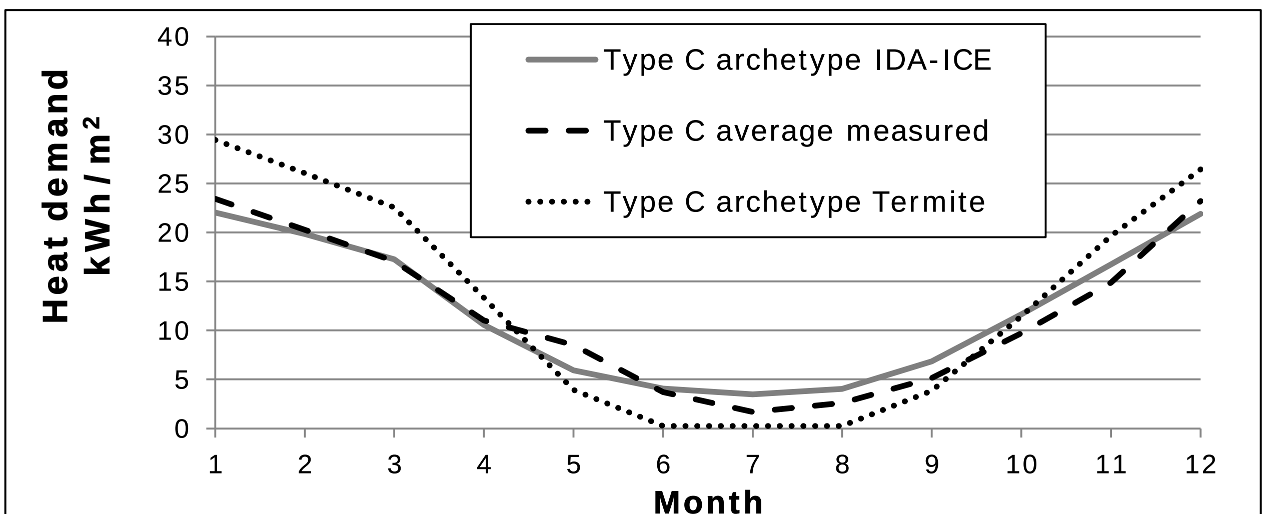
- The houses were classified into five building **types** based on their construction age

Based on:
- Rhinoceros® (CAD design)
- Grasshopper™ (visual parametric interface)
- Be10 -EN ISO 13790:2008 (energy simulations)

- One **archetype** building represented each type

- Two energy simulation **tools** were implemented:
  - Termite – Be10 (simplified)
  - IDA-ICE (dynamic)

- These were compared to heat consumption **measurements**



Implementation of city energy model

- Heat demand results from all five building types were **aggregated** according to:

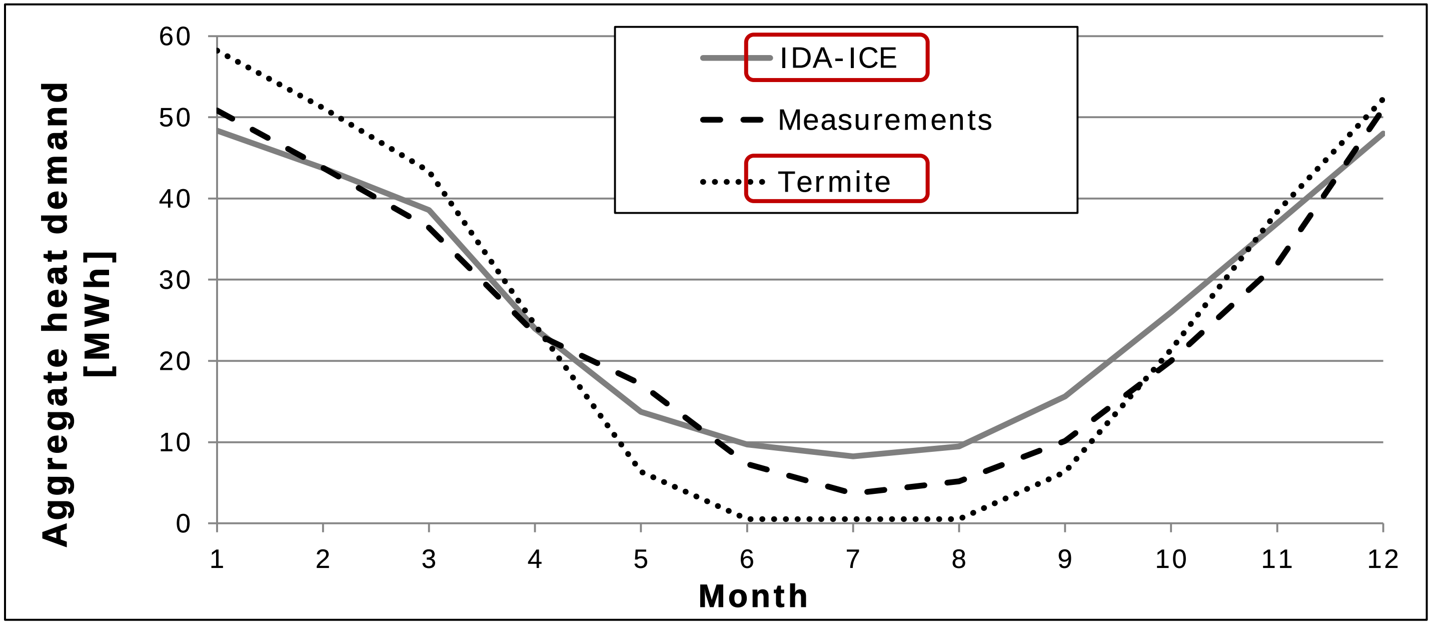
$$Y = \sum_{j=1}^{N} EUI(j)\, A(j)$$

j = building type

N = total number of building types describing the stock

EUI = energy demand per floor area [kWh/m^2] for each building type

A = total floor area [m^2] of all buildings included in the respective type



Sønderborg – Data sets

1st data set: 16 houses

- Constructed mainly in 1960s
- Floor areas: 85 - 175 m^2
- No solar heating panels
- No mechanical cooling

2nd data set: Ringgade

- Expand the sample to hundreds of houses
- District heating measurements - provided by Kamstrup (hourly data)
- Data collected since Dec. 2014
- Gas & electricity data

Sønderborg - Data sets

<u>3rd data set: Sønderborg city</u>

- o 72,717 registered addresses
- o BBR data
- o Provided by MBBL

- o Heat measurements
  - MBBL (annual values)
- o Electricity measurements

How to aggregate them?

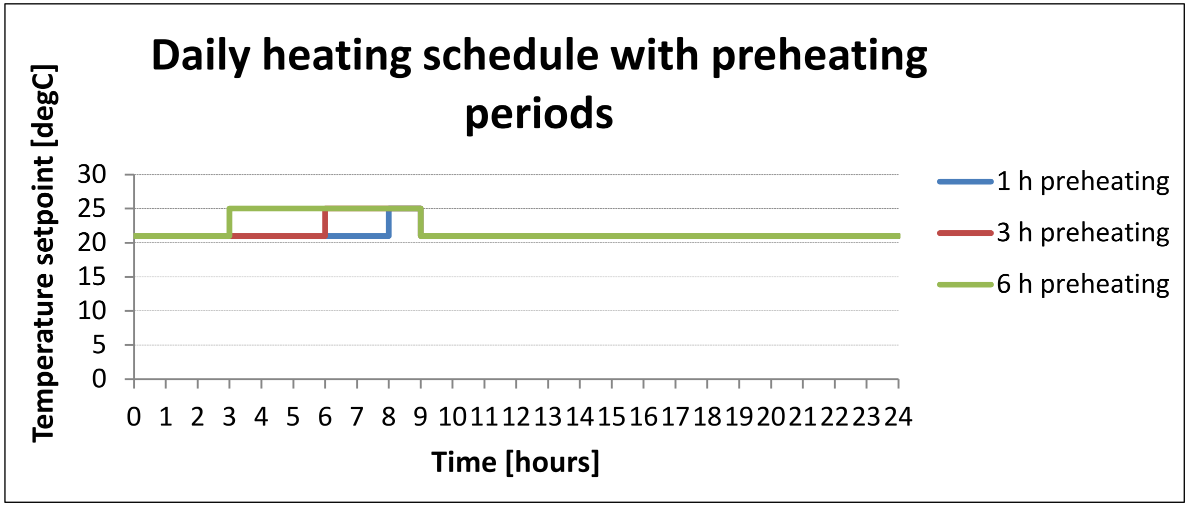
- ✓ Use of archetypes
- ✓ Use of statistical methods (regression) to predict unknown parameters
- ✓ Use of urban scale energy simulation programs

Domestic flexibility – work status

Results by student Frederik Lynge Halvorsen

- BESTEST building modeled in **Comsol** (8x6x2.7m)
- 4 external walls, floor and ceiling
- The room is heated from 21ºC to 25ºC
- 3 cases of **preheating** the room were studied: 1h, 3h, 6h

Element	λ [W/m*k]	Thickness [m]	Density [kg/m³]	Cp [J/kg*K]
External wall (from inside to outside)				
Concrete block	0,510	0,100	1400	1000
Foam insulation	0,040	0,0615	10	1400
Wood siding	0,140	0,009	530	900
Floor (from inside to outside)				
Concrete slab	1,130	0,080	1400	1000
Insulation	0,040	1,007	10	1400
Roof (from inside to outside)				
Plasterboard	0,160	0,010	950	840
Fibreglass quilt	0,040	0,1118	12	840
Roof deck	0,140	0,019	530	900



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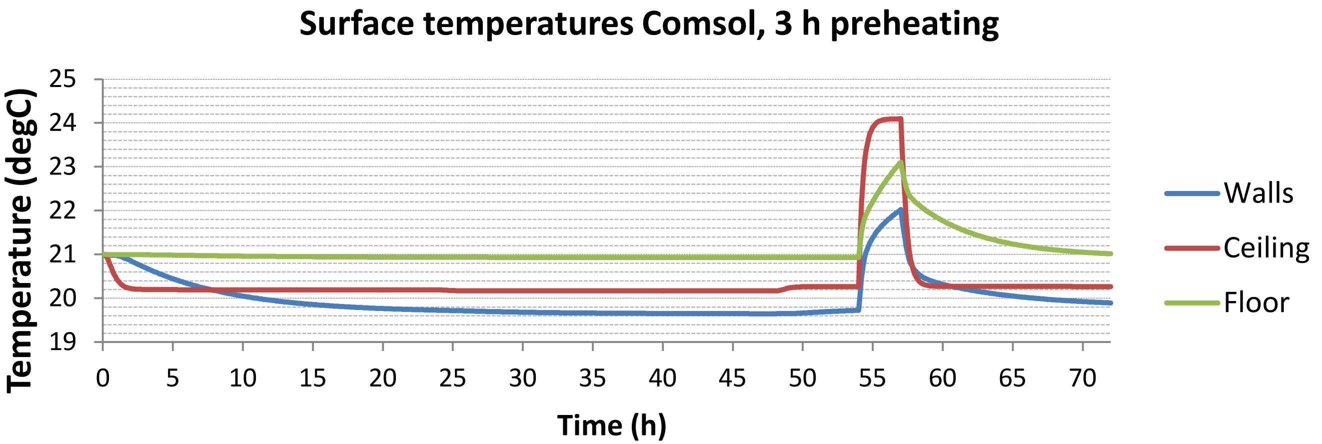
Domestic flexibility – work status

Results



- The ceiling is very easy to heat up, but it also loses the heat quickly (made of plasterboard)
- The walls and floor is made of concrete. These take a longer time to heat up, but they also release the heat slower (made of concrete)
- The flexibility of the **walls** can be utilized to postpone the heating demand.
- By heating the walls during the preheating period we can **shift** the heating demand by some hours.

Preheating period	1 hour	3 hours	6 hours
Load shift potential	0.5 hours	1 hour	4 hours

Next steps – To be answered

- Expand the sample to a **larger** building population → collect case studies
- **Combine** dynamic and steady-state energy simulation methods to fit measured data
- **Challenges** to be met at **national** scale:
  - Data availability:critical
  - Simplify building models
  - Reduce simulation times
  - Majority of buildings are old
  - Lack of smart energy systems (energy metering) in most buildings
  - User profiles differentiate every building
- **Flexibility** potential: test more simulation tools (heat transfer models)
- What is the **minimum** possible level of **information** to model building stock?
- How much can building **typologies** contribute to this?
- Which **time step** is the optimum for building energy simulations?

Thank You!

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