Energy flexibility using the thermal inertial of Swedish single-family houses

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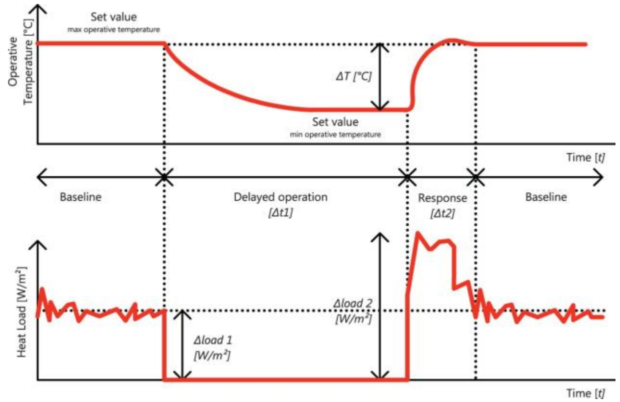
Energy flexibility in buildings

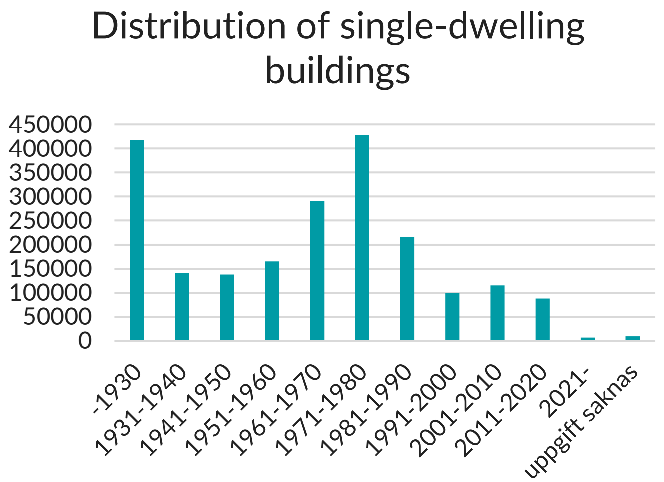
*"The **flexibility** refers to the deviation of energy demand against normal operation of buildings mechanical systems during grid peak hours" (Zhang et al., 2018)*

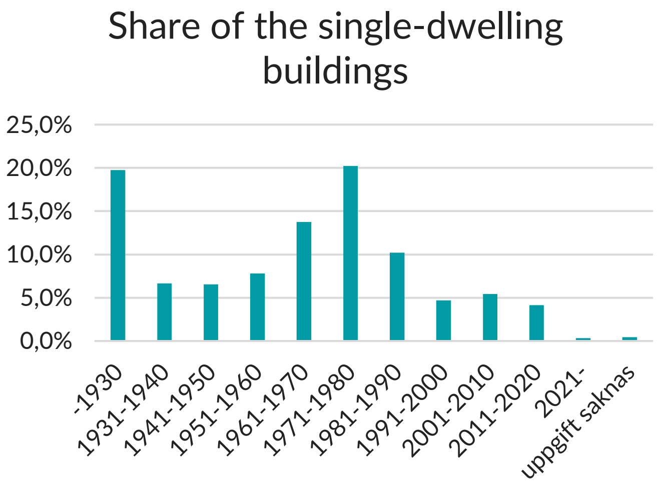
- *Reduce the energy demand at peak hours (**peak shaving**)*
- *Shift the energy consumption from peak to off-peak hours (**load shifting**)*



Picture source: Weiß et al. (2019)

Swedish building stock – single-dwelling buildings





Småhus avser friliggande en- och tvåbostadshus samt par-, rad- och kedjehus (exklusive fritidshus).
Data source: SCB Statistikdatabasen

About 2 million single family houses in Sweden, out of 1.3 million have some form of electrical heating system.

Space heating for single-family houses has a great potential of energy flexibility and has higher power capacity than other household devices.

Energy flexibility using the thermal inertial of Swedish single-family houses

Overall goal:

- *Explore the potential of using thermal mass a resource to increase energy flexibility for different types single-family houses*
- *Quantify the characteristics of energy flexibility in relation to building typologies*

- *Focus on heating energy (heating need, heating demand)*

Energy flexibility in buildings mainly depends on:

- *Insulation level*
- *Heat distribution systems*
- *Type of ventilation*
- *Weather*

Method

Using IDA-ICE as a tool

(Prototype including renovation)

IDA Indoor Climate and Energy
Building, its systems, and controllers
Detailed, dynamic simulation

Define simple control strategies to modulate the heating power

(Set-point: 21±2˚C)

Case studies
Winter (very cold, cold day)
Spring/autumn day

Shiftable heating demand/thermal energy during peak hours

Reference case
Flexibility control cases

Input data

Parameters (BETSI+assumptions)

- U-value, ∑UA/Atemp
- Ventilation
- Heat emitter
- Air tightness (infiltration rate)

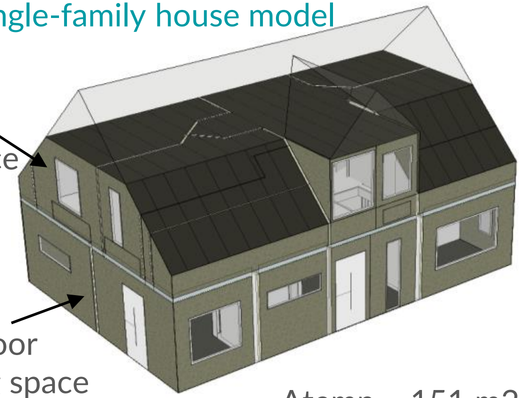
Location: Borås

Weather: design reference year 1991-2020 (SMHI-SVEBY)

House category (BETSI)

- 2010-
- 1996-2009
- 1986-1995
- 1976-1985
- 1941-1975
- 1940-1960

Single-family house model



Atemp = 151 m2

Examples of input data

	2010-	1961-1975
Building envelop U_{ave}	0.26 W/K m²	0.49 W/K m²
UA_{tot}	85 W/K	160 W/K
U_{walls}	0.17 W/K m²	0.31 W/K m²
$U_{ceiling}$	0.11 W/K m²	0.23 W/K m²
U_{floor}	0.15 W/K m²	0.32 W/K m²
U_{window}	1.2 W/K m²	1.6 (2.3) W/K m²
Ventilation	Exhaust ventilation	Natural ventilation
Air flow rate	0.35 (l/s m²)	About 0.25 (l/s m²) during winter (from IDA)
Air tightness q_{50}	0.4 (l/s m²)	0.8 (l/s m²)
Heat distribution system	Floor heating + water radiator	water radiator
Internal heat load (people, equipment)	30 kWh/m2 year	30 kWh/m2 year
Space heating demand (from IDA-ICE)	84 kWh/m2 year	116 kWh/m2 year

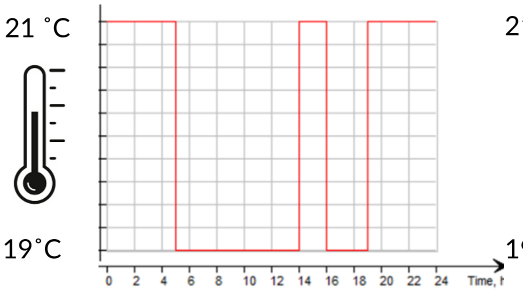
Flexibility control strategies

	Control 1	Control 2	Control 3	Control 4
Morning peak 05:00-09:00	19 ˚ C	19 ˚ C	19 ˚ C	19 ˚ C
Evening peak 16:00-19:00	19 ˚ C	19 ˚ C	19 ˚ C	19 ˚ C
Non-occupied hours 9:00-14:00	19 ˚ C	21 ˚ C	19 ˚ C	21 ˚ C
Overheating 1st floor during night	/	/	23 ˚ C	23 ˚ C

Reference case with Tmin = 21 ˚C

	A very cold	Cold	Spring/autumn
Date	28th Jan	7th Feb	16th Mar
Tave out door	-13 ˚ C	-6 ˚ C	5 ˚ C
Solar radiatorn	No	No	Yes

Different controls to reduce heating demand during the peak hours



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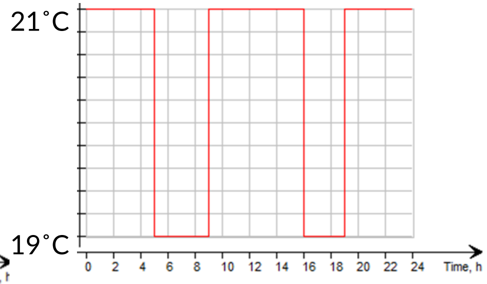

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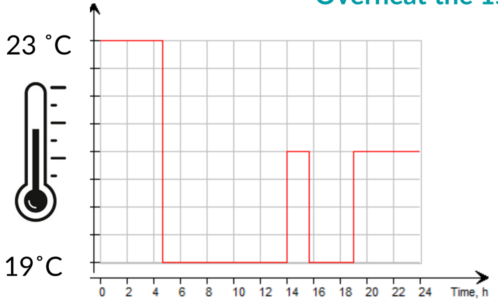
Overheat the 1st floor to 23 ˚C



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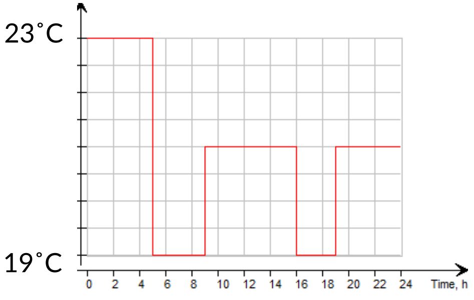

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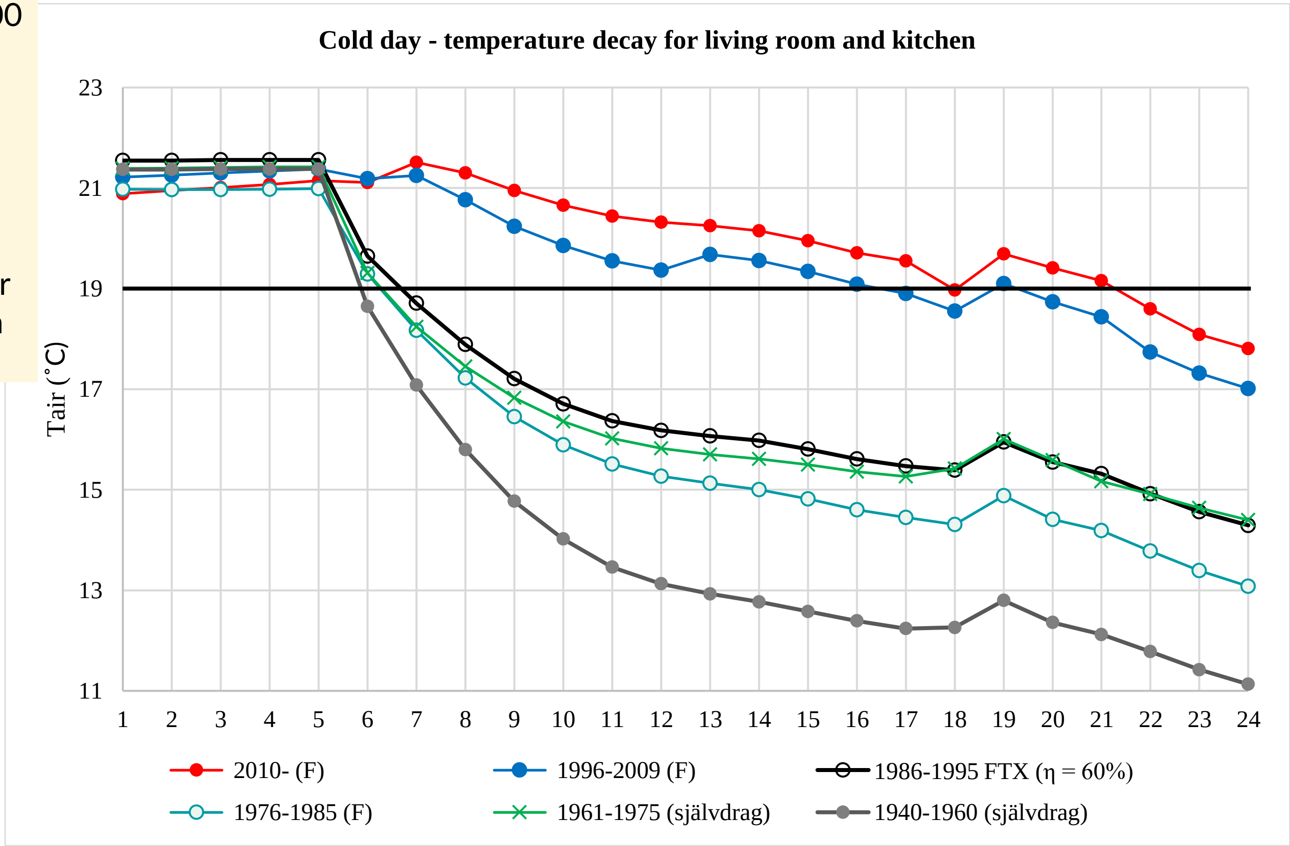
Preliminary results: temperature decay

Case study:
- Turn off heating at 05:00
- A cold day
- Temperature decay for living room and kitchen

Results
- Insulation
- Floor heating or radiator
- Ventilation + infiltration



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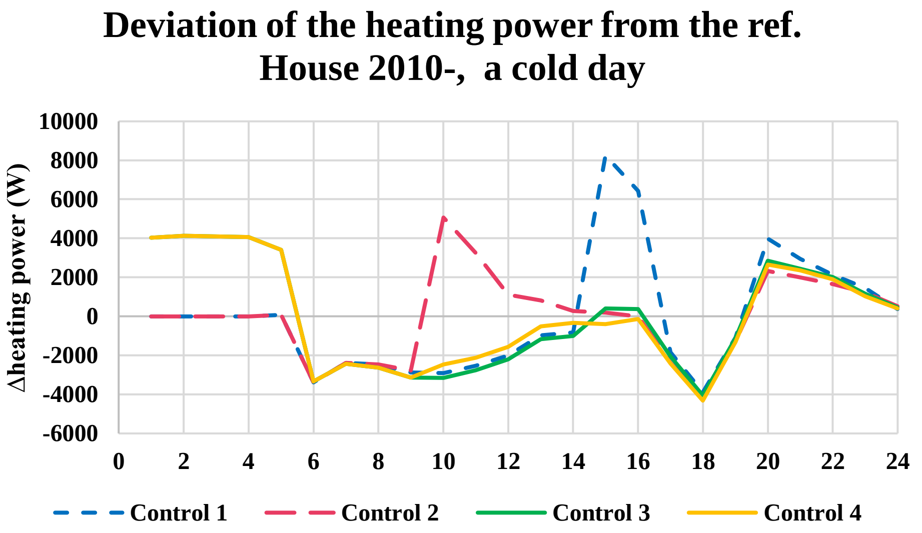
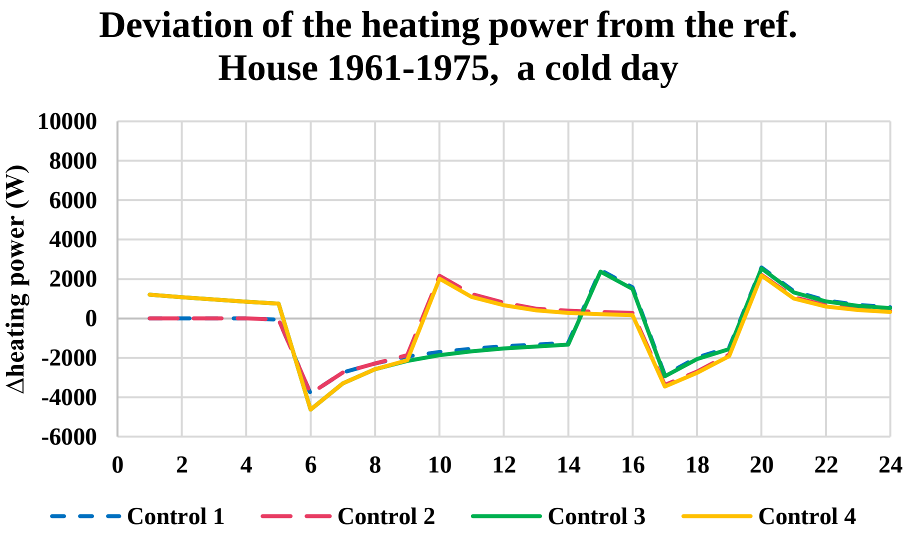
Preliminary results: Δheating power





Control strategy:

- Control 1: 19 ˚C (non-occupied hours)
- Control 2: 21 ˚C (non-occupied hours)
- Control 3: 23 – 19 ˚C
- Control 4: 23 – 21 ˚C

Shiftable heating demand Wh = ∑ (heating power – ref. case) during the peak hours

shiftable heating demand % = shiftable heating demand/total heating demand for the reference case where Troom = 21 ˚C.

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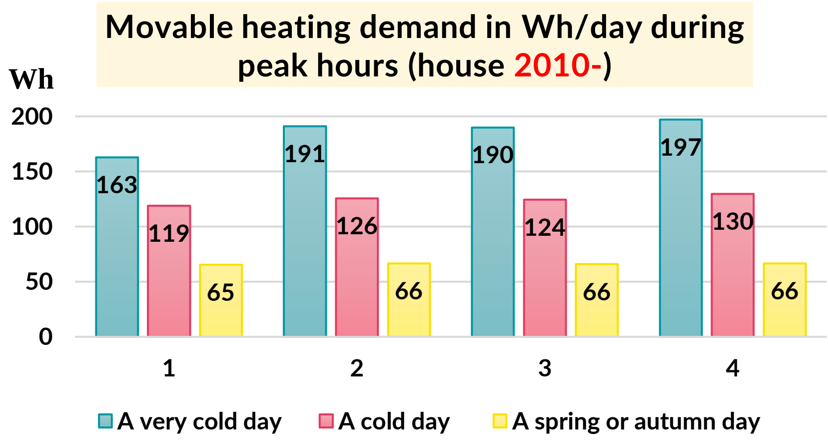
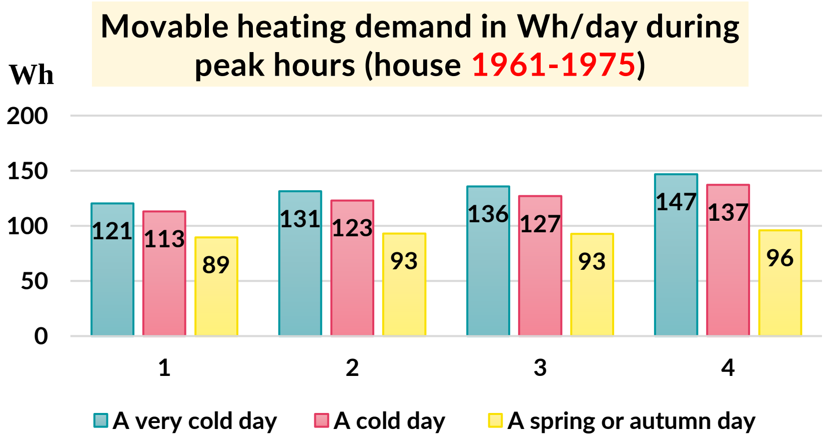
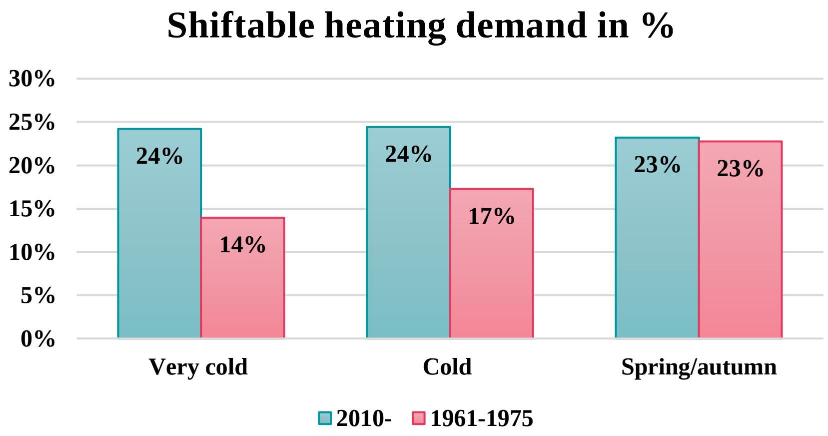
Preliminary results: flexibility of heating demand







Flexibility of heating demand

For a very cold day

- house 2010- provides higher flexibility potential.

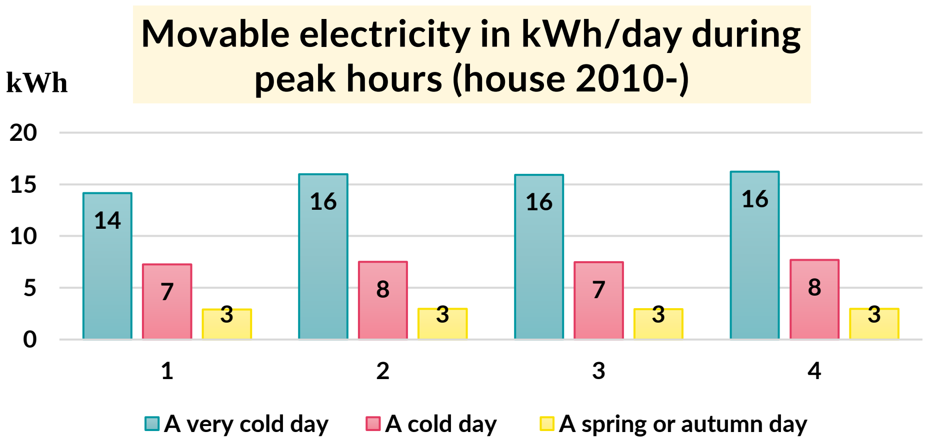
For a spring/autumn day

- the potential is higher with 1961-1975 house.

More heating energy is moved during winter than spring/autumn due to higher heating demand.

Results could be relevant for houses connected to district heating.

Preliminary results: flexibility of electricity



Exhaust air heat pump for house 2010-

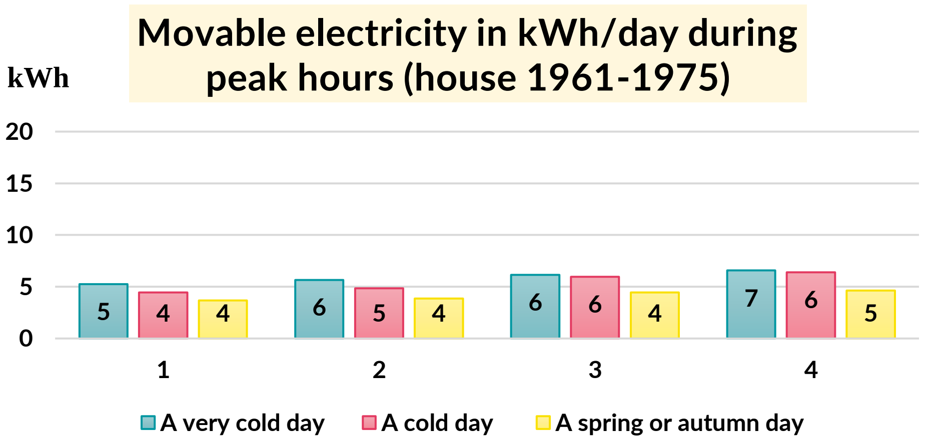
COP ≈2.5, Qheating power ≈4 kw

COP ≈3.7, Qheating power ≈1.3 kw

Ground source heat pump for house 1961-1975

COP ≈ 3, Qheating power ≈8 kw

COP ≈ 3.6, Qheating power ≈3.6 kw



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Thank you for your attention!

Questions and suggestions?

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