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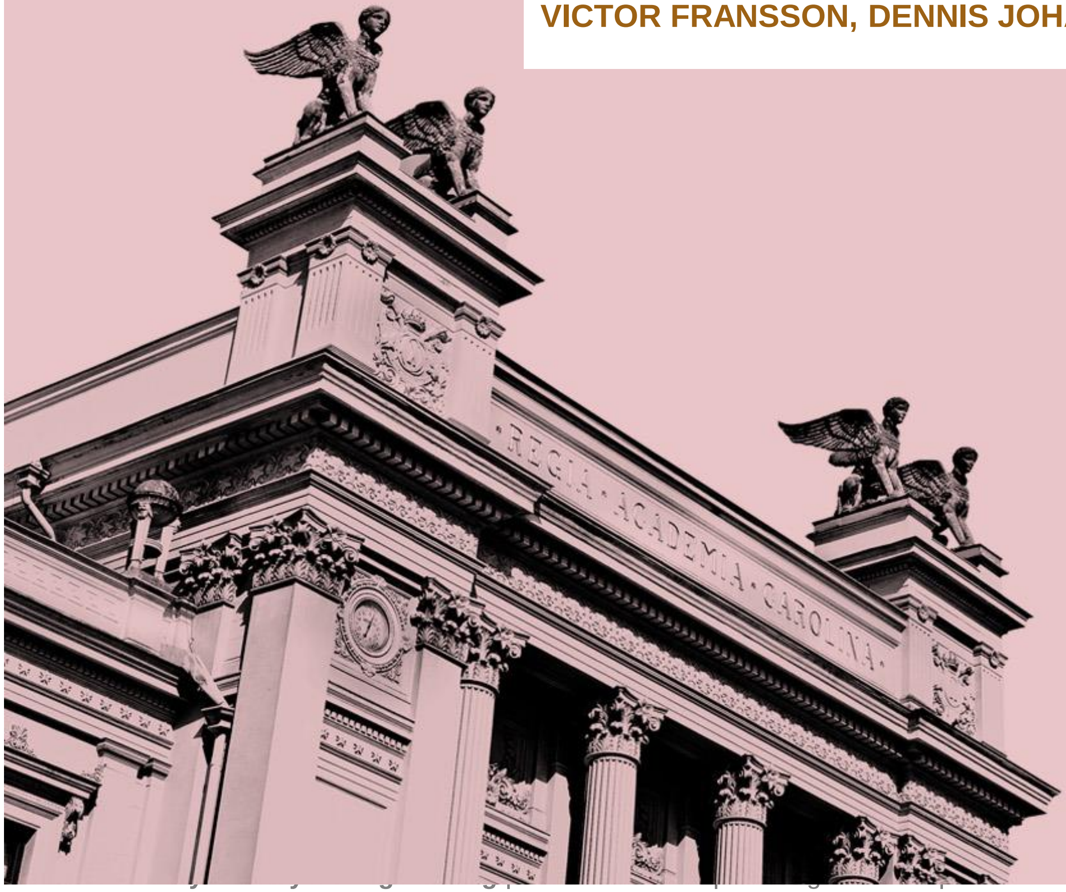
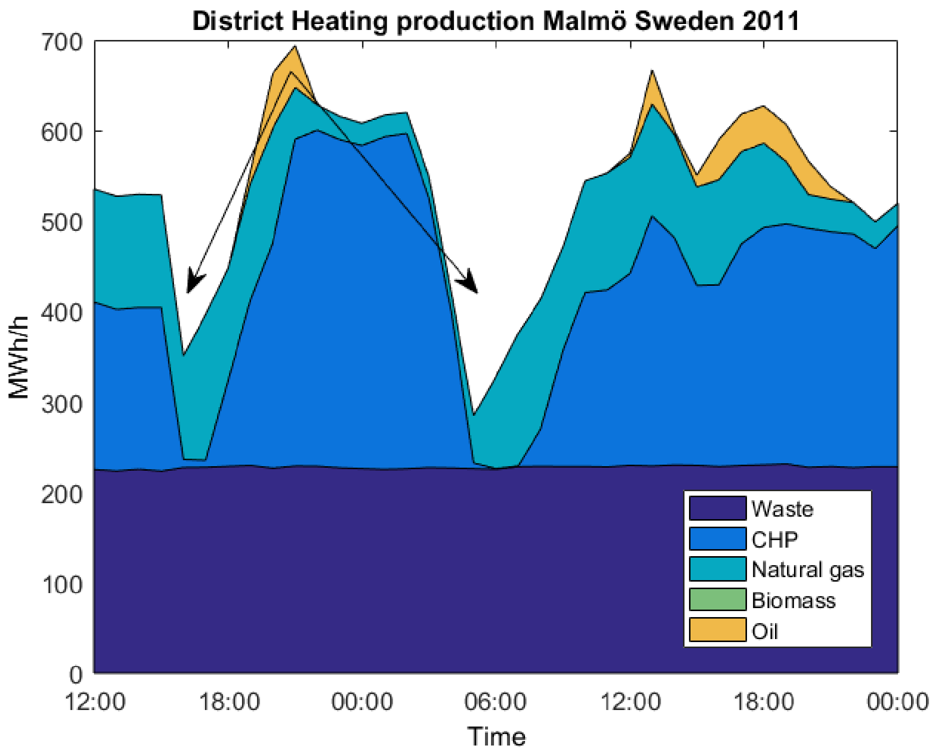
Using the Thermal Mass of a Building to Reduce the Magnitude of the Peak Power Demand of the Primary Heating System—A Whole-Building Simulation with Parametric Analysis

VICTOR FRANSSON, DENNIS JOHANSSON, HANS BAGGE



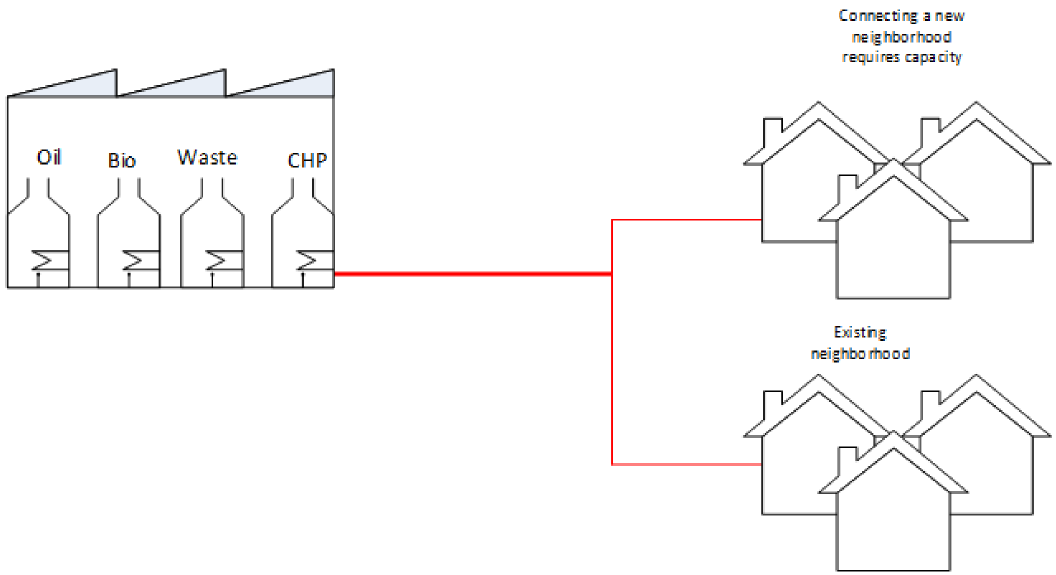
Background

- Power is the issue as well as energy use
- During the heating season when demand is high
- Power production either expensive or using fossil fuel



Background

- District heating major source of heating in Sweden
- Starting new boilers with different efficiencies
- Connecting new neighborhood

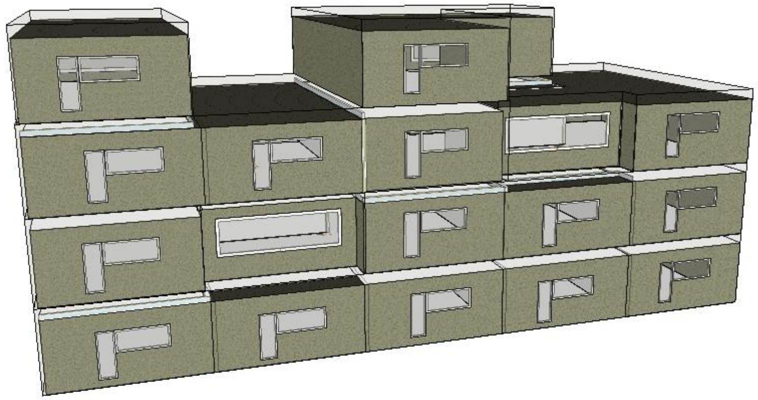


Background

- Demand side management
- Communication through Smart-Grid technology
- Demand side modify their heating requirement in order to lessen the demand on the heating supplier
- Using the energy stored in the building envelope to cover for the loss and allowing an impact on the indoor temperature

Method

- Whole building simulation of an existing multifamily dwelling
- 1077 m² heated area divided into 15 apartments
- Design temperature 21 ° C
- Entire heating season between October-April simulated

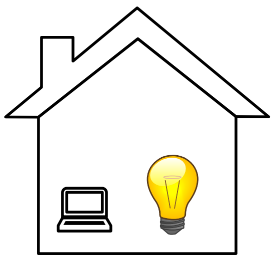


Overview

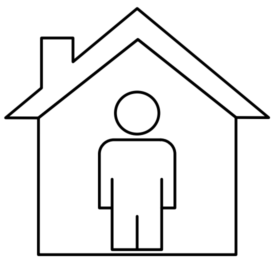
- First setup: Only the variables occupancy and household electricity randomized
- Second setup: Different climatic years are investigated with variables randomized
- Third setup: Building envelope properties investigated
- Heating modification correspond to a complete power cut-off for 2,4,6 hours starting at midnight and 6 in the morning respectively

Variables: Occupancy, Household electricity and Climate data

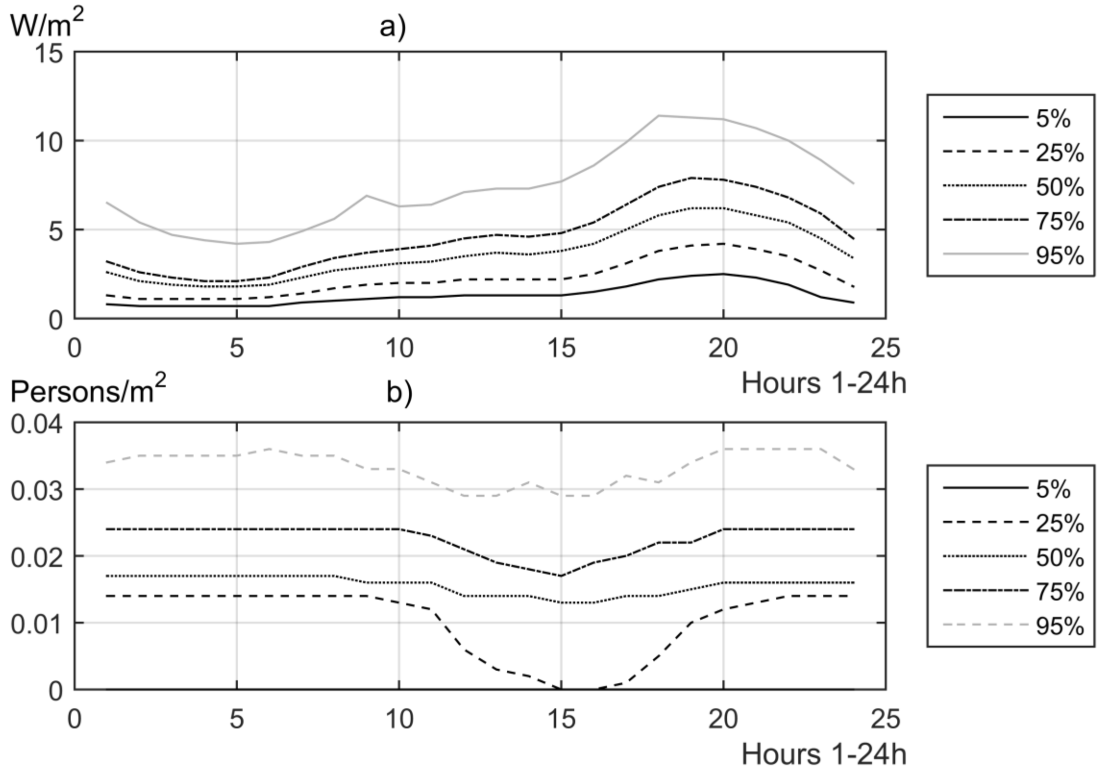
- 12 years of meteorological data where gathered from the Swedish Meteorological and Hydrological Institute (2002-2013)



Houshold electricity loads measured hourly in over 1000 apartments over a two year period



Occupancy measurements in 85 apparments over a 14 day period. Hourly data



First -and second setup building properties

- Building envelope as it is constructed (2013)
- Ventilation 0.5 ACH
- Heat exchanger with a temperature transfer efficiency of 78 %
- Hydronic underfloor heating embedded in the concrete floors

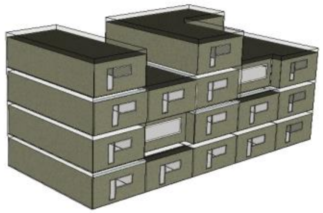
Building Envelope	Area / m^2	U / W/(m^2K)	U·A / (W/K)	% of total
Walls	630	0.16	100.5	16.2
Roof	330	0.17	56.2	9.1
Windows	199	1.36	270.5	43.6
Ground	330	0.07	25.0	4.0
Thermal bridges	-	-	168	27.1

Third setup building properties

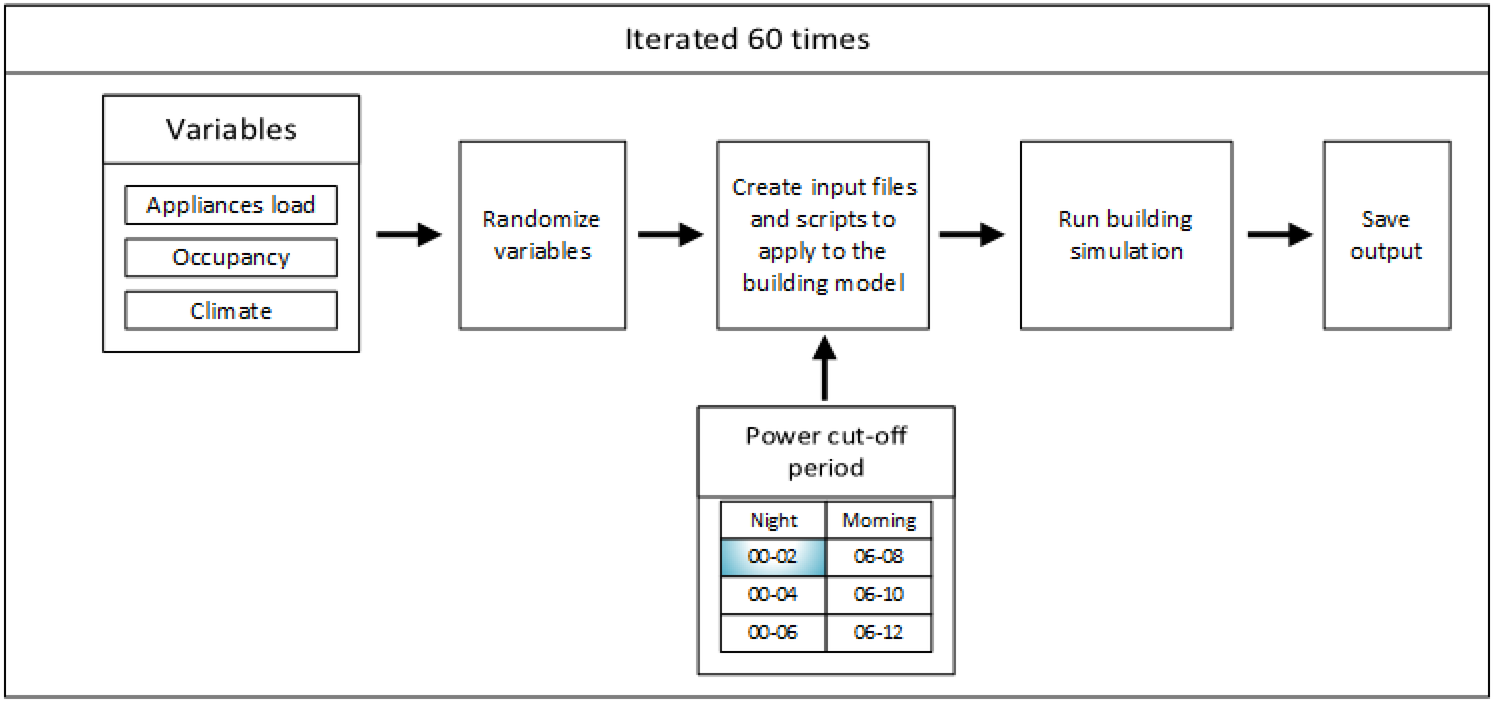
- Ventilation 0.5 ACH
- Heat exchanger with a temperature transfer efficiency of 78 %
- Hydronic underfloor heating embedded in the concrete floors
- Heavy and light structures with the same U-values

Building component	PH Values	Std Values	1960s Values
Exterior wall	0.1 W/(m²K)	0.18 W/(m²K)	0.4 W/(m²K)
Roof	0.08 W/(m²K)	0.13 W/(m²K)	0.25 W/(m²K)
Window	0.8 W/(m²K)	1.3 W/(m²K)	2 W/(m²K)
Ground	0.1 W/(m²K)	0.18 W/(m²K)	0.4 W/(m²K)
Air leakage	0.3 l/(s m²) ext. area at 50 Pa	0.6 l/(s m²) ext. area at 50 Pa	1.2 l/(s m²) ext. area at 50 Pa
Thermal bridges	20 % (U·A)	20 % of U·A	10 % of U·A

Simulation procedure

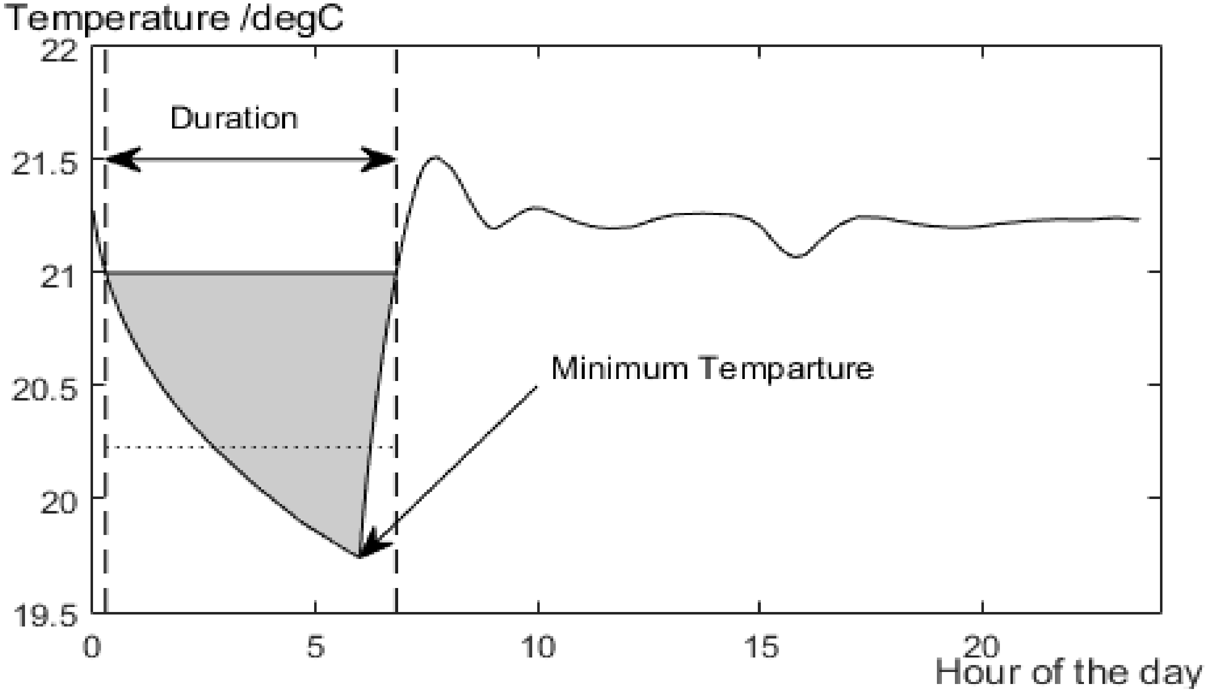
MathWorks →  → MathWorks

EQUA



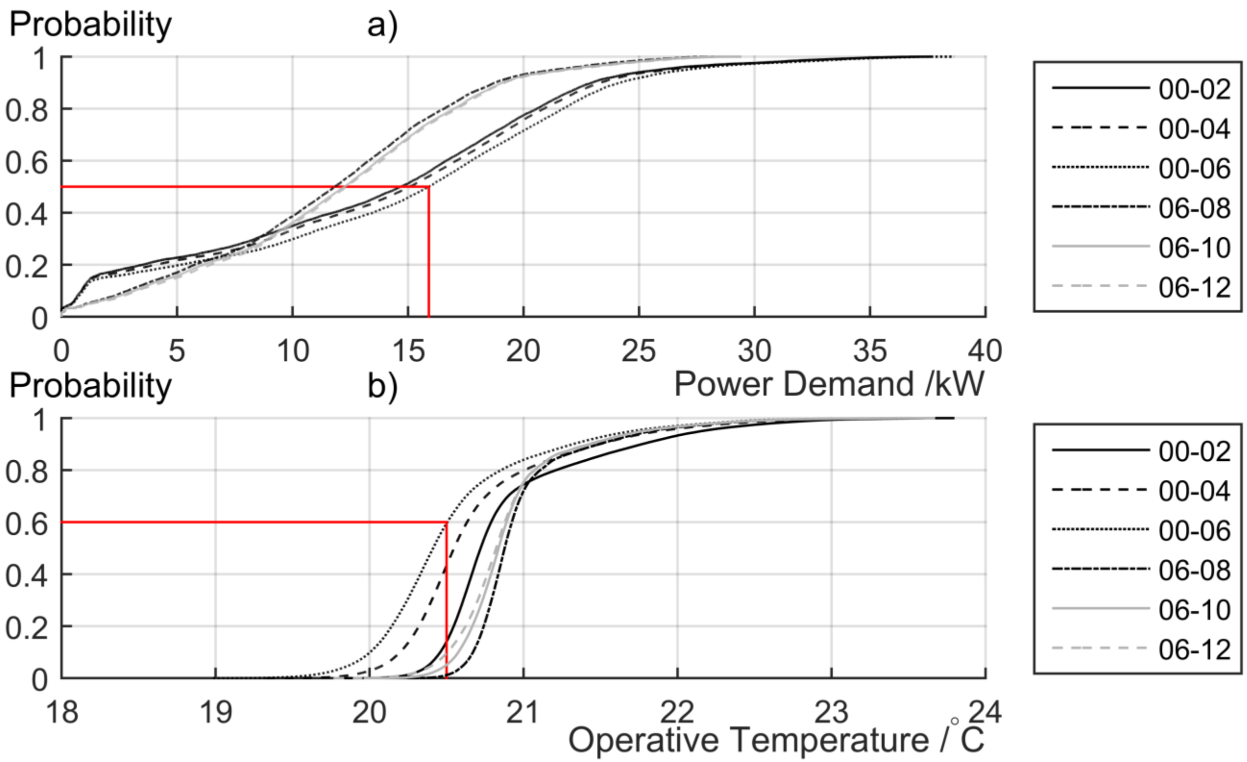
Simulation results

- Minimum operative temperature is gather for each apartment each day
- Power demand prior to the power cut-off for the entire building



Results first setup: Variables

- 60 heating seasons for each cut-off period
- 15 ap* (30days*7 months)*60years ≈ 190 000 data points/ graph



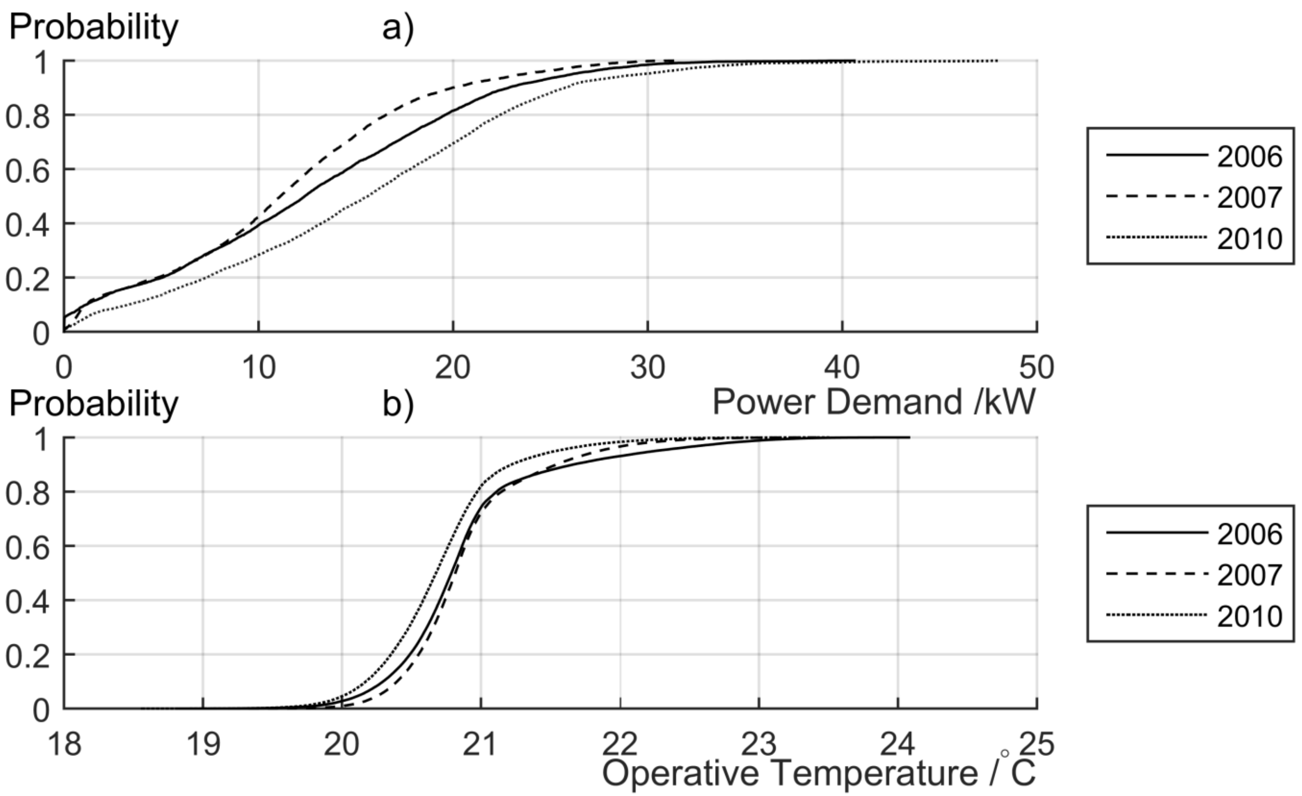
Results first setup: Variables

- Median for power cut-off between 00-06: 16 kW
- Probability of dropping 0.5° C or more 60 % for the same cut-off period (the red lines)

Time	Lowest temp	Probabiltiy of < 0.5 °C	Probability of < 1 °C	Highest demand /kW	50 % percentile / kW	90 % percentile / kW
00-02	19.9	14	0	37.6	14.7	23.0
00-04	19.3	43	3	37.7	15.0	23.3
00-06	19.0	60	10	38.6	15.9	24.2
06-08	20.3	1	0	29.4	11.8	18.8
06-10	20.0	5	0	29.3	12.3	19.1
06-12	19.8	10	0	29.4	12.3	19.2

Results second setup: Climate

- The cut-off periods aggregated into one graph/year
- 30 heating seasons/year



Results second setup: Climate

Year	Lowest temp	Probability of < 0.5 °C	Probability of < 1 °C	Demand highest /kW	50% percentile / kW	90 % percentile / kW
2002	19.2	21	2	43.5	13.2	21.6
2003	18.7	23	3	43.1	13.3	23.1
2004	19.0	21	2	34.9	13.1	21.9
2005	18.8	21	2	37.7	12.6	23.5
2006	18.8	21	3	40.6	12.4	22.8
2007	19.2	16	1	31.4	11.1	20.0
2008	19.2	18	1	33.8	11.6	20.5
2009	19.1	22	2	37.6	13.4	22.0
2010	18.6	32	5	48.0	15.6	25.8
2011	19.1	20	2	35.4	12.3	22.0
2012	18.9	21	2	39.7	12.3	23.9
2013	18.9	23	3	40.6	13.1	23.8

Results third setup: Envelope properties

House type	Mass	Added interior Wall Area/m²	Lowest temp	Probability of < 0.5 °C	Probability of < 1 °C	Max demand /kW	50% percentile /kW	90 % percentile /kW
PH	Light	20	19.5	9	2	3.2	1.5	2.1
		40	19.7	6	1	3.2	1.4	2.1
		60	19.7	4	0	3.2	1.4	2.1
	Heavy	20	20.2	1	0	3.2	1.5	2.1
		40	20.3	1	0	3.2	1.5	2.1
		60	20.3	0	0	3.2	1.4	2.1
Std	Light	20	18.7	22	2	38.6	13.5	23.3
		40	18.9	17	1	39.0	13.4	23.3
		60	19.0	14	1	40.9	13.4	23.5
	Heavy	20	20.0	5	0	40.7	13.5	23.8
		40	20.1	3	0	40.7	13.8	24.0
		60	20.1	2	0	40.9	13.3	23.3
1960s	Light	20	17.5	38	12	56.6	23.0	35.3
		40	17.8	32	8	56.9	22.6	35.5
		60	18.0	27	6	59.3	22.5	36.3
	Heavy	20	19.3	18	1	56.4	21.6	34.6
		40	19.4	15	0	57.1	21.6	35.1
		60	19.4	13	0	57.0	21.5	35.1

Conclusion

- Although a building with passive house standard receives very low impact on the indoor temperature not much power can be saved due to the low demand of the building
- More suitable are the 1960s buildings, which there are also many of in Sweden, where a lot of potential power reduction exist to a not so much higher risk of negatively impacting the indoor temperature
- Randomization a step towards better description of the stochastic behavior of the variables affecting the indoor climate

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Lunds Tekniska Högskola

Thank you for listening