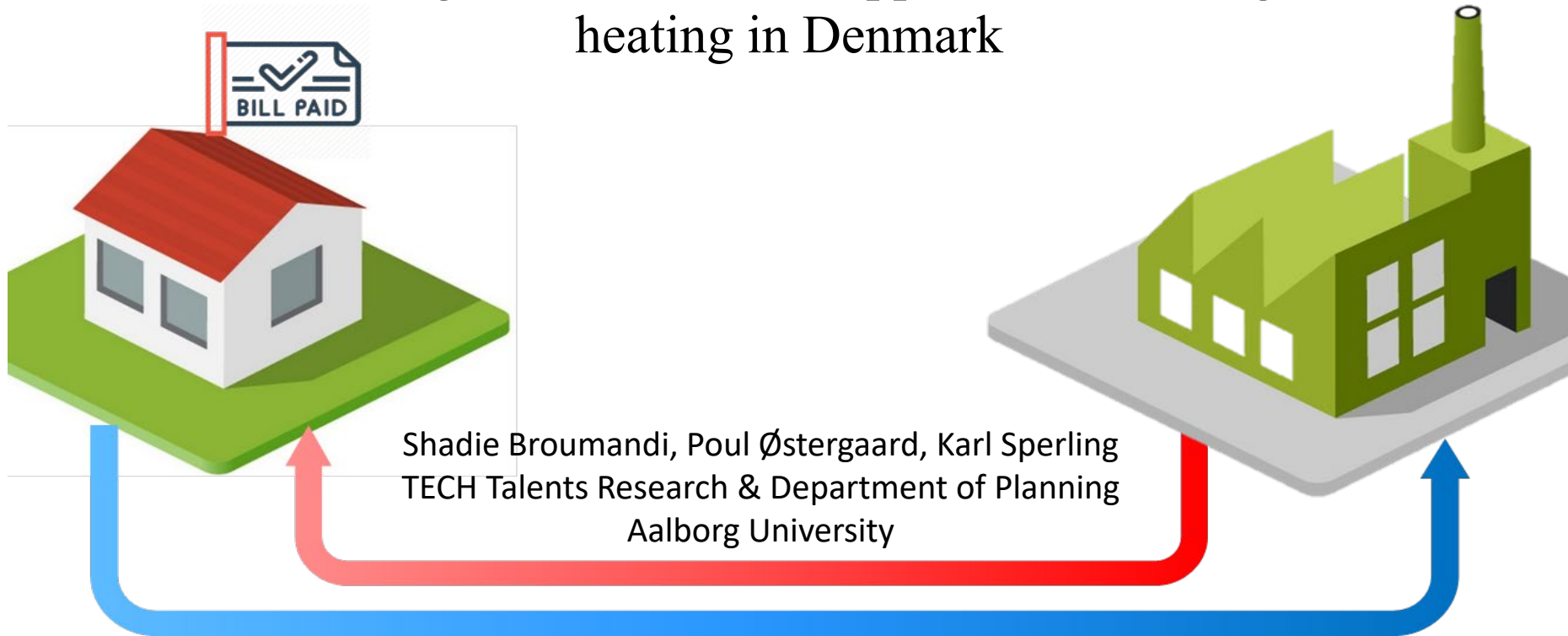


Residential heat consumption analysis towards 4th generation district heating: An econometric approach for Viborg district heating in Denmark



Introduction



- Lowering DH temperature ➡ moving towards 4GDH
- Lowering consumption in residential buildings

Research Question

To what extent do the tariff prices, supply and return temperature have an impact on the consumption pattern of residential district heating consumers?

Main focus is on demand side

- Heat consumption analysis/behavior of end users/smart meter Case Study
- Viborg Distric heating

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Viborg DH



- Population 96,000(40,000 live in Viborg)
- The Heat of Viborg DH produced by Viborg CHP
- Viborg DH (1953) is distributor and consumers owned company
- 16,000 houses and companies are connected to Viborg DH

Total Tariff

Fixed expenses (DKK/m²)

- Maintenance and distribution system
- Employees
- Meter rent

Variable expenses (DKK/kWh)

- Purchase of heat
- Losses in pipes
- Water treatment

Motivation tariff

- Since 2002

Methodology

Case study

- 100 residential houses (random, anonymized)
- Daily data for one year (2018, kWh)

Data Processing

- Data collection
- Correspondence data gathering technique
- Data sorting and cleaning
- Data analysis

Econometric model

- Log transformation of Cobb-Douglas function
- Variance inflation factor (VIF)
- P-value (0.05)

Tools

- MS Excel
- MATLAB software R2018b

Characteristics of Segmented Zones

55%



Motivation Zone	Building Age Category	No. of Buildings	Average Age (years)	Average Size (m ²)	Average Motivation (% of Total Bill)	Average Supply Temp. (°C)	Average Return Temp. (°C)
Bonus Zone	1850 - 1930	1	92	153	-1.71%	64	33
	1931 - 1950	8	77	145	-2.77%	64	31
	1951 - 1960	8	62	114	-1.27%	63	34
	1961 - 1972	13	52	156	-1.95%	63	33
	1973 - 1978	13	43	145	-2.01%	59	34
	1979 - 1985	5	35	101	-2.03%	57	34
	1986 - 1998	3	29	125	-1.35%	59	35
	1999 - 2006	3	15	123	-2.51%	60	33
	2007 - 2011	1	10	159	-0.07%	60	37

35%



Motivation Zone	Building Age Category	No. of Buildings	Average Age (years)	Average Size (m ²)	Average Motivation (% of Total Bill)	Average Supply Temp. (°C)	Average Return Temp. (°C)
Neutral Zone	1850 - 1930	2	94	102	-	65	39
	1931 - 1950	7	80	122	-	66	36
	1951 - 1960	5	62	116	-	65	37
	1961 - 1972	12	53	135	-	64	37
	1973 - 1978	5	42	152	-	63	37
	1979 - 1985	3	35	111	-	59	39
	1986 - 1998	1	31	114	-	61	38
	1999 - 2006						
	2007 - 2011						

10%



Motivation Zone	Building Age Category	No. of Buildings	Average Age (years)	Average Size (m ²)	Average Motivation (% of Total Bill)	Average Supply Temp. (°C)	Average Return Temp. (°C)
Penalty Zone	1850 - 1930	1	115	237	1.64%	67	41
	1931 - 1950	1	73	124	3.23%	62	47
	1951 - 1960	2	62	162	0.69%	60	43
	1961 - 1972	6	53	159	0.85%	65	42
	1973 - 1978						
	1979 - 1985						
	1986 - 1998						
	1999 - 2006						
	2007 - 2011						

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DENMARK



DISTRICT ENERGY
IN CITIES
INITIATIVE

sEEnergies

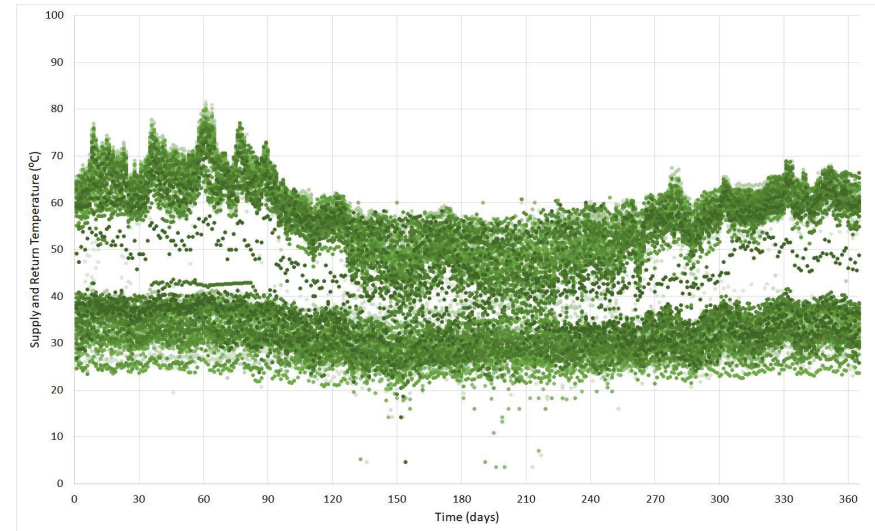
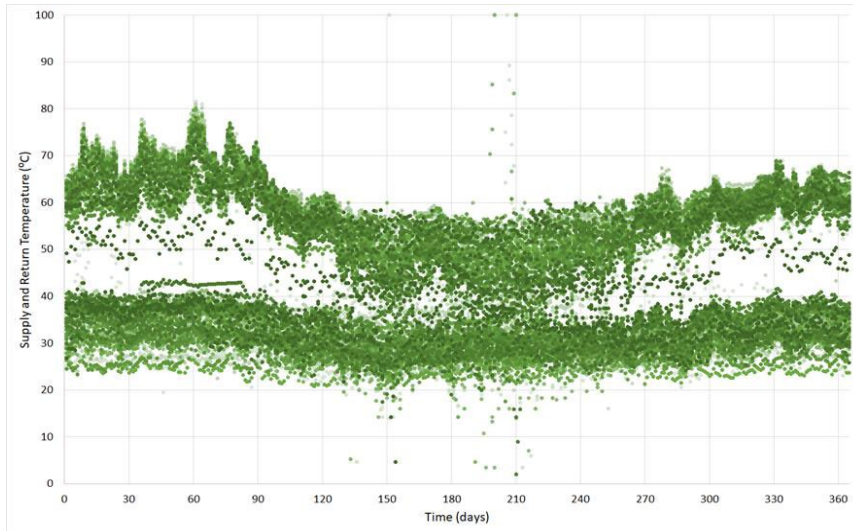


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Outlier Detection and Rectification



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Results



$$\ln HC_t = \beta_0 + \beta_1 \ln SP_t + \beta_2 \ln RE_t + e$$

VIF ✓ ✓ ✓
P-Value ✓ ✓ ✓

Regression Statistics	Bonus Zone	Neutral Zone	Penalty Zone
R Square	0.807523463	0.749611578	0.682340816
Adjusted R Square	0.807503715	0.749571468	0.682162004
Observations	19496	12488	3556

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Results



Supply Temperature Changes	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
Heat Consumption Changes (Bonus Zone)	0.00%	0.02%	0.06%	0.17%	0.43%	1.00%	2.15%	4.32%	8.20%	14.86%	25.83%
Heat Consumption Changes (Neutral Zone)	0.00%	0.02%	0.06%	0.18%	0.44%	1.00%	2.08%	4.06%	7.52%	13.29%	22.58%
Heat Consumption Changes (Penalty Zone)	0.01%	0.02%	0.07%	0.19%	0.45%	1.00%	2.04%	3.92%	7.15%	12.46%	20.91%

Return Temperature Changes	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
Heat Consumption Changes (Bonus Zone)	1.12%	1.09%	1.06%	1.04%	1.02%	1.00%	0.98%	0.97%	0.96%	0.95%	0.93%
Heat Consumption Changes (Neutral Zone)	0.57%	0.66%	0.75%	0.83%	0.92%	1.00%	1.08%	1.16%	1.24%	1.31%	1.39%
Heat Consumption Changes (Penalty Zone)	0.86%	0.90%	0.93%	0.95%	0.98%	1.00%	1.02%	1.04%	1.06%	1.08%	1.09%

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Conclusion

- Heat consumption shows a stronger reaction to changes in supply temperature for all the motivational zones
- The heat consumption has little reaction to changes in the return temperature
- Neutral zone shows more sensitivity to heat consumption with respect to the changes in return temperature in comparison to the bonus and penalty zones

Thank You for the Attention



The final word of thanks goes to Tom Diget (Chief Operating Officer) of Viborg DH in Denmark for providing the anatomized data and his ongoing support and comments during the project.

