*By Gorm Bruun Andresen, Rasmus Pedersen from Department of Engineering, Aarhus University Aarhus, Denmark*

Adam Bruun from AffaldVarme Aarhus, Denmark

USER INCENTIVES FOR LOW-ENERGY RENOVATIONS IN DISTRICT HEATING SYSTEMS OF DIFFERENT SCALES

AARHUS UNIVERSITY
DEPARTMENT OF ENGINEERING

Driving questions

- How are the consumer incentives for low energy retrofit affected by:
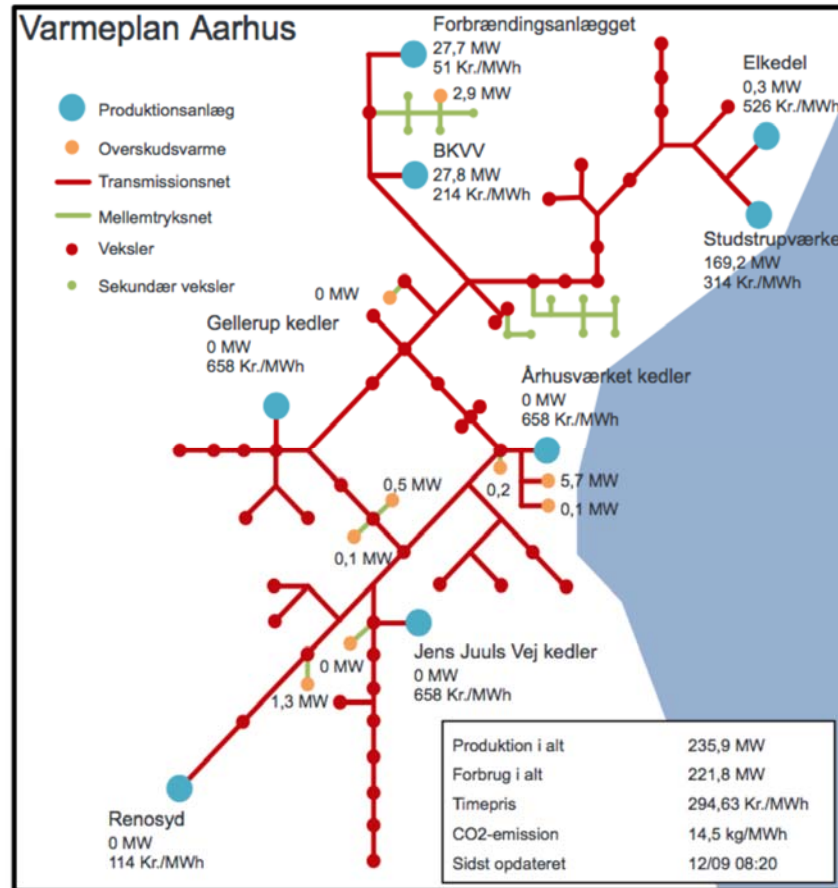 - The DH company size?
  - The fixed-variable cost ratio?

50 kWh/m²/yr

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING
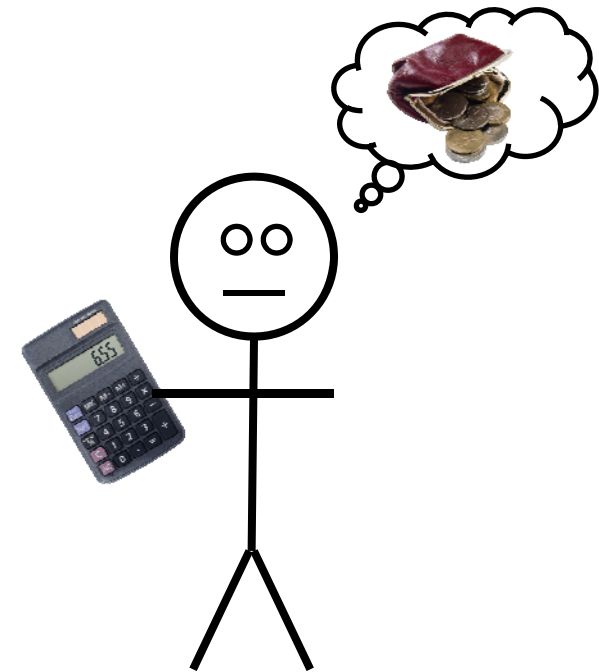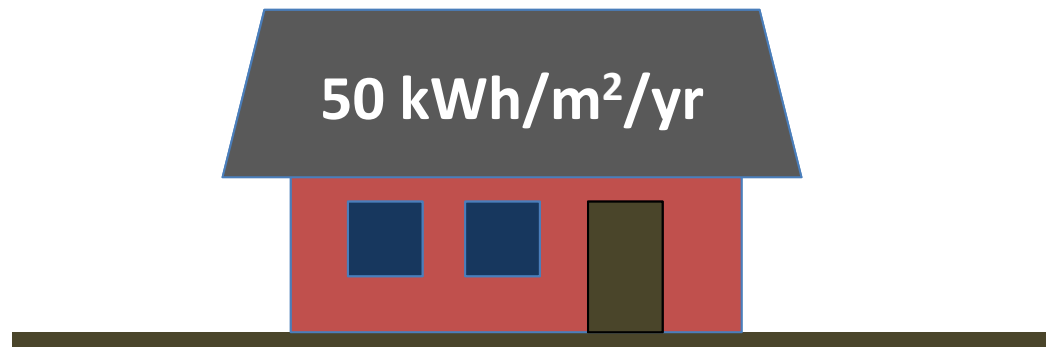
District heating
Aarhus is our lab

Investments and O&M costs

Variable fuel costs

Pipe network costs

Heat loss

DISTRICT HEATING COST MODEL

G.B. Andresen, September – 2017
gba@eng.au.dk

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

Heat production cost

Varmeplan Aarhus

Forbrændingsanlægget
27,7 MW
51 Kr./MWh
2,9 MW

Elkedel
0,3 MW
526 Kr./MWh

- Produktionsanlæg
- Overskudsvarme
- Transmissionsnet
- Mellemtryksnet
- Veksler
- Sekundær veksler

BKVV
27,8 MW
214 Kr./MWh

Studstrupværket
169,2 MW
314 Kr./MWh

0 MW

Gellerup kedler
0 MW
658 Kr./MWh

Århusværket kedler
0 MW
658 Kr./MWh

0,5 MW   0,2   5,7 MW
0,1 MW

0,1 MW

Jens Juuls Vej kedler
0 MW
0 MW   658 Kr./MWh
1,3 MW

Renosyd
0 MW
114 Kr./MWh

Produktion i alt	235,9 MW
Forbrug i alt	221,8 MW
Timepris	294,63 Kr./MWh
CO2-emission	14,5 kg/MWh
Sidst opdateret	12/09 08:20

http://transmissionsnet.varmeplanaarhusapps.dk/

- Fixed cost for the heat transmission network and production units are **302 million dkk/yr**. The fixed cost are shared according to the total heat supplied to each area.

- Variable costs are calculated hour by hour. On average the cost is **249 dkk/MWh**.

AARHUS UNIVERSITY
DEPARTMENT OF ENGINEERING

# Distribution network cost (DNC$_i$)
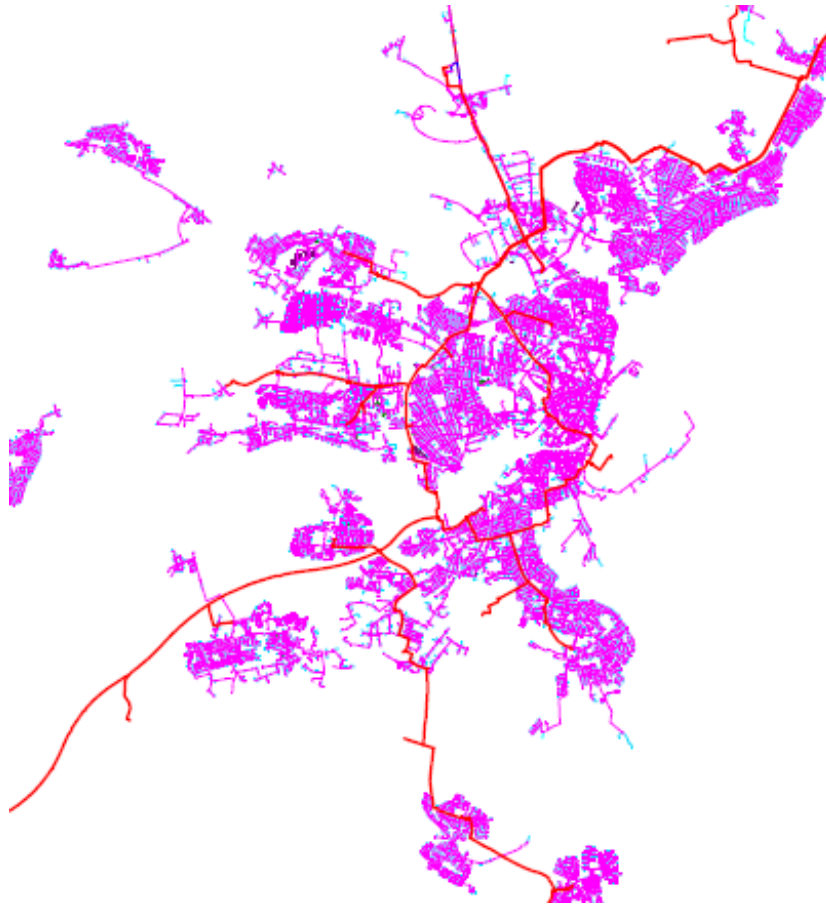
- Database of 65,000+ individual pipes
  - Length (L_i)
  - Diameter (d_i)
  - Location
- Database of 100,000+ buildings (BBR)
  - Building foot-print (a_{ii})
  - Land area (A_i)

Cost model

$$\text{DNC}_i = \text{annuity} \cdot (C_1 + C_2 \cdot d_i) \cdot L_i$$

Urban Persson and Sven Werner. Heat distribution and the future competitiveness of district heating. *Applied Energy*, 88(3):568–576, 2011.
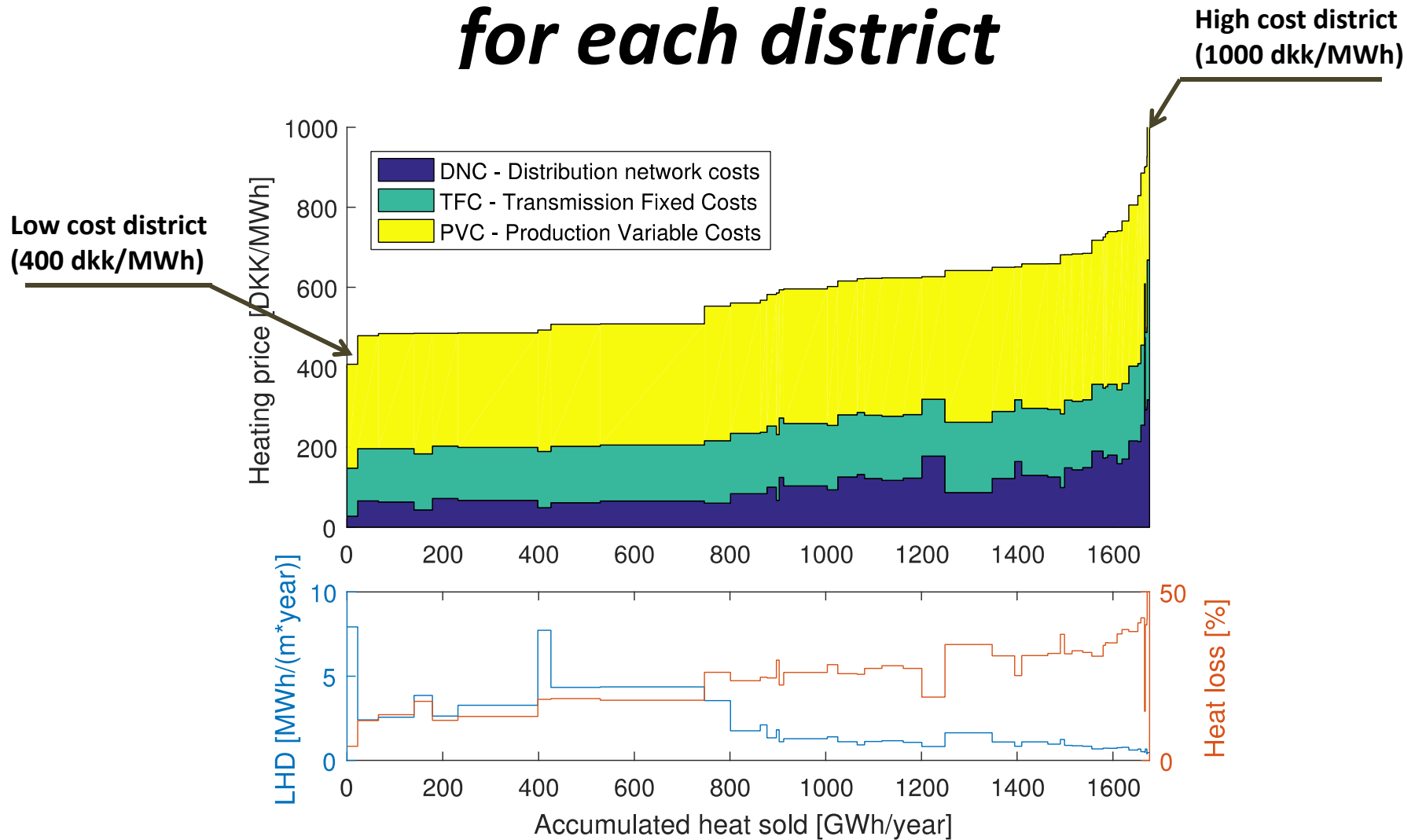
AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING
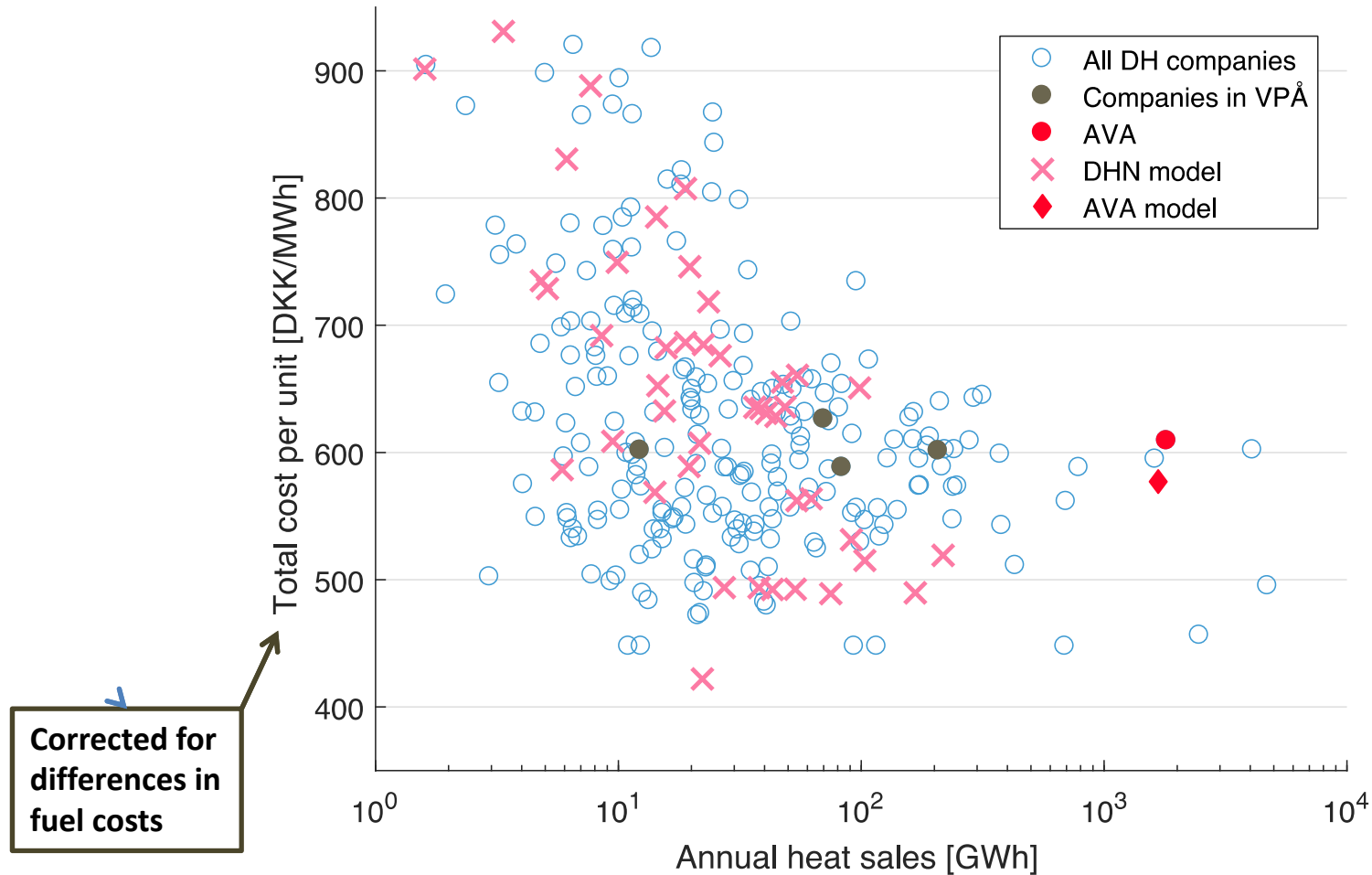
Heat sales and Heat loss
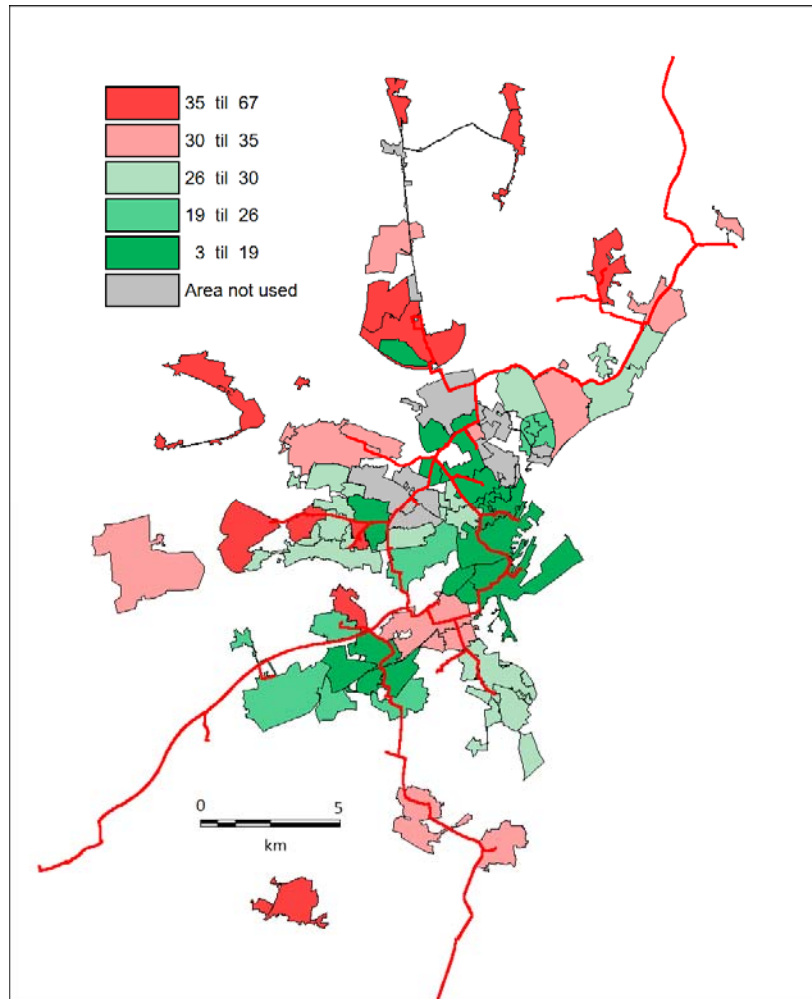
- Database of 55,000+ individual consumer installations
  - 3 years of annual heat consumption (q_i).

- Heat delivered to each of the 50+ districts
  - Hourly heat load (Q_i).

$$\text{Heat loss}_i = \frac{Q_i - q_i}{Q_i}$$

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

Cost per unit sold
for each district

G.B. Andresen, September − 2017
gba@eng.au.dk

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

The districts of Aarhus are representative for DH in Denmark

Corrected for differences in fuel costs

AARHUS
UNIVERSITY
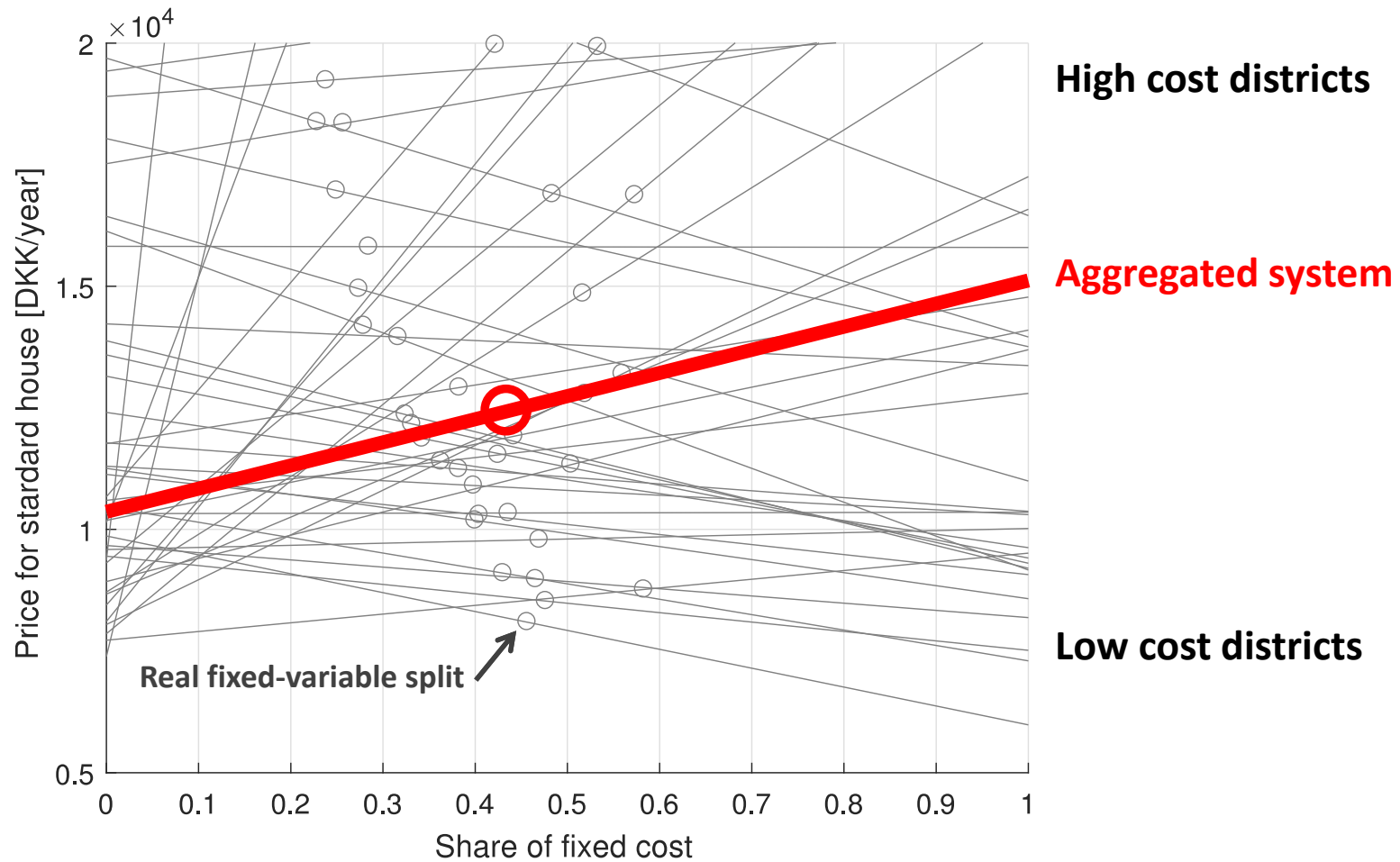DEPARTMENT OF ENGINEERING

$$\text{Consumer cost} = f \times \frac{\text{system cost}}{\text{number of consumers}} \; +$$

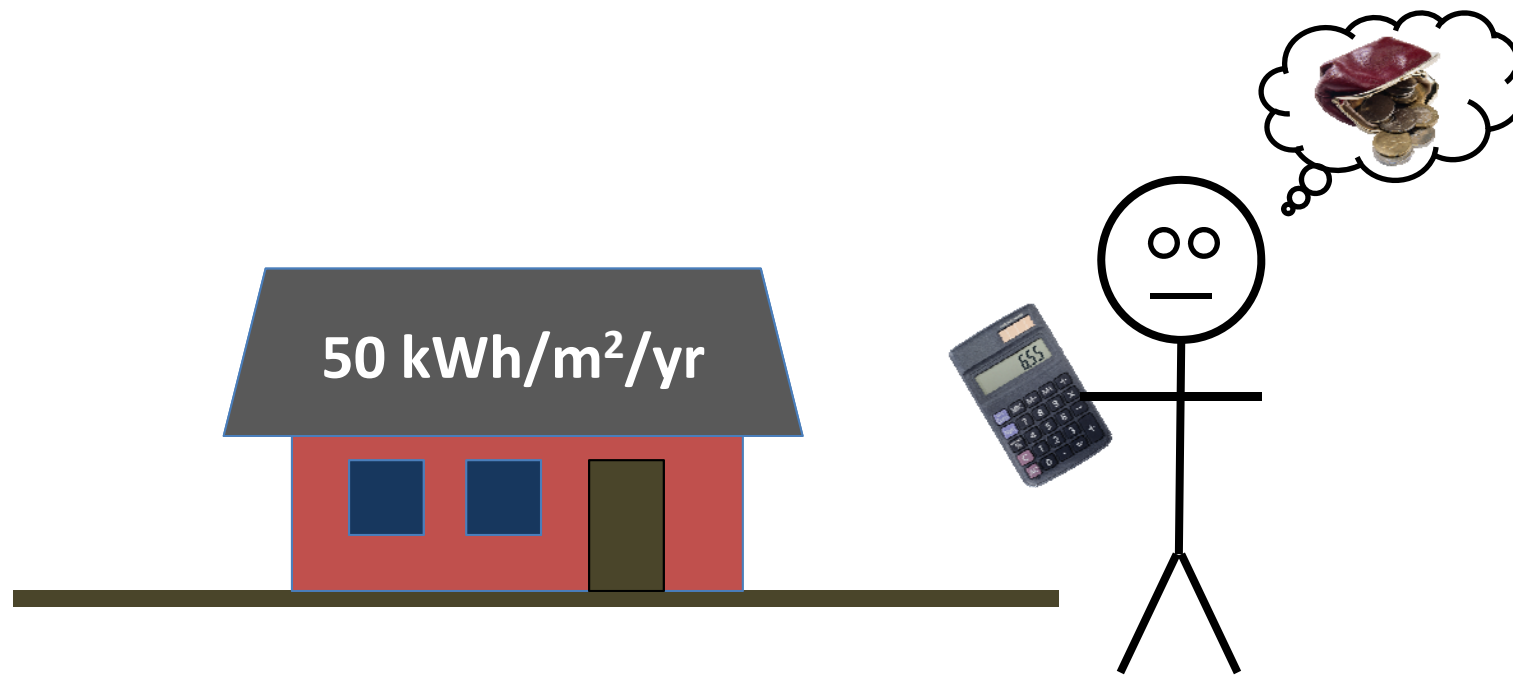$$(1 - f) \times \frac{\text{system cost}}{\text{total heat sales}} \times \text{consumer heat purchase}$$

Fixed fraction   **Variable fraction**

Location

Fixed costs

Variable costs

CONSUMER COST MODEL

G.B. Andresen, September – 2017
gba@eng.au.dk

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

Example of consumer cost in different areas

High cost districts

Aggregated system

Real fixed-variable split

Low cost districts

Price for stardard house [DKK/year]

Share of fixed cost

G.B. Andresen, September – 2017
gba@eng.au.dk

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

50 kWh/m²/yr

What is in it for me?

CONSUMER INCENTIVES

Current consumption

About 95% of consumers use more than 50 kWh/m²/yr

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING
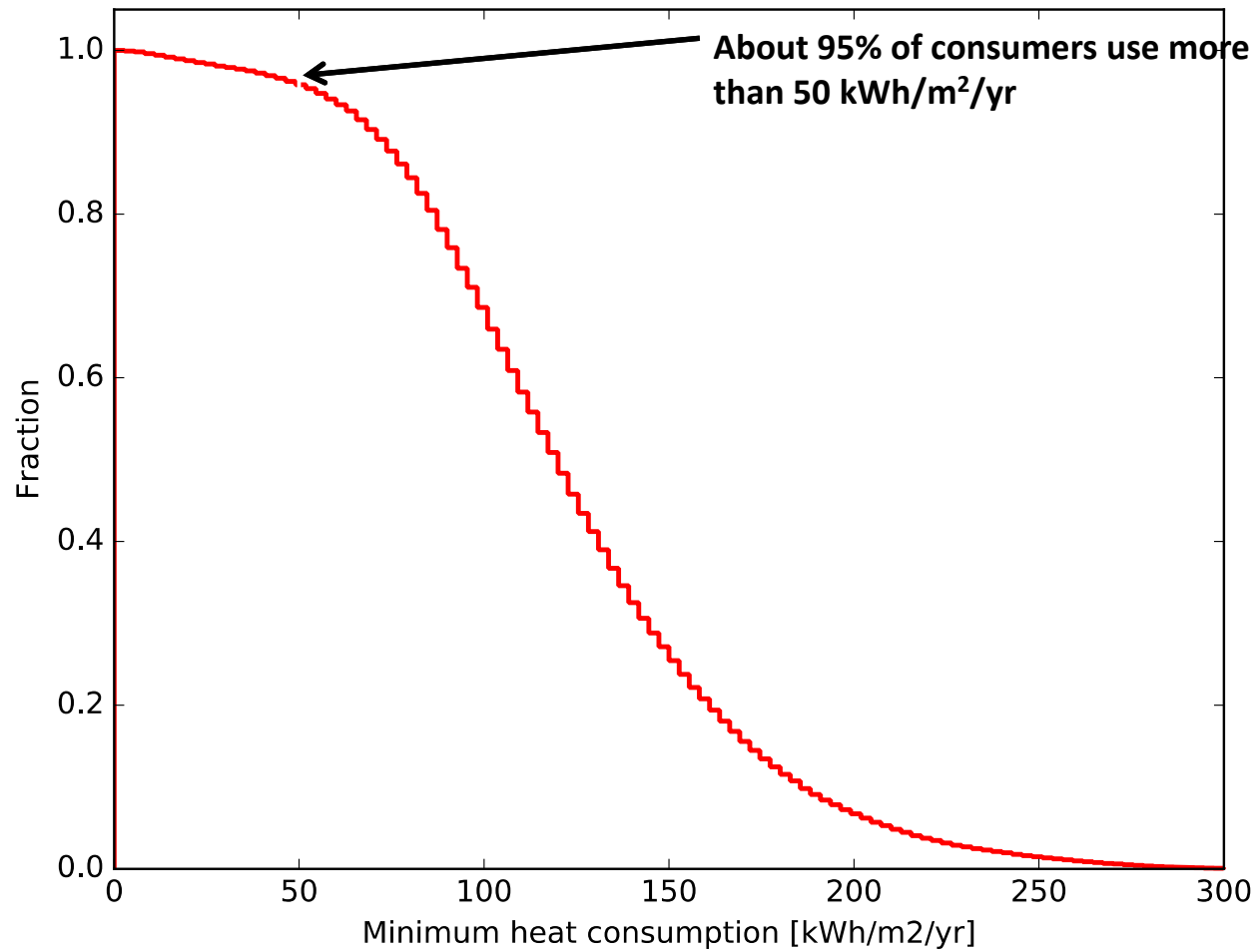
Consumer cost distribution

Fixed/variable
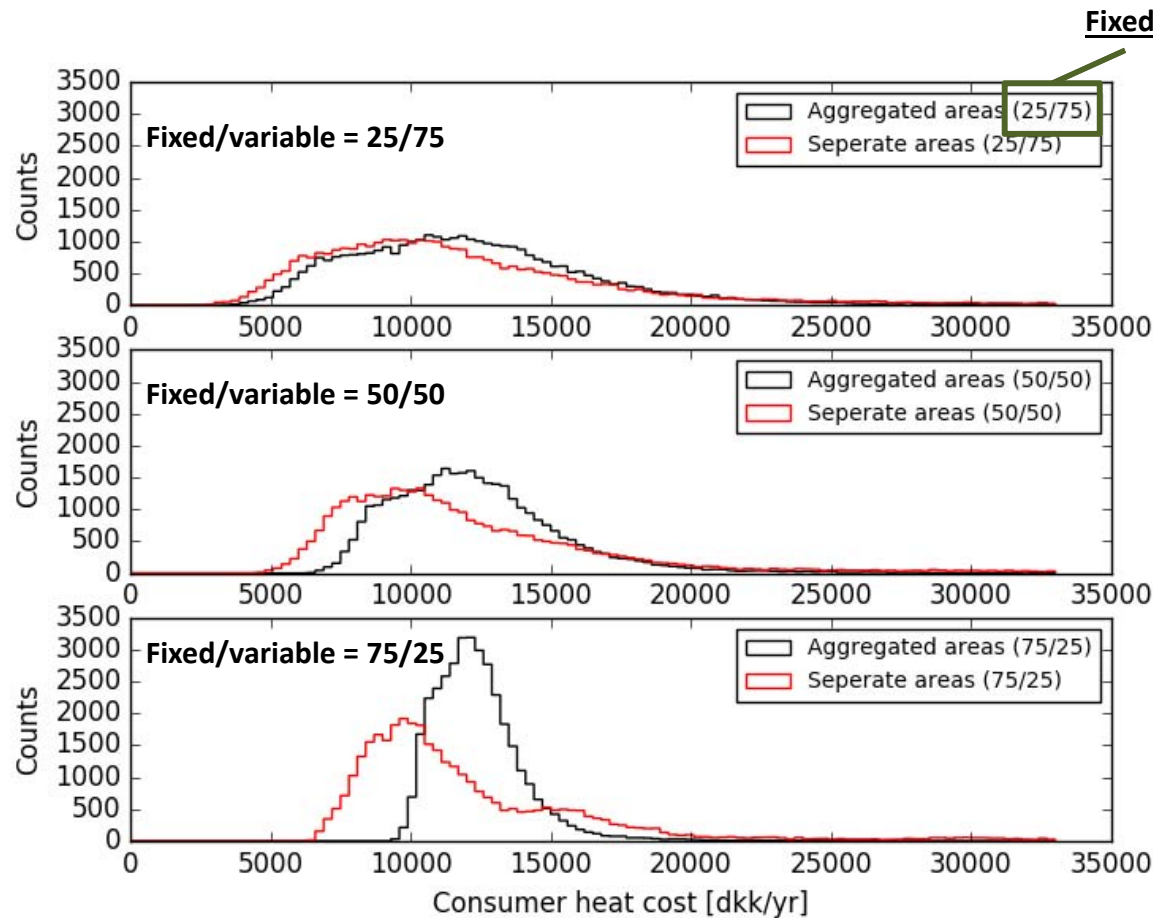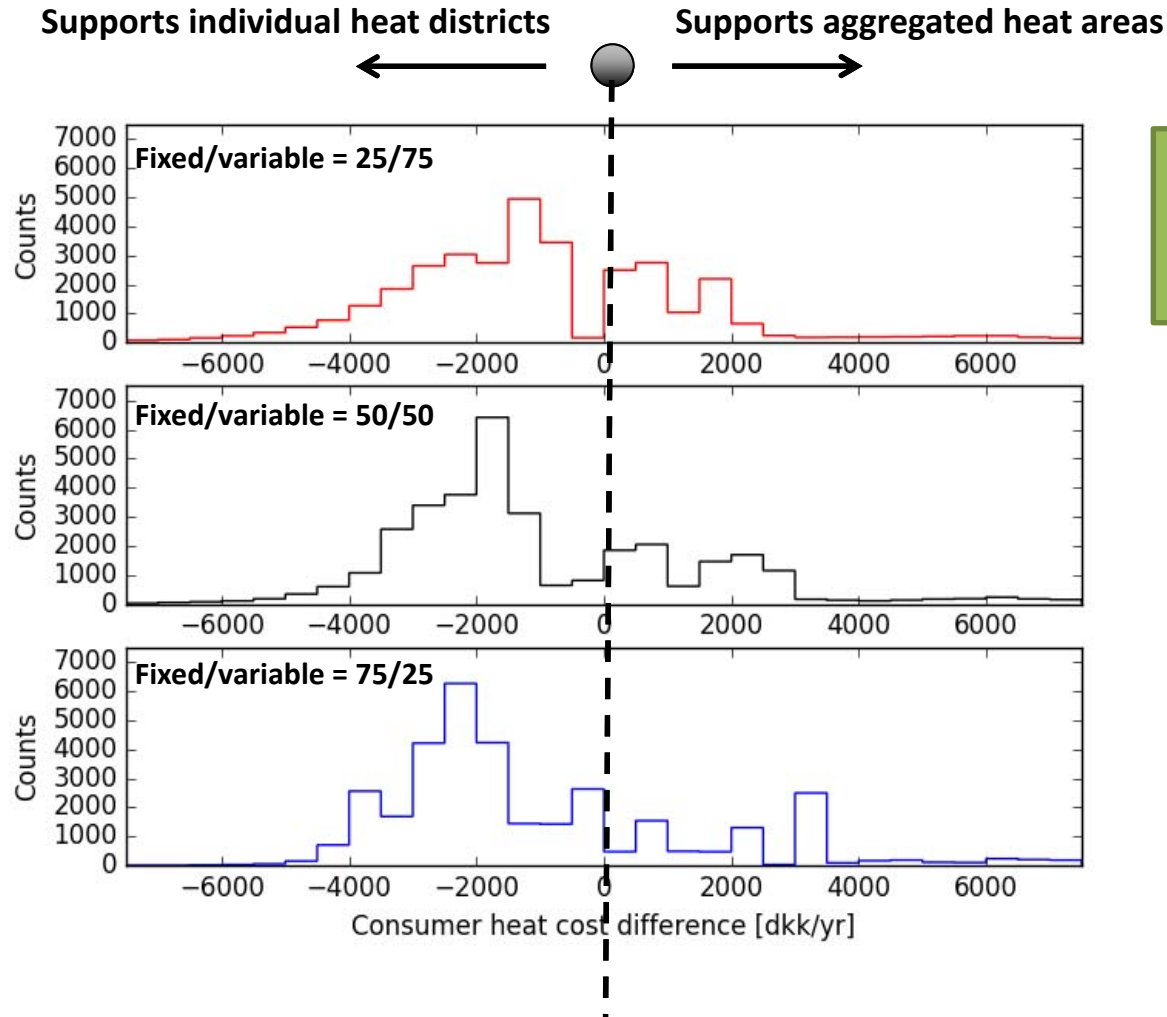

For **35,696 consumers**, we have highly detailed consumption and building data.

You cannot save more than your heat bill!

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

Consumer benefit of aggregation

G.B. Andresen, September – 2017
gba@eng.au.dk

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

Retrofit to 50 kWh/m²/yr

Both **localized and aggregated** cost models provide similar incentives for low energy retrofit.

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

Conclusion

In Aarhus:

- The cost of heat varies from 400 to 1000 dkk/MWh.
  - *Aggregation can ensure that socio-economical DH also becomes attractive for all consumers.*
- Most consumers would benefit from a localized cost model.
- An aggregated cost model leads to slightly higher incentives for low energy retrofit.
- In absolute numbers the incentives are low, about 25 dkk/MWh/m^2.

re INVEST

READY

Smart Cities and Communities

AARHUS UNIVERSITY
DEPARTMENT OF ENGINEERING