Swedish experience of district heating, transportation and biomass

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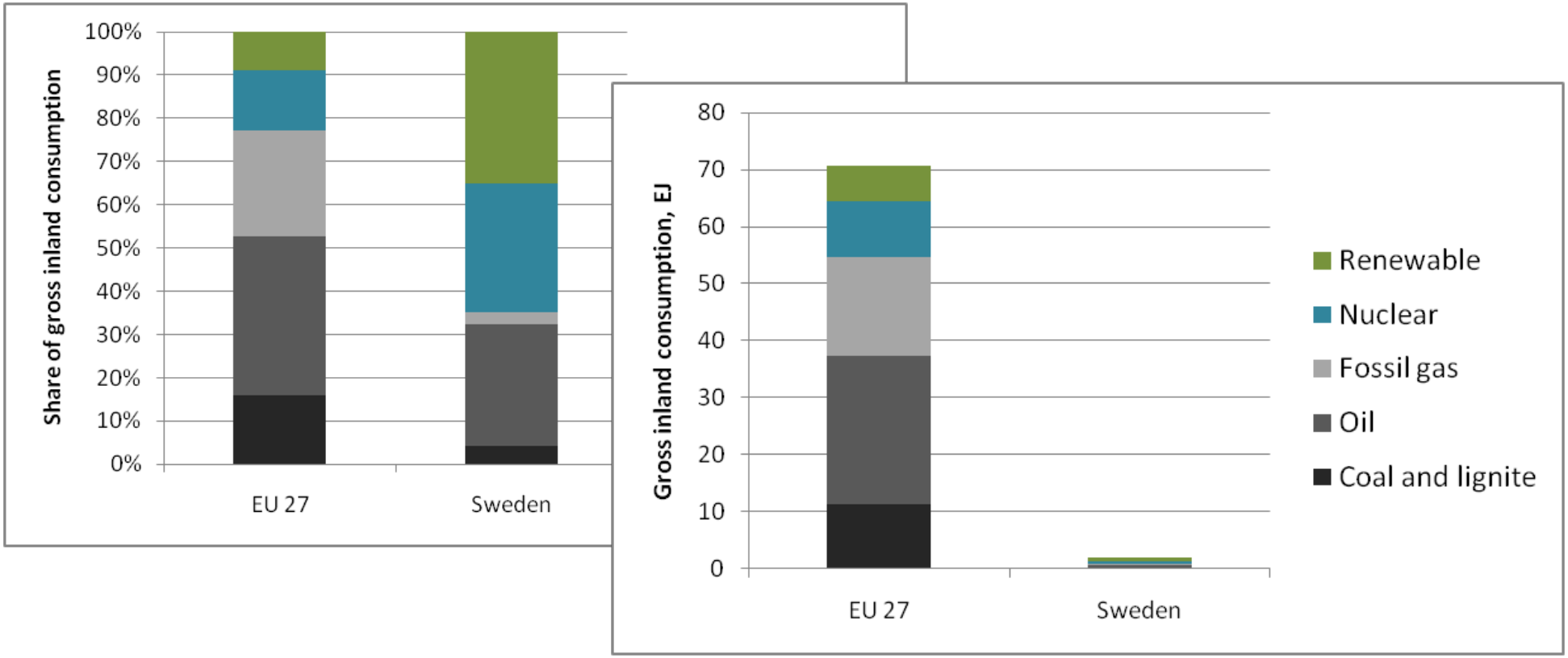
Global primary energy use in 2009 (≈500 Exajoule)

• Oil	33%
• Coal	27%
• Gas	21%
• **Total fossil**	**81%**
• Bioenergy	10%
• Nuclear	6%
• Other	3%

Exa = 10^{18}

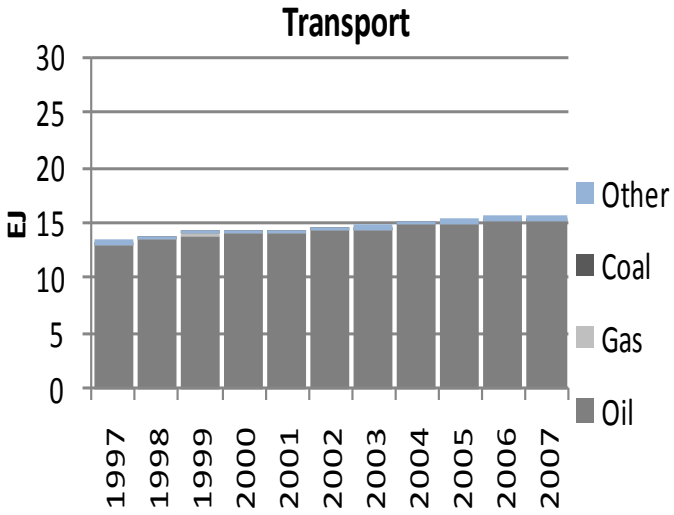
Source: International Energy Agency, 2011. *Key World Energy Statistics*

Primary energy use in Sweden and the EU 2009

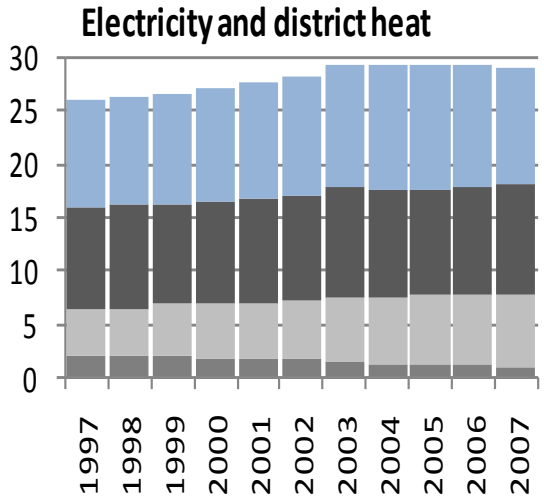


Source: Eurostat, online database, 2011

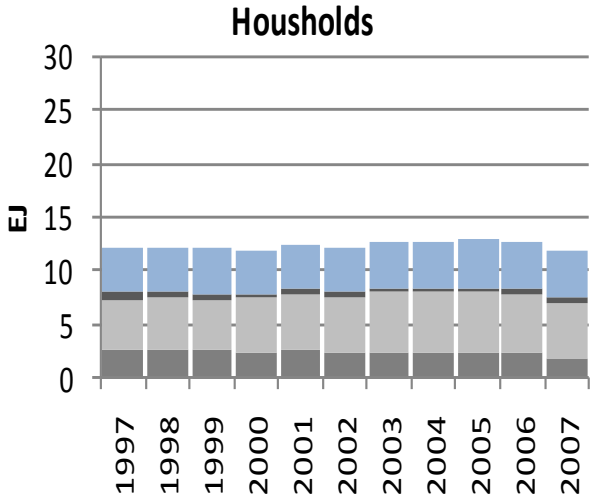
Energy use in the EU – Three typical applications



Mobile



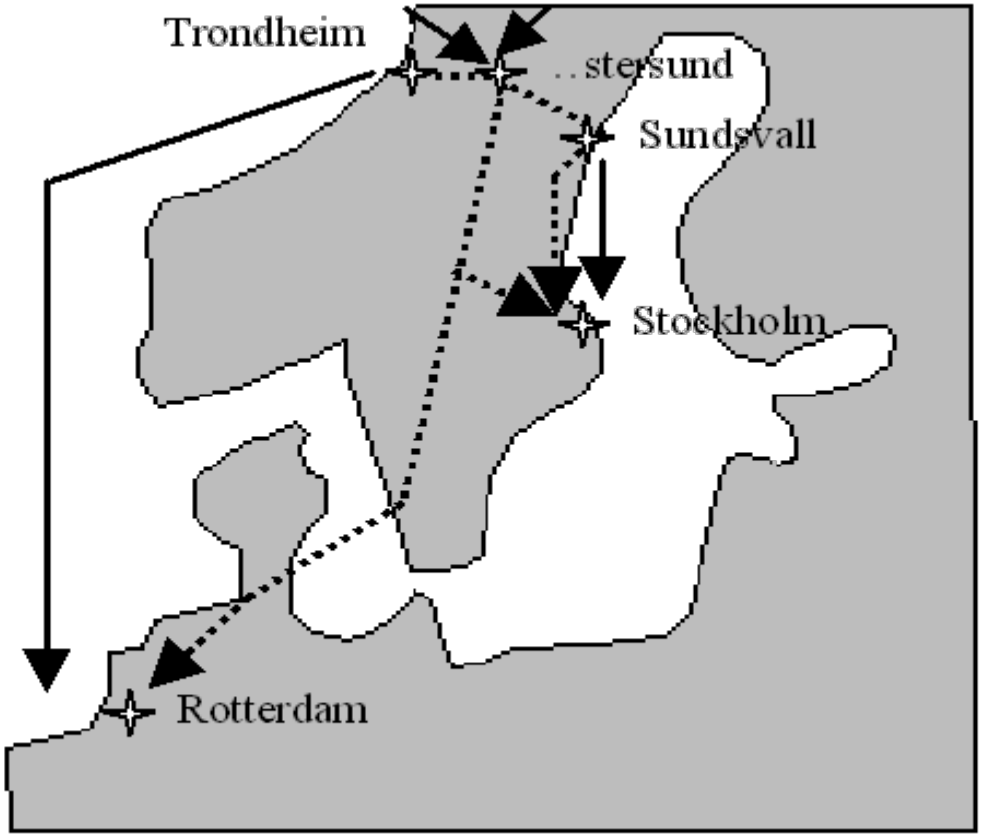
Large-scale stationary



Small-scale stationary

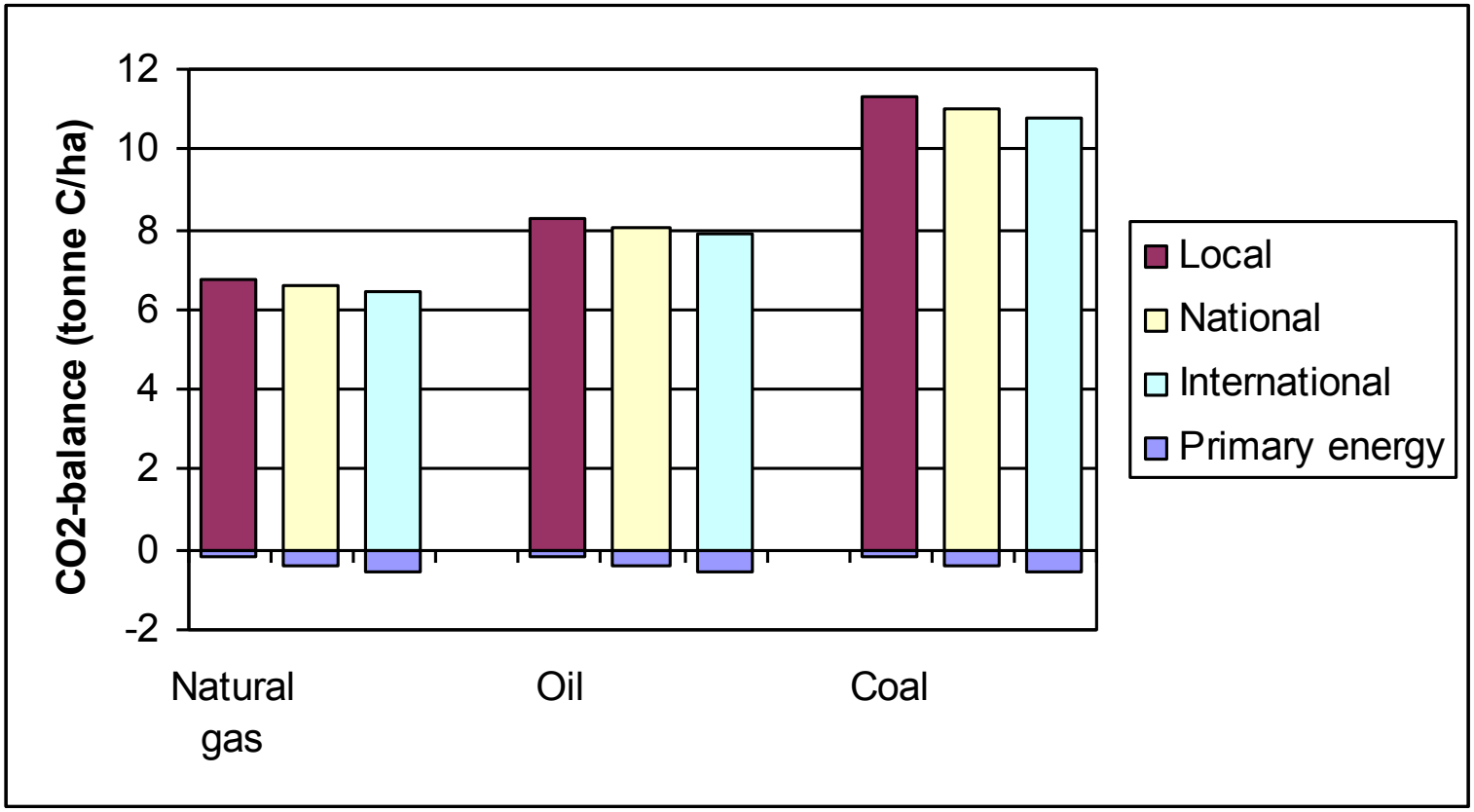
Eurostat data

Woody biomass (logging residues) harvest in Jämtland replace fossil fuels in non-mobile plants at different locations



- A system analysis from **forest area** to **local** (80km), **national** (600km) and **international** (1100km) large **end-users**
- Functional unit is 1 MWh of delivered wood chips at the local, national and international large end-users
- Data for forest residues based on experience in central Sweden

CO_2 balance when woody biomass replace fossil fuels in none-mobile plants at different locations

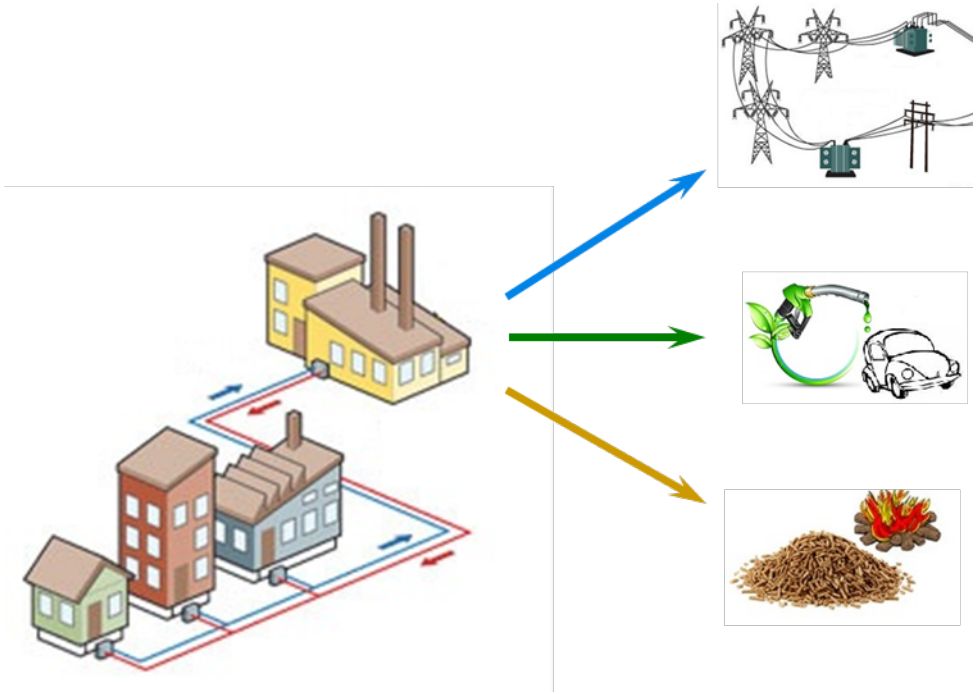


Source: Gustavsson et al, 2011

Objective

- We analyze the potentials of coproducing
  - Bioelectricity
  - Biomotor fuels
  - Biopellets

  in district heating systems



References

- Gustavsson, L. and Truong, N.L., *Coproduction of district heat and electricity or biomotor fuels*. Energy, 2011. 36(10): p. 6263-6277
- Truong, N.L. and Gustavsson, L., *Integrated biomass-based production of district heat, electricity, motor fuels and pellets of different scales, Manuscript 2012*

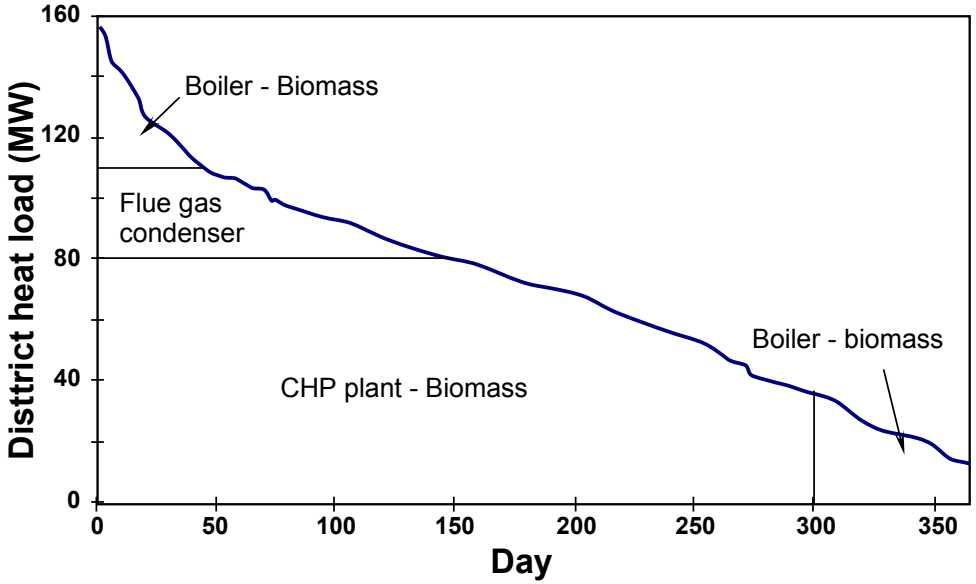
- Gustavsson, L., Dodoo, A., Truong, N.L., and Danielski, I., *Primary energy implications of end-use energy efficiency measures in district heated buildings*. Energy and Buildings, 2011. 43(1): p. 38-48.

Value of cogenerated electricity and motor fuels equals to the lowest production cost of stand-alone plants

Analyzed heat load duration curve

- Using a heat load duration curve in Östersund, Sweden

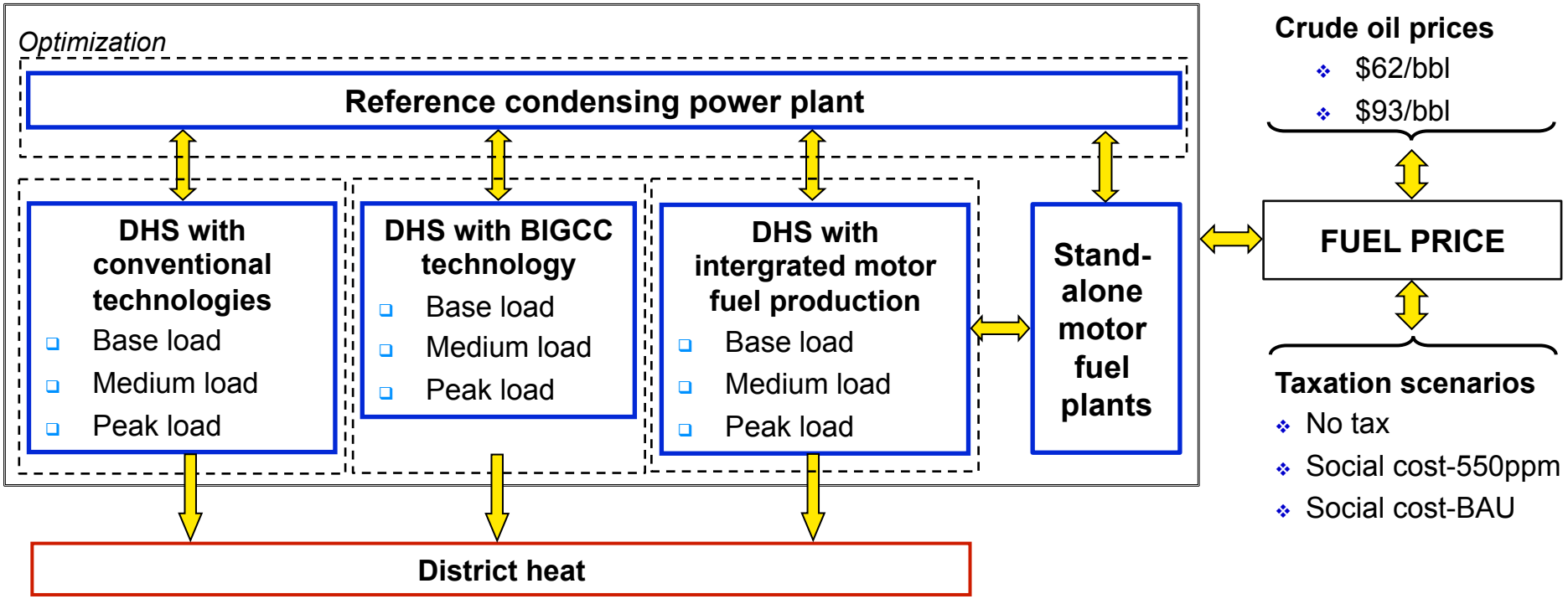
  - ☞ Yearly heat load: 612 GWh
  - ☞ Peak demand: 160 MW



Environmental taxation scenarios

- No tax
- Social cost-550ppm: carbon damage cost of \$30/t CO_2 (Stern et al., 2006)
- Social cost-BAU: carbon damage cost of \$85/t CO_2 (Stern et al., 2006)

Schematic diagram



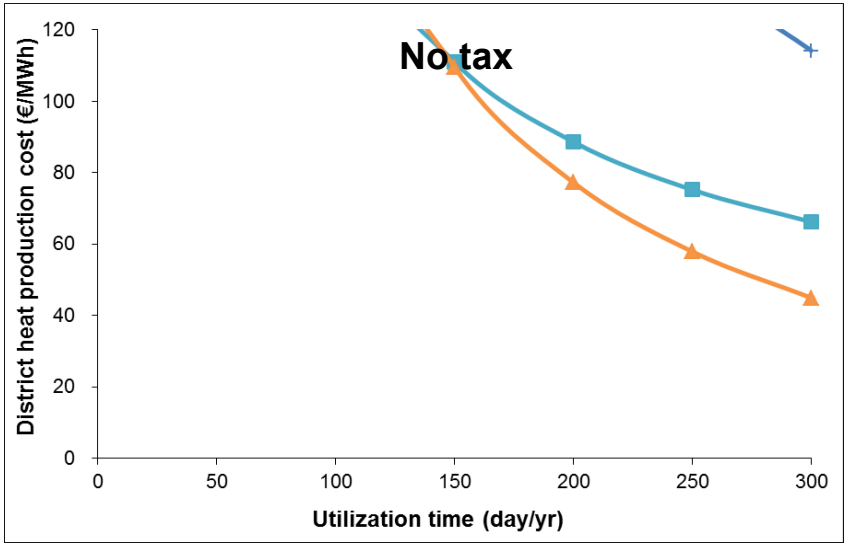
Production costs of standalone electricity (€/MWh)

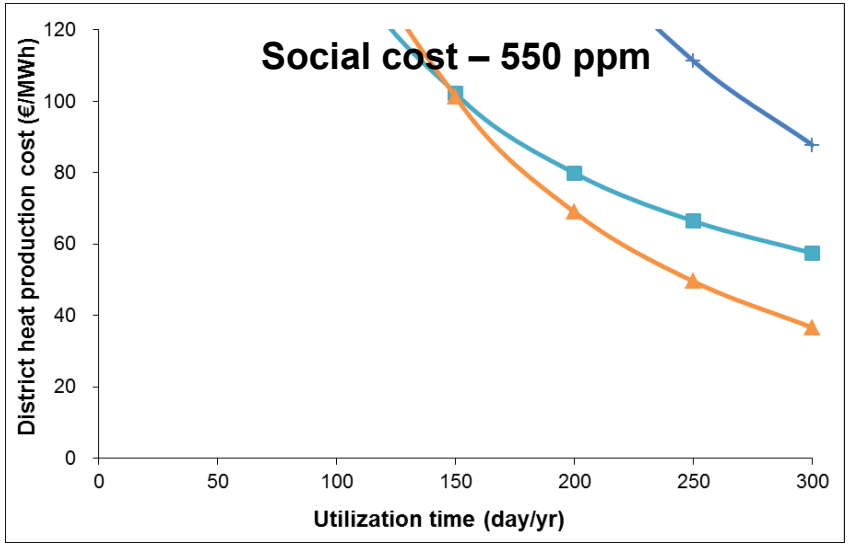
Technology	*No tax*	*Social cost-550ppm*	*Social cost-BAU*
BIGCC	67.7	68.2	69.1
BST	59.8	60.3	61.2
CST	41.9	59.6	92.0
CST with CCS	68.9	71.0	74.8
FGCC	79.4	87.5	103
BIGCC	67.7	68.2	69.1
BST	59.8	60.3	61.2

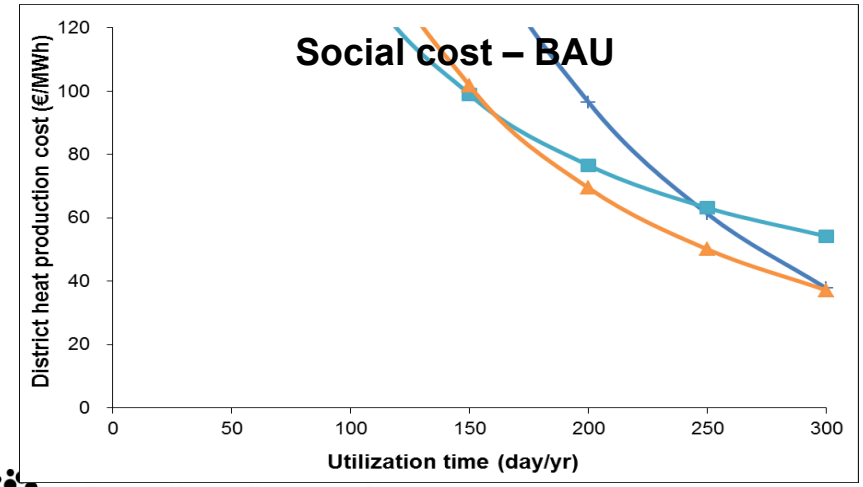
Production costs of standalone biomotor fuels and fossil fuel prices (€/MWh)

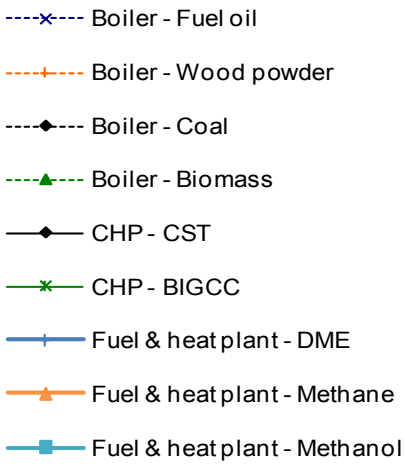
Motor fuel type	*No tax*	*Social cost-550ppm*	*Social cost-BAU*	*Data source*
DME-1	65.7	67.8	68.6	Boding et al. 2003
DME-2	60.2	62.3	63.1	Thunman et al. 2008
DME-3	52.1	54.0	**54.7**	Hansson et al. 2007
DME-4	60.1	61.6	62.3	Nyström et al. 2007
Diesel	**37.3**	**44.2**	57.0	
Methane-1	44.5	**43.6**	**44.1**	Thunman et al. 2008
Methane-2	49.9	50.4	51.0	Hansson et al. 2007
Methane-3	52.9	54.2	54.9	Nyström et al. 2007
Fossil gas	**39.6**	44.2	52.6	
Methanol-1	70.0	72.2	73.1	Boding et al. 2003
Methanol-2	70.7	67.8	68.4	Thunman et al. 2008
Methanol-3	72.3	71.6	72.4	Hansson et al. 2007
Methanol-4	49.1	50.8	**51.6**	Hamelinck and Faaij 2006
Gasoline	**39.6**	**46.5**	59.3	

District heat production cost of integrated biomotor fuel production units

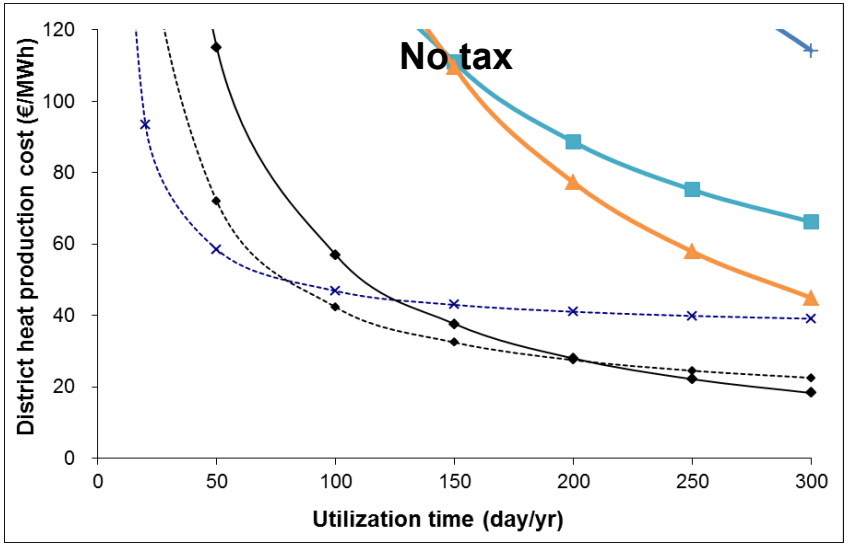


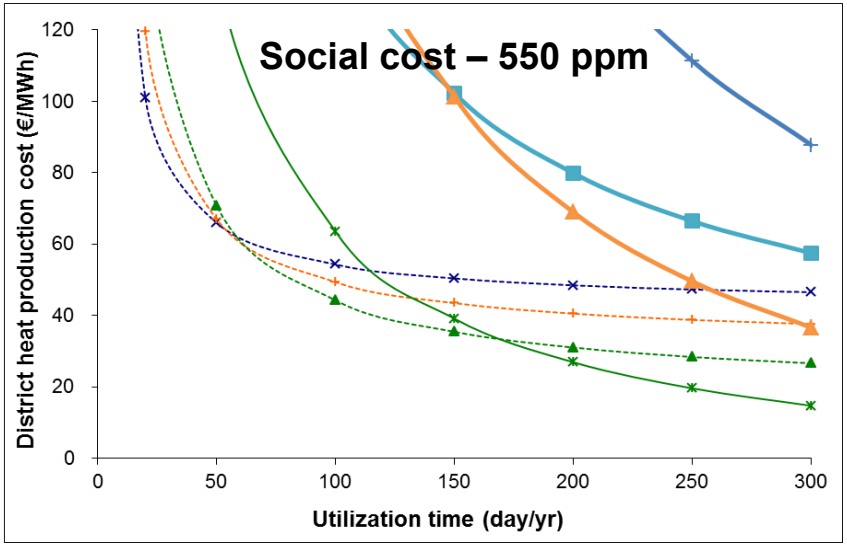


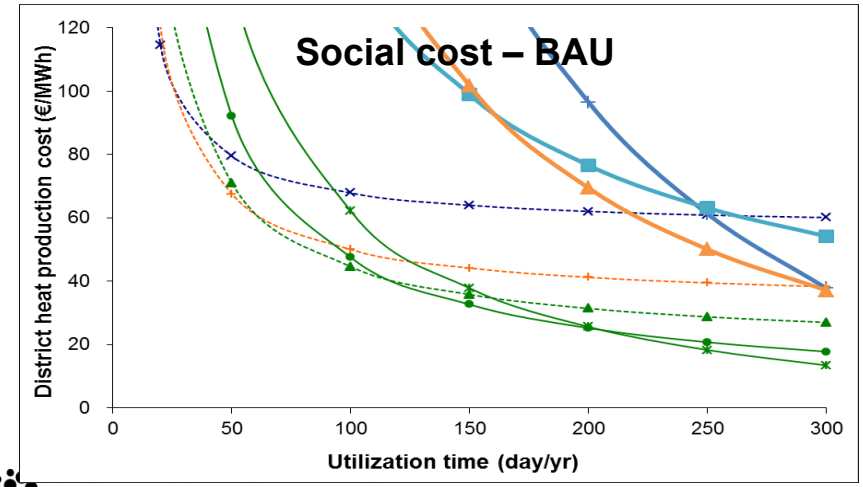


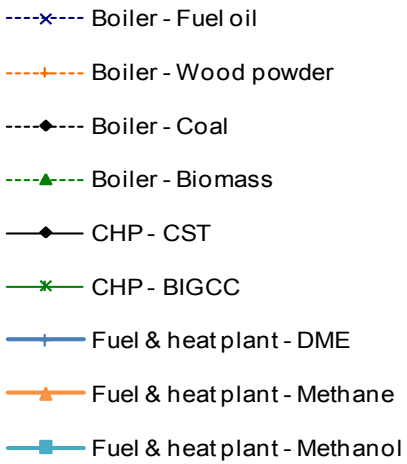


District heat production cost of integrated biomotor fuel production units and the most cost-efficient units

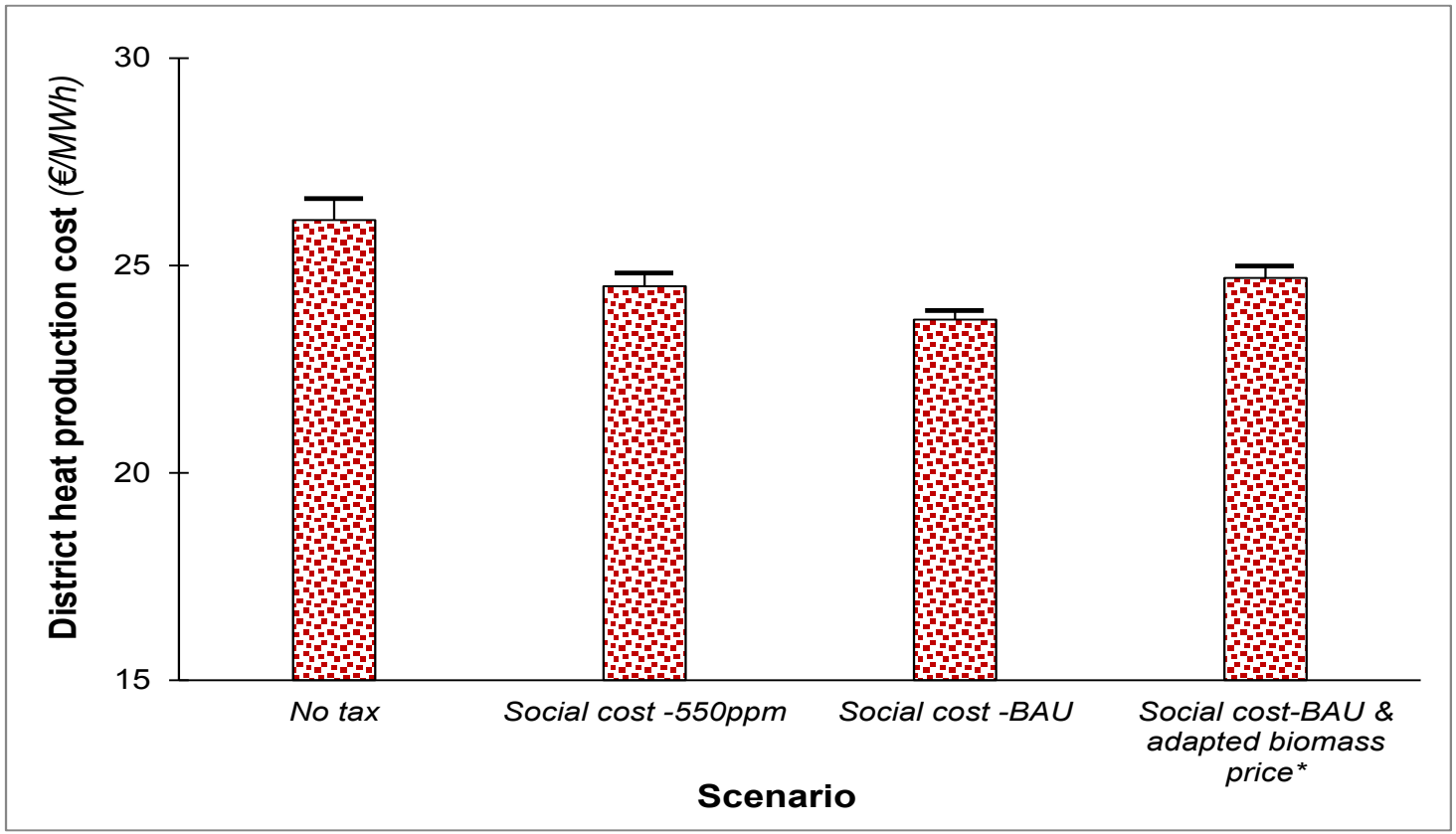








District heat production cost for different crude oil scenarios and technologies



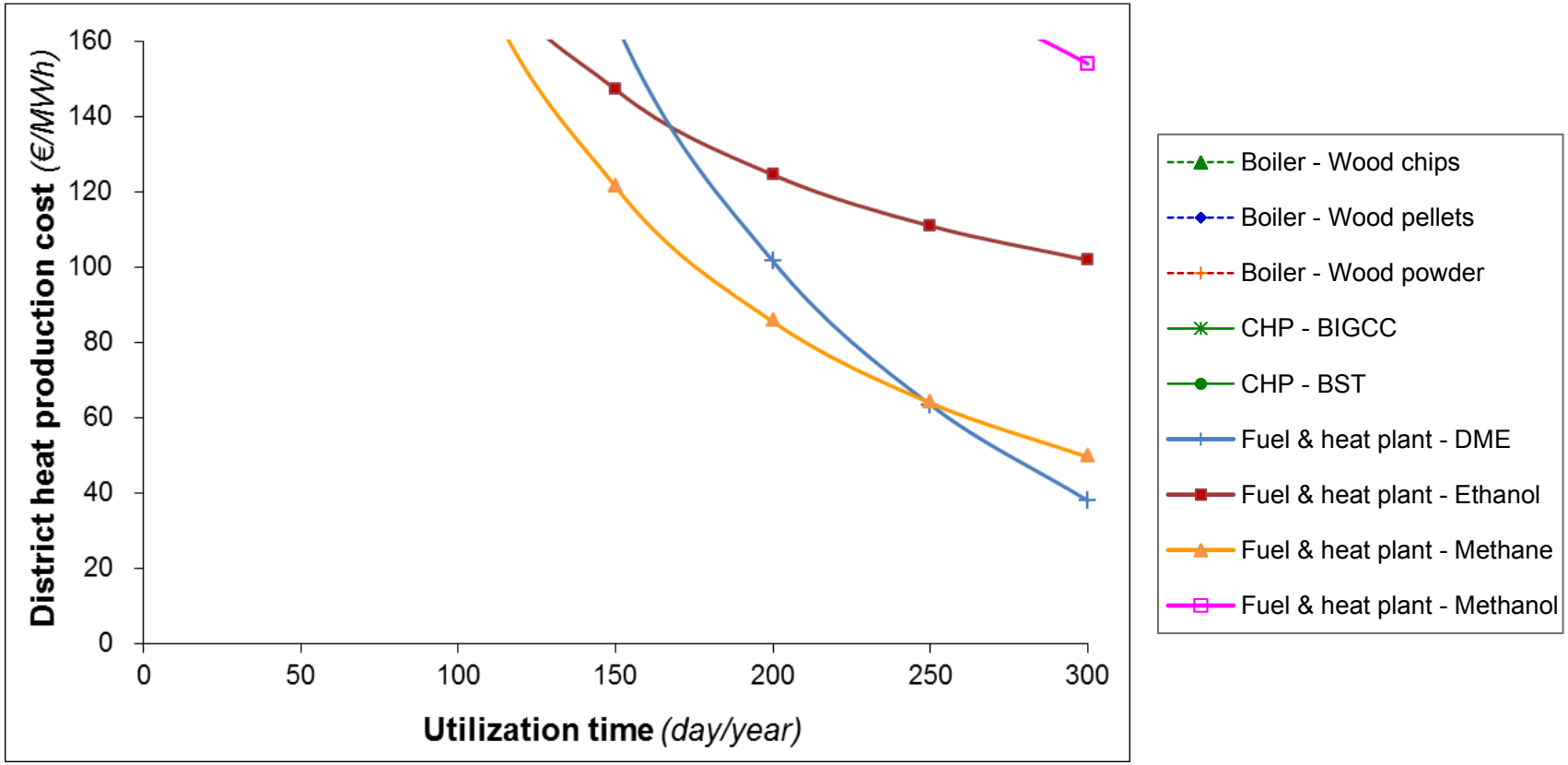
** If biomass price is driven by standalone fossil power plants*

The error bar: if crude oil price at $93/bbl instead of $62/bbl

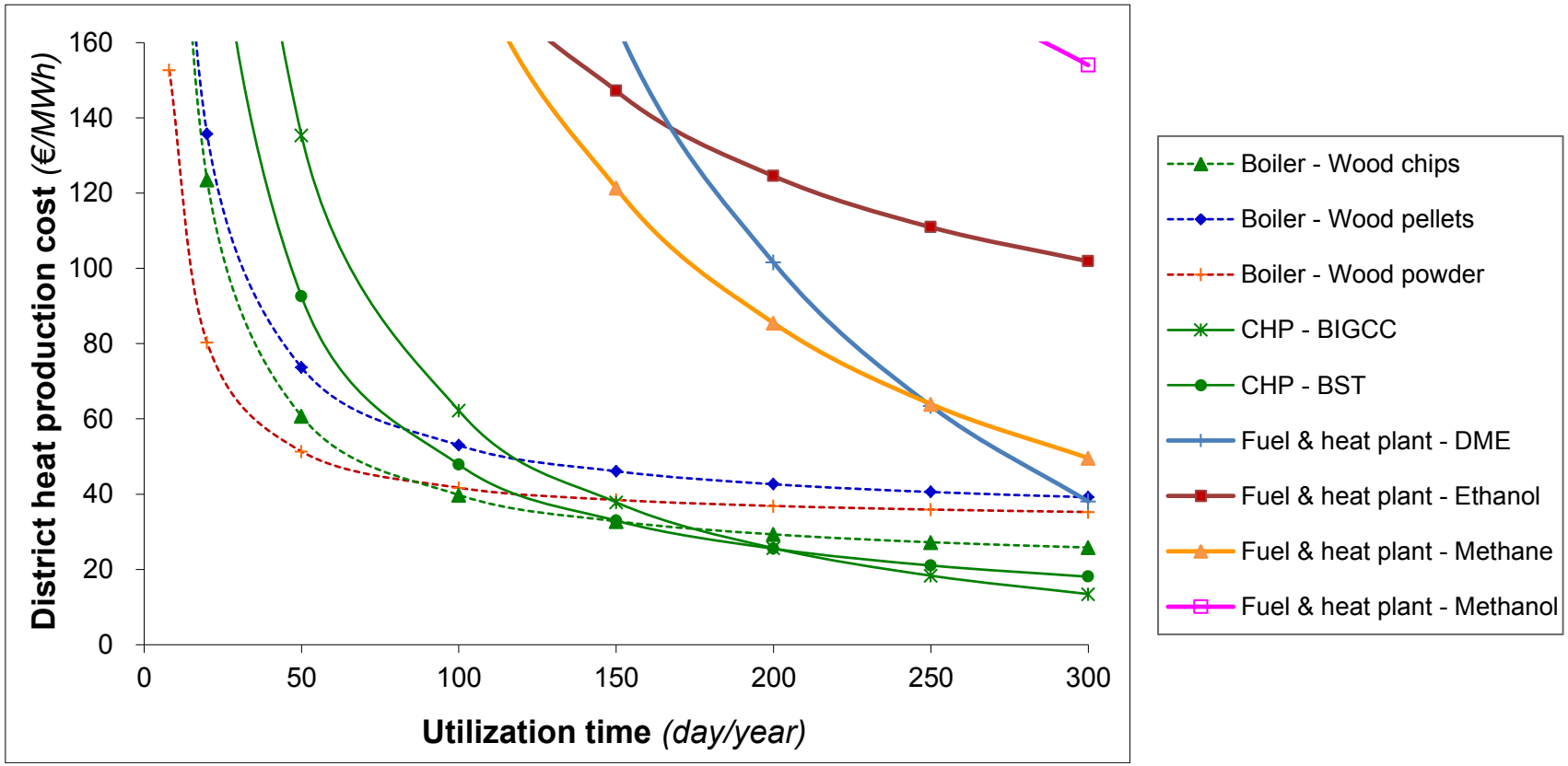
Environmental scenarios

- 100% woody biomass

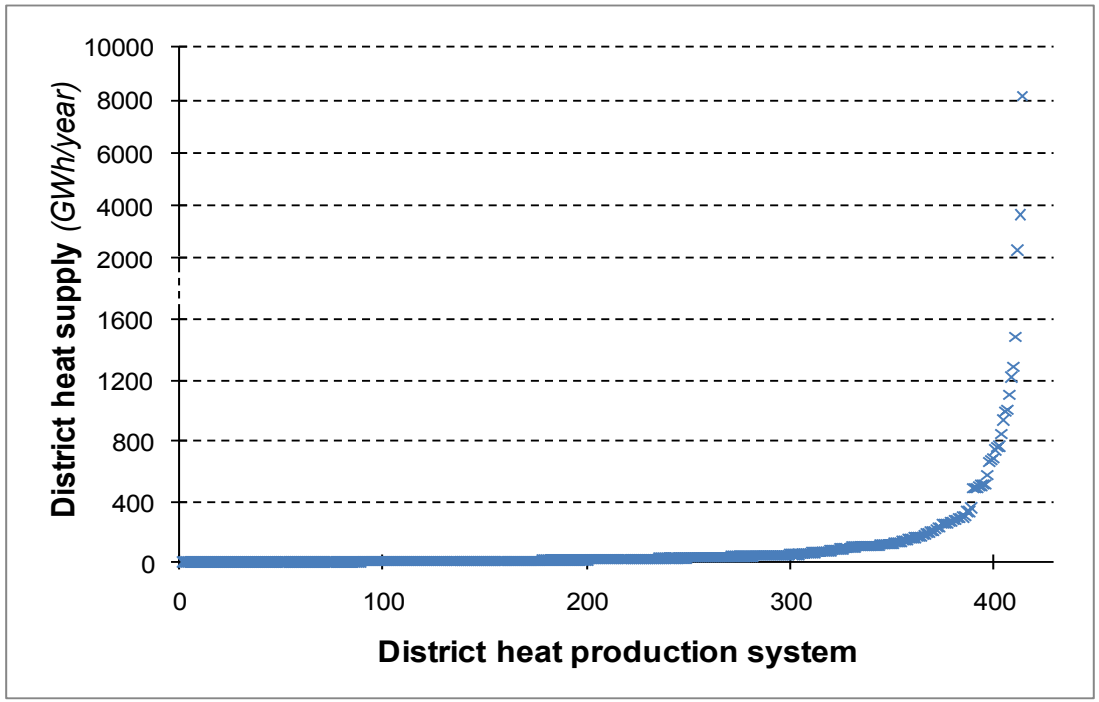
District heat production cost of integrated biomotor fuel production units (only biomass-based system)



District heat production cost of integrated biomotor fuel production units and the most cost-efficient units (only biomass-based system)



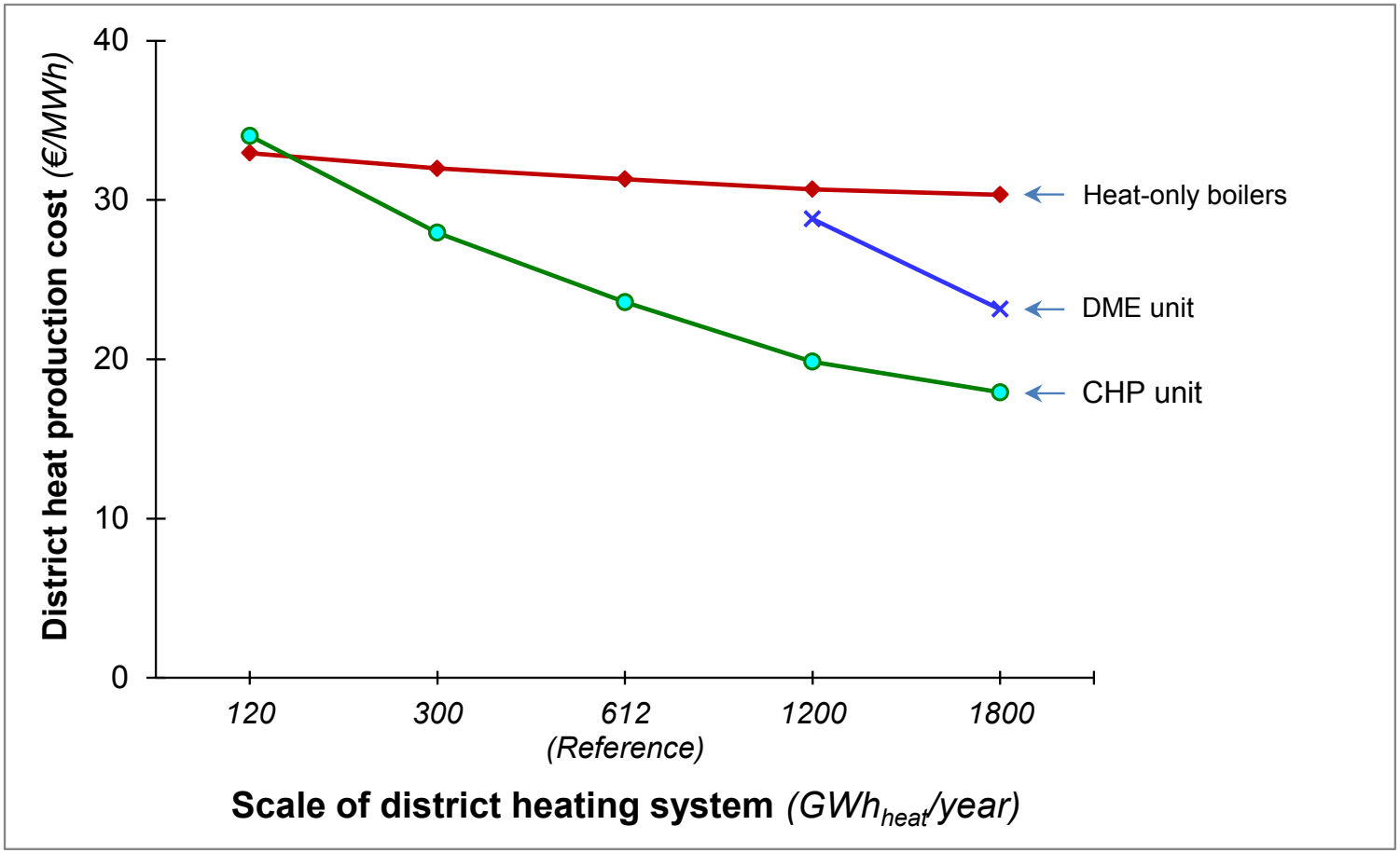
Delivered district heat from Swedish district heat production systems in 2008



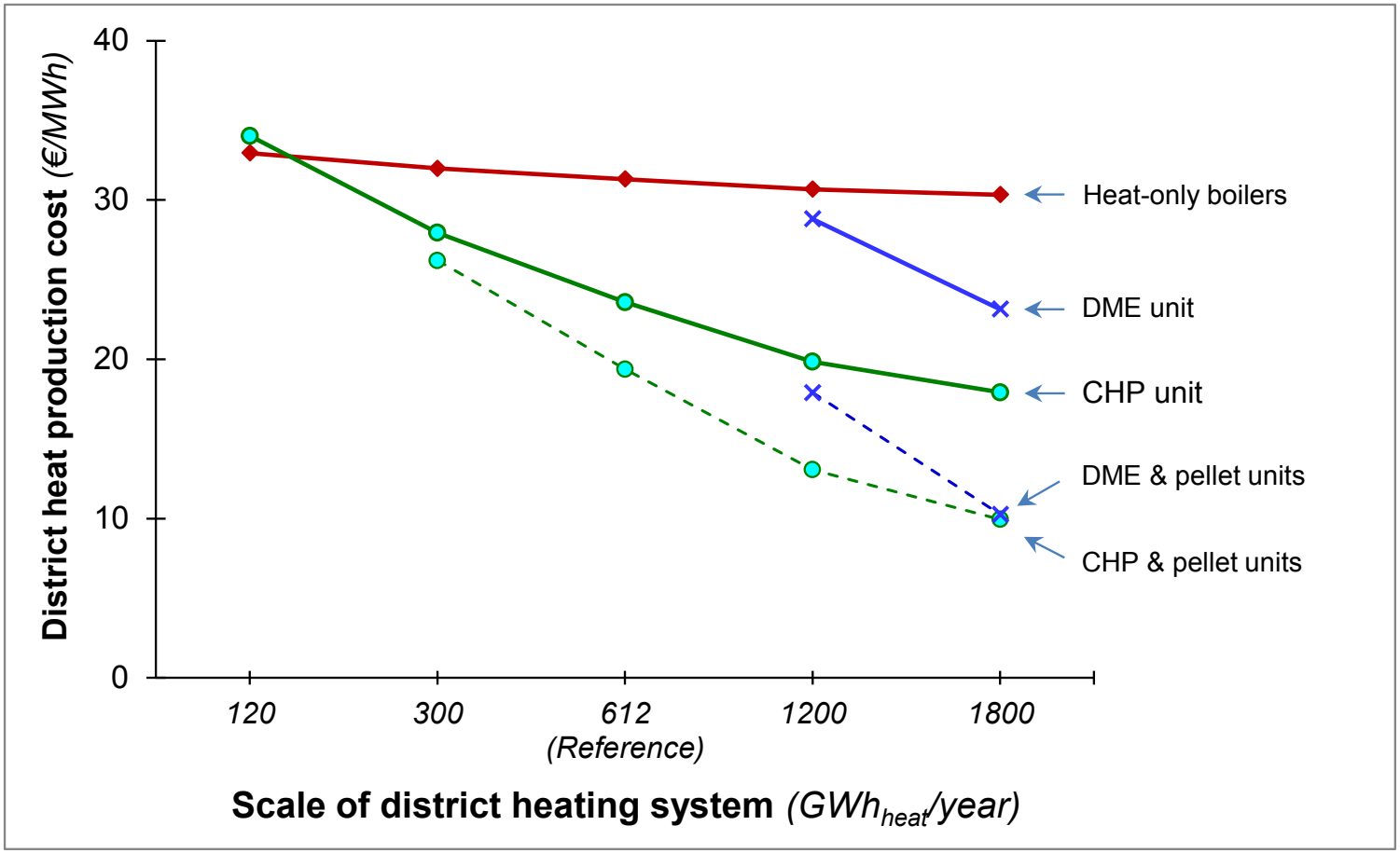
More than 400 Swedish district heating systems (DHS)

- 84% based on heat-only boilers
- DHS with CHP normally deliver more than 100 GWh/yr of district heat
- DHS with CHP supplied 70% of total district heat

The cost efficiency of biomass-based district heat production for different scale and technologies



The cost efficiency of biomass-based district heat production for different scale and technologies



Conclusions

- Biomotor fuel production in a district heating system is typically not cost-efficient
- But, uncertain investment costs of biomotor fuel production
- Composition and district heat production costs of a minimum-cost district heat production system depend on the scale of the system