Effects of energy-efficiency measures and climate change mitigation policy instruments on primary energy use in district-heated buildings

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Introduction

We analyzed the effects of energy-efficiency measures in a building heated by a local district heat production system (DHS) and powered by a regional grid under 2 different taxation scenarios:

- Social cost-550ppm: €21.6/t CO_2 ($30/t CO_2)
- Social cost-BAU: €61.1/t CO_2 ($85/t CO_2)

Case-study building and energy-efficiency measures

A wood-frame residential building:

- 4 storeys, 16 apartments
- Total heated floor area: 1190 m^2

Three groups of energy-efficiency measures:

1. Measures to reduce only heat demand: improved taps, additional insulation to external walls and roof, replaced windows & doors
2. Measure to reduce heat demand but increase electricity demand: incorporation of a heat recovery unit in the ventilation system
3. Measures to reduce electricity but increase heat demand: use of electric efficient household appliances

District heat supply system:

District heat from DHS of different sizes:

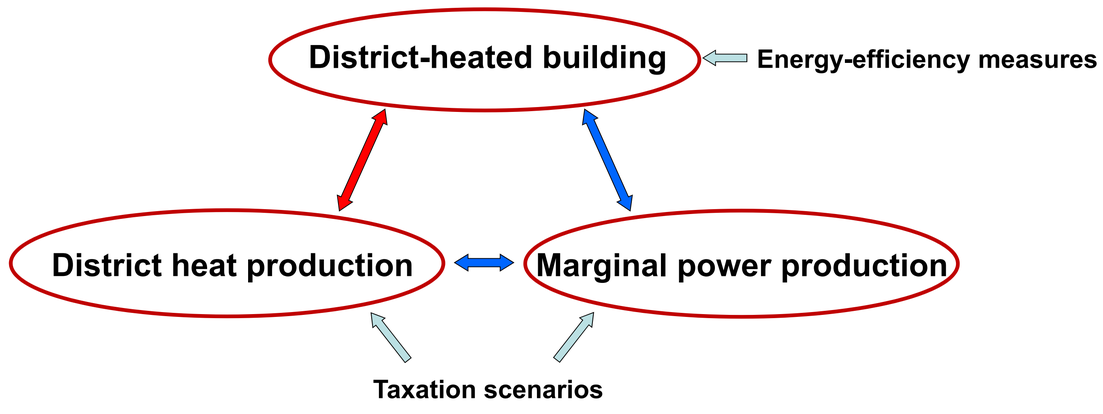
- Small DHS: 100 GWh_{heat}/year, 30 $MWh_{heat\text{-}peak}$
- Large DHS: 610 GWh_{heat}/year, 180 $MWh_{heat\text{-}peak}$

Method

Changes in energy demand were considered as marginal for the energy supply system.

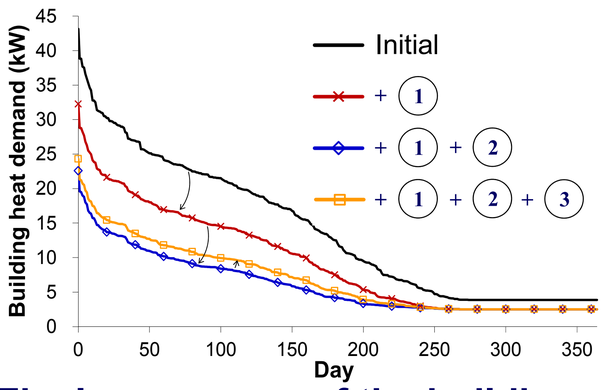
Four steps were conducted:

- Estimating the final energy use of the district-heated building without and with energy-efficiency measures
- Identifying minimum-cost marginal power plant under different taxation scenarios (selected from various technologies of BIGCC, BST, CST, FGCC)
- Identifying minimum cost district-heat production under different taxation scenarios (selected and optimized from various technologies of heat-only production and combined heat and power production)
- Analysing the interactions between the demand and the supply sides.



Results

The final heat and electricity use, can be reduced by up to 58% and 34%, respectively.

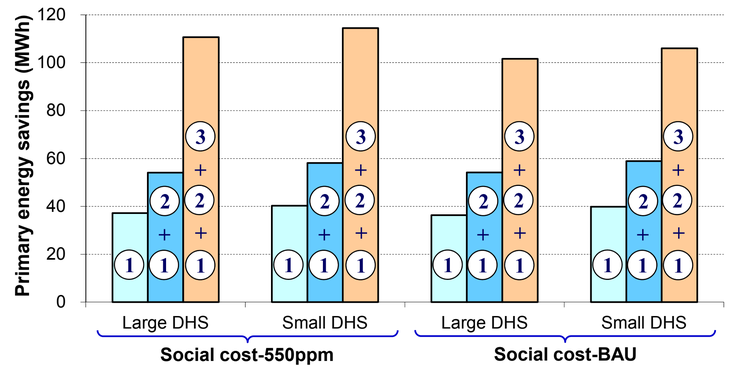


Final heat use of the building

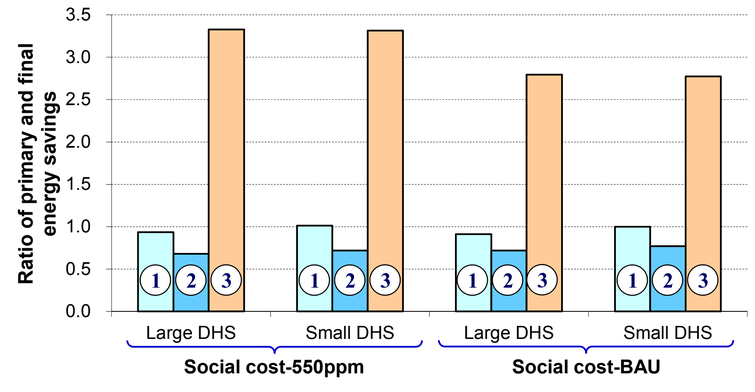
Final energy use of the building:

kWh/m²	Space heating	Tap water heating	Ventilation electricity	Household/facility electricity	Final energy savings
Initial	65.1	25.0	4.05	44.8	-
+ 1	41.7	15.0	4.05	44.8	33.4
+ 1 + 2	16.9	15.0	8.01	44.8	54.2
+ 1 + 2 + 3	23.1	15.0	8.01	24.3	68.5

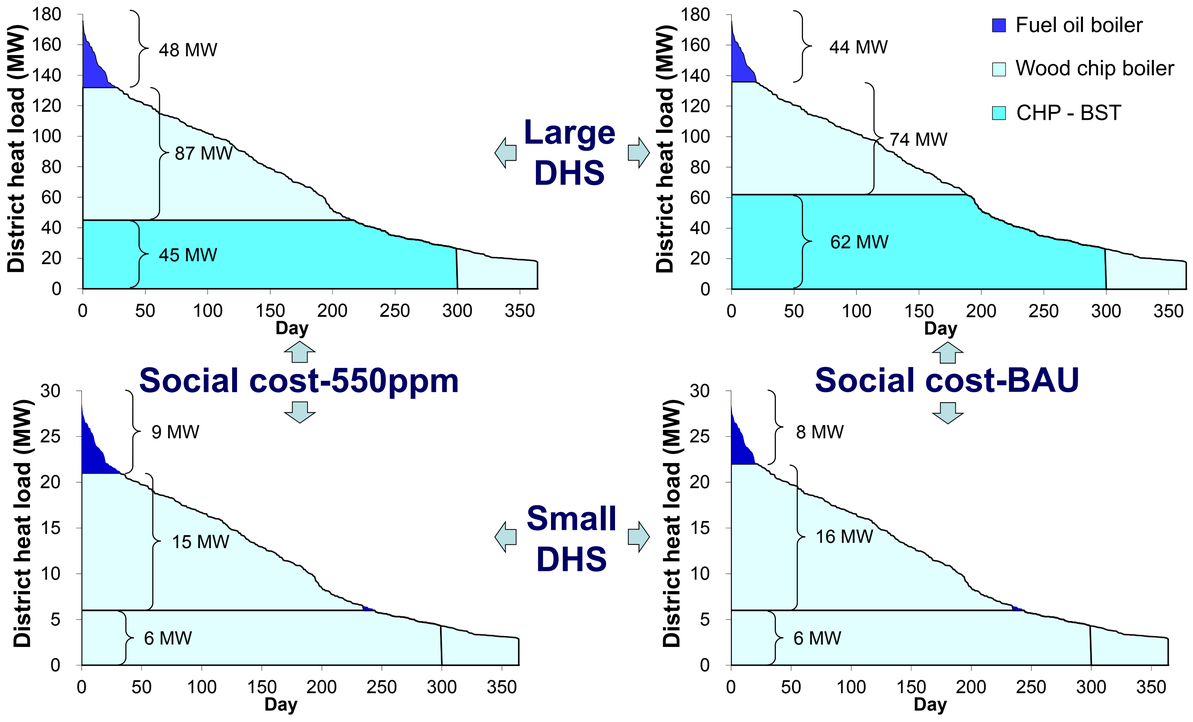
Primary energy savings



Ratio of Primary and Final energy savings



Minimum cost DHS:



Conclusion

- Large potential reductions in final electricity and heat use in the case-study building
- The reduction of primary energy use depends on the energy supply system and the type of energy-efficiency measure
- The measures that reduce electricity result in the highest primary energy savings
- The scale of a DHS influences both the selection of technologies for a minimum-cost DHS and the overall energy efficiency of the system.
- The interactions between the supply and demand sides is important for estimating the primary energy savings of energy-efficiency measures.

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