CO_2 mitigation costs of smart space heating systems for private households in Germany

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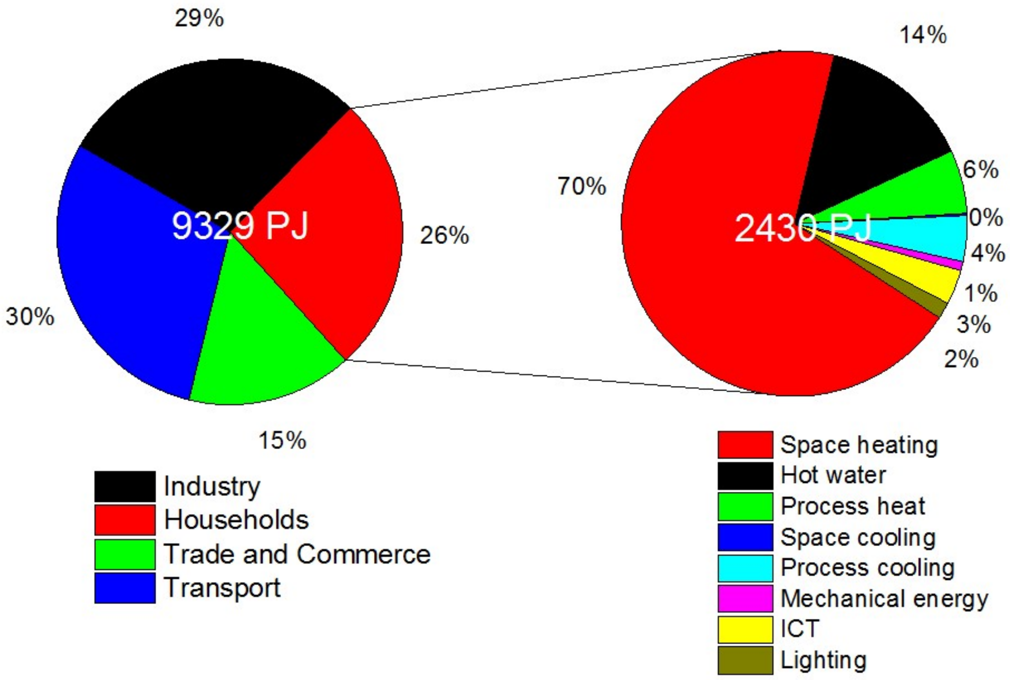
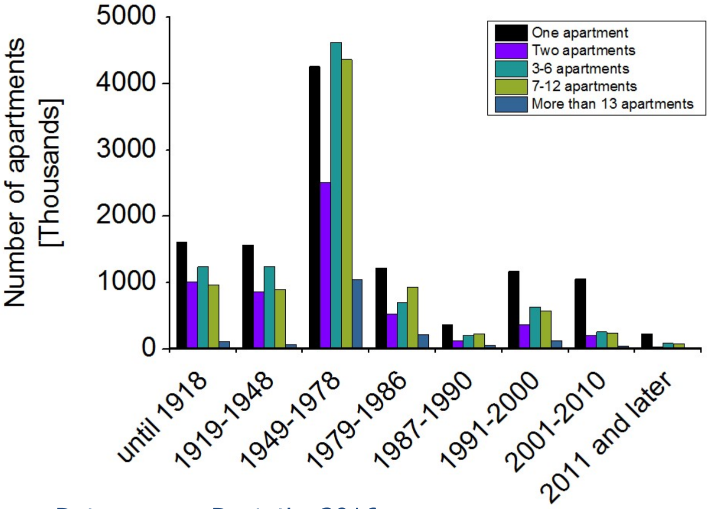
Motivation



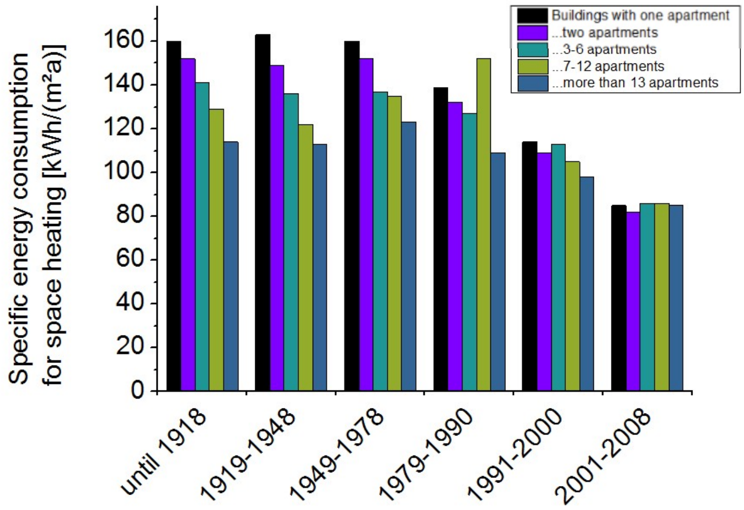
Data Source: BMWi, 2018

- Space heating in private households contributes significantly to total final energy consumption

Motivation



Data source: Destatis, 2016



Data source: dena, 2016

- Buildings constructed between 1949 and 1978 are dominating in number
- Specific energy consumption of these buildings is relatively high
- ➢ Building stock, especially buildings constructed before 1978 need to be adressed

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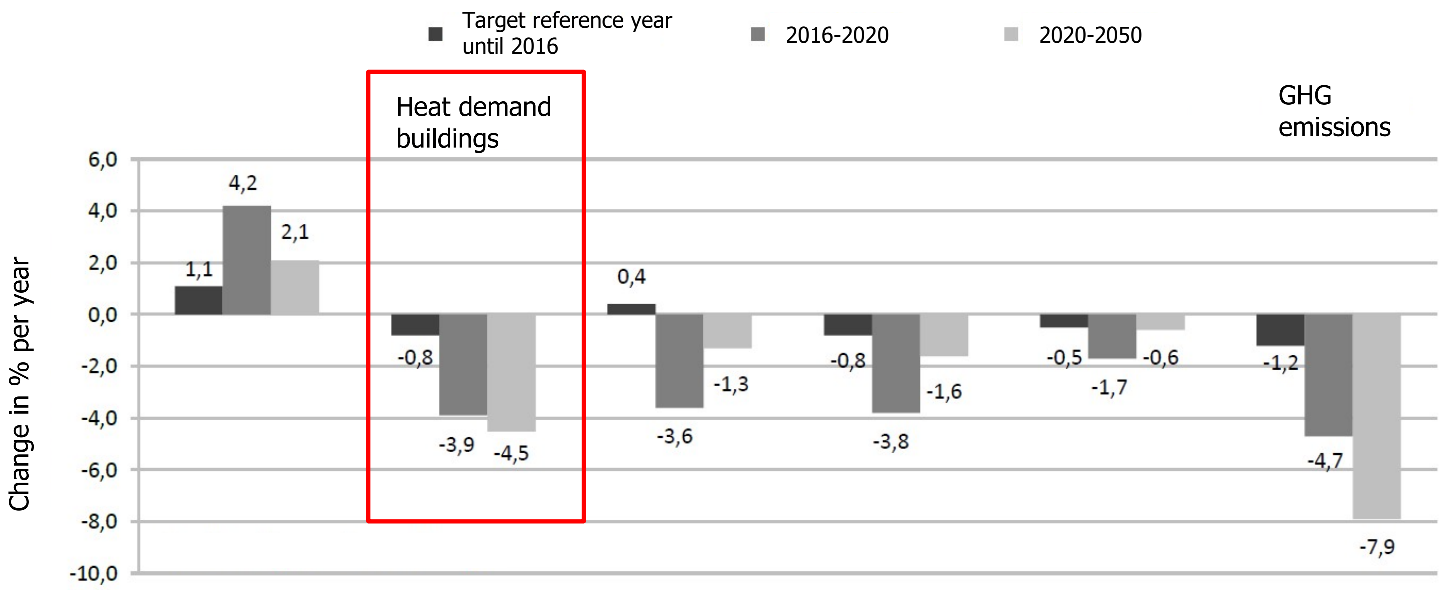


Source: Monitoring expert commission, 2018

- Reduction of heat consumption in buildings must be accelerated significantly
- Rates of high-investment refurbishments are well below what is needed
- Low-effort, low-investment measures might help…like smart space heating

Scope and objective

- Reduction of wasted space heat through smart control of space heating on room level
- Typical features: Programmable time schedules, Remote control, Automatic reaction to window/door operation, Geo-fencing (reaction to GPS-position), Assimilation of weather forecast

➢ Under which conditions is SSH a cost-effective measure for German households to save heating energy and reduce GHG emissions?

Methods: Approach and basic equations

- Case study estimates of average CO_2 mitigation costs and payback times
- Investor/user perspective
- Payback time:

$$NPV_{SSH} = -C_i + \int_{t=1}^{n} \Delta C_{tot} \cdot (1+i)^{-t}$$

For $NPV_{SSH} = 0$, t = payback time

- Average CO_2 mitigation costs:

$$C_m = \frac{C_{SSH} - C_r}{E_r - E_{SSH}} = \frac{-NPV_{SSH}}{t_{SSH}\,(E_r - E_{SSH})_{\Delta t}} = \frac{C_i - \int_{t=1}^{t_{SSH}} \Delta C_{tot} \cdot (1+i)^{-t}}{t_{SSH} \cdot q_{sh} \cdot A_l \cdot \delta_{SSH} \cdot e_f}$$

- Hardly any empirical data on savings through SSH in Germany or Europe
- Savings strongly depend on occupant behavior before and after installation

➢ Relative savings through SSH (δ_SSH) used as independent variable

Methods: Parameterization

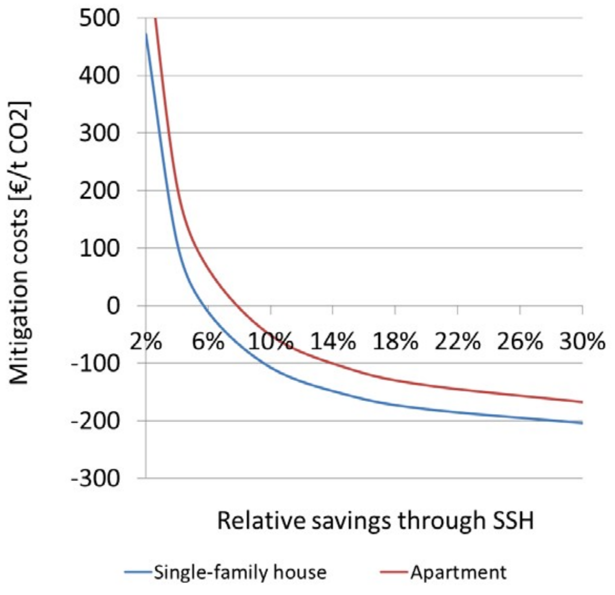
- General
  - Consumer fuel price: 6.44 Ct/kWh
  - Interest rate: 1%
  - Operating life of SSH system: 10 years
  - Specific emissions: 2.42·10(-4) tCO_2/kWh

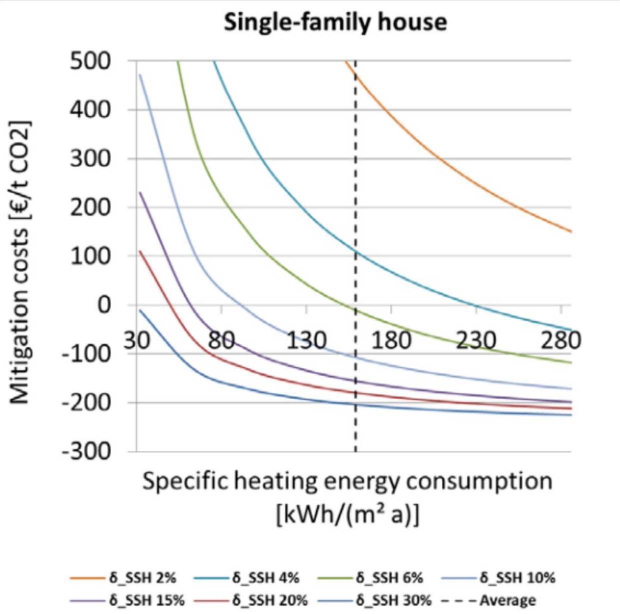
1. Case: Average single-family house built between 1949 and 1978
   - Living area: 127 m²
   - Specific heating energy consumption: 159 kWh/(m²a)
   - System price/ investment cost: 670 € (8 rooms)

2. Case: Average apartment in apartment building built between 1949 and 1978
   - Living area: 64 m² (apartment), 640 m² (building)
   - Specific heating energy consumption: 134 kWh/(m²a)
   - System price/ investment cost: 340 € (4 rooms)
   - Consumption cost share: 70%

- Sensitivity studies to investigate variations in parameters and their impact

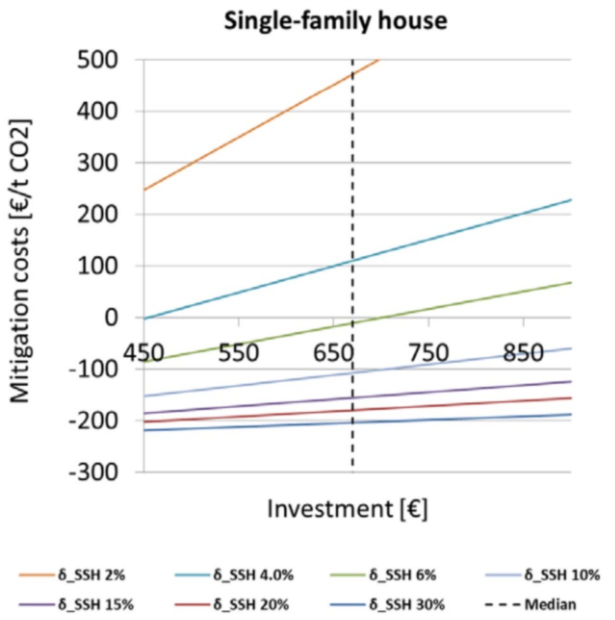
Results: Relative savings and Specific energy consumption

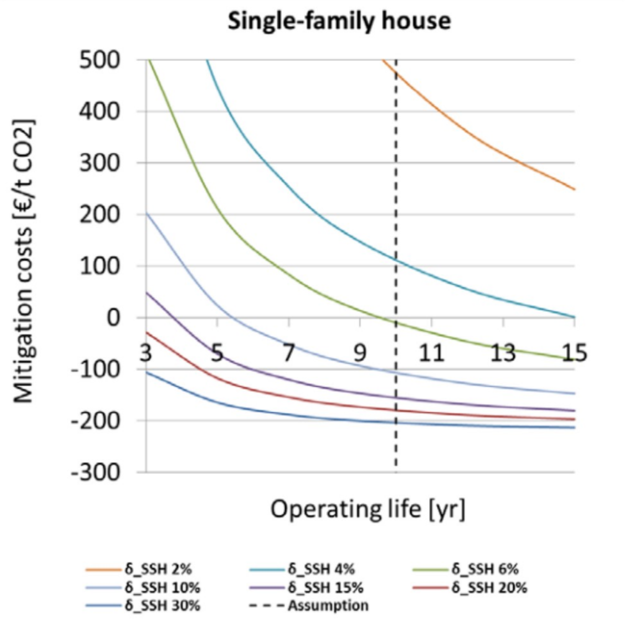




- Mitigation costs (MC) and relative savings follow a 1/x relation
- For savings of about 6%, MC become negative in the avg single-family house case
- Specific heating energy consumption has a considerable impact on MC: -22 €/tCO2 for 10% increase and +27 €/tCO2 for 10% decrease starting from average (at 6%)

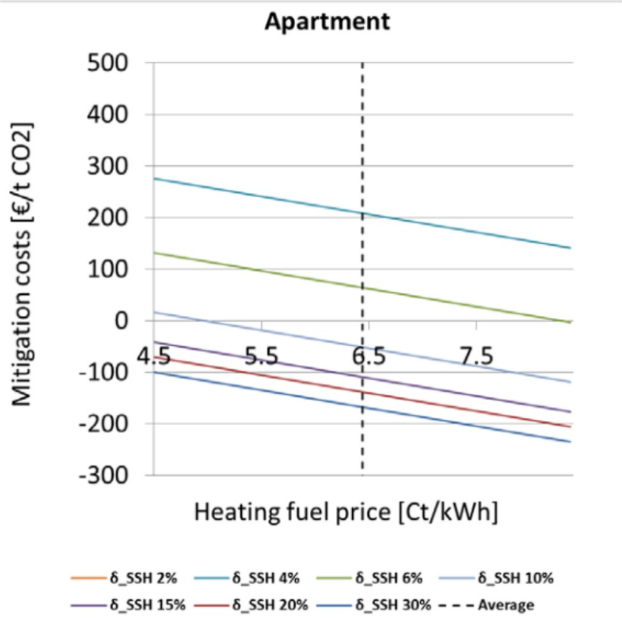
Results: Investment costs and Operating lifetime





- For large savings MC are rather insensitive to investment costs and operating life
- For a 10% decrease in investment costs, MC decrease by -23 €/tCO_2 (for 6% savings)
- For an operating lifetime of only 9 years, MC is 24 €/tCO_2 higher than for 10 years (6%)

Results: Fuel price and Consumption Cost Share



MC [€/tCO2]		**Consumption Cost Share**	
		50% share	70% share
Savings (%)	2	698	641
	4	265	209
	6	121	64
	10	6	-51
	15	-52	-109
	20	-81	-138
	30	-110	-167

- Increasing fuel prices by 10% yields decreases in MC of -22 €/tCO2 (for 6% savings)
- Using a consumption cost share of 70% instead of 50% yields -57 €/tCO2 lower MC

Summary and Conclusions

- For small relative savings (2-10%), mitigation costs of smart space heating decrease strongly with increasing relative savings
- For small relative savings (2-10%), MC are sensitive towards variability in energy consumption, investment costs and operating lifetime
- SSH can be cost-effective with savings of at least 6% for an average German single-family house and at least 8% for an average apartment

- Empirical data on realizable savings with smart space heating is needed urgently; potential support could be connected to monitoring participation
- Households in inefficient buildings should think about investing in SSH first; potential support should target these households first
- Increasing the regulatory minimum for consumption cost share would increase incentives for SSH in apartments

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