

# Equitable decarbonization of heat supply in residential multi-apartment rental buildings: Optimal subsidy allocation between landlord and tenants

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## Abstract

The core objective of this work is to demonstrate equitable decarbonization of heat supply in residential multi-apartment rental buildings. A modeling framework is developed determining a socially balanced financial governance's support strategy between the building owner (landlord) and tenants to trigger a heating system change. The results of different decarbonization scenarios of a partly renovated old building switching from gas-fired heat supply either to the district heating network or to being equipped with a heat pump system show that an equitable switch is possible, but with massive public subsidy payments. Particularly, the investment grant to the landlord and additional rent-related revenues due to building renovation are decisive for the profitability of the investment. Simultaneously, subsidy payments to the tenants are required at the beginning of the investment period to limit their energy and rent-related spendings. Results also show that the heat pump alternative is not competitive compared to district heating, even in case of extensive retrofitting of the building. Allocating the costs of inaction (opportunity costs associated with rising CO<sub>2</sub> prices) between the governance, landlord, and tenants turns out as an important lever as required subsidy payments can be reduced significantly.

**Keywords:** Equitability, decarbonization, residential, heat supply,

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## Nomenclature

Type	Description	Unit
Set and index		
$y \in \mathcal{Y} = \{1, \dots, Y\}$	Years, index by $y$	
$m \in \mathcal{M} = \{1, \dots, M\}$	Months, index by $m$	
Decision variables		
$\Psi$	Investment grant to the landlord	EUR
$\Omega_{y,m}$	Subsidy payment to a tenant in $y$ and $m$	EUR
$d_{y,m}$	Total heat demand per tenant/unit in $y$ and $m$	kWh
$q_{y,m}$	Heat demand supplied by the new heating system alternative in $y$ and $m$	kWh
$\pi$	Capacity of the new heating system alternative	kW
$r_{y,m}$	Rent charge adjustment in $y$ and $m$	EUR/m <sup>2</sup>
Relevant parameters		
$n$	Number of tenants within the multi-apartment building	1
$i$	Interest rate of an agent (governance, landlord, tenant)	%
$d_{y,m}$	Total heat demand per unit in $y$ and $m$	kWh
$\alpha_m$	Load factor (ratio total and peak demand) in $m$	1
$c_{alt}$	Investment costs of the heat system alternative	EUR/kW
$c_{con}$	Construction costs (for adaption of one dwelling/unit) of the heat system alternative per unit	EUR
$\bar{r}$	Initial rent price	EUR/m <sup>2</sup>
$\rho$	Upper limit of the biannual rent charge adjustment	%
$a$	Rented area per tenant/unit	m <sup>2</sup>
$p_{init,y}$	Energy price fueling the initial heating system	EUR/kWh
$p_{alt,y,m}$	Energy price fueling the heating system alternative	EUR/kWh

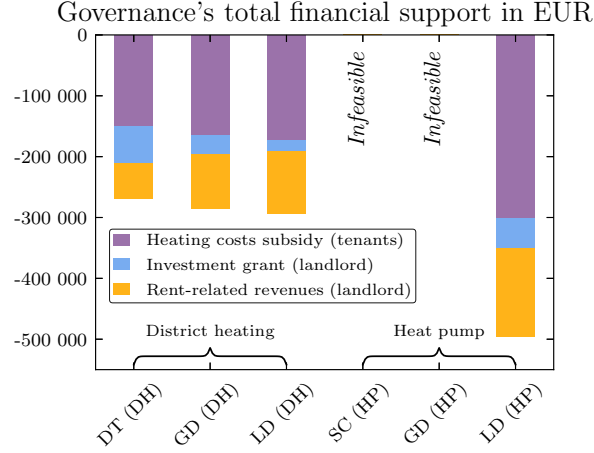


Figure 5: Comparison of governance's total financial support for the landlord and the tenants for district heating (DH) and heat pump (HP) implementation in the different scenarios

#### 4.4. Allocation of CO<sub>2</sub> pricing related costs between the governance, landlord and tenant

This section examines the impact of the costs of inaction (i.e., sticking to the initial gas-based heating system) on the governance's total financial support. In detail, this means the CO<sub>2</sub> costs (i.e., opportunity costs) to be expected due to increasing CO<sub>2</sub> prices have to be allocated to the different parties/agents (or a single one): governance, landlord, and tenant. Table 4 provides an overview of the different cases on the allocation of the opportunity cost (i.e., CO<sub>2</sub> costs of inaction) compared to the alternative on district heating implementation in the *Gradual Development* scenario.

Rel. allocation of opportunity costs	Governance	Landlord	Tenants
Case A (equally)	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
Case B (landlord & tenant)	0	$\frac{1}{2}$	$\frac{1}{2}$
Case C (landlord)	0	1	0
Case D (governance & tenant)	$\frac{1}{2}$	0	$\frac{1}{2}$
Scenarios from Sec. 3.3.2 (governance)	1	0	0

Table 4: Allocation of the CO<sub>2</sub>-related opportunity costs (costs of inaction) among the governance, the landlord, and tenants

Exemplarily, "Case A (equally)" takes into account that the CO<sub>2</sub> costs are