

Gas use variability in space heating: end- user costs of switching to district heating

Authors: M. Tsekpokumah (Utrecht University), P. Mulder (TNO & Utrecht University), R. Harmsen (Utrecht University)

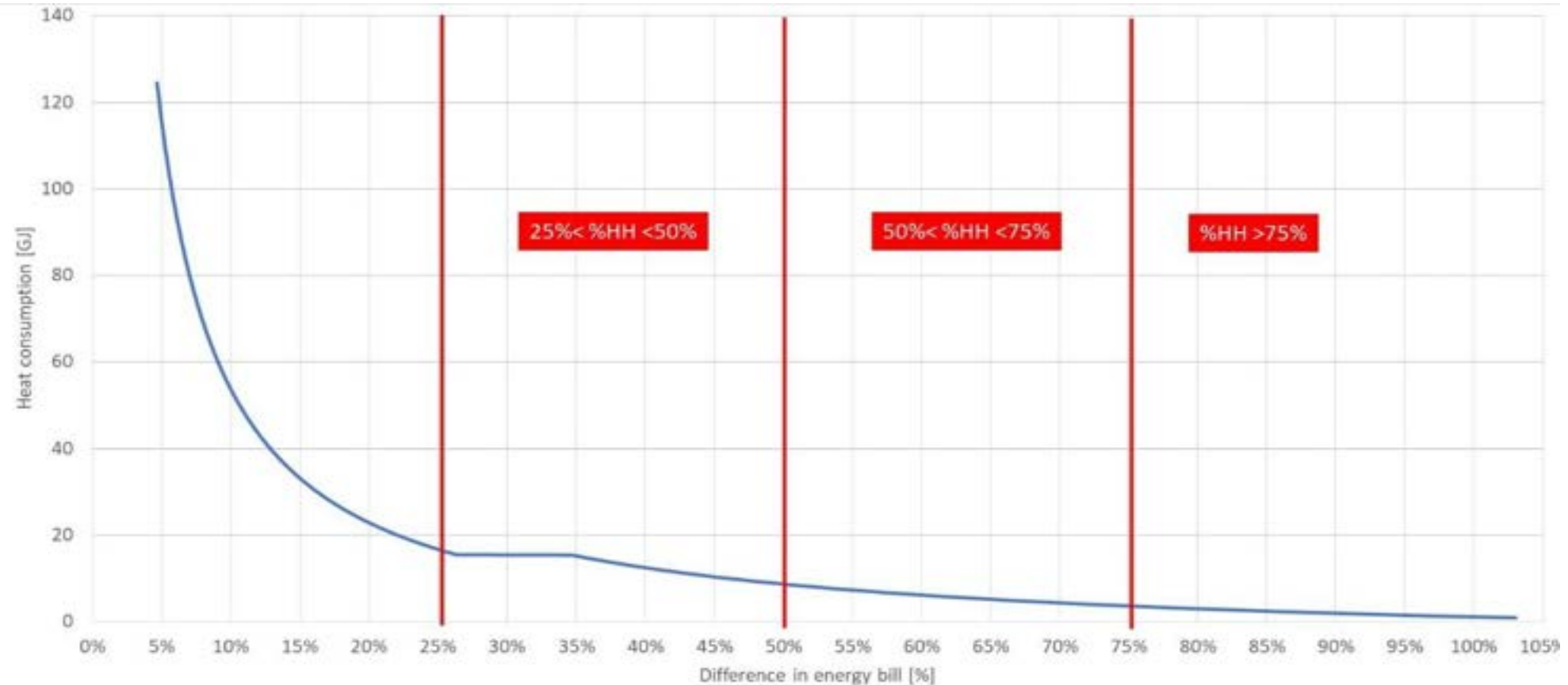


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Flat rate in the context of DH



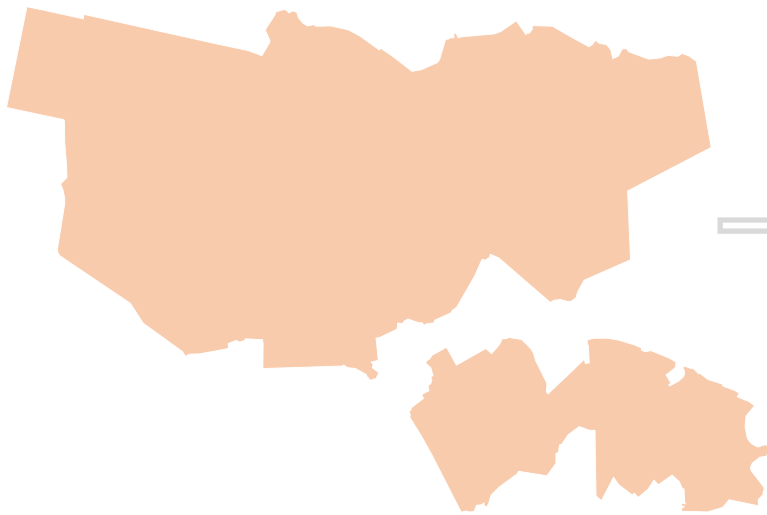
DH consumption and the difference in energy bill compared to the natural gas reference. (Note: the flat part in the curve between 15.5 and 15.6 GJ DH is due to change in the fixed tariff of natural gas to the tariff for small consumers (<500 m³/yr).

Who wins or loses under DH tariffs



District heating (DH) as least-cost for
35% households (van Polen et al.,
2025)

Who wins or loses under DH tariffs

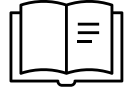


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DH as least-cost option for **77%** of
Amsterdam homes (PBL, 2025)

The problem



Studies based on averages



Averages mask wide variations
in individual heat demand

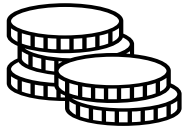


Ours go beyond averages to
household-level perspective

Key questions



how big is household gas use variation?



who would see large bill change?



what does it mean for policy?

Expectation



Variation in gas usage



Zoom in to case-study



Results and policy
implications

Background

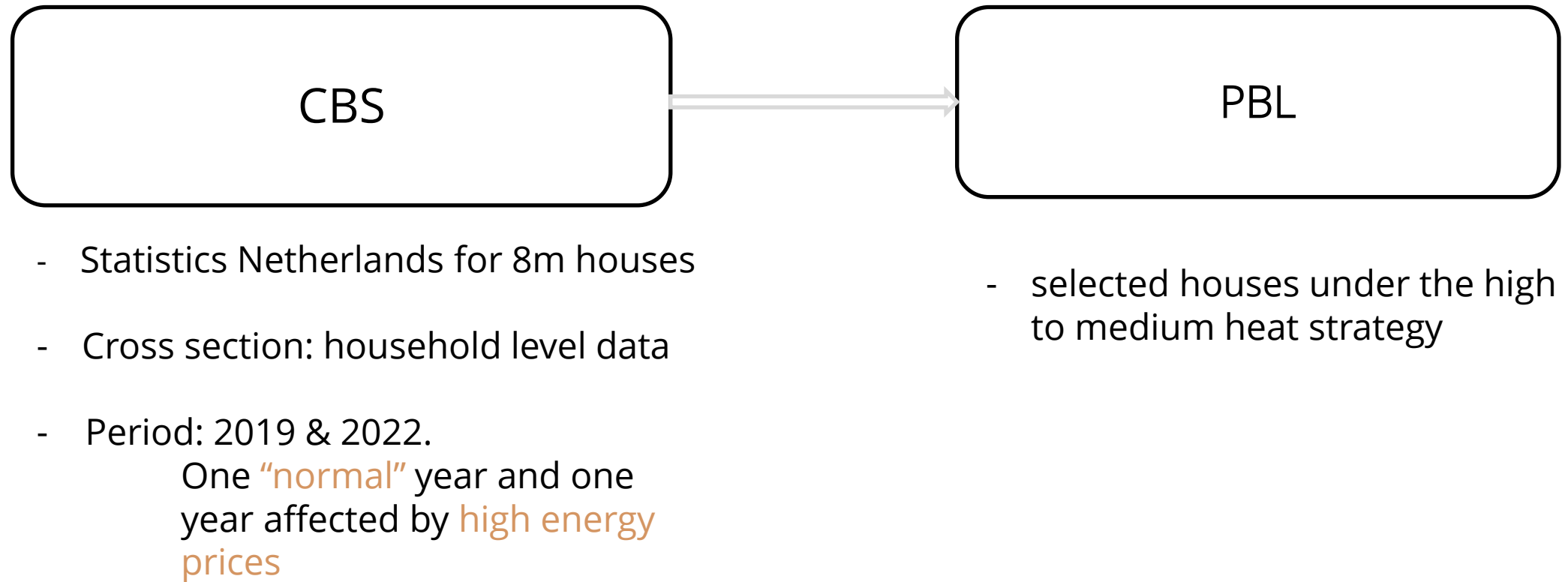
- Heating account for **64% of final residential energy consumption: DH supplies 11%** (Eurostat, 2022)
- DH is key to decarbonize residential heat (Baquet et al., 2022)
 - the potential for Netherlands is pegged at **73%** (Möller et al., 2019)
- PBL study on least cost-effective heating options
- **4** primary strategies identified

PBL's least cost advantage strategies

1. All- electric strategy (s1)
2. Medium to high temperature DH (**s2**)
3. Low temperature DH mixed with electric heat pumps (s3)
4. Hybrid heat pumps with green gas (s4)

→ **s2** set the basis for this study

2. Data

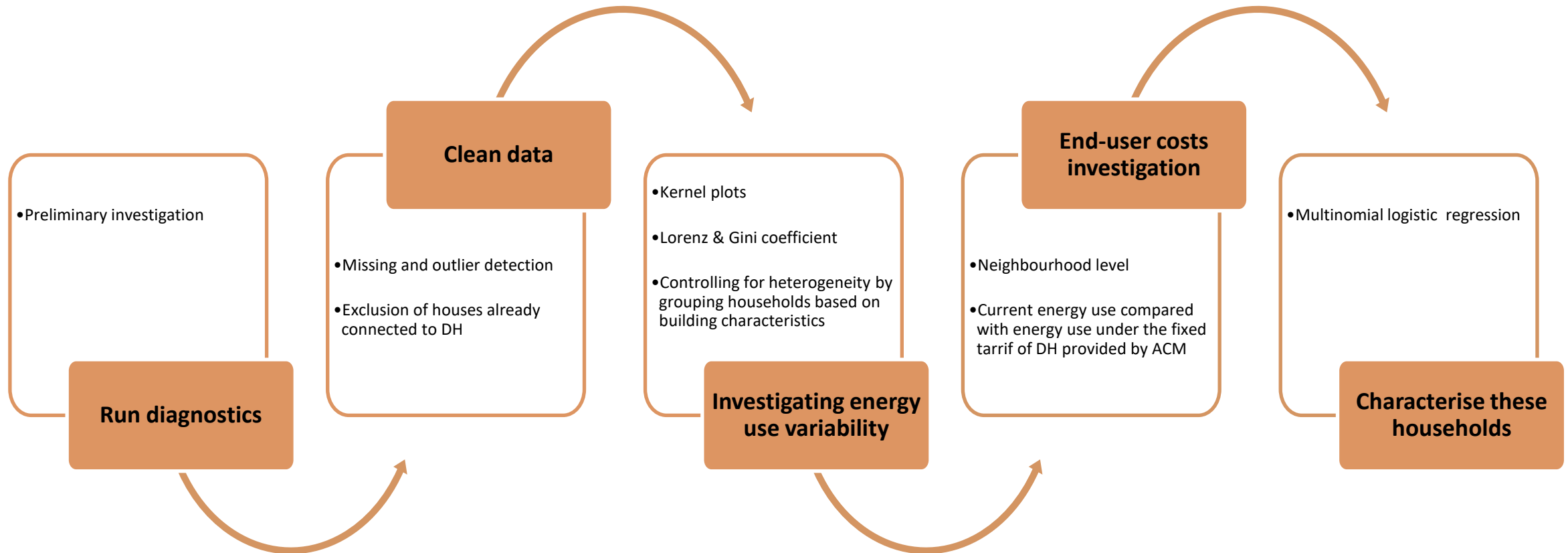


Data Descriptives (Case study)

- ~250,000 households
- 276 of 299 neighborhoods
- >96% apartments
- 46% social rent
- Mean floor ~72 m²



Methodology



Gas use variation (Amsterdam)

- Distribution skewed to the right
→ households can vary significantly in their consumption
- Most households' consumption falls below the mean
- Mean gas consumption for 2022 falls below that of 2019
- More variation in (a) than (b)
→ Floor area plays a key role in gas use variability

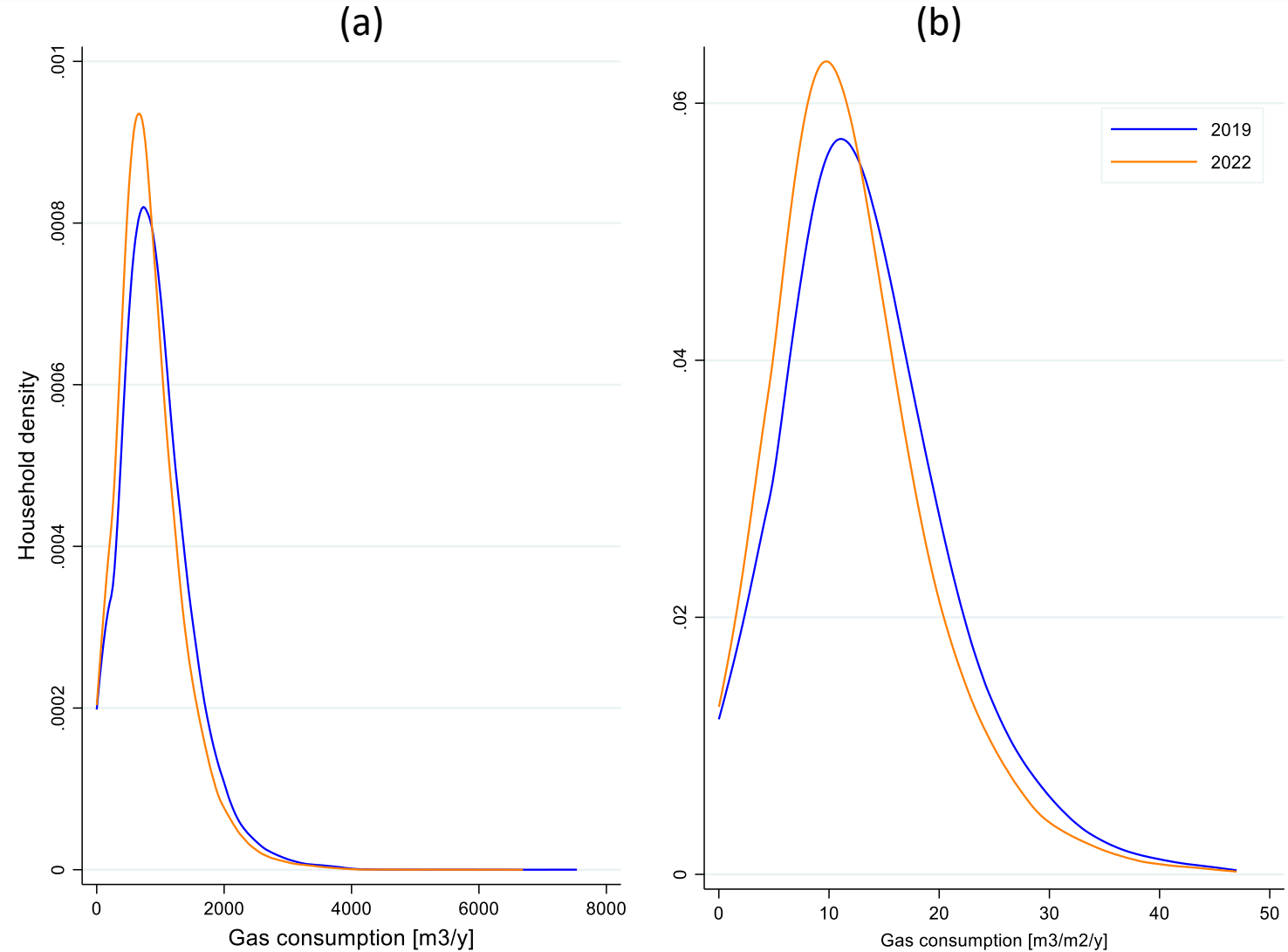


Fig. 2 Kernel distribution plots. Note: Plots have different scales

Gas use vs. income inequality

- Amsterdam gas-use Gini below income but still prominent
→ About **33%**

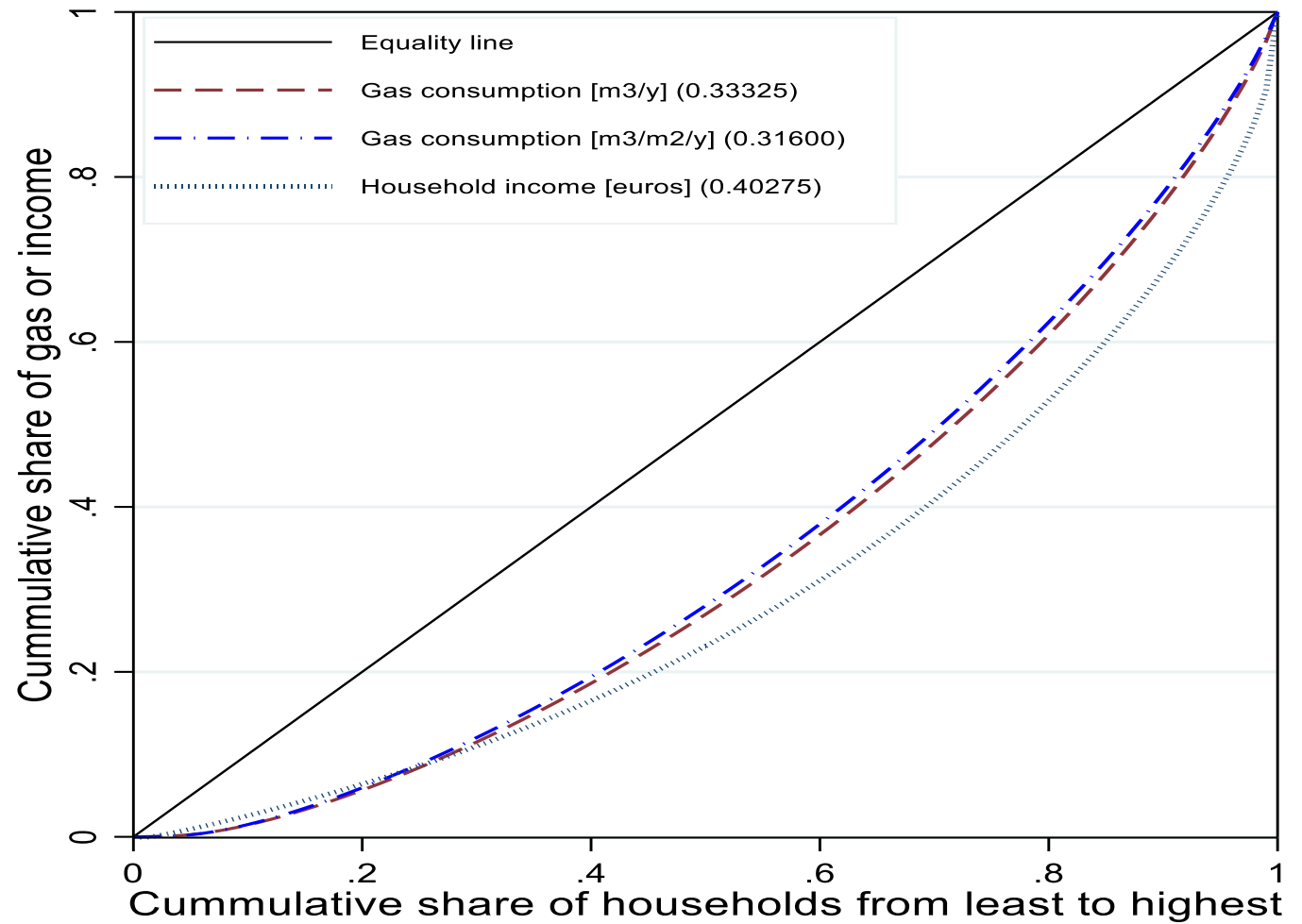
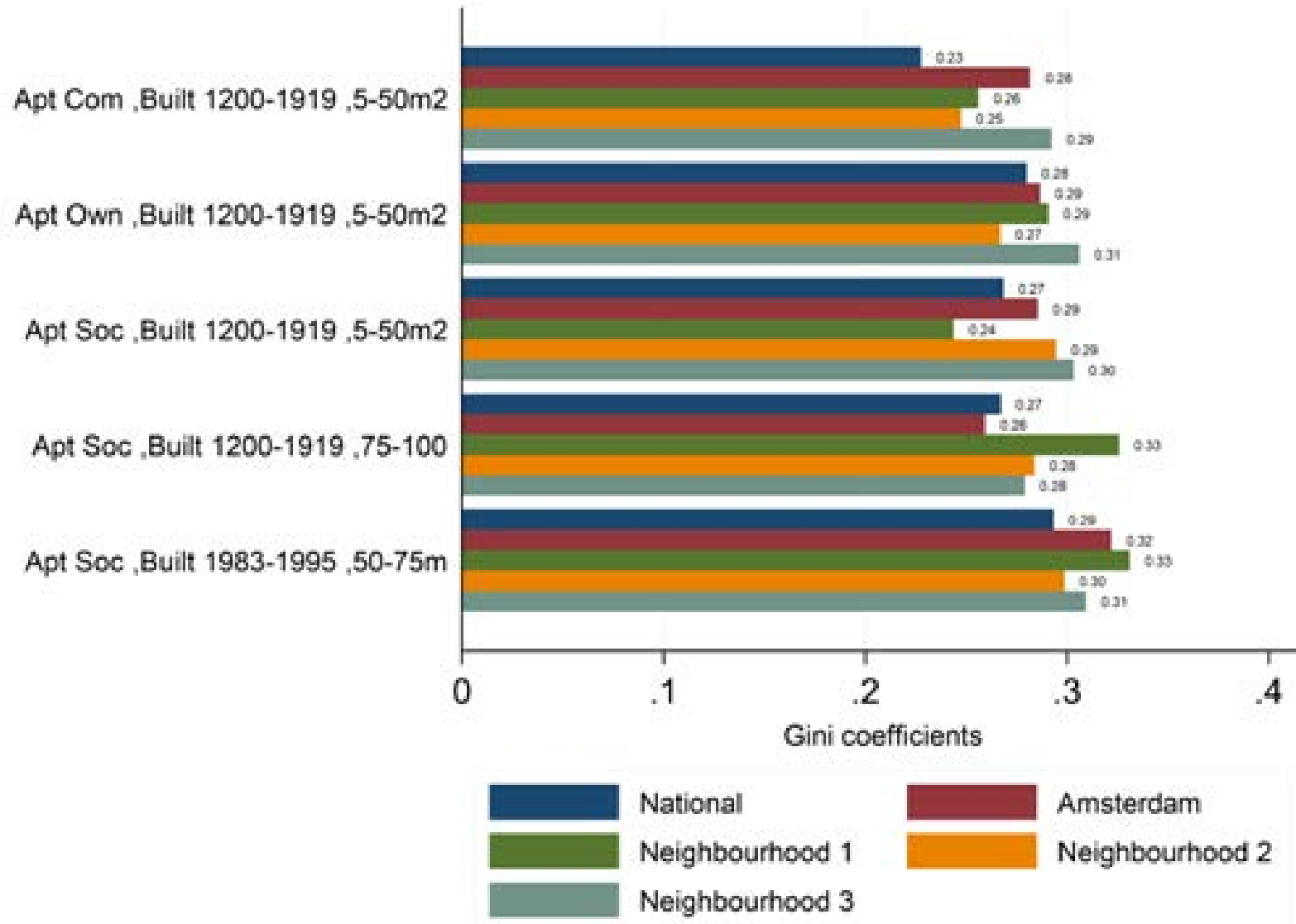


Fig. 3 Lorenz curves of residential gas use versus income variation

More homogeneity: More variation



- Even with increasing homogeneity variation still **persists**
→ sometimes even more in neighbourhoods
- Heating policies cannot assume uniform behaviour

Fig. 4 Variation of same archetypes under different levels of homogeneity. Note that the plot is based on the year 2022

Who would see a bill increase

- **Moderate High Increase in Bill: ~ 74% of households**
- **High Increase in Bill: ~15%**
- **Very High Increase in Bill: ~4%**
- **Extremely High Increase in Bill: ~6%**
- **Low demand users pay more under flat DH tariffs**

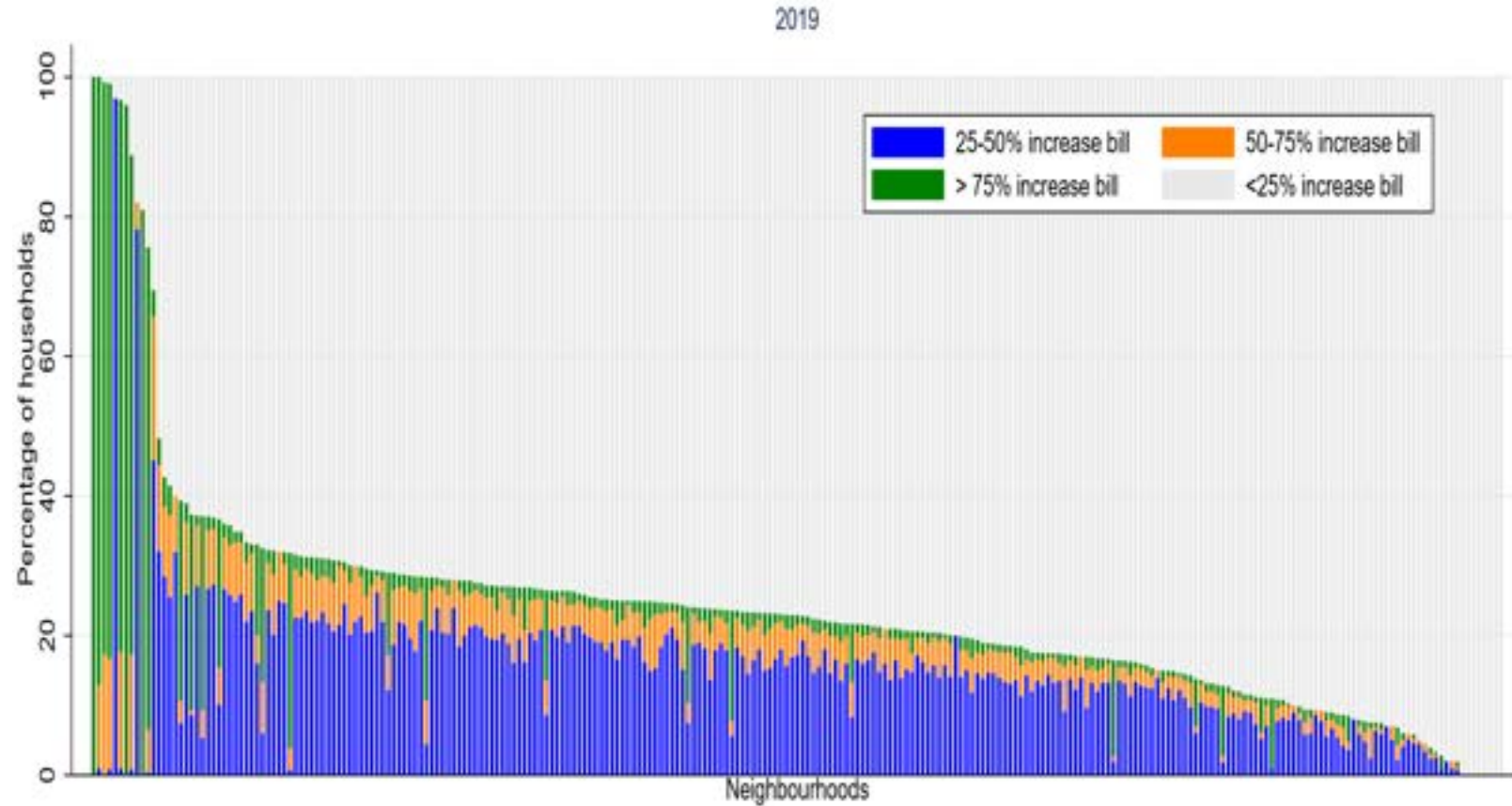


Fig. 5 Percentage of households that experience an increase in energy bill in neighbourhoods of Amsterdam if they switch to DH

At-risk households (Extreme High Increase in Bill group)

- **9%** are energy-poor
- **26%** have low-incomes
- **dominated** by small, highly insulated apartments in comm. rent

Predictors of bill-increase

Highly insulated homes face a **3.7× risk of extreme change**

Private renters have **~2×** the odds of an extreme

Owner-occupied also fare worse than social

Low-income and energy-poor households more vulnerable

Building at most risk are those built between 1946-1974 and 1996-2000

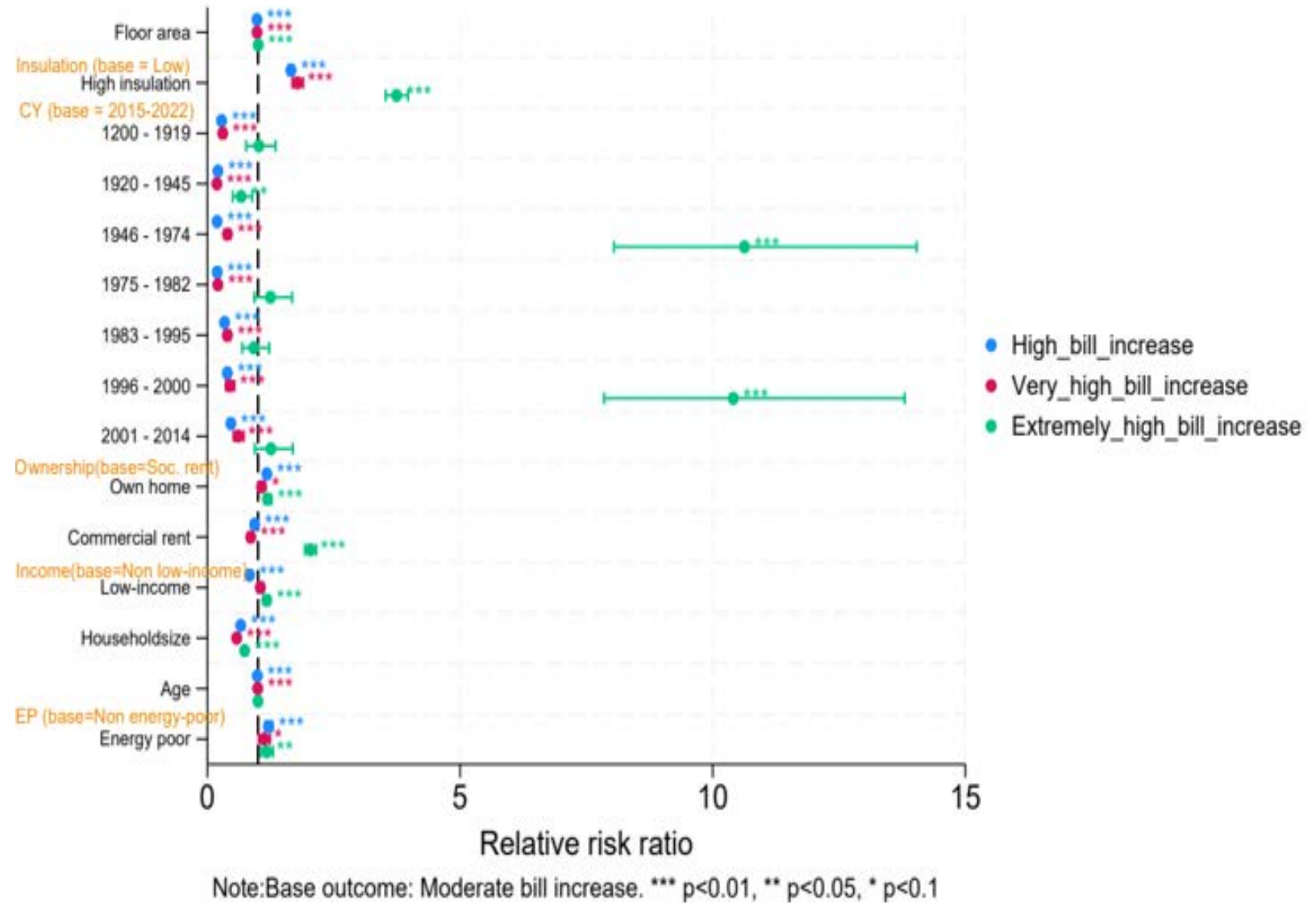


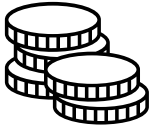
Fig. 6 Multinomial logistic results for bill increase groups in Amsterdam 2019 data

Summary



The average household does not exist

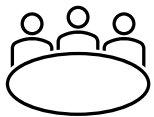
→ Household gas use varies significantly, even among similar homes



A flat rate is disadvantageous

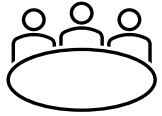
→ About 74% households could see bills rise of up to 25% under flat tariffs

6% of more than 75% increase



Small, well-insulated apartments, often occupied by low-income renters, are most vulnerable

Policy implications



Current structure DH tariffs risk burdening households we want to protect

For fairness, policies should consider:

- tariff structure based on more stratified heat consumption
- targeted subsidies for vulnerable groups

Without these adjustments, the heat transition risks worsening inequality

Thank you!

Looking forward to further
discussions

Email: m.tsekpokumah@uu.nl



Appendix

Study objectives

- To what extent does the transition from natural gas to DH leads to an energy bill increase
- How can the affected households be characterized.

Relevance

Household perspective: Incorporating the end-user perspective is a critical (and planned) next step for refining the analysis and designing effective policies to accelerate the heat transition.

Context

- Heat transition: Phasing out fossil fuels used for heating (space heating, hot water, cooking)
- Built environment focused on residences
- Variance in energy use: Difference in gas consumption at the household level
- Municipality (Gemeente): The primary local government, responsible for public services, zoning, and local policies; there are 345 municipalities as of 2025.
- Neighbourhood (Buurt): The smallest official geographic unit, typically a few streets or a housing estate.
- Energy use: gas consumption because 90% of Dutch households are connected to gas
- Energy-poor households: those with low-incomes and low insulation (Murder et al. 2023)
- Municipalities are tasked to steer the local heat transition
- To support these local strategies, the Dutch Environmental Assessment Agency (PBL) developed a “start analysis” using the Vesta Multi Actor Impact Simulation (Vesta mais model)

Data Descriptives (Case study)

2019			2022	
	Mean	SD	Mean	SD
Gas use (m³)	938.04	573.769	844.884	529.571
Floor area (m²)	75.325	35.757	76.045	37.894
Disposable income	45929.16	59434.61	52751.96	61768.66
Household size	1.931	1.187	1.897	1.154
Age	50.926	16.596	50.946	17.023

Table 2: Statistics of categorical variables for the Amsterdam dataset			
Variable	Categories	2019	
		Freq.	%
House type	Detached	241	0.1
	Semi-detached & corner	1429	0.61
	Terraced	6665	2.84
	Apartments	226531	96.45
	Social rental	108029	46
Ownership type	Own home	68785	29.29
	Commercial rental	58052	24.72
Construction year (CY)	1200-1919	57.779	24.6
	1920-1945	63.018	26.83
	1946-1974	44.692	19.03
	1975-1982	14.193	6.04
	1983-1995	34.653	14.75
	1996-2000	6.933	2.95
	2001-2015	10.917	4.65
	2015-2022	2.681	1.14

Note: Mean is the mean of gas used in cubic meters per year; SD is the standard deviation.

Data Descriptives (National)

	2019		2022	
	Mean	SD	Mean	SD
Gas use (m³)	1313.295	730.054	1131.661	646.328
Floor area (m²)	119.514	64.075	120.638	65.114
Disposable income (€)	47686.441	47645.757	53205.449	43874.712
Household size	2.243	1.254	2.217	1.246
Age	55.014	16.842	55.434	17.059

- **Scope: All houses**
- **Sample: 6,515,704 households in 2019; 6,597,891 in 2022 (excludes student housing and outliers)**
- **Housing: ~31% Terraced , mix of social rent (~29%), private rent, and owner-occupied.**
- **Typical unit: mean floor ~112 m²**

Table 1: Descriptives of categorical variables for the Dutch residential sector

Variable		2019	
		Freq.	%
House type	Detached	903654	13.87
	Semi-det & corner	1526977	23.44
	Terraced	2032774	31.2
	Apartments	2052299	31.5
Ownership	Social rental	1911764	29.34
	Own home	3987119	61.19
	Comm. rental	616821	9.47
	1200-1919	458798	7.04
Construction year	1920-1945	743355	11.41
	1946-1974	2165078	33.23
	1975-1982	812154	12.46
	1983-1995	1150049	17.65
	1996-2000	369925	5.68
	2001-2015	680381	10.44
	2015-2022	135964	2.09

Note: Mean is the mean of gas used in cubic meters per year

Heat Demand Variance (National)

- The distribution is **skewed to the right** with a long tail
→ indicating that households can vary significantly in their consumption
- The highest point of the distribution (the mode) shows that most households' consumption **falls** below the mean
- For both cases, the mean gas consumption for 2022 falls below that of 2019, explained by the effect of high gas prices
- More variation in (a) than (b)
→ Floor area plays a key role in gas variability

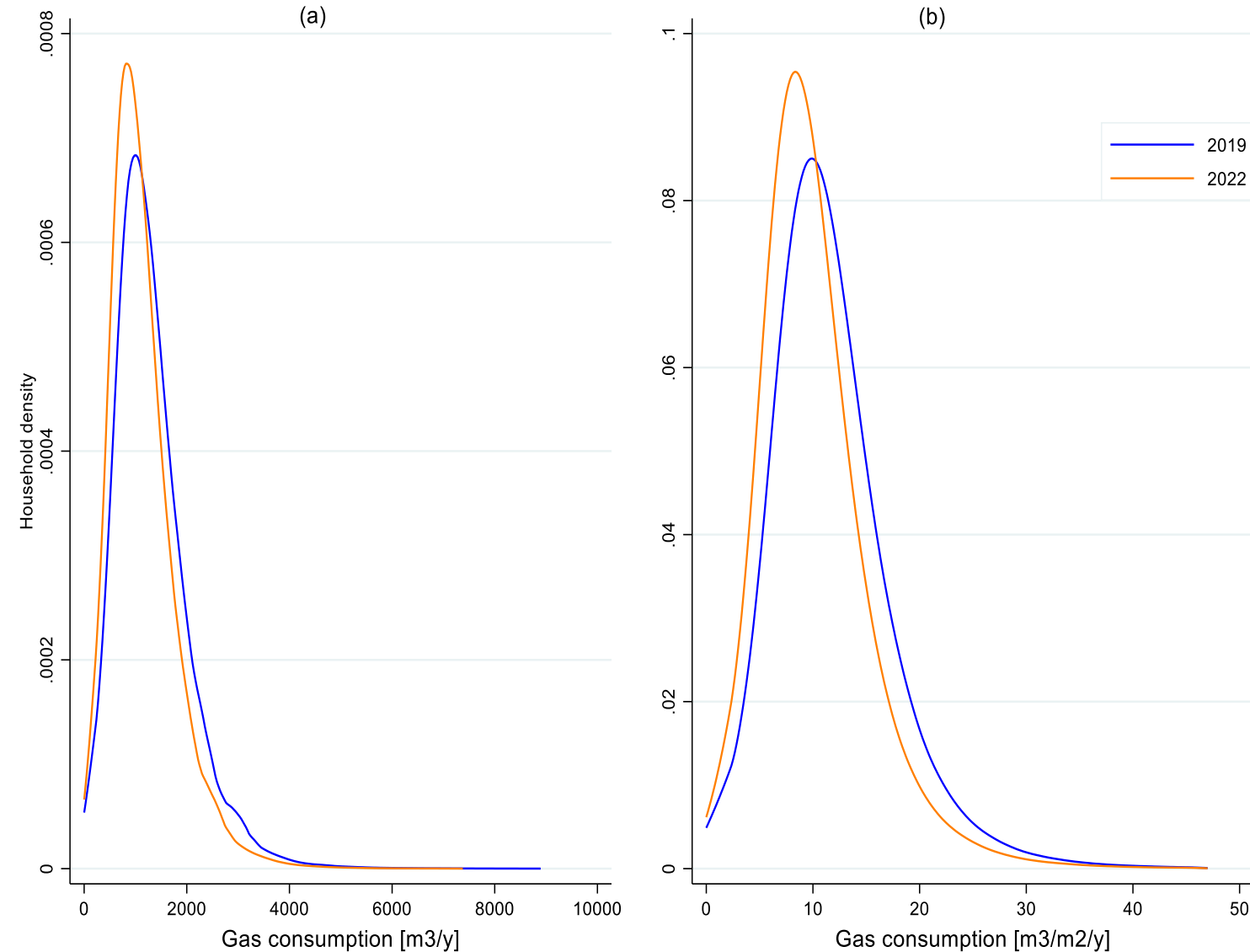


Fig. 1 Kernel distribution plots. Note: Plots have different scales

Investigating Gas use variation

- Kernel density plots
- Lorenz curve and gini coefficients

$$\text{Gini coefficient} = 1 - \sum_{i=1}^N [(X_{i+1} - X_i)(Y_{i+1} - Y_i)] \quad (1)$$

X_i is the cumulative proportion of households (with $X_N = 1$). X_i is measured as the number of gas users i divided by total population with X_i indexed in an increasing order. Y_i is the cumulative proportion of gas consumption. Y_i is measured as the quantity of gas used by household i divided by total gas use, with Y_i ordered from lowest to highest gas consumption.

End-user implication

- The data allowed us to calculate the annual gas bill of an Amsterdam household, and the DH bill, assuming an equivalent amount of natural gas and DH use.

→ Assumption:

- No change in behaviour=> i.e., future DH use is equivalent to the current gas use

-No change in building efficiency

Parameters used for end-use cost calculations (prices including 21% VAT)

	Description	value	Source
Reference gas price	Average price of a one-year fixed contract on January 1, 2025	€1.3636/m ³	ACM factsheet DH tariff 2025 ACM DH tariff calculation sheet
DH price	Maximum 2025 tariff & tariff set by the Amsterdam DH supplier	€43.79/GJ	ACM.nl - maximum tariff DH 2025 Vattenfall - DH tariffs 2025
Fixed fee gas delivery	Average of energy companies	€101.48	ACM.nl - maximum tariff DH 2025
Fixed tariff gas (grid management)	Households that consume <500 m ³ /year	€176.92/yr	Liander-annual network costs-gas-2025.pdf
	Households that consume 500-4000 m ³ /year	€239.46/yr	
Fixed tariff DH	Maximum 2025 tariff & fixed tariff set by the Amsterdam DH supplier - including the DH delivery set	€760.77/yr	ACM.nl - maximum tariff DH 2025
Fixed tariff DH	Maximum 2025 tariff - excluding the DH delivery set	€610.28/yr*	Vattenfall - DH tariffs 2025
Conversion factor GJ -> m ³	Accounting for share space heating (71%) and hot water 29%), the efficiencies of space heating production (94%) and hot water production (68%), and using higher heating value of gas (35.17 MJ/m ³)	32.11 GJ/m ³	Derived from ACM DH tariff calculation sheet

Determining characteristics of households that face a higher energy bill

Empirical Model:

Multinomial logistic model

$$DEH_{ijt} = \alpha_{ij} + \beta_j X_{it} + \varepsilon_{ijt} \quad (2)$$

where DEH_{ijt} is the group category j of the it th household to experience an increase in their energy bills by more than 75%, between 50 to 75%, between 25 to 50% and less than 25% if they switch to district heating at each time t . X_{it} is the explanatory variables. α_{ij} is the time-invariant unobserved household heterogeneity and ε_{ijt} is the random error term

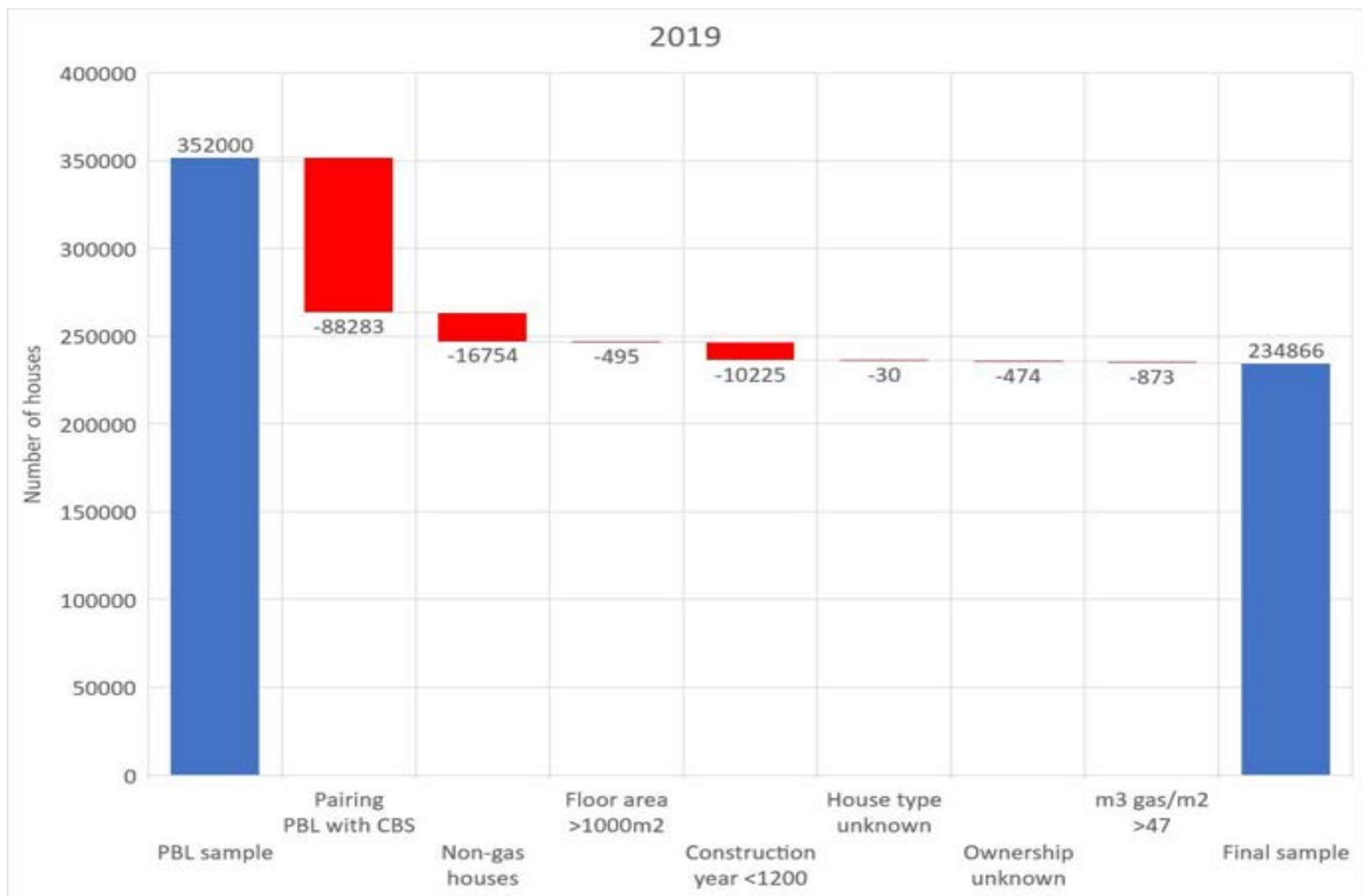




Table 5: Population, mean, and sd of certain characteristics energy change groups.

Household to experience	# of HH	Energy Poor		Low-income HH		Mean statistic				Housetype	Ownership	Insulation	Energy labels
		#	%	#	%	SA	Cx	HH size	Age				
2019													
Moderate high increase in bill (MHIB; 0-25%)	177102	16690	9	44230	25	75.1	1943	1.982	50.76	96% apt	45% social rent	54% high	50% not labeled & 15% label C
High relative increase in bill (HIB; (25-50%)	35339	2516	7	8871	25	59.1	1947	1.469	46.127	98% apt	46% social rent	69% high	43% not labeled & 12% label B
Very high increase in bill (VHIB; 50-75%)	10285	826	8	3331	32	60.2	1952	1.396	49.433	99% apt	55% social rent	72% high	43% not labeled & 19% label C
Extremely high Increase in bill (EHIB; >75%)	12140	692	6	3832	32	75.4	1966	1.74	52.624	99% apt	50% social rent	79% high	42% not labeled & 25% label C
Total	234866	20724	9	60264	26								
2022													
Moderate high Increase in bill (MHIB; 0-25%)	172939	11185	7	38905	23	77.4	1937	1.98	50.94	96% apt	42% social rent	69% high	44% not labeled & 15% label B
High increase in bill (HIB; 25-50%)	47453	2297	5	10750	23	59.6	1943	1.507	46.158	99% apt	43% social rent	77% high	37% not labeled & 17% label B
Very high increase in bill (VHIB; 50-75%)	14286	811	6	4195	29	60.5	1948	1.367	49.628	99% apt	51% social rent	79% high	37% not labeled & 19% label C
Extremely high Increase in bill (EHIB; >75%)	12818	614	5	3859	30	74	1963	1.673	53.671	95% apt	49% social rent	82% high	34% not labeled & 25% label B
Total	247496	14907	6	57709	23								