# Regression models of actual and theoretical heating energy use in the Dutch labelled dwelling stock

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Background

Actual and theoretical gas consumption for each energy label
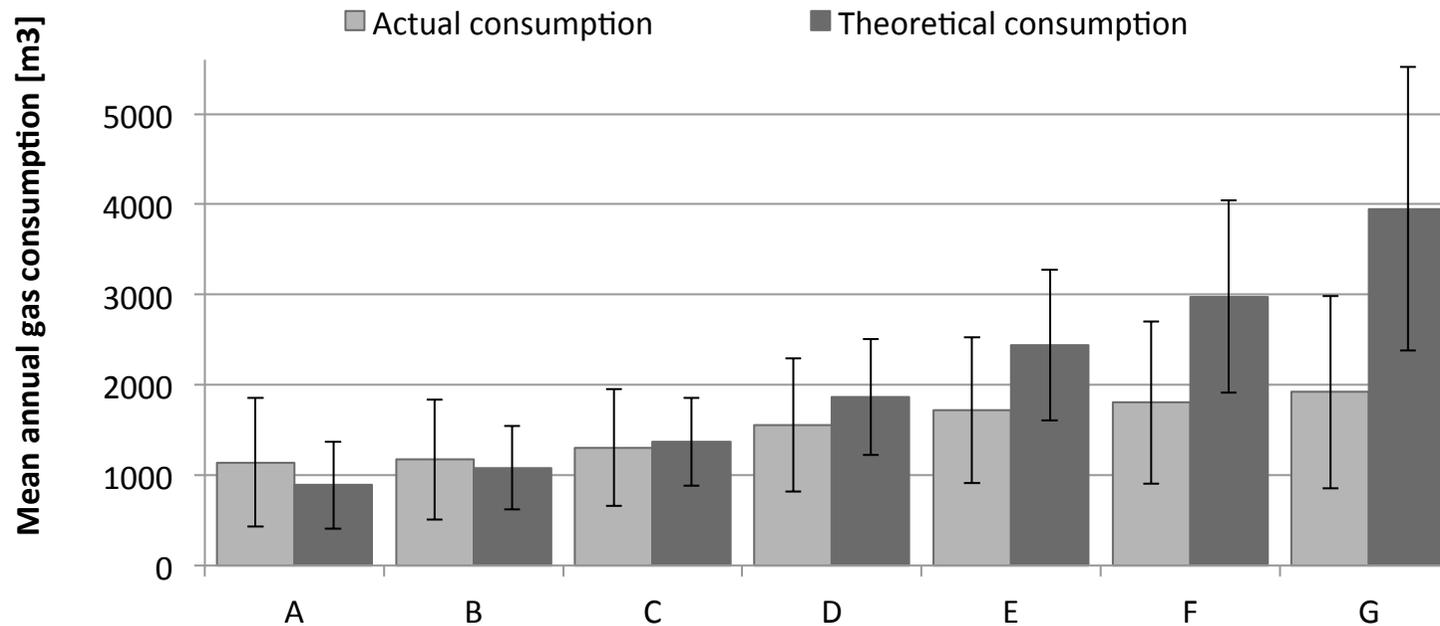
- normalized conditions vs. building use
- occupant behaviour and lifestyle

- actual energy data coupled with survey data (dwelling/household/ occupant) in order to understand the patterns

Analysis

- Survey of 400 dwellings including energy label data and annual actual heating (gas) data
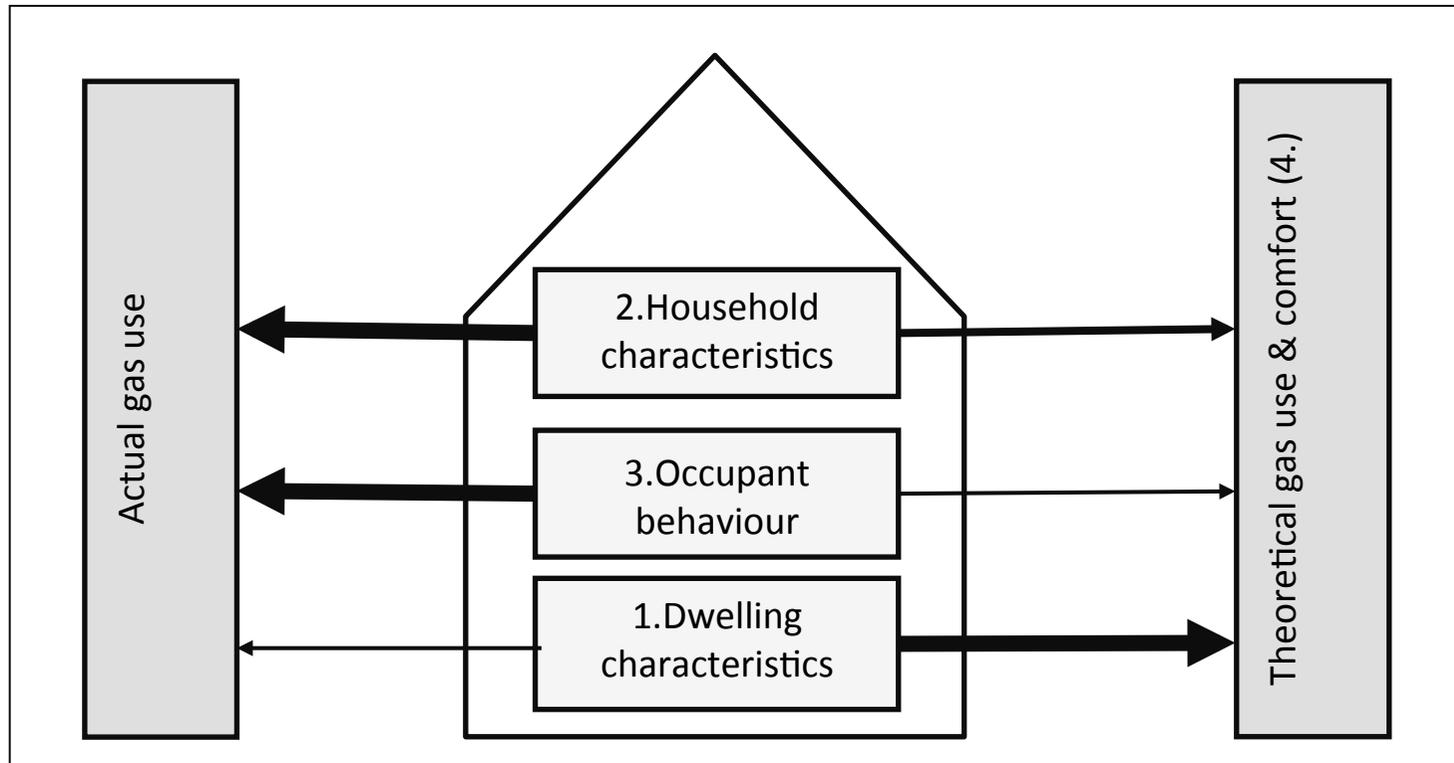
Analysis

1. Correlations between the variables (4 groups) and actual and theoretical consumption

2. Linear regression analysis of actual, theoretical energy use and the difference between them
   - separately for underpredictions and overpredictios

3. Regression of actual gas use using theoretical consumption as predictor together with additional dwelling information
   - improved model

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1. Correlations between the variables and actual and theoretical consumption

Dwelling characteristics	Label class (cat.), dwelling type (cat.), heating type (cat.), ventilation type (cat.), electrical boiler presence (cat.)[1], heating of the hall yes/no (cat.)[12], programmable thermostat presence (cat.)[1], floor area (cont.)[2], number of rooms (cont.)[12], age of the building (cont.), presence of water saving shower head (cat.)[1]
Household characteristics	Ownership type (cat.)[1], Household composition (cat.)[2], education (cat.)[2], ability to pay the energy bills (cat.)[2], age of respondent (cont.)[1], spendable income (cont.)[1], number of occupants (cont.)[2]
Occupant behaviour	Perception dwellings/ households energy performance (cat.), awareness of the label certificate (cat.)[12], ventilation practices - living room/ kitchen/ bathroom/ bedrooms (cat.)[12], ventilation habits weekends (cat.)[1], perceived household energy behaviour (cat.)[2], not setting thermostat too high (cat.), not ventilating while heating (cat.)[2], no energy saving measures taken (cat.), number of weekdays of presence – morning(cont.)[12], number of weekdays of presence – midday(cont.)[2], number of weekdays of presence – evening(cont.)[12], number of weekdays of presence – night(cont.)[12] , average temperature during the day – day(cont.)[2], average temperature during the evening(cont.)[2], average temperature during the night(cont.)[2], average temperature when nobody at home(cont.) , showers per week (cont.)
Perceived Comfort	Perception of heat/cold(cat.)1, Perception of dry/humid(cat.)[12] and perception of draft (cat.)[1], Unpleasant long waiting for hot water (cat.)[12]

[1] Insignificant correlation/Chi-square/Mann-Whitney U with actual gas consumption per m^2
[2] Insignificant correlation/Chi-square/Mann-Whitney U with theoretical gas consumption per m^2

2. Linear regression analysis of actual, theoretical energy use and the difference between them

R² values	Dwelling characteristics	Household characteristics	Occupant behaviour	Comfort	Total
Act. gas use per m²	8,6	3,1	10,7	0	**23,8**
Th. gas use per m²	64,3	4,3	7,5	0	**65,1**
DBTA	39,3	4,3	9,1	0	**40,9**

- Act gas use: building age, floor area, age of respondent, number of occupants, <u>presence at home, reported indoor temperature, reported behaviour</u> (efficient vs inefficient)
- Th. gas use: building age, floor area, <u>dwelling type, heating installation type, hot tap water installation</u>, ventilation pattern (weekly vs weeday), draft perception

		All data (R^2=40,9%)			Underpredictions (R^2=19,9%)			Overpredictions (R^2=50,8%)		
		B	SE	Beta	B	SE	Beta	B	SE	Beta
	(Constant)	21,28	2,11		-4,21	2,02		23,70	2,31	
Dwelling characteristics	Age of the building	0,07	0,01	0,20				0,06	0,01	0,21
	Floor area							-0,07	0,02	-0,14
	Maisonette vs. gallery house							5,35	2,77	0,09
	Flat with a staircase entrance vs. gallery house							0,84	1,27	0,04
	Row house vs. gallery house							-0,24	1,92	-0,01
	Semidetached vs. gallery house							10,11	2,77	0,16
	Missing data vs. gallery house							2,51	7,06	0,01
	Heat. with η<83% boiler vs. gas stove	-2,97	3,00	-0,04				-4,66	2,33	-0,09
	Heat. with η>90% boiler vs. gas stove	-14,89	3,28	-0,19				-10,86	2,86	-0,16
	Heat. with η>96% boiler vs. gas stove	-16,24	1,49	-0,62				-12,82	1,20	-0,62
	Heat. with η>83% boiler vs. gas stove	-10,46	1,98	-0,27				-8,81	1,59	-0,29
	Heat. other vs. gas stove	-12,95	6,78	-0,08				-13,99	7,05	-0,08
Occupant behaviour	No. of weekdays of presence - morning				1,27	0,54	0,30			
	No. of weekdays of presence - midday	-0,94	0,23	-0,16	-1,78	0,56	-0,42			
	Average reported T, nobody at home	-0,19	0,06	-0,12				-0,23	0,05	-0,18
	Programmable thermostat				5,49	1,79	0,29			
	Water saving shower head				-4,93	1,39	-0,34			
Comfort	Missing data vs. average temperature							-5,51	7,00	-0,03
	Too cold vs. average temperature							2,18	0,97	0,09

3. Linear regression of actual gas consumption using theoretical consumption as predictor

overpredictions

R^2=33,8%	B	Std. Error	Beta
(Constant)	1,224	1,438	
Theoretical gas use per m^2	0,305	0,032	0,611
Maisonette vs. gallery house	-1,183	1,863	-0,03
Flat with staircase entrance vs. gallery house	0,787	0,844	0,056
Row house vs. gallery house	3,083	1,308	0,124
Semidetached vs. gallery house	4,167	2,015	0,107
Missing data vs. gallery house	-1,02	5,142	-0,009
Heating with η<83% boiler vs. gas stove	2,219	1,552	0,073
Heating with η>90% boiler vs. gas stove	2,6	2,116	0,059
Heating with η>96% boiler vs. gas stove	2,417	0,993	0,187
Heating with η>83% boiler vs. gas stove	3,529	1,11	0,183
Heating other vs. gas stove	4,644	5,17	0,04

underprediction

| R^2=60,0%	B	Std. Error	Beta
(Constant)	12,747	3,837	
Theoretical gas use per m^2	0,94	0,106	0,656
Floor area	-0,075	0,039	-0,144
Programmable thermostat	-5,246	1,871	-0,191
Water saving shower head	4,008	1,429	0,188

3. Linear regression of actual gas consumption using theoretical consumption as predictor
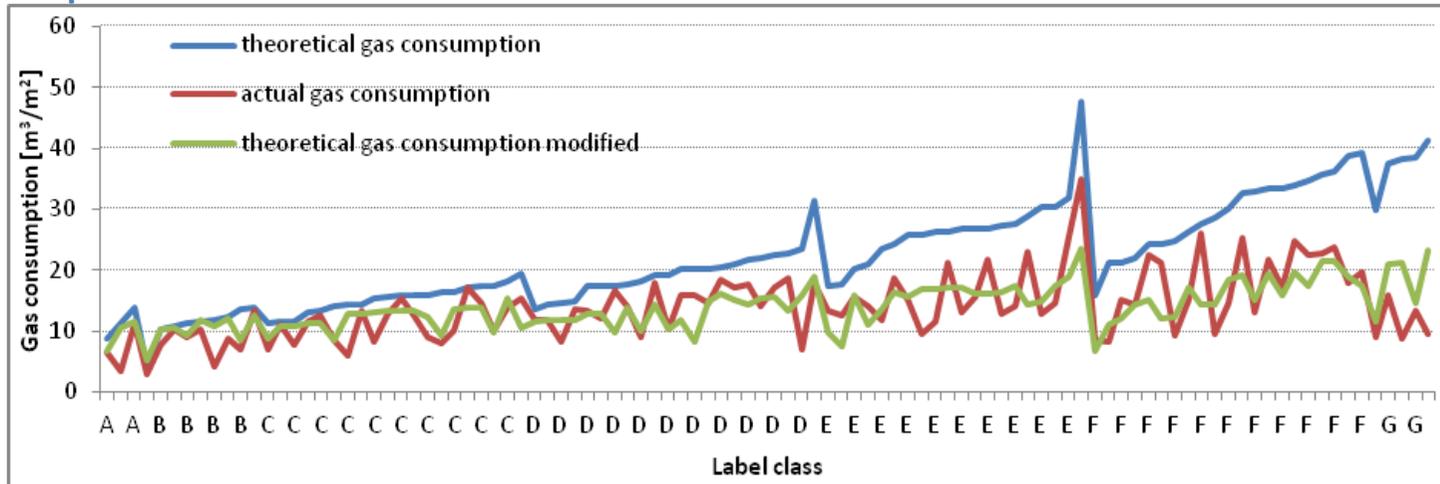
overpredictions

underprediction
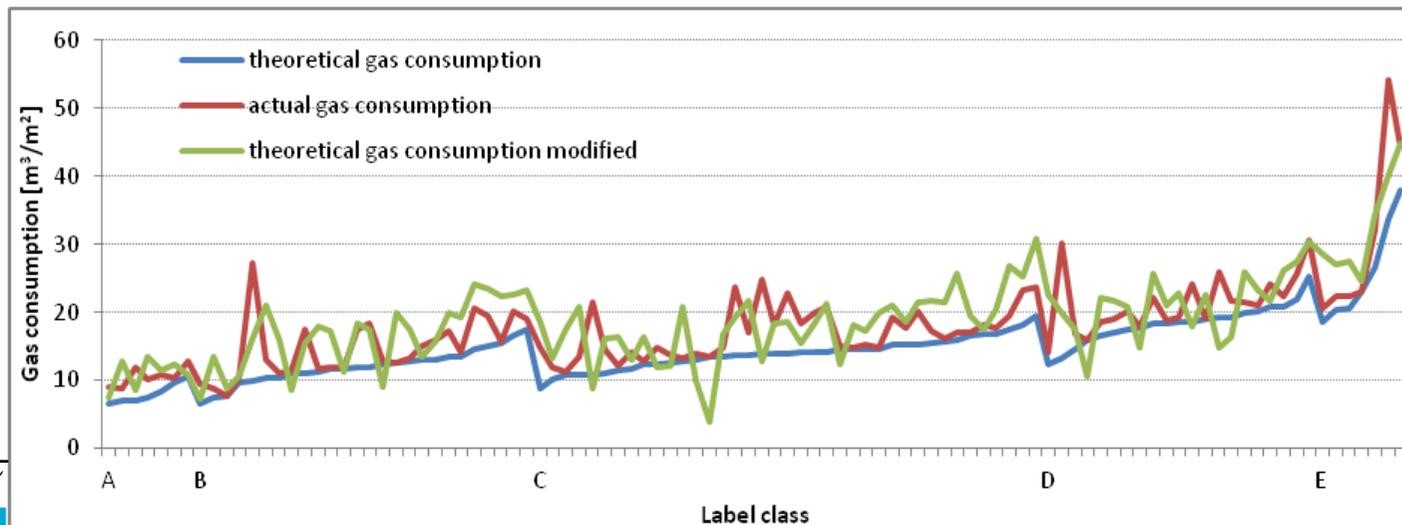
Discussion

- variation in actual gas use is complex and difficult to explain even by using detailed survey data – monitoring?
- positive vs negative DBTA
    - different causes - analyse DBTA in different label classes
    - underprediction - more behaviour dependent?
    - variation in the actual consumption is more easily explained by a normalised theoretical consumption (smaller discrepancy)

- more accurate predicted heating consumption on the stock level by using regression analysis to calculate correction factors

- problems of surveying: no guidelines, granulation of questions is a problem (composition, presence at home)

Questions?