Effectiveness of energy renovations: a reassessment based on actual consumption savings

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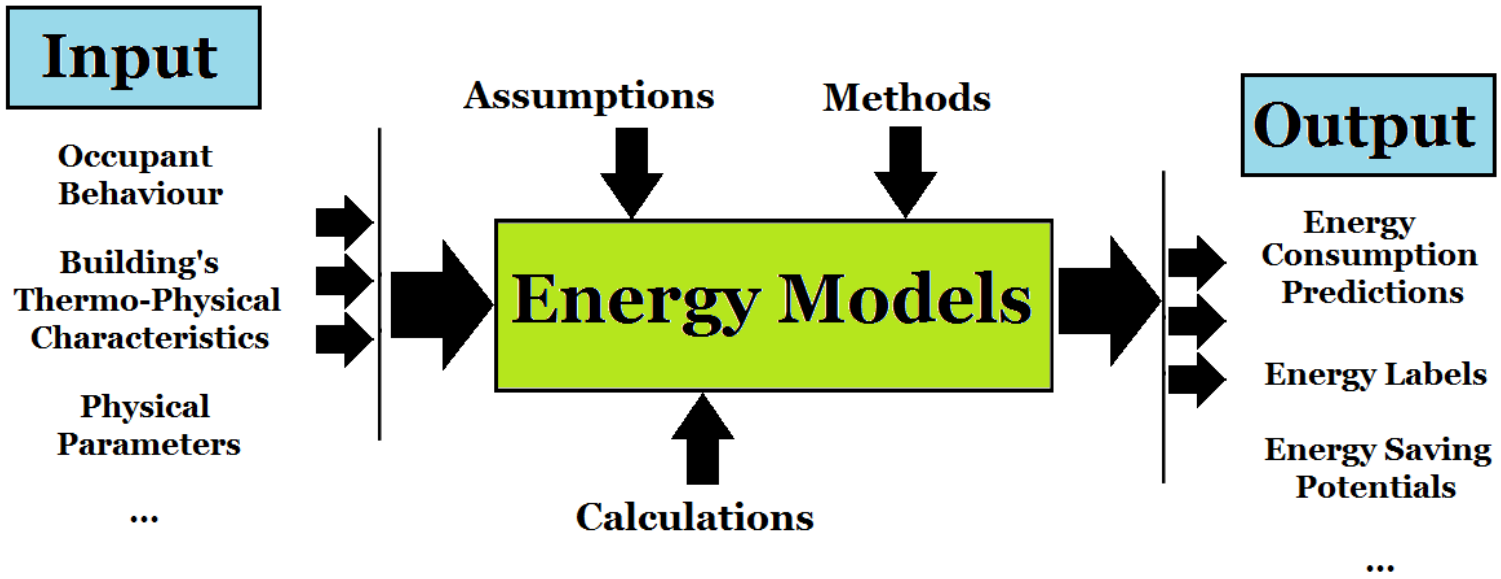
Energy in Buildings

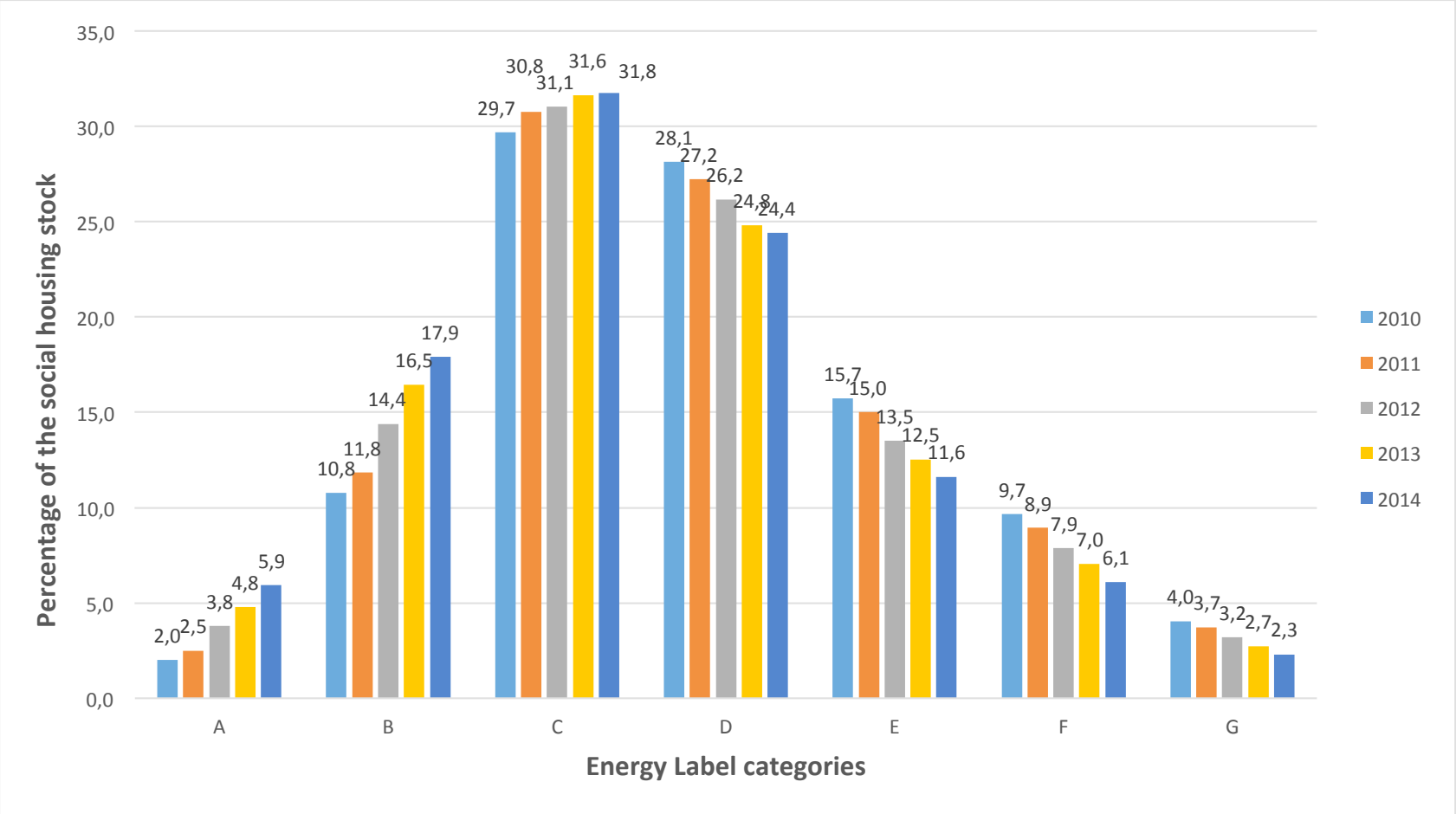


Improving the energy performance through its thermo-physical properties, energy installations, appliances and occupant behaviour

(figure source: Ir. Arash Rasooli)

Research question

What is the effectiveness of the energy renovations, in terms of actual energy savings?

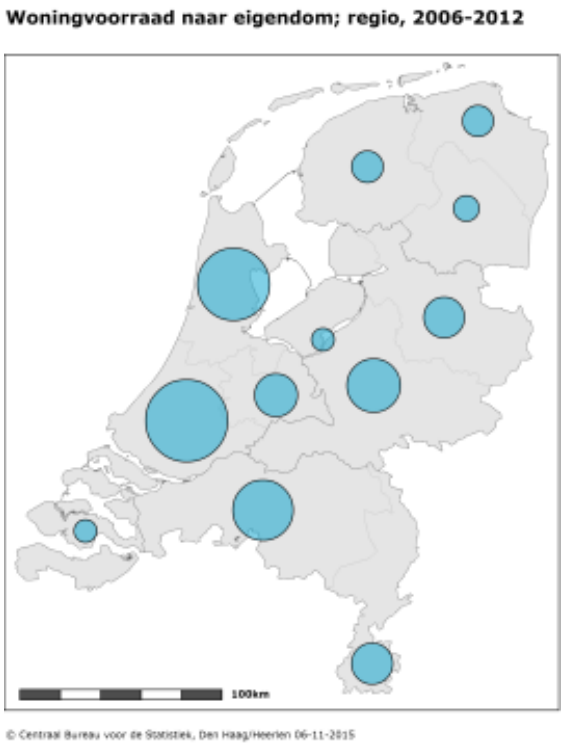


Energy efficiency directives and requirements

- Dutch EPN (Energie Prestatie Norm) for newly built dwellings → EPC (Energy Performance Coefficient) 1995
- Energy Performance Buildings Directive (EPBD 2002/91/EC, 2002 and recast 2010)
- Dutch Energy Labelling Scheme for existing dwellings 2008 based on the Energy Index (EI)
- Dutch Covenant Energiebesparing Huursector 2008:
  - Social housing → Average energy label B in the end of 2020
  - 80% of private owned rented → Average label C by the end of 2020

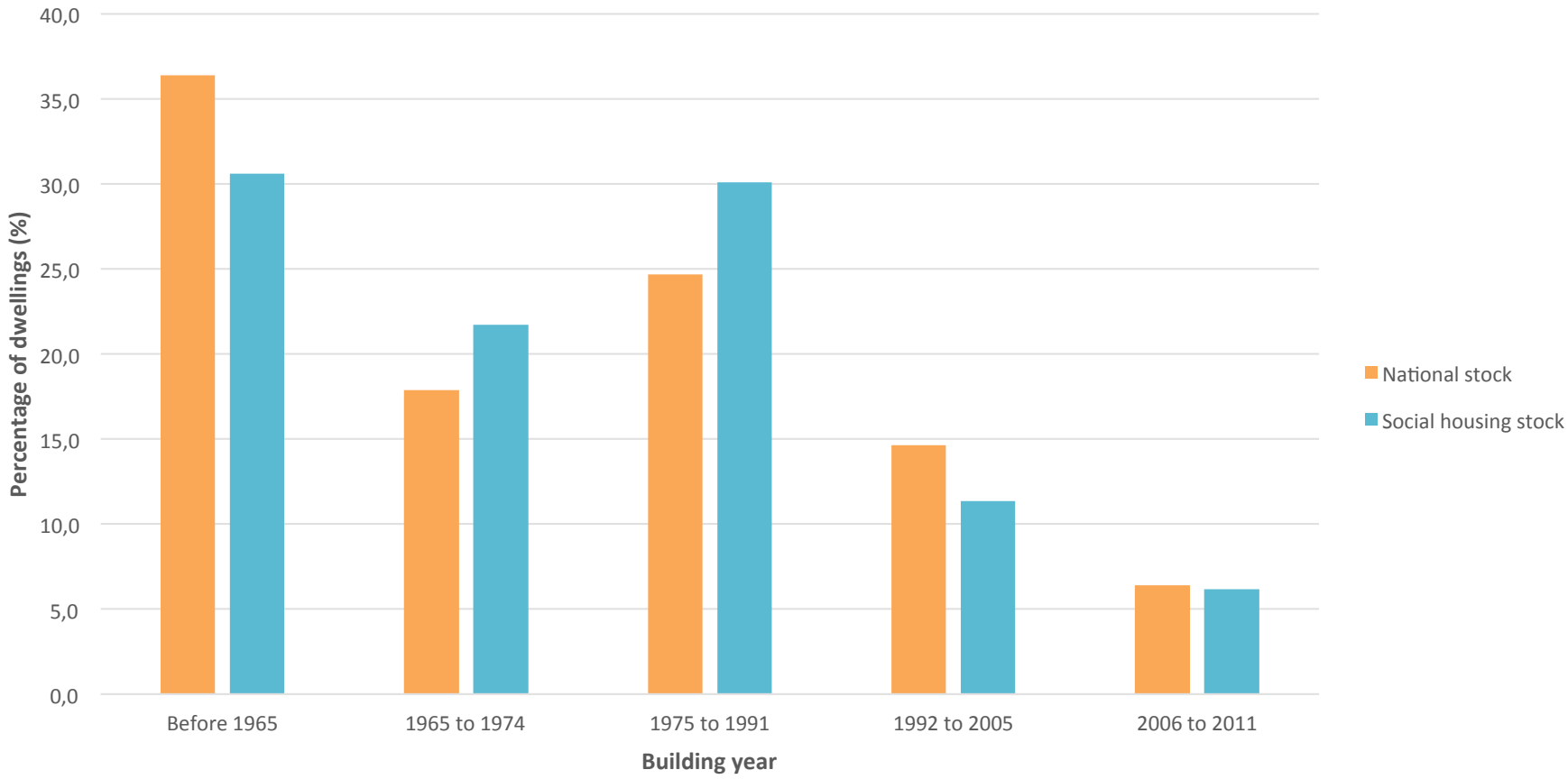
Non-profit rented housing stock

Nowhere else in Europe does social housing dominate the housing market as it does in the Netherlands. Over 1/3 of all households rent a social-sector dwelling. There are 2.4 million dwellings, a number that has been stable during the last 10 years. (M. Elsinga & F. Wassenberg, 2007)

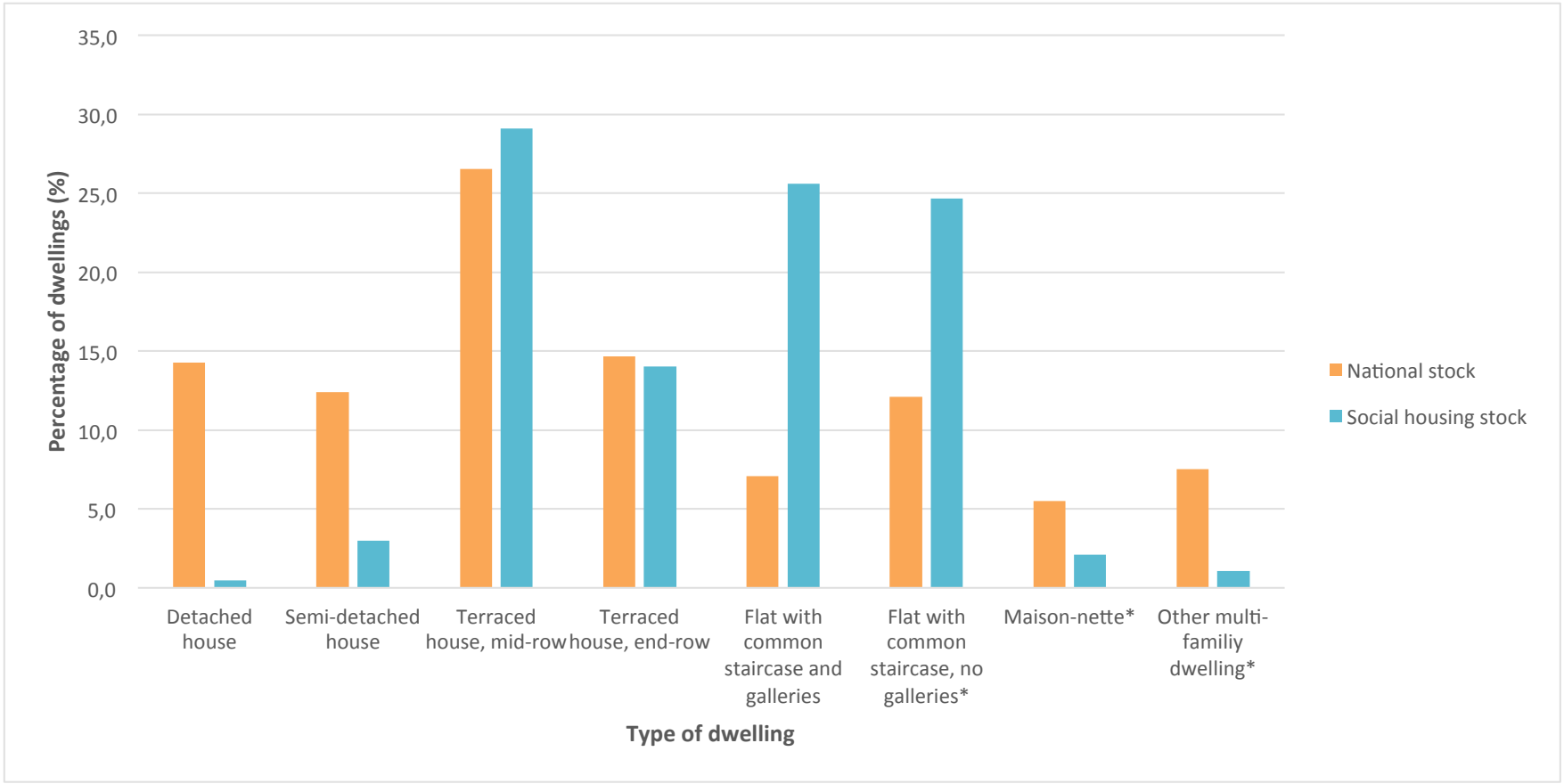


2,3 million dwellings (Aedes, 2014)
31% of the total housing stock in the Netherlands

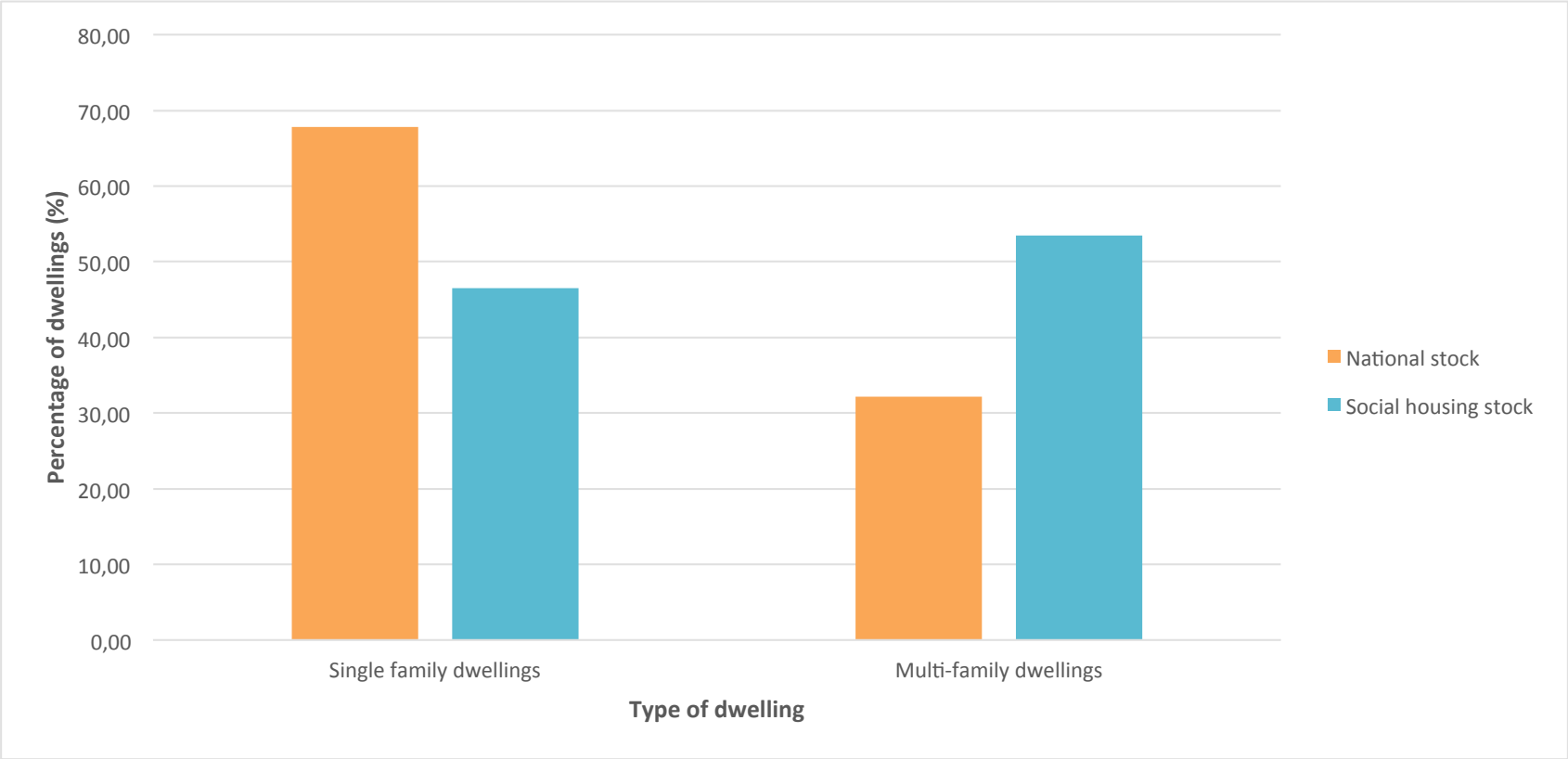
National and non-profit housing stock - building year



National and non-profit housing stock - dwelling typology



National and non-profit housing stock - single and multi-family dwellings



Dutch energy labelling system for existing dwellings

Energy Label	**Energy Index**	**Mean predicted primary energy consumption** (Kwh/m^2/year) (Majcen et al., 2013)	**Mean actual primary energy consumption** (Kwh/m^2/year) (Majcen et al., 2013)
A (A+, A++)	<1.05	96.8	138.5
B	1.06 – 1.3	132.5	162.1
C	1.31 - 1.6	161.6	174.3
D	1.61 - 2.0	207.8	195.6
E	2.01 - 2.4	265.0	211.5
F	2.41 - 2.9	328.0	223.8
G	> 2.9	426.9	232.1

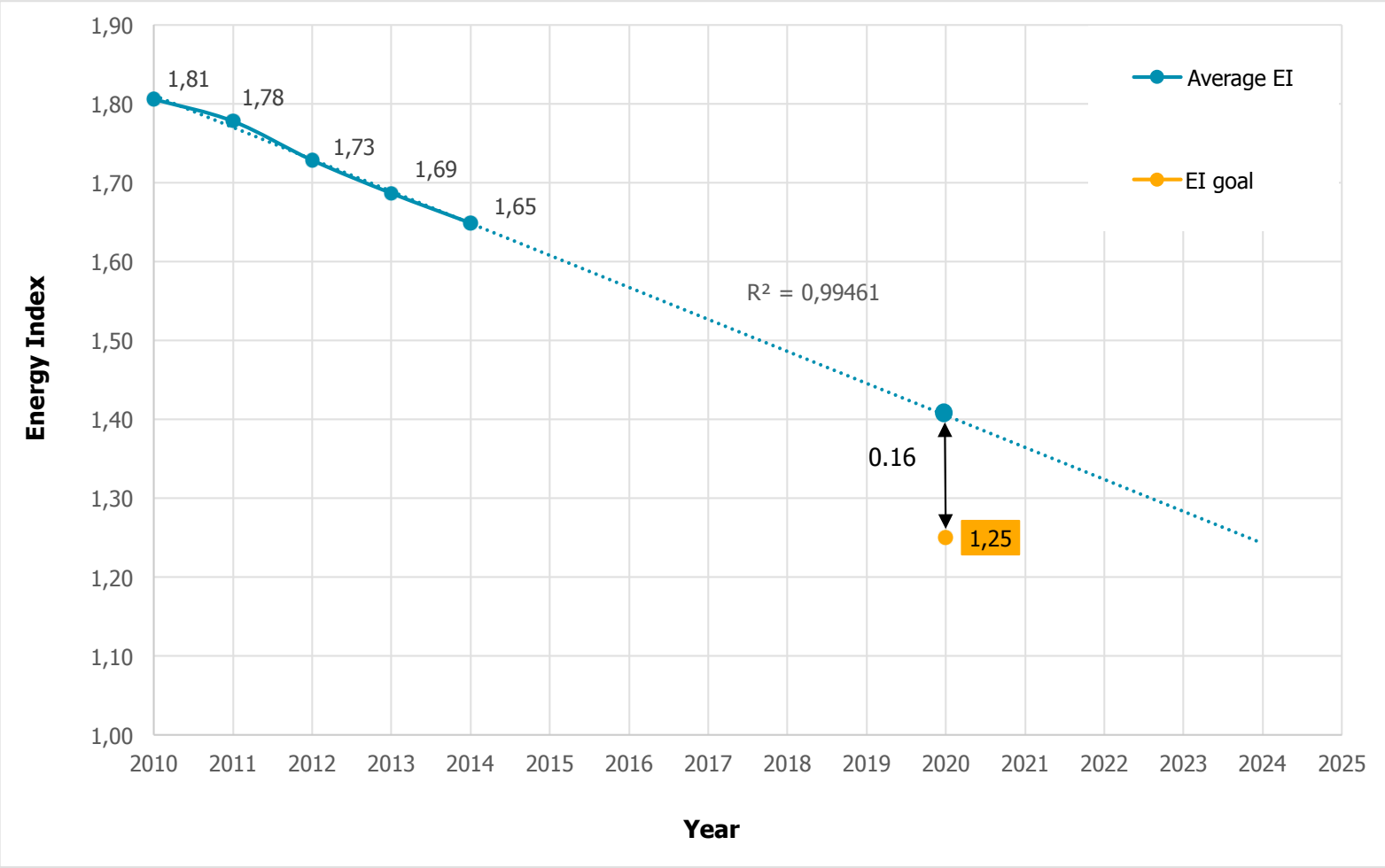
$$EI = \frac{Q_{total}}{155 * A_{floor} + 106 * A_{loss} + 9560}$$

Q_{total} yearly primary energy use

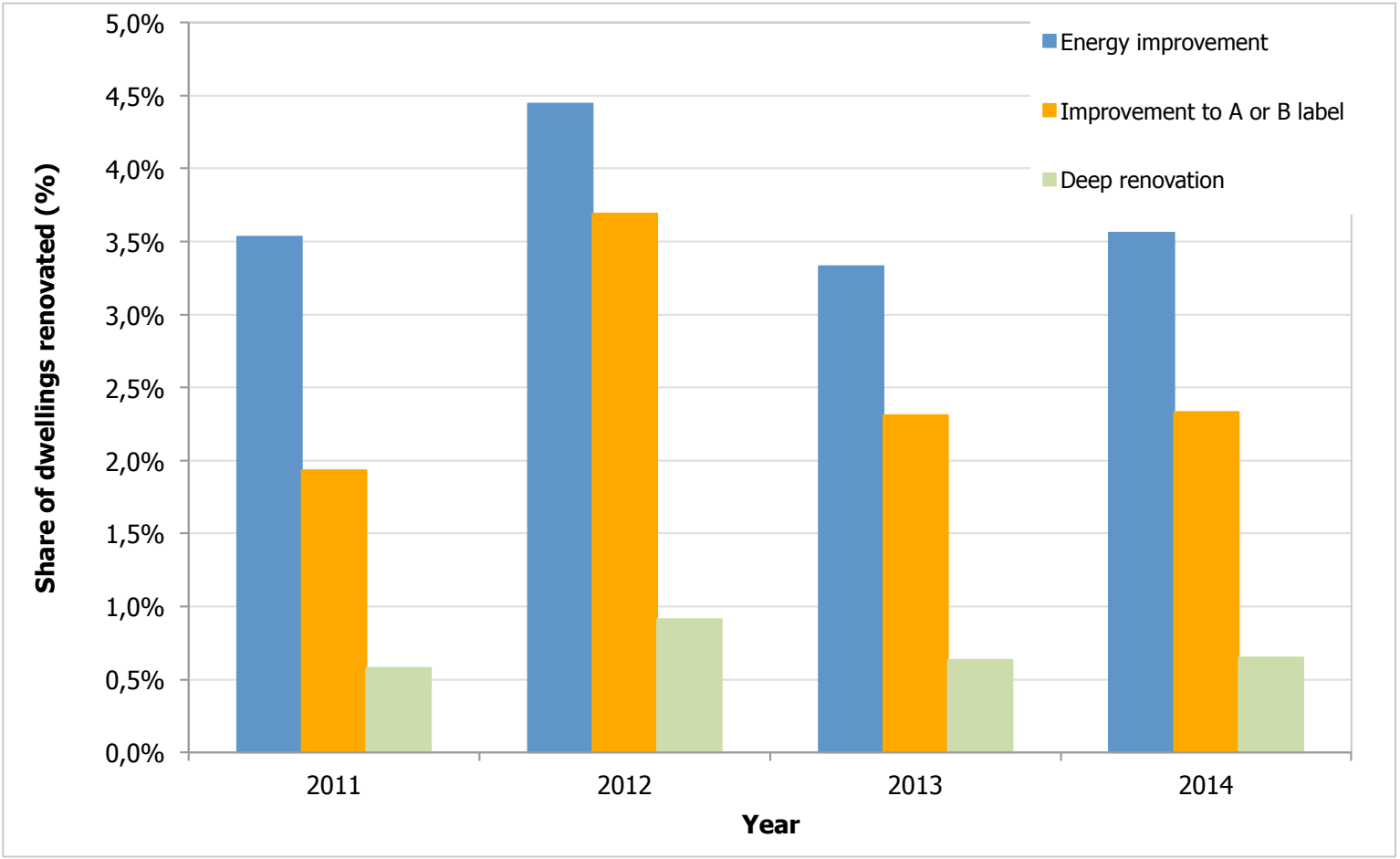
A_{floor} area of the dwelling

A_{loss} areas that are not heated in the dwelling

The energy renovation rate of the Dutch non-profit housing: are we moving fast enough?



The energy renovation rate of the Dutch non-profit housing



Data: SHAERE and CBS

- SHAERE (Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing)
- A collective database including data on:
    - Predicted energy consumption , CO_2 emissions , the average EI etc.

Year of reporting	Nr. of dwellings	Percentage of the social stock
2010	1,132,946	47.2%
2011	1,186,067	49.4%
2012	1,438,700	59.9%
2013	1,448,266	60.3%
2014	1,729,966	73,7%
2015	1,275,390	53,3%

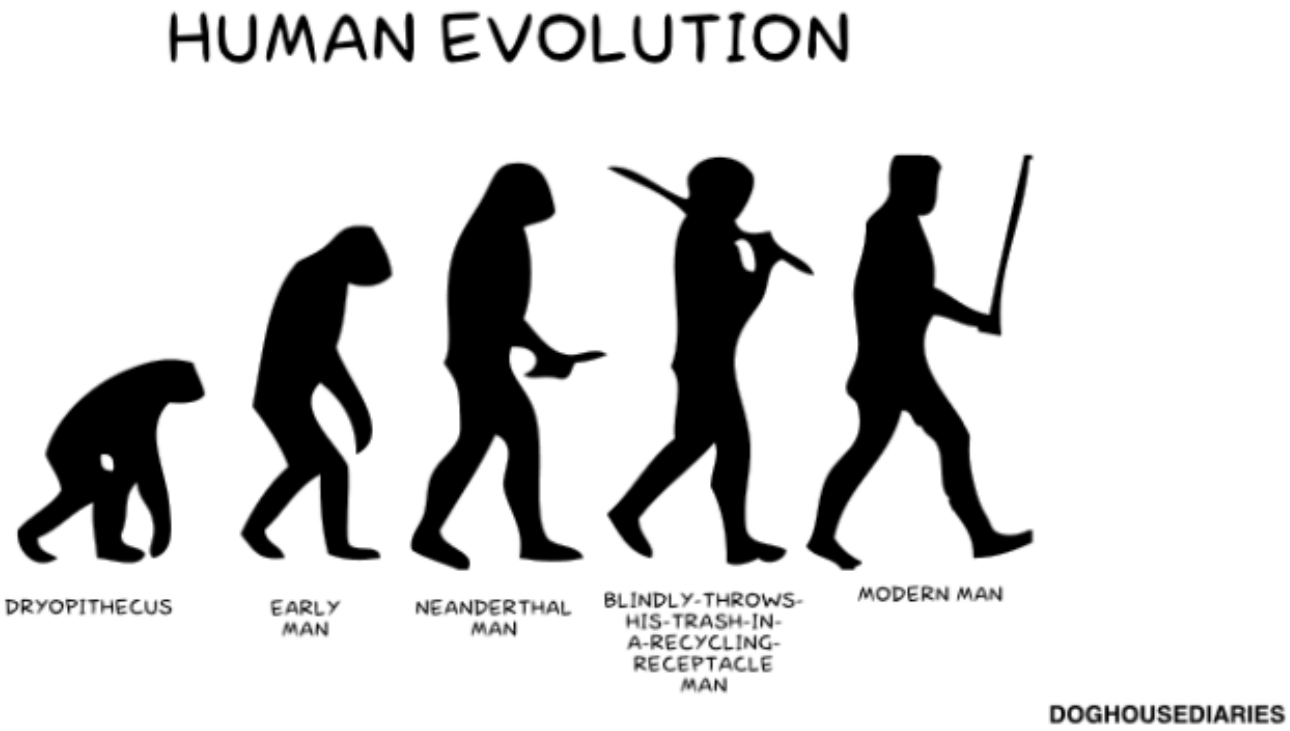
- CBS (Statistics Netherlands) Energy consumption data on national scale
    - Gas, electricity and heat
- All variables are categorized per property (microdata)

SHAERE - variables

- Dwelling characteristics
  - Type
  - Energy Index
  - Energy Label
  - Area
  - Year of construction etc.
- Envelope elements
  - Glazing
  - Wall U value
  - Roof U value
  - Frame U value
  - Type of frame and glass etc.
- Installations
  - Space heating
  - Hot tap water
  - Ventilation
  - Systems' efficiencies
  - Calculated energy consumption etc.

Methods

Longitudinal data analysis



Number of Energy Saving Measures (ESMs) and savings

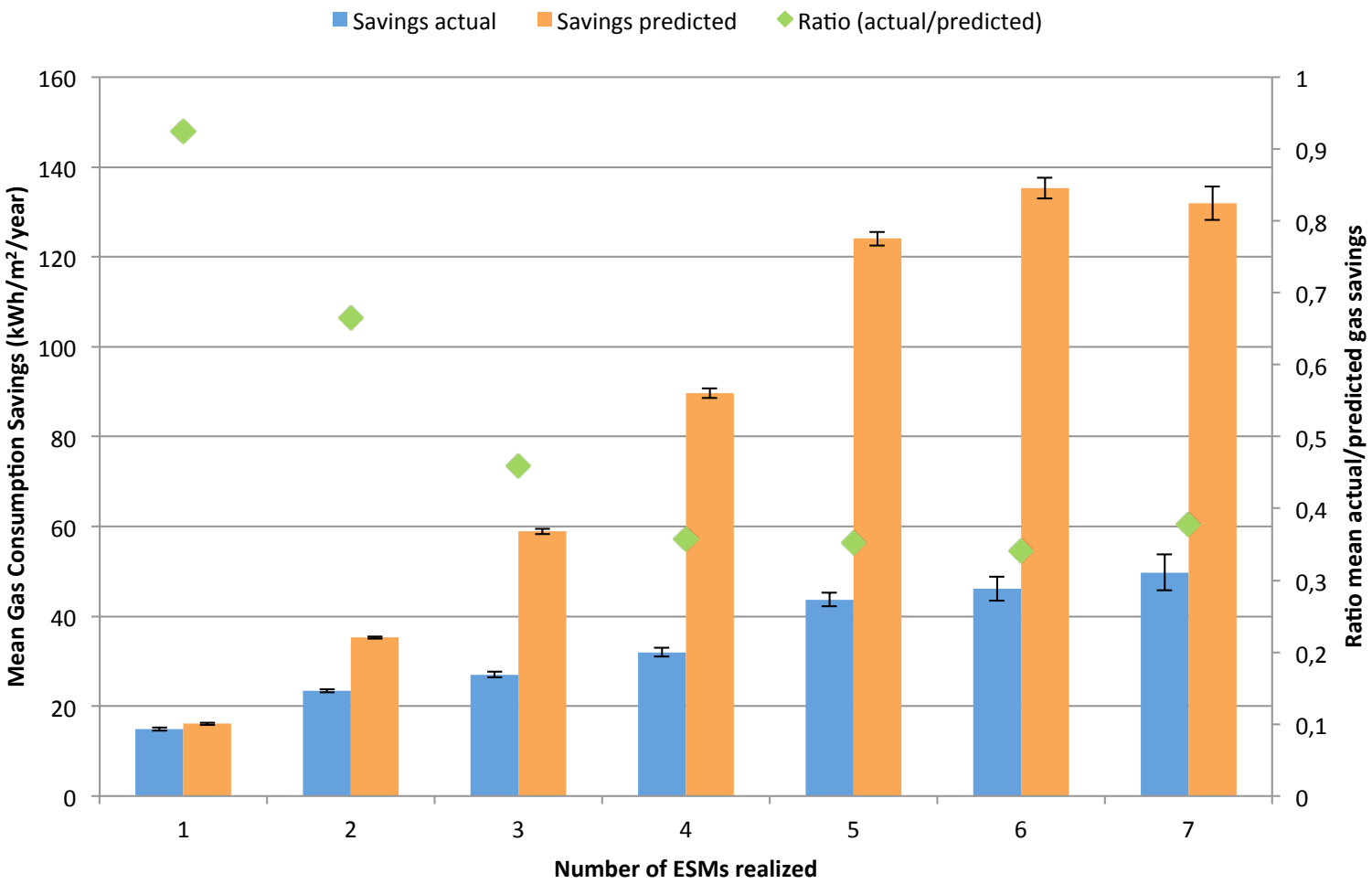
Number of ESMs	Frequency (number of dwellings)	Percentage (%)
0	384,069	59.0
1	108,131	16.6
2	100,211	15.4
3	35,506	5.5
4	14,052	2.2
5	5,871	0.9
6	1,967	0.3
7	653	0.1
Total	650,460	100.0

The actual and predicted energy savings are calculated as follows:

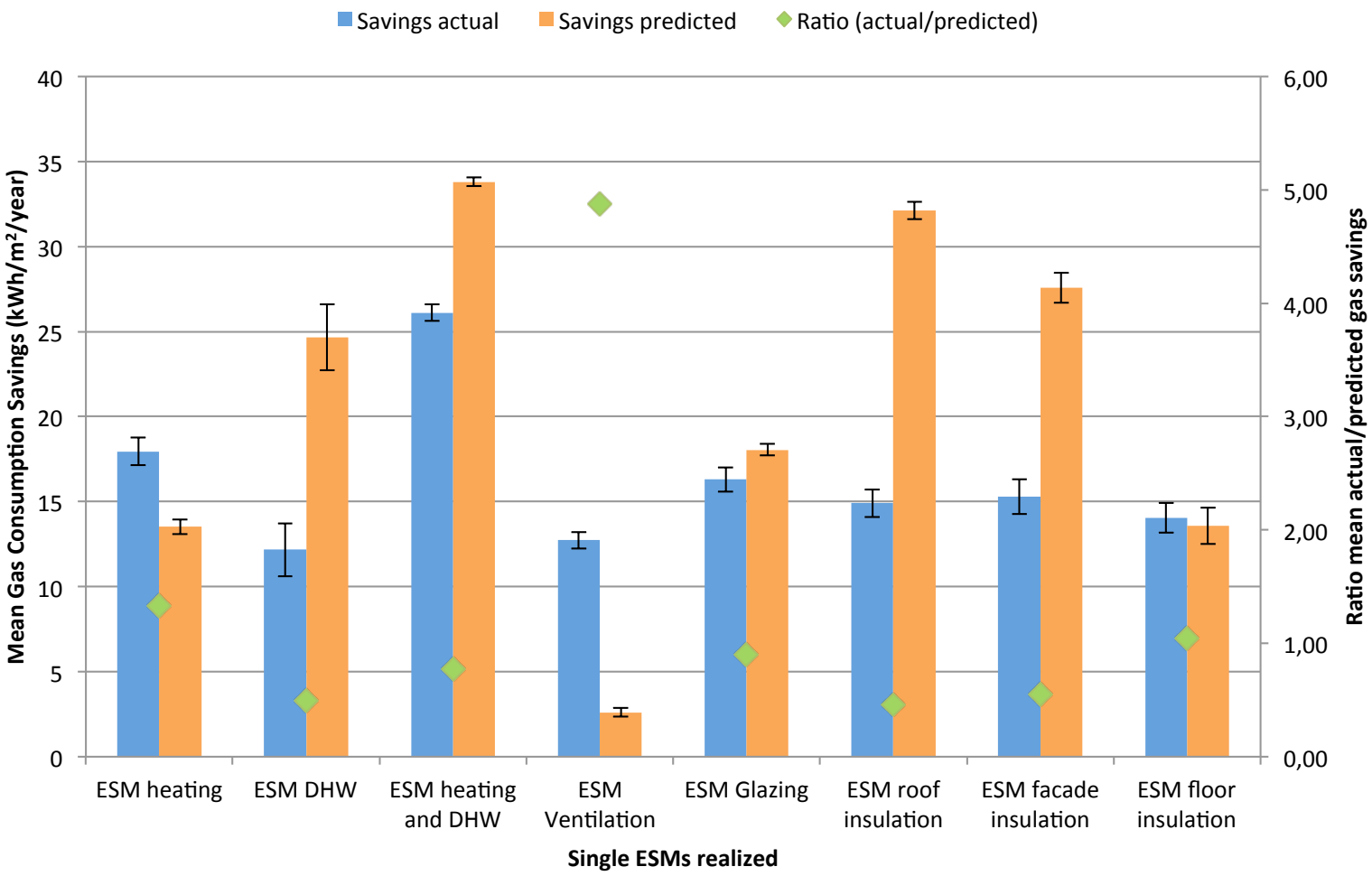
$$Savings\downarrow actual = Q\downarrow actual,\ before - Q\downarrow actual,after \quad [\text{kWh}/m\uparrow 2\ /\text{year}] \qquad (1)$$

$$Savings\downarrow predicted = Q\downarrow predicted,\ before - Q\downarrow predicted,after \quad [\text{kWh}/m\uparrow 2\ /\text{year}] \qquad (2)$$

Number of Energy Saving Measures (ESMs) and savings



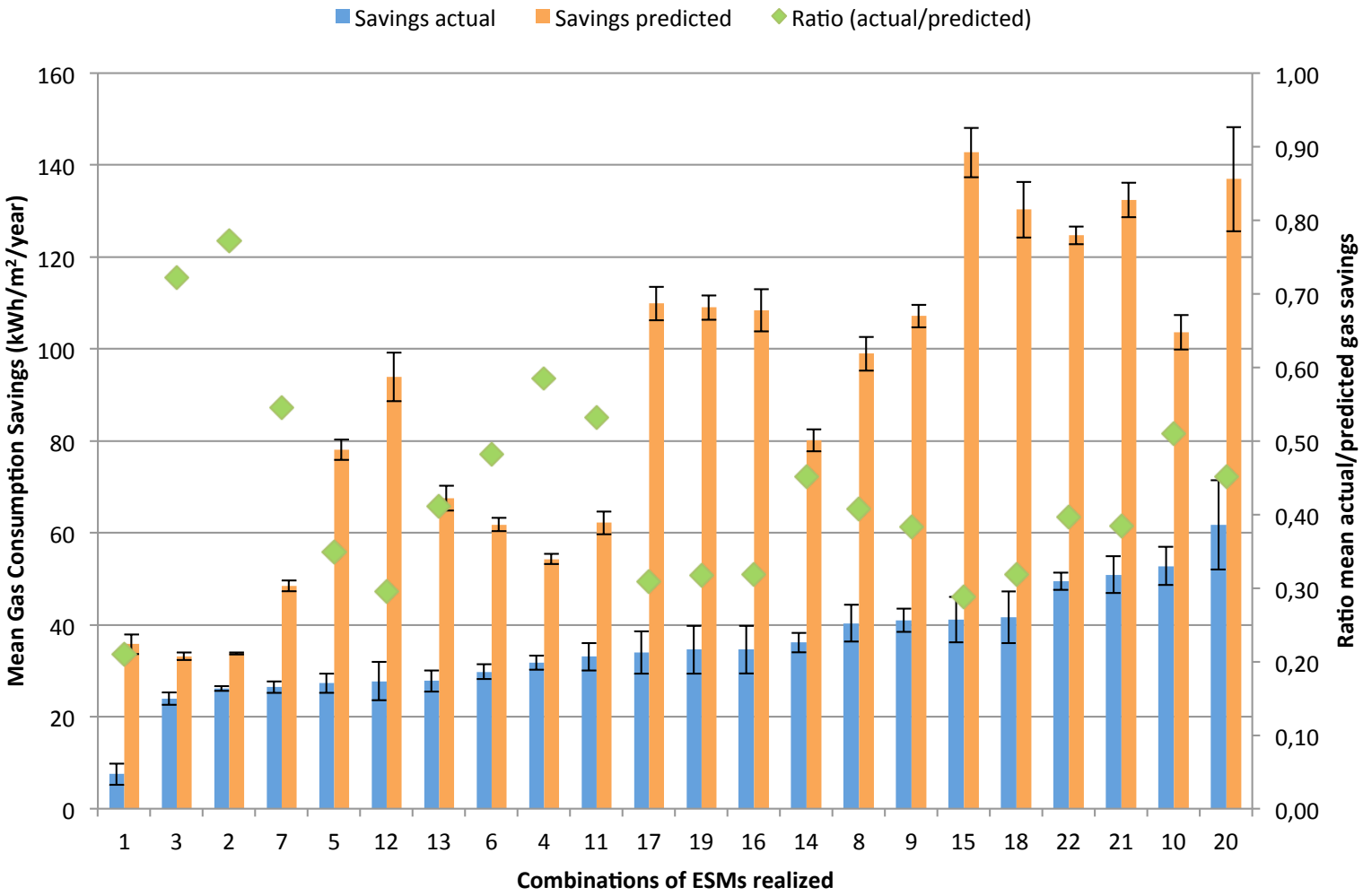
Actual and predicted savings of single ESMs



Combinations of ESMs realized

Index of combinations of ESMs	Combinations of ESMs	Frequency	Ratio mean actual/ predicted savings
1	Primary and secondary heating system	1584	0.21
2	Heating system and domestic hot water system	63675	0.77
3	Heating system and ventilation	9256	0.72
4	Heating system and glazing	6379	0.58
5	Heating system and roof insulation	2993	0.35
6	Heating system and façade insulation	5373	0.48
7	Heating system and floor insulation	7208	0.55
8	Heating system, glazing and roof insulation	944	0.41
9	Heating system, glazing and façade insulation	2223	0.38
10	Heating system, glazing and floor insulation	1407	0.51
11	Heating system, ventilation and glazing	1835	0.53
12	Heating system, ventilation and roof insulation	577	0.30
13	Heating system, ventilation and façade insulation	2090	0.41
14	Heating system, ventilation and floor insulation	2554	0.45
15	Heating system, glazing, ventilation and roof insulation	490	0.29
16	Heating system, glazing, ventilation and façade insulation	770	0.32
17	Heating system, glazing, ventilation and floor insulation	910	0.31
18	Heating system, glazing, ventilation, roof and façade insulation	417	0.32
19	Heating system, glazing, ventilation, roof and floor insulation	472	0.32
20	Heating system, glazing, ventilation, roof, floor and façade insulation	71	0.45
21	Heating system, domestic hot water system, ventilation, glazing, roof, floor, and façade insulation	642	0.38
22	Glazing, roof, floor and façade insulation	2898	0.40

Actual and predicted savings of combination ESMs



Multivariate regression analyses of actual and predicted savings

	Actual Savings [kWh/m²/year] **(R^2= 1.6%)**				**Predicted Savings** [kWh/m²/year] **(R^2= 27.5%)**			
	B	Std. Error	Beta	Sig.	B	Std. Error	Beta	Sig.
(Constant)	8.987	0.241		*	-5.947	0.187		*
ESM Heating system vs. Not changed	10.584	0.313	**0.089**	*	10.007	0.243	0.093	*
ESM DHW vs. Not changed	5.247	0.305	0.044	*	31.461	0.237	**0.290**	*
ESM Ventilation vs. Not changed	1.910	0.269	0.014	*	9.233	0.208	0.075	*
ESM Glazing vs. Not changed	7.262	0.287	**0.050**	*	24.708	0.223	0.188	*
ESM Roof vs. Not changed	7.979	0.331	0.048	*	5.678	0.256	**0.302**	*
ESM Façade vs. Not changed	5.319	0.293	0.036	*	31.709	0.227	**0.238**	*
ESM Floor vs. Not changed	5.014	0.303	0.033	*	16.248	0.235	0.117	*

*=<0.001

Conclusions

- Lack of deep renovations in the non-profit stock in the Netherlands.
- In the majority of renovated dwellings either 1 or 2 ESMs have been realized (78.2% of the renovated stock).
- As the number of measures increases the gap between actual and predicted savings is also increasing.

Conclusions

- The heating systems (space heating and DHW) and glazing are predicted better than the ventilation and insulation values.
- The results of the regression analyses only revealed that the improvements ESMs alone do not explain the actual or predicted savings.
- The reality is far different from what is modelled at the time!

Thank you for listening

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