

# Scalable façade renovation solution for Dutch system-built houses

MSc in Architecture, Urbanism, and Building Science: Building Technology  
TUDelft

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Existing building stock

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Circularity

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Design criteria

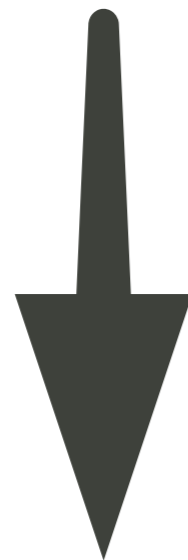
Design concept



## Conclusion



200.000 renovations per  
year by 2030



Renovate entire stock by  
2050

NET 0 CO<sub>2</sub>





Non-uniform building stock



Embodied energy of renovations



System-built houses / Systeemwoningen





“How can a **scalable** and **circular** façade renovation system be designed for Dutch system-built houses from the post-war period?”

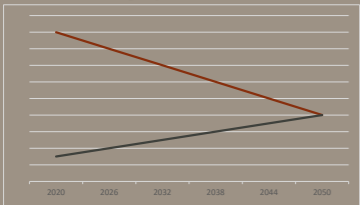


### Literature research

Existing building stock



Energy efficiency



Facade renovation



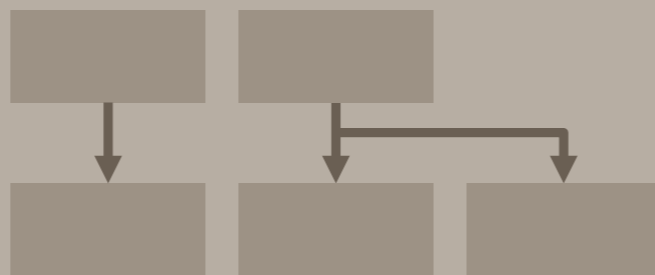
Circularity



Scalability



### Analysis

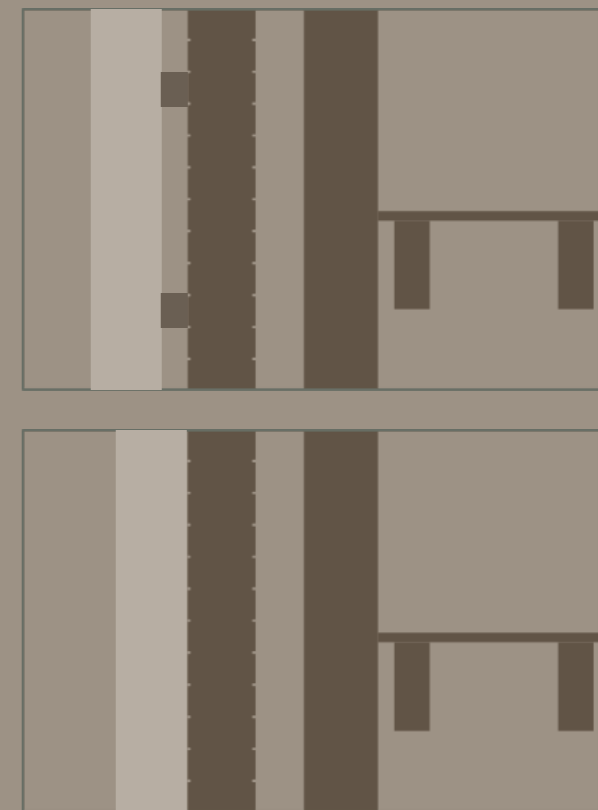


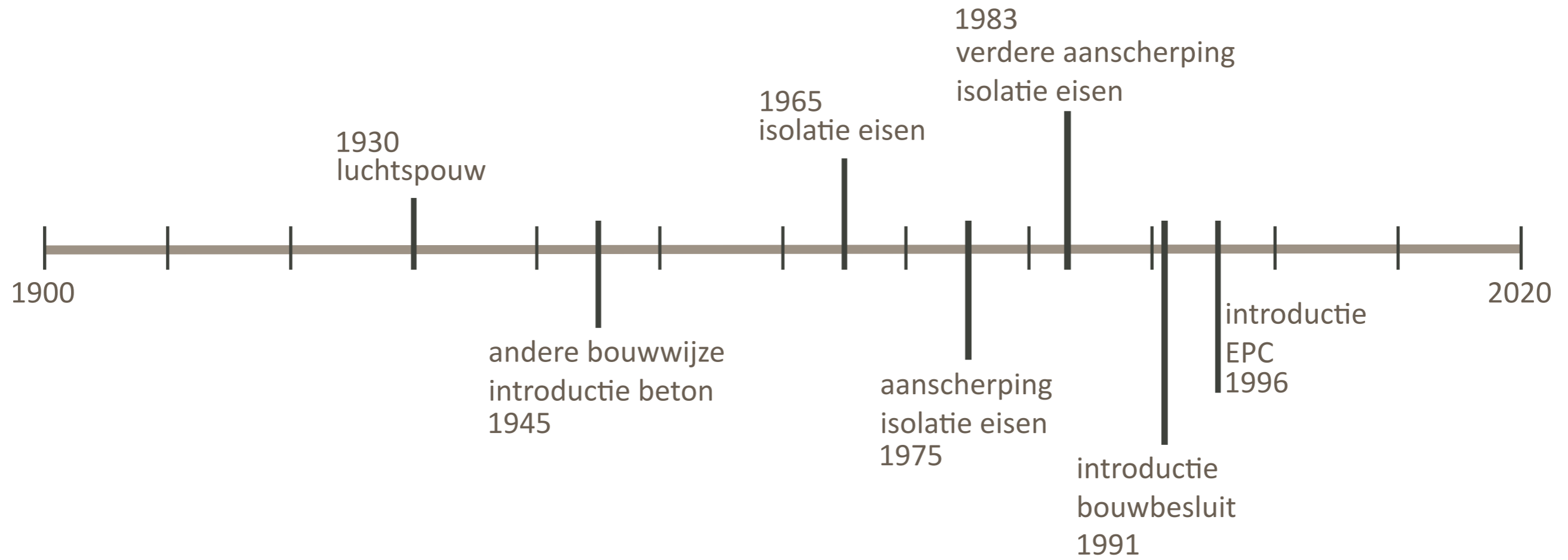
### Design

Criteria



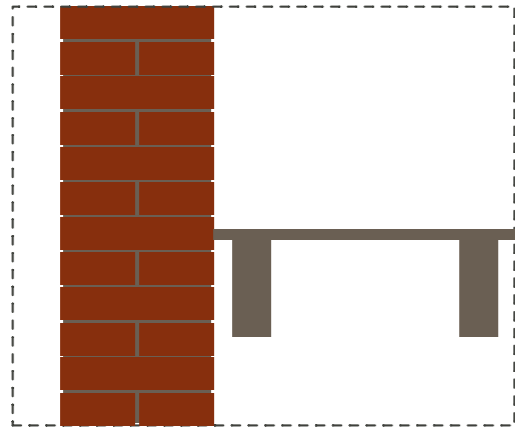
Concept



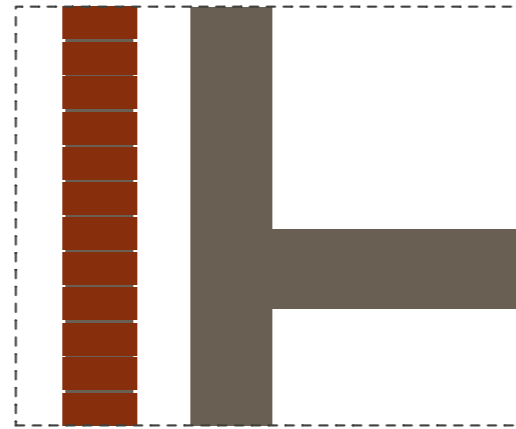




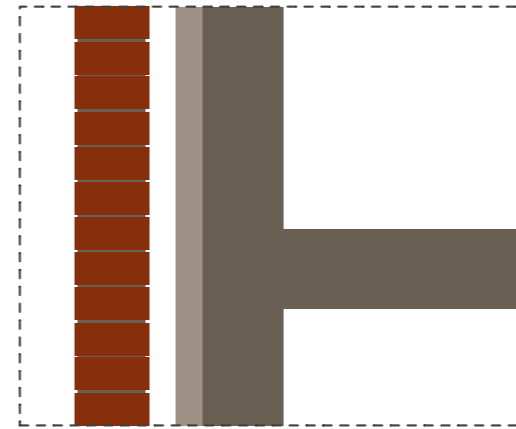
Construction periods



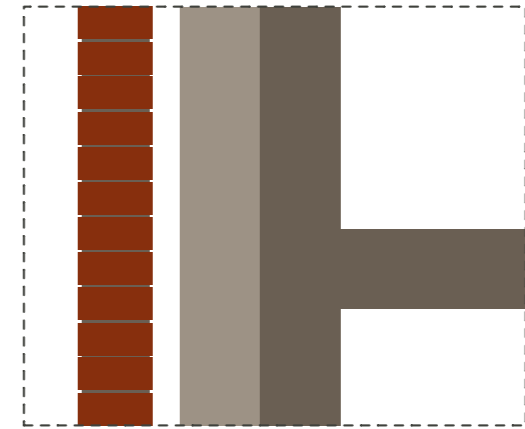
Before 1945



1945-1975

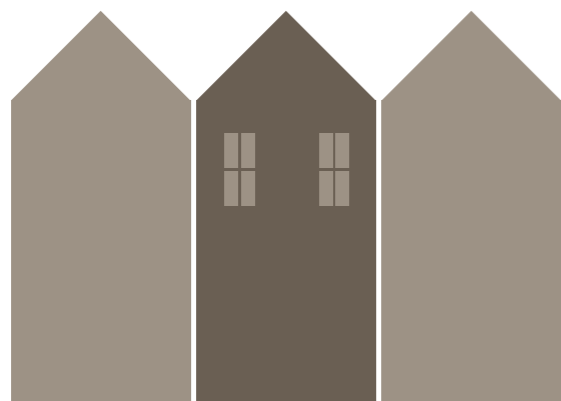


1975-1995



After 1995

Housing types



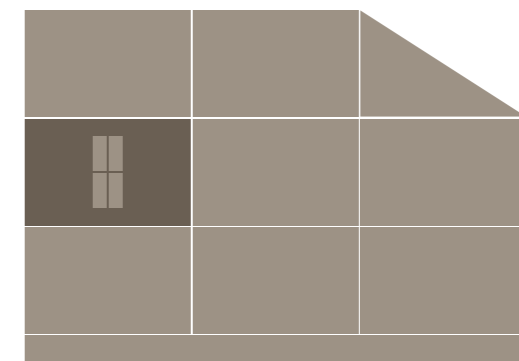
Dutch terraced house



Semi-detached houses

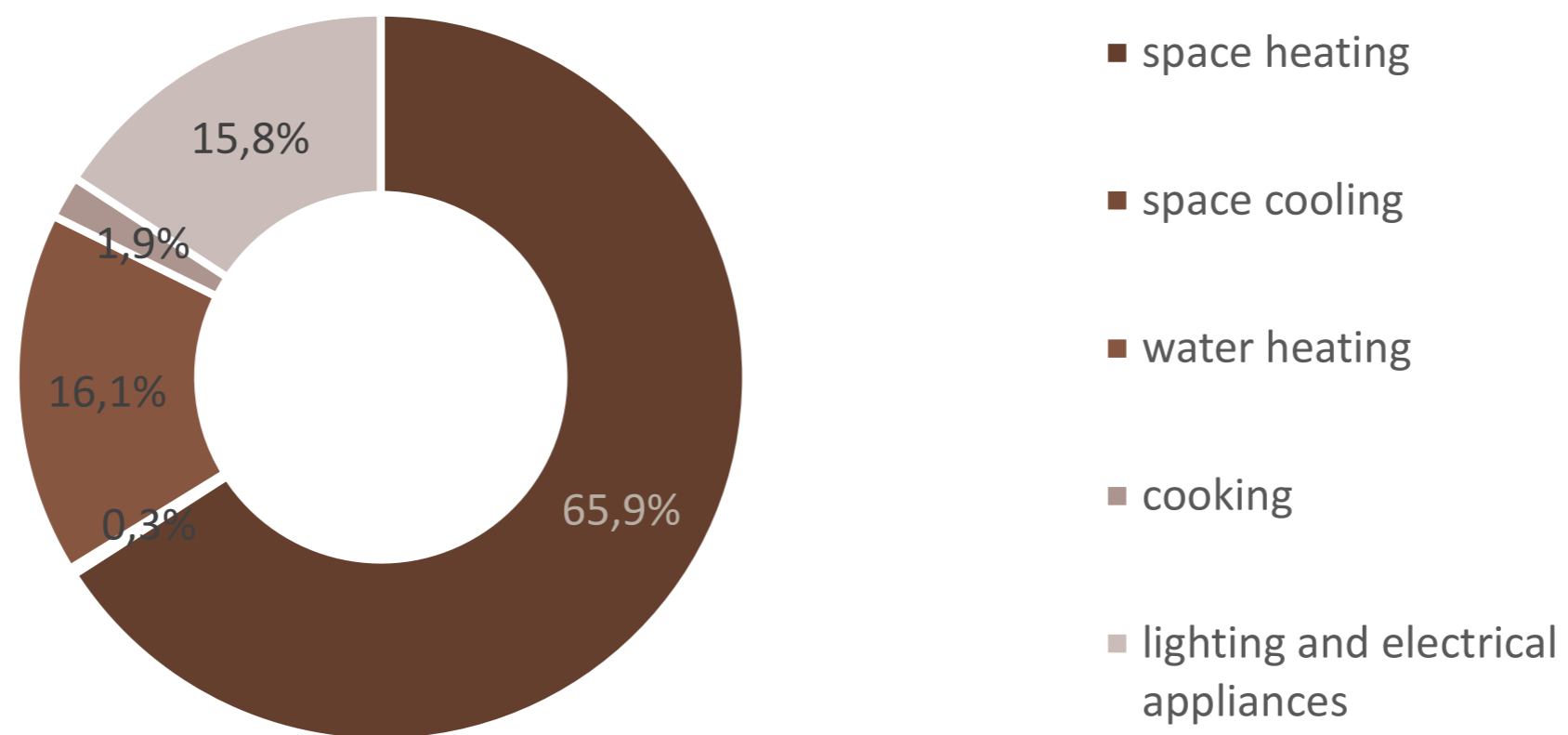


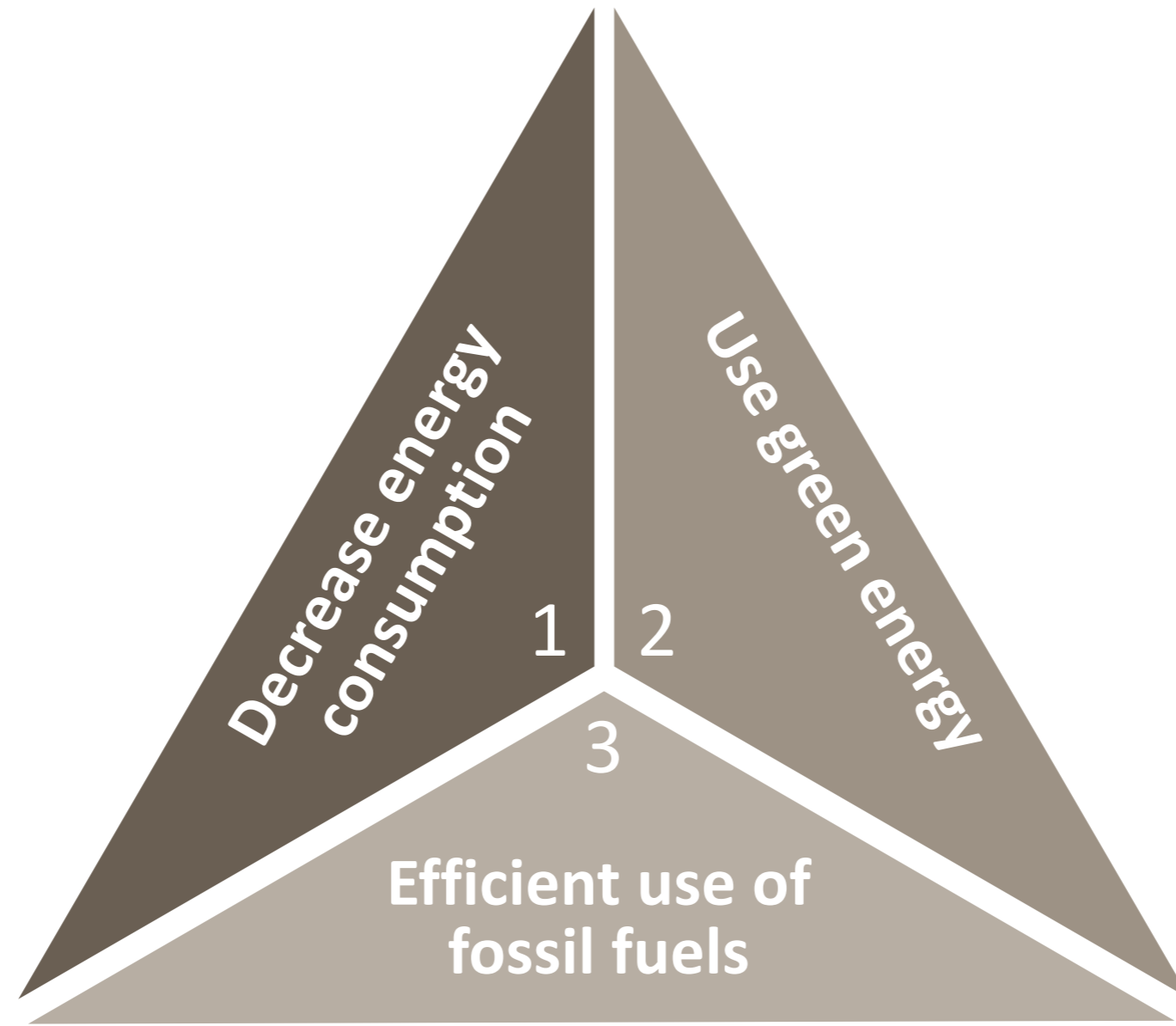
Detached houses



Gallery / Porch  
apartments

Share of final energy consumption in the Dutch residential sector by end-use, 2021

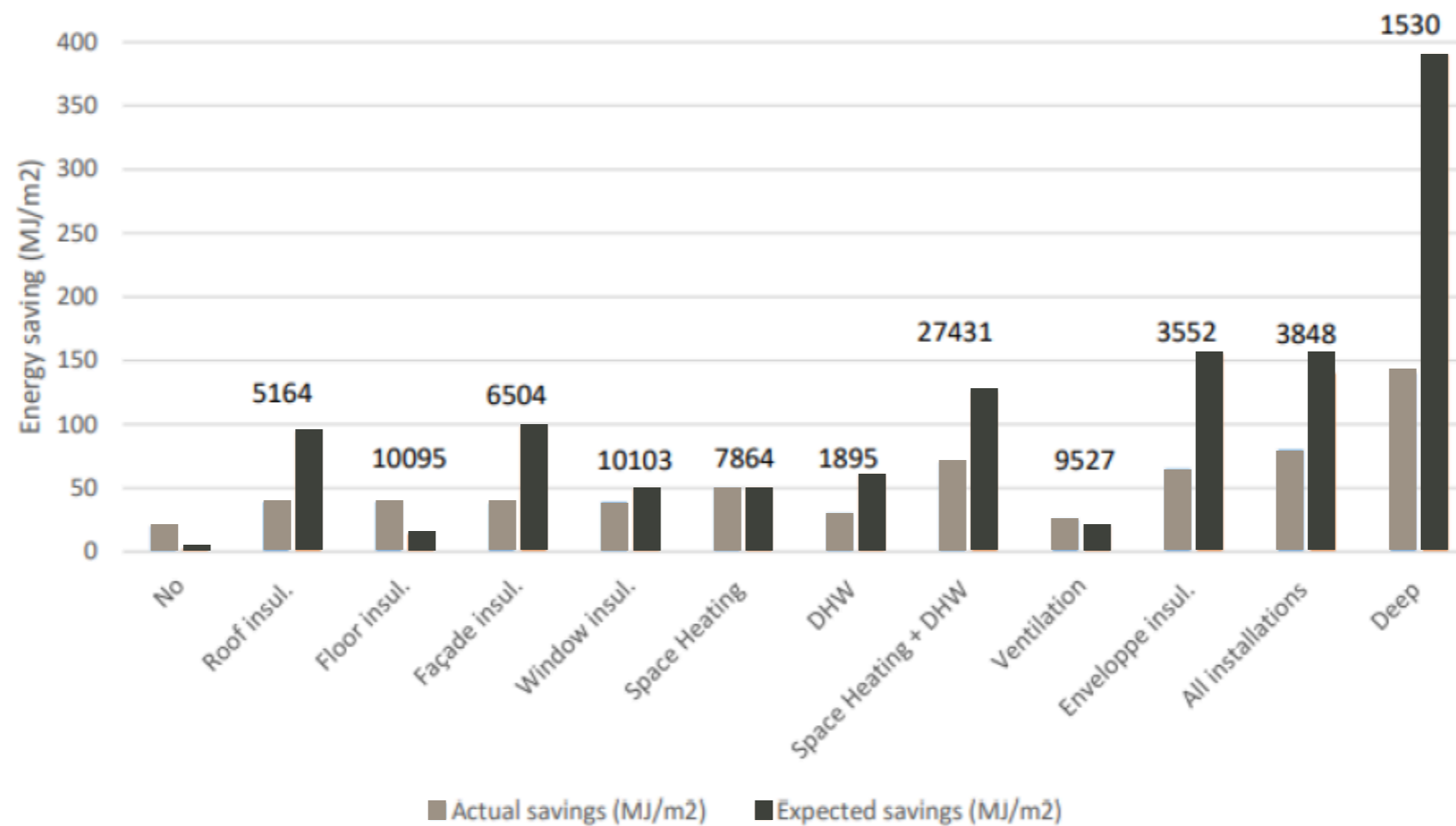




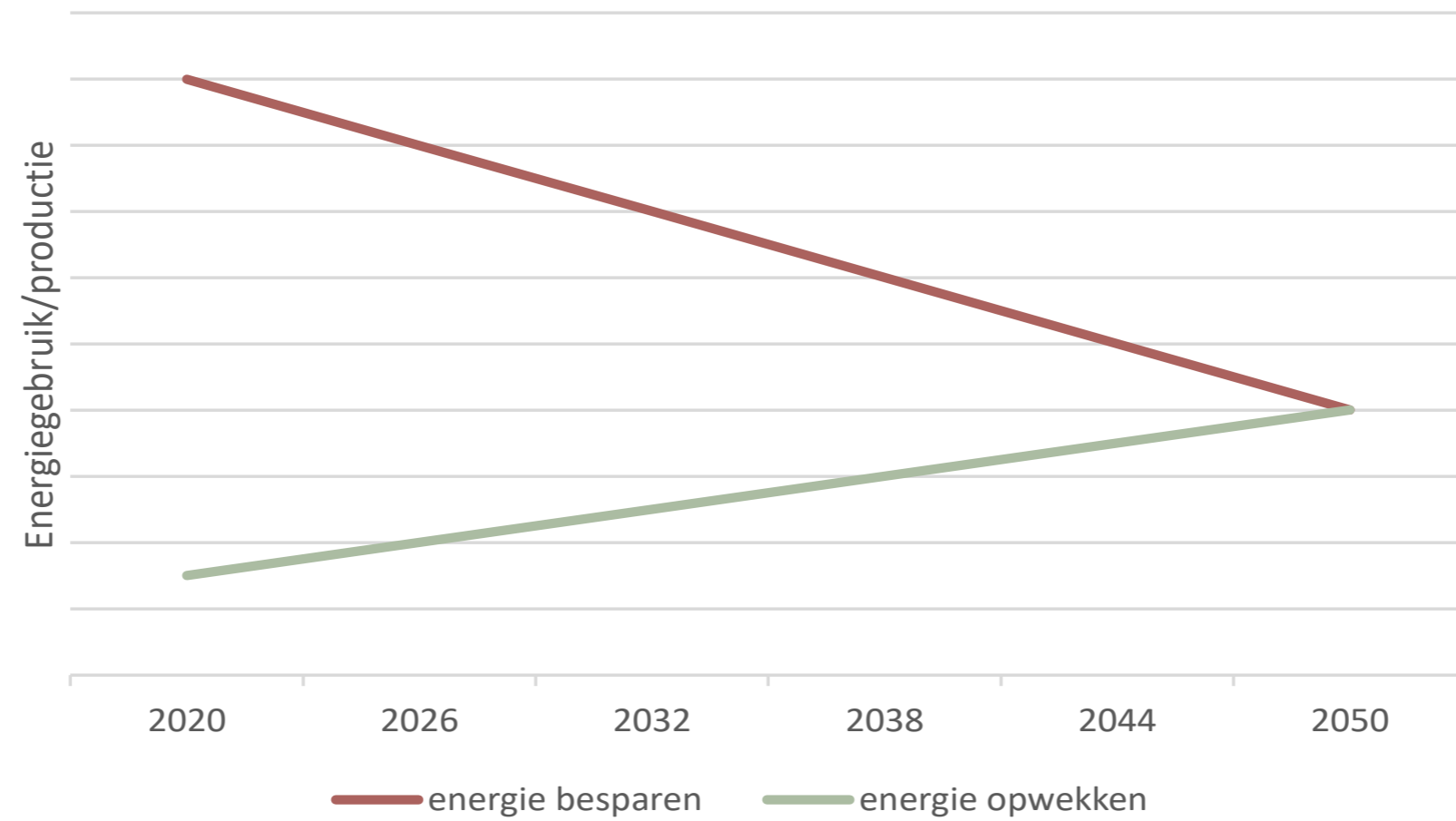
Trias Energetica by Kees Duijvestein (1979) - TUDelft



Energy label → Energy index → NTA 8800

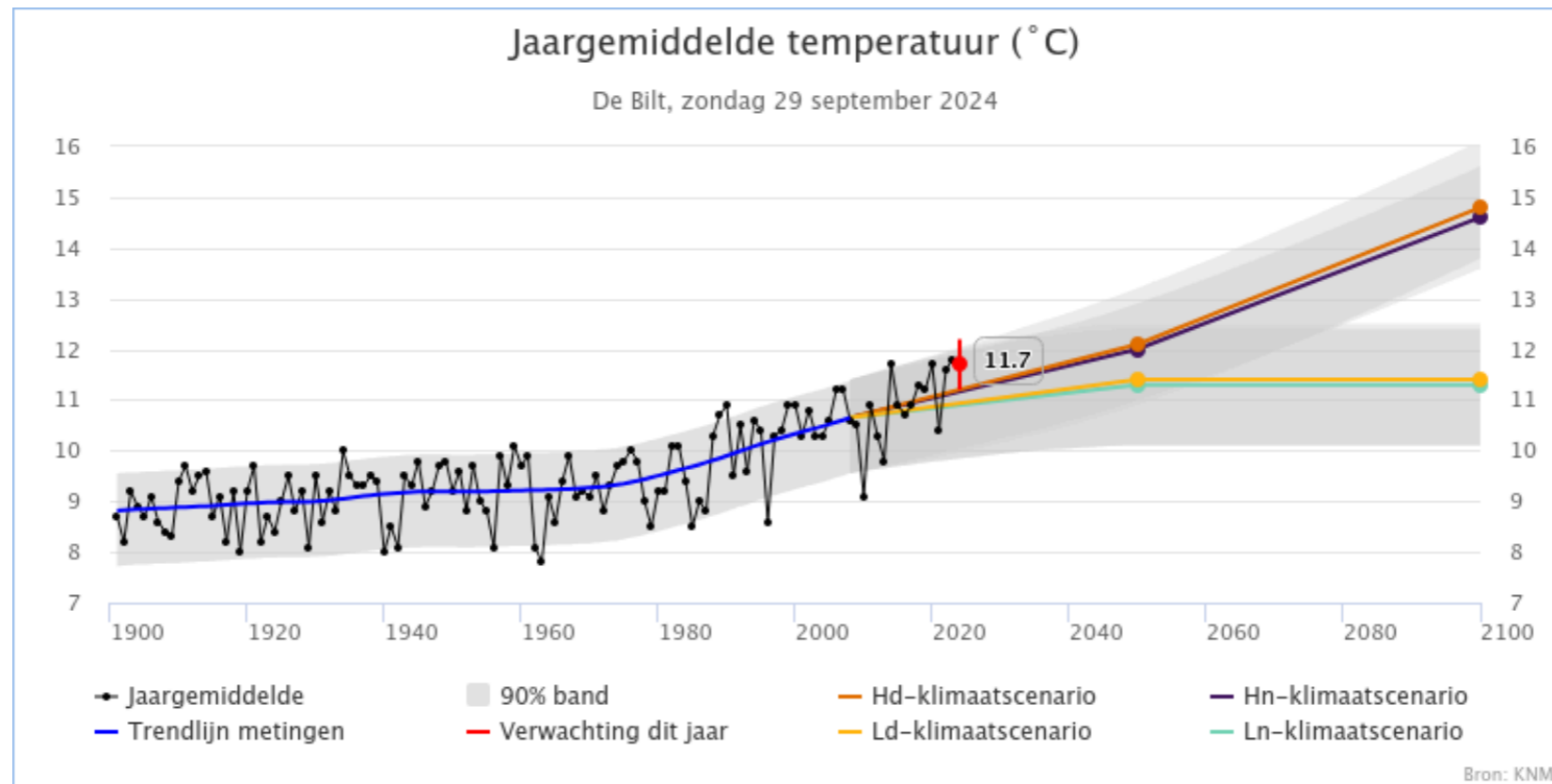


Actual savings vs expected energy savings in renovation projects (Guerra-Santin et al., 2021)



CO2 neutral by energy savings and green energy production  
(van Bruggen, 2023)

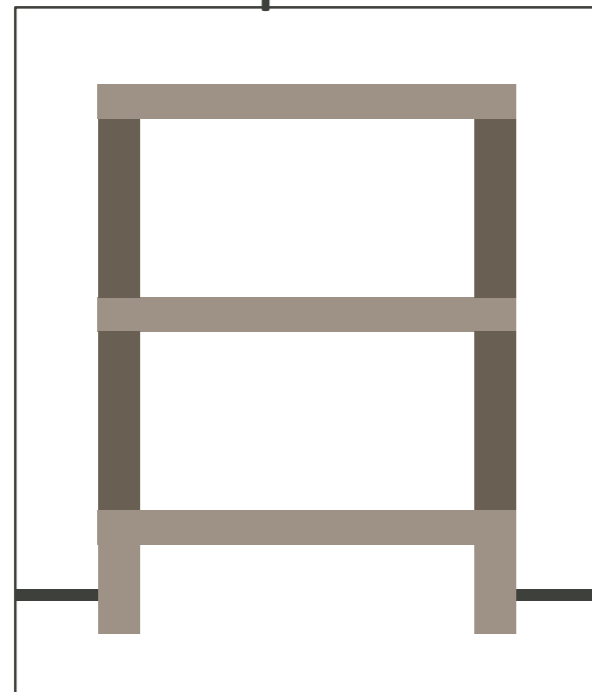
### Dutch Climate



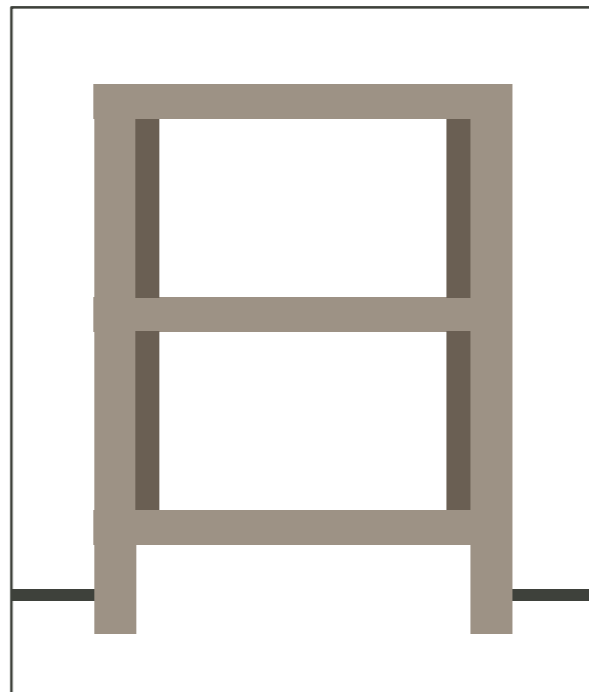
(KNMI, 2024)



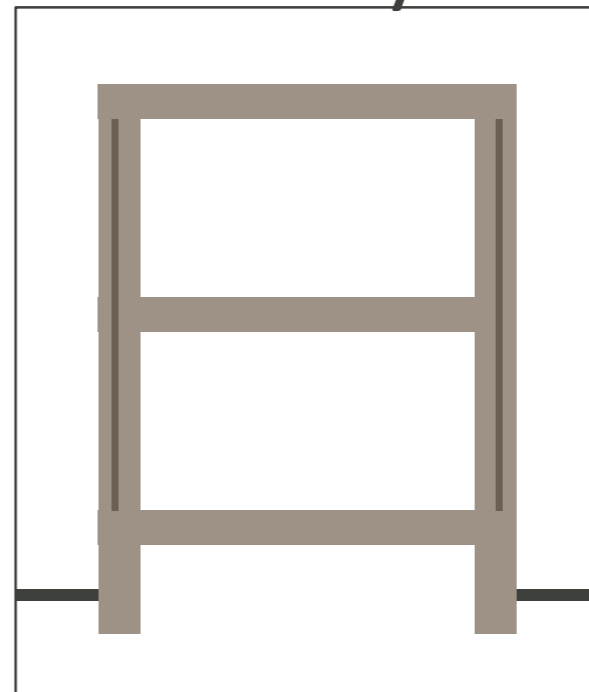
Replace



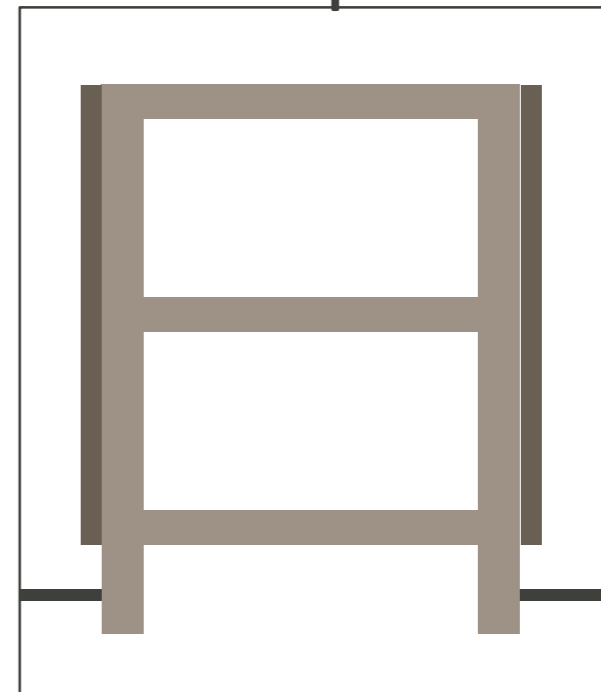
Add-in



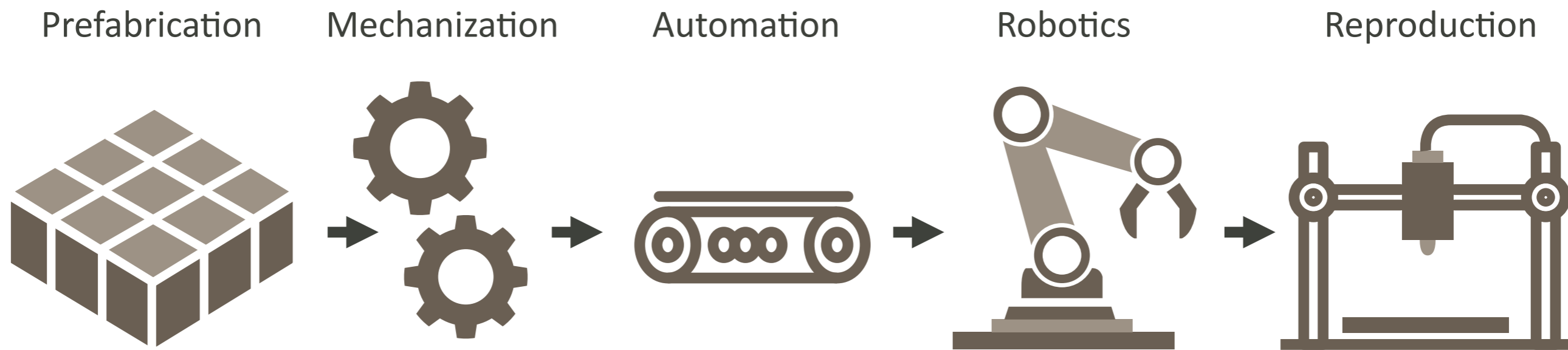
Cavity



Wrap-it



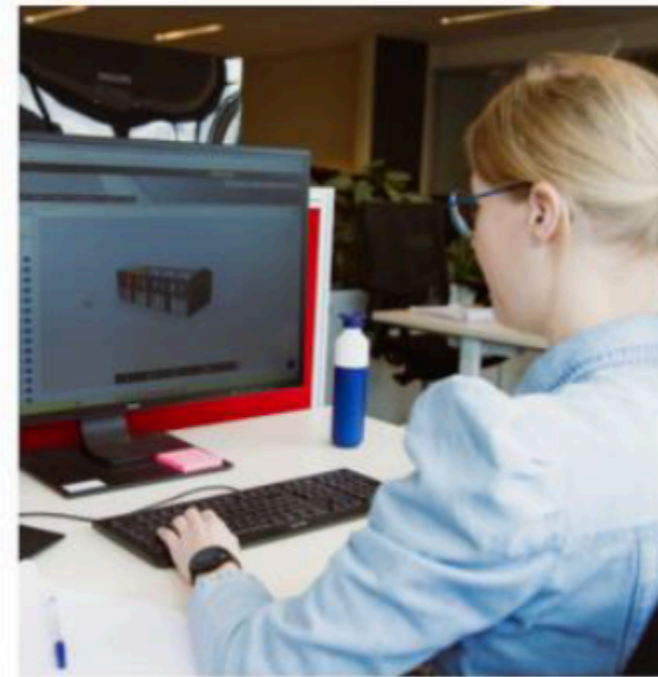
Refurbishment strategies modified from (Konstantinou, 2014)



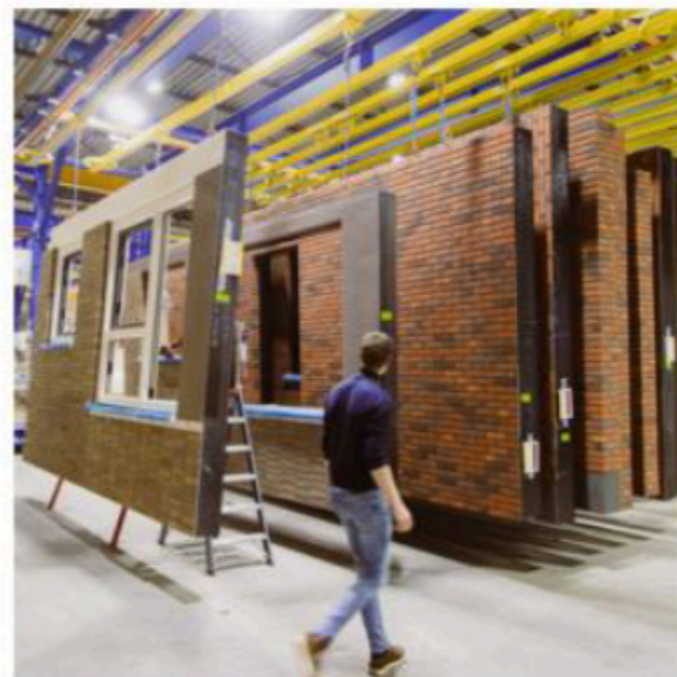
1 Scanning



2 3D modelling



3 Production



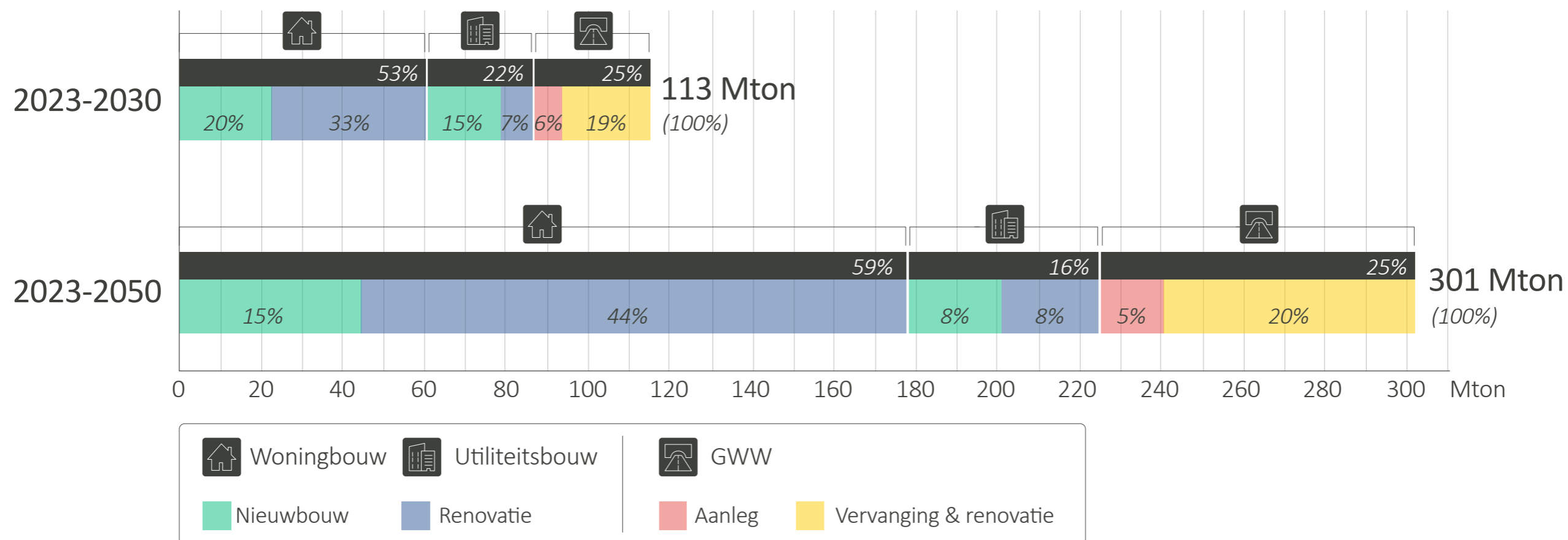
(RcPanels, n.d.)

4 Installation



CO2 budget of 47 Mtons for 1.5 degrees increase, 234 Mtons for 2.0 degrees

Emissions from Dutch construction with the current building methods, for 2023-2030 and 2023-2050 (Copper 8, 2023)





## Environmental payback time

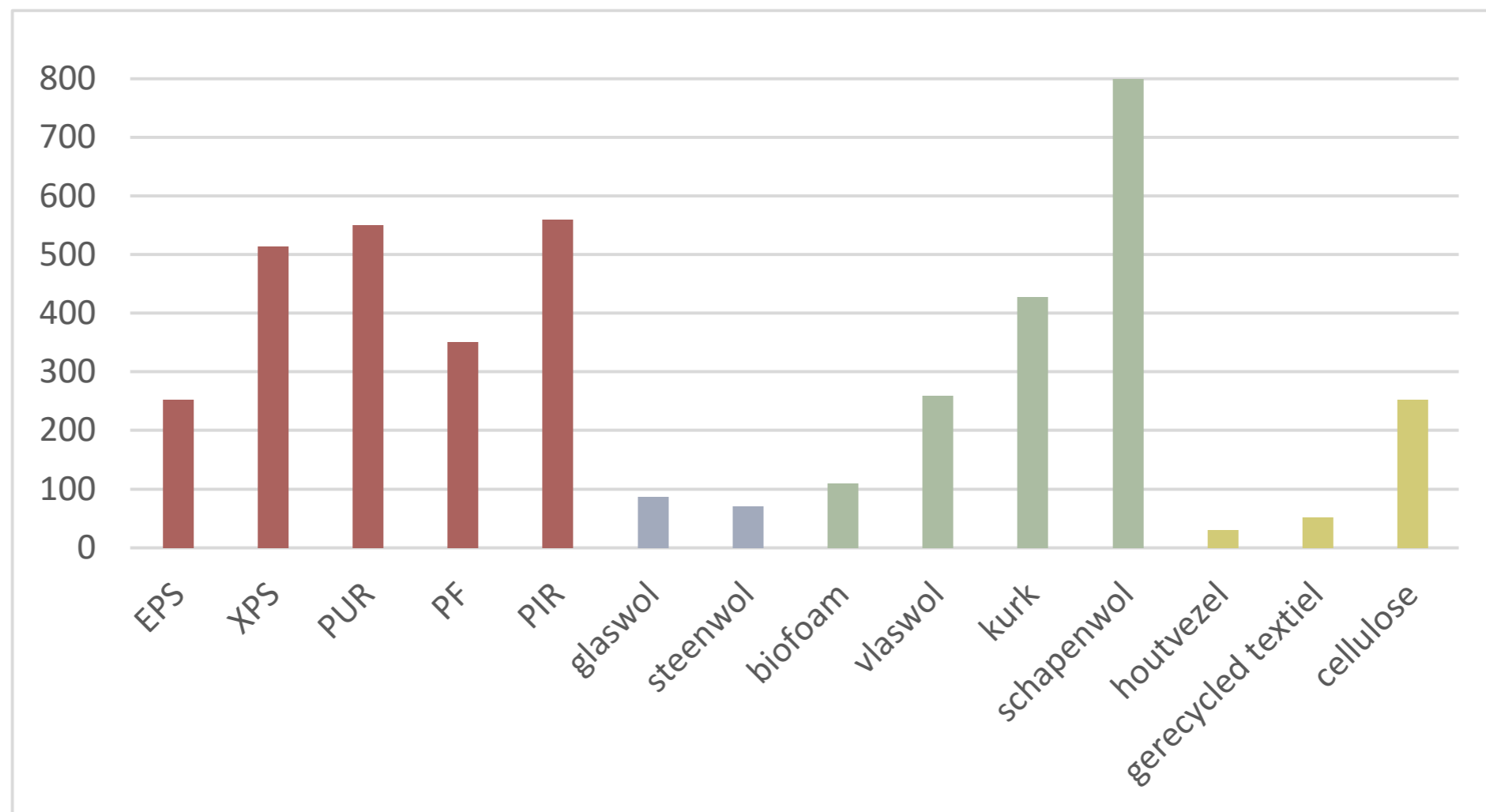
### Operational energy

Grondgebonden woning: 35 kWh/m<sup>2</sup>

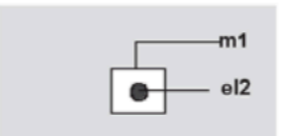
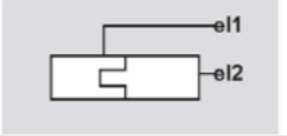
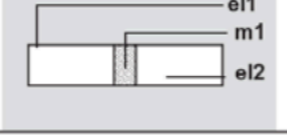
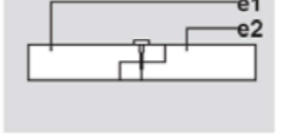
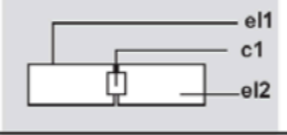
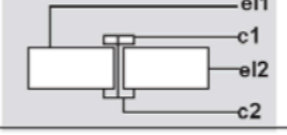
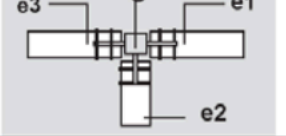
Appartement: 45 kWh/m<sup>2</sup>

### Embodied energy

100 kg CO<sub>2</sub>-equivalent per square meter



The shadow costs of different insulation materials (Muntinga, 2018)

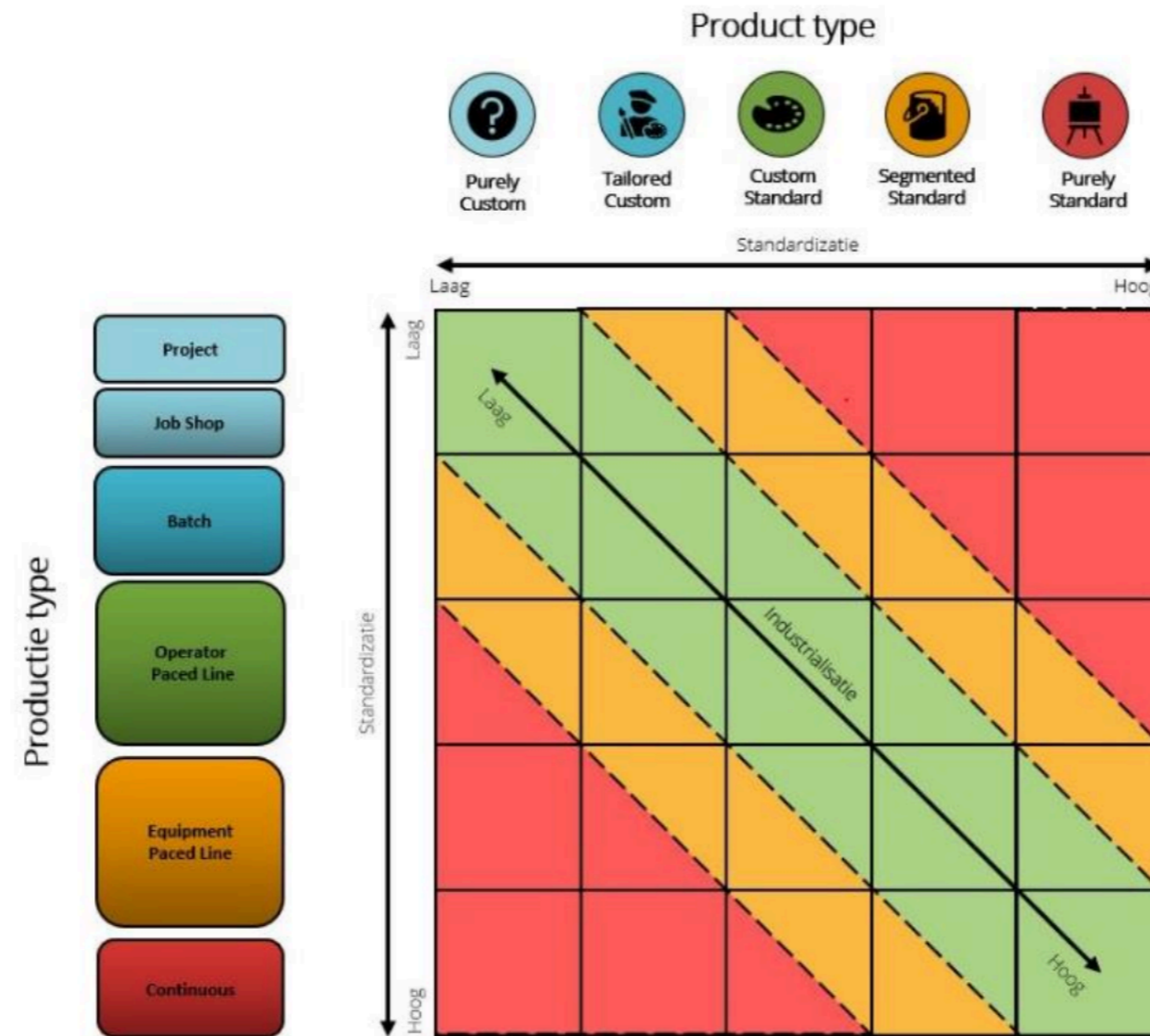
	type of connection	graphic representation	dependence in assembly
fixed	<b>I Direct chemical connection</b> two elements are permanently fixed (no reuse, no recycling)		$m1 \text{---} el2$
	<b>II direct connections between two pre-made components</b> two elements are dependent in assembly/ disassembly (no component reuse)		$el1 \text{---} el2$
	<b>III indirect connection with third chemical material</b> two elements are connected permanently with third material (no reuse, no recycling)		$el1 \text{---} m1 \text{---} el2$
	<b>IV direct connections with additional fixing devices</b> two elements are connected with accessory which can be replaced. If one element has to be removed than whole connection needs to be dismantled		$el1 \text{---} c1 \text{---} el2$
	<b>V indirect connection via dependent third component</b> two elements/components are separated with third element/component, but they have dependence in assembly (reuse is restricted)		$el1 \text{---} c1 \text{---} el2$
	<b>VI indirect connection via independent third component</b> there is dependence in assembly/ disassembly but all elements could be reused or recycled		$el1 \text{---} c1 \text{---} el2$ $el1 \text{---} c2 \text{---} el2$
	<b>VII indirect with additional fixing device</b> with change of one element another stays untouched all elements could be reused or recycled		$e3 \text{---} c \text{---} el1$ $e2 \text{---} c$
flexible			

Seven principles of connections ranged from fixed to flexible connections (Durmisevic, 2005)

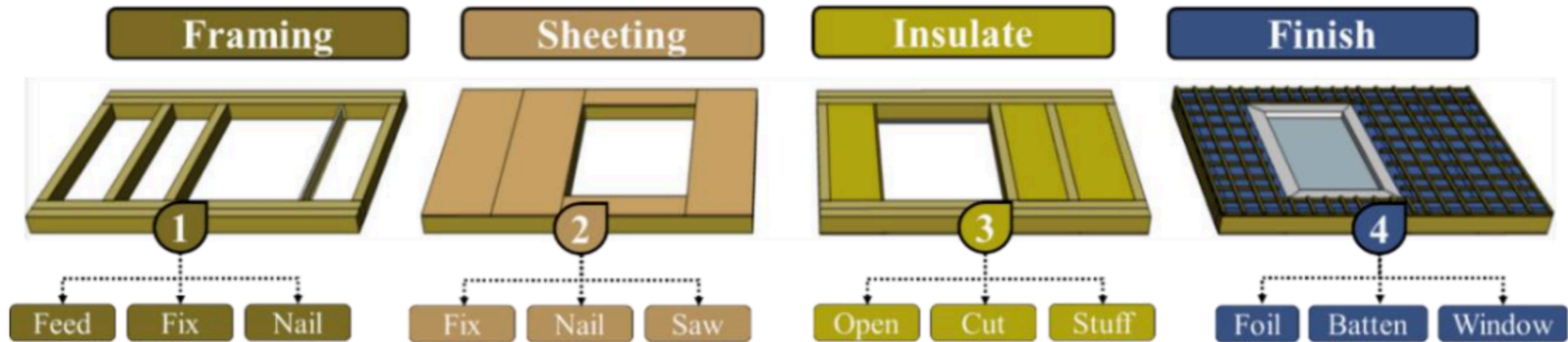


Housing characteristics that govern the design of clustering methods	Number of categories	Categories
Roof shape	3	Pitched roof Flat roof Others
Construction type of roof	2	Wooden roof Other
Construction type of wall	2	Brick masonry Other
Existing insulation level - façade	2	Level 1 Level 2
Existing insulation level - roof	2	Level 1 Level 2
Existing insulation level - windows	2	Level 1 Level 2
Ownership type	3	Housing association Individual homeowner Others
Typology	2	Apartment Row houses & other
Presence of existing cavity	2	Yes cavity No cavity

Classification characteristics for standardization (Mohan, 2022)



Alignment between the production system and the product type (van Groesen, 2022)



Overview of manufacturing processes (Van Groessen, 2022)



	<b>System name</b>	<b>Amount of cases</b>	<b>Construction method</b>
1	Muwi	37.831	stapelbouw
2	RBM	32.292	gietbouw
3	Coignet	31.378	montagebouw
4	BMB (o.a. HeBoMa)	29.369	montagebouw
5	Pronto	17.836	stapelbouw
6	Rottinghuis/IBC	17.000	montagebouw
7	Korrelbeton	15.394	gietbouw
8	VAM	14.000	montagebouw
9	BBB: Bredero en Bredero '55	13.118	stapelbouw
10	Pege	11.000	stapelbouw
11	Wilma	12.579	gietbouw
12	Smit	10.000	montagebouw
13	Airey	9.975	montagebouw
14	ERA	9.810	gietbouw
15	EBA	19.291	gietbouw
16	Elementum, later PLN	8.574	montagebouw
17	Vaneg	7.000	montagebouw
18	Bakker	5.643	stapelbouw
19	Welschen	5.602	gietbouw
20	B-G	5.581	montagebouw
21	Tramonta	4.845	montagebouw

(Platform31, 2013)



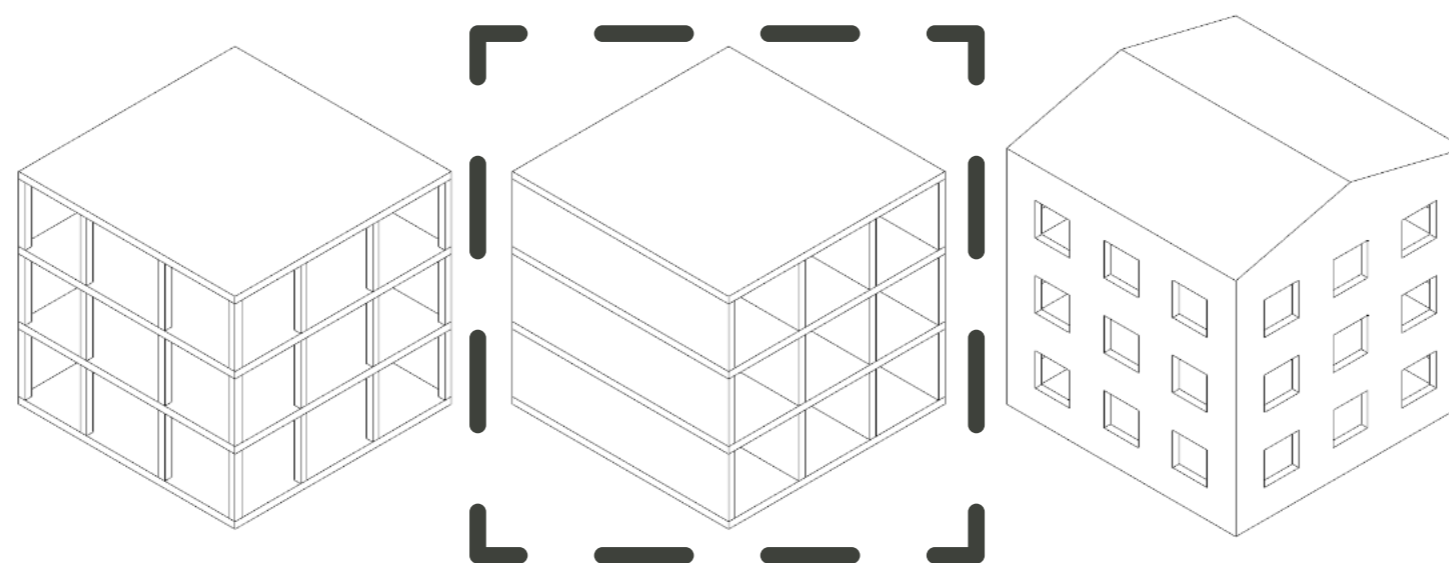
Stapelbouw



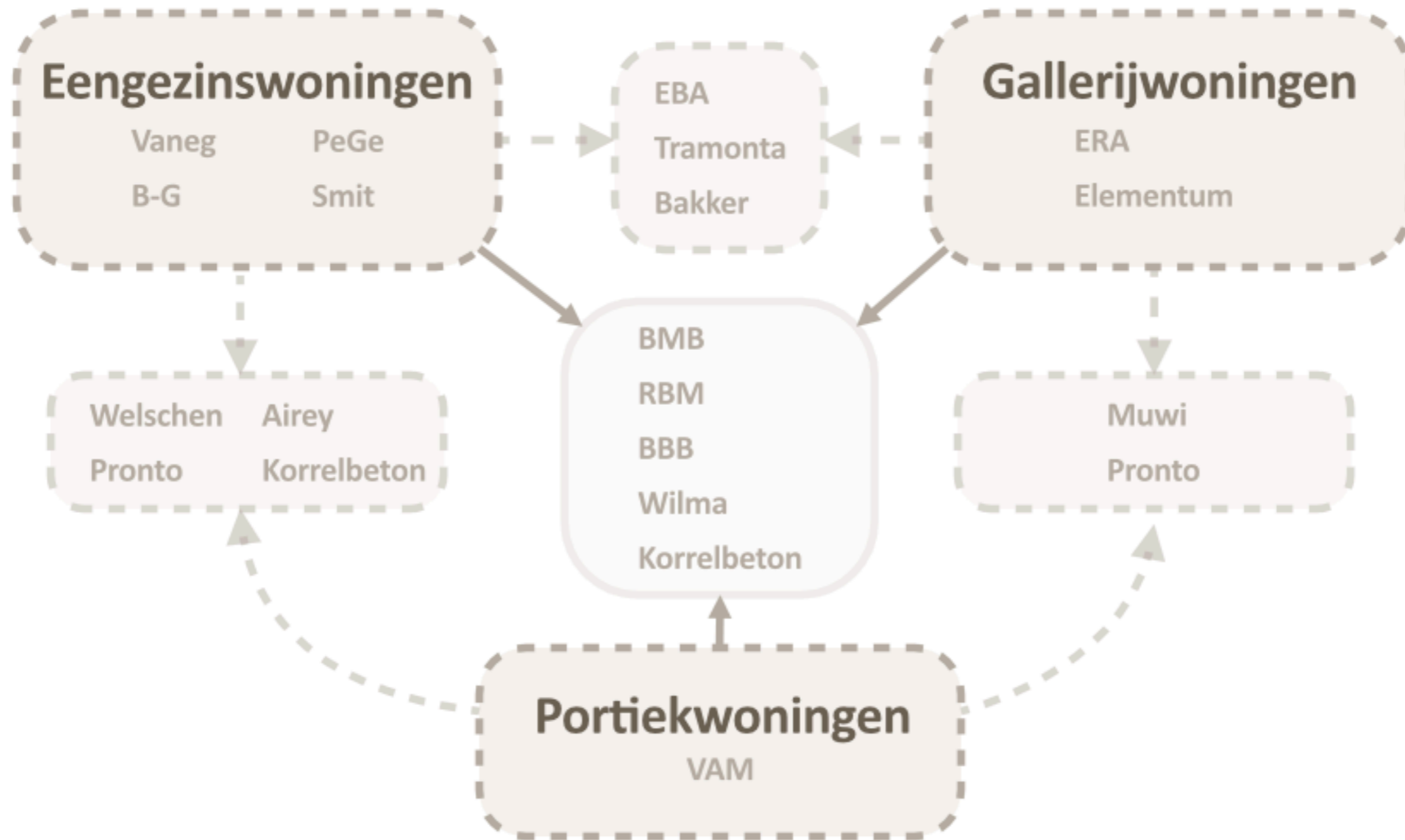
Gietbouw

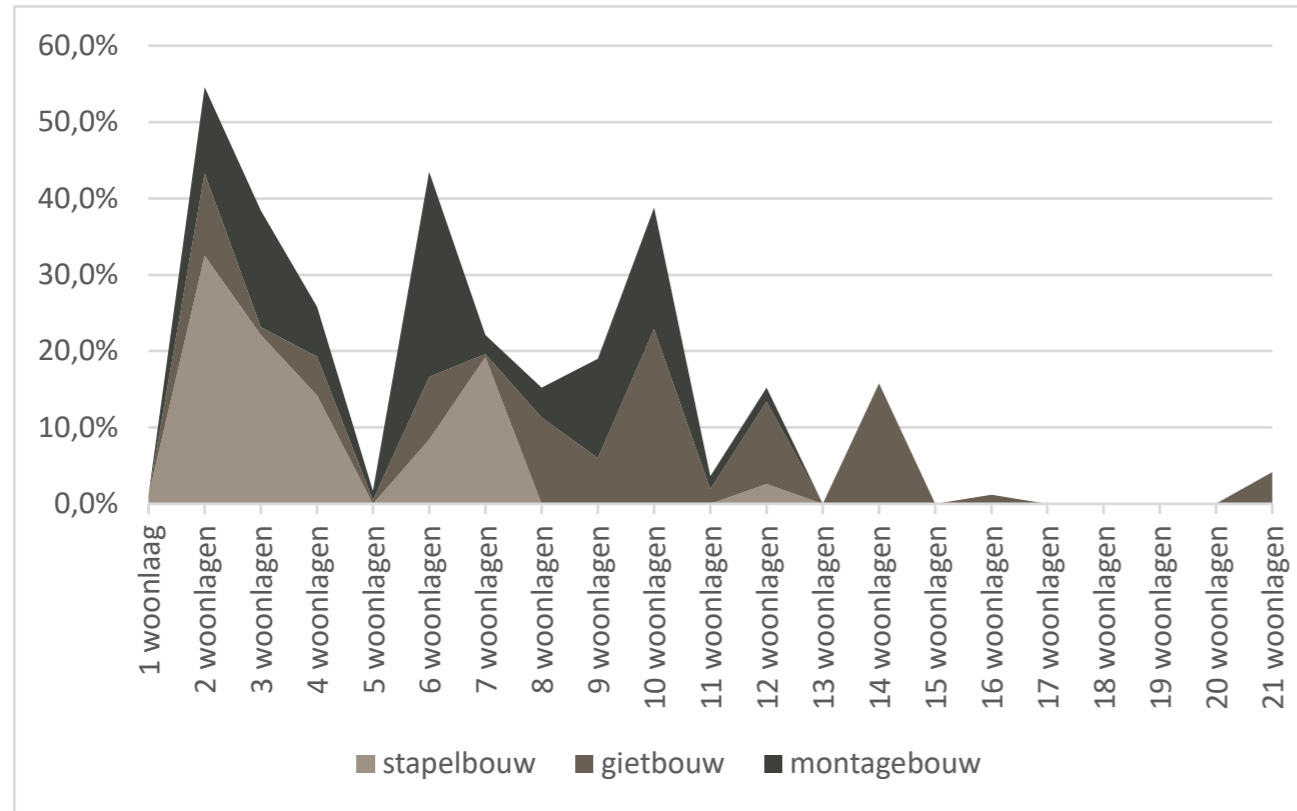


Montagebouw

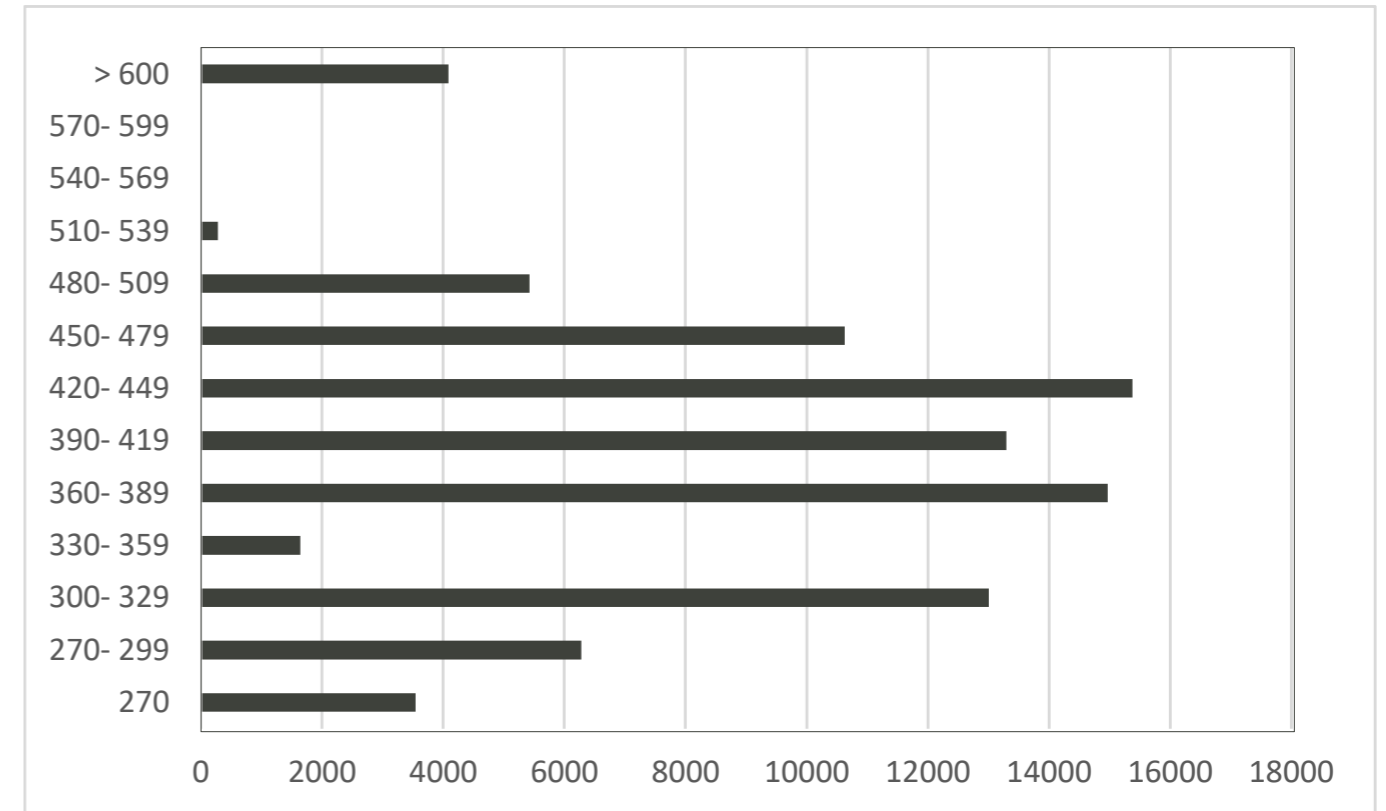


Different construction frames, modified from (Konstantinou, 2014)

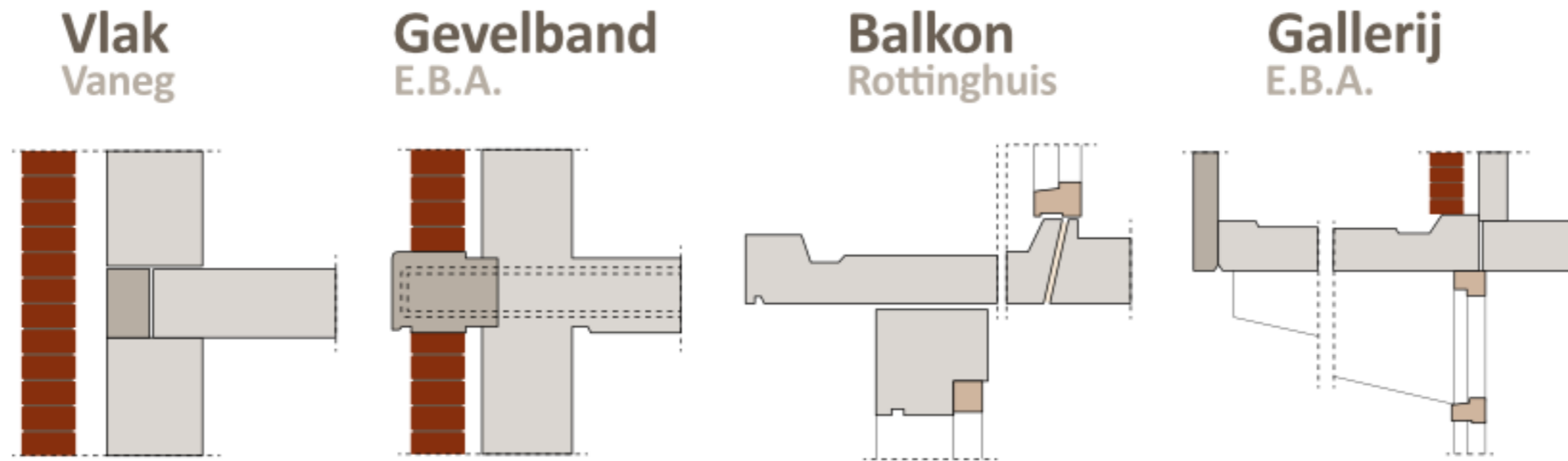




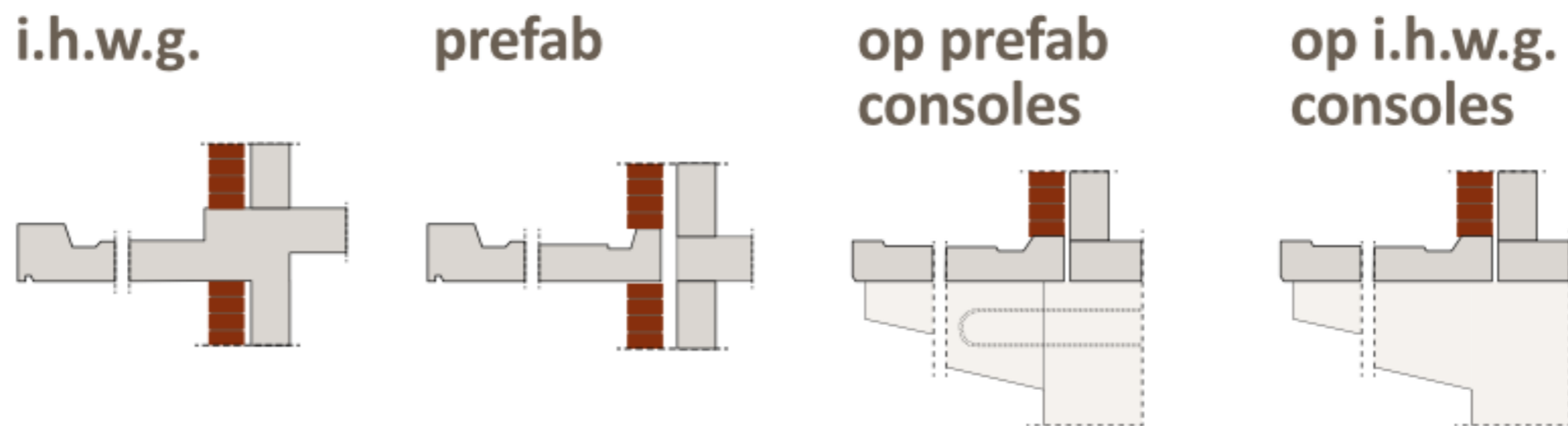
Relation of number of floors to construction method



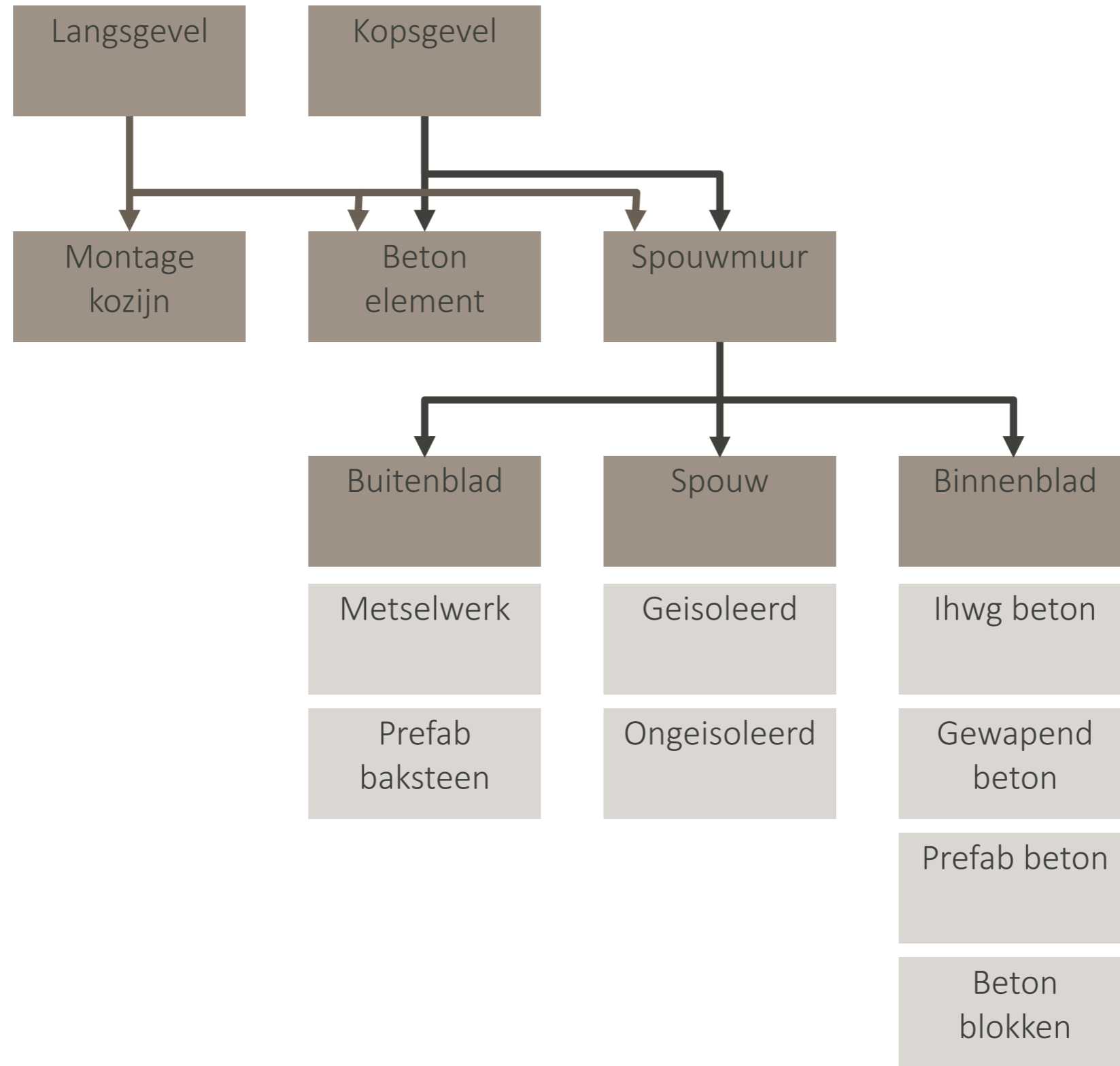
Grid measurements between structural elements



Different facade implications illustrated with the systeemwoningen



Different connections for balconies and galleries for the systeemwoningen



**Energy**

Rc-value of 4.7 m<sup>2</sup>K/W

**Comfort**

winter: 20°C

summer: 25°C

25 m<sup>3</sup>/h per person

**Circularity**

Recyclable or circular materials

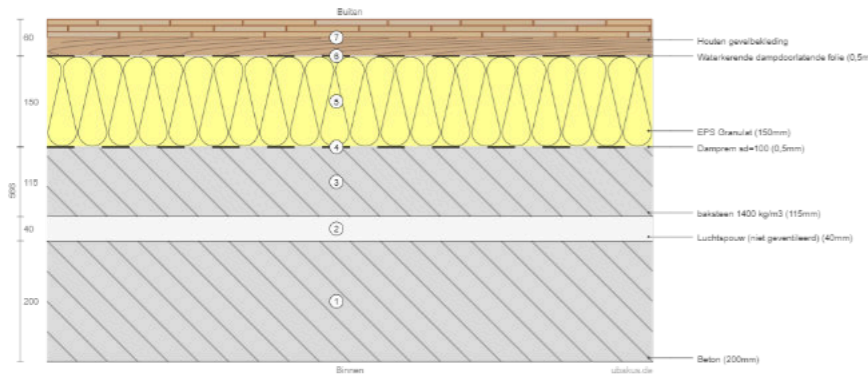
Mechanical joints, no chemical joints if possible

**Scalability**

Planbased approach can decrease renovation costs by around 15% compared to a project-based approach

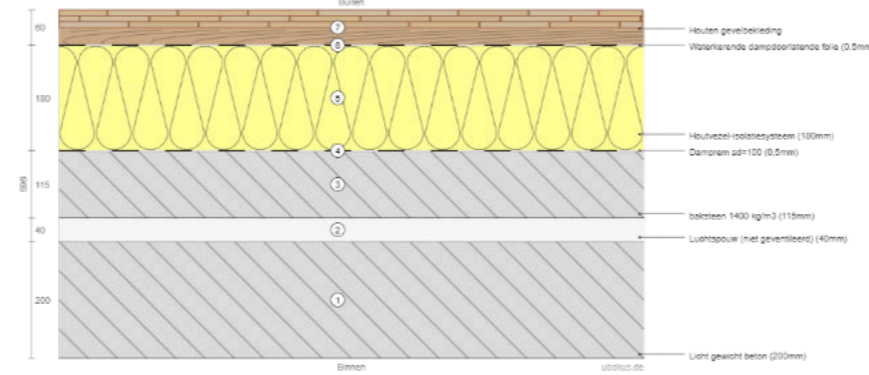
Different adjustments for specific building characteristics

**Binnenblad**



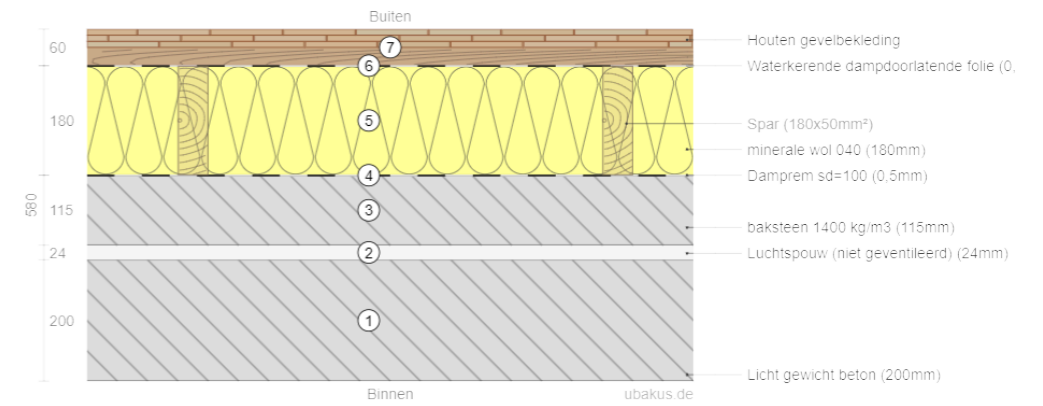
Rc = 5.2 m<sup>2</sup>K/W  
Beton

**Insulation**

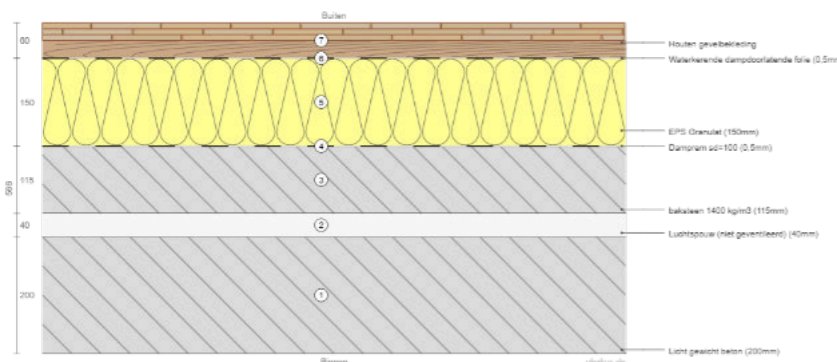


Rc = 5.0 m<sup>2</sup>K/W  
Houtvezel

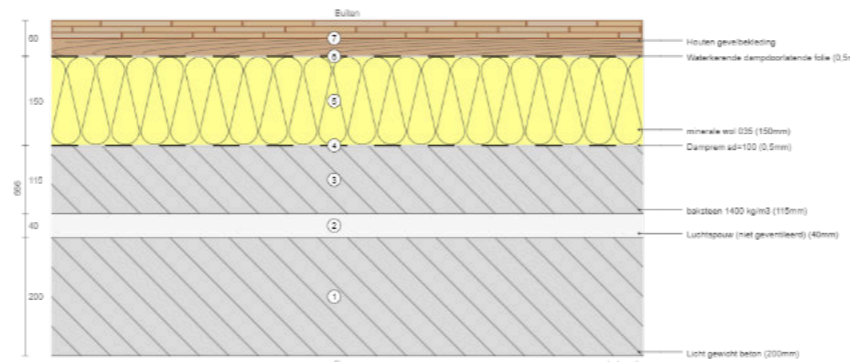
**Wooden frame**



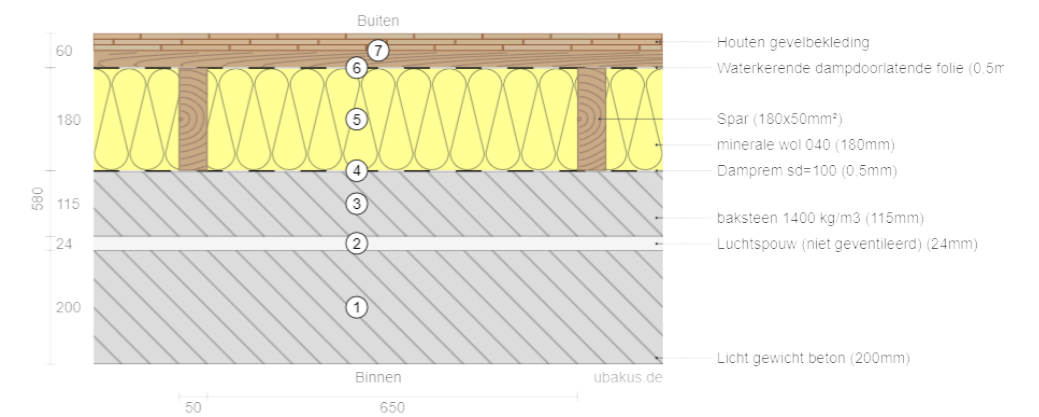
Rc = 5.5 m<sup>2</sup>K/W



Rc = 5.3 m<sup>2</sup>K/W  
Lichtgewicht beton



Rc = 5.2 m<sup>2</sup>K/W  
Minerale wol



Rc = 4.9 m<sup>2</sup>K/W



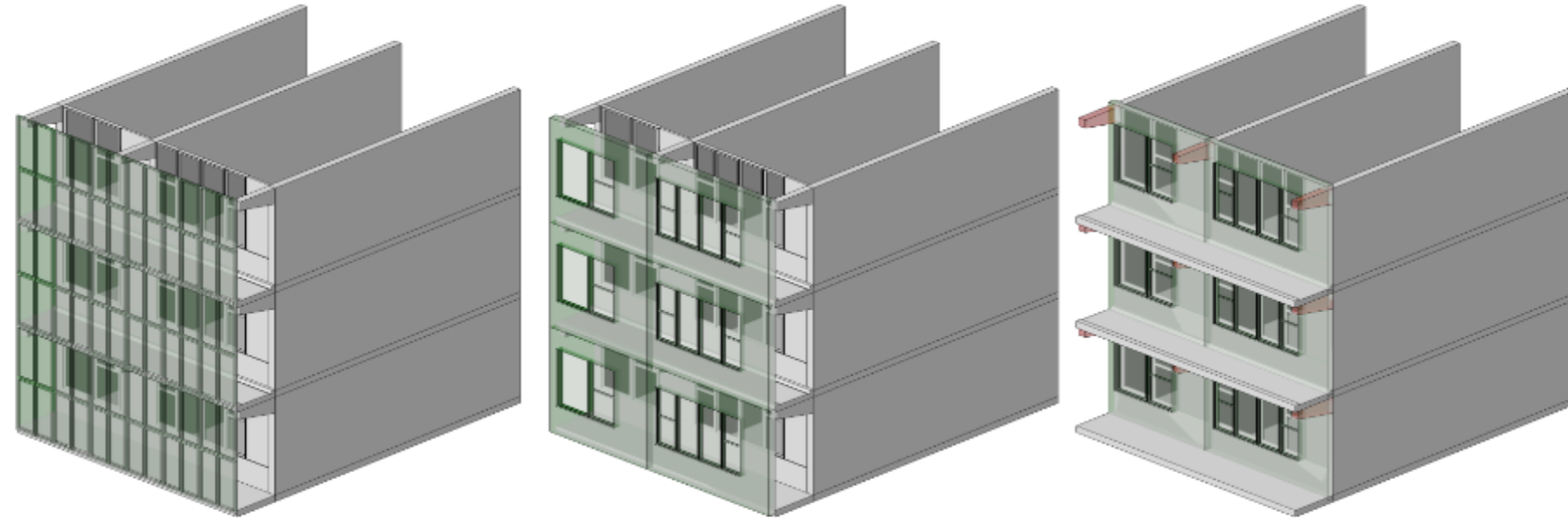
VanderSanden - Baksteenstrips



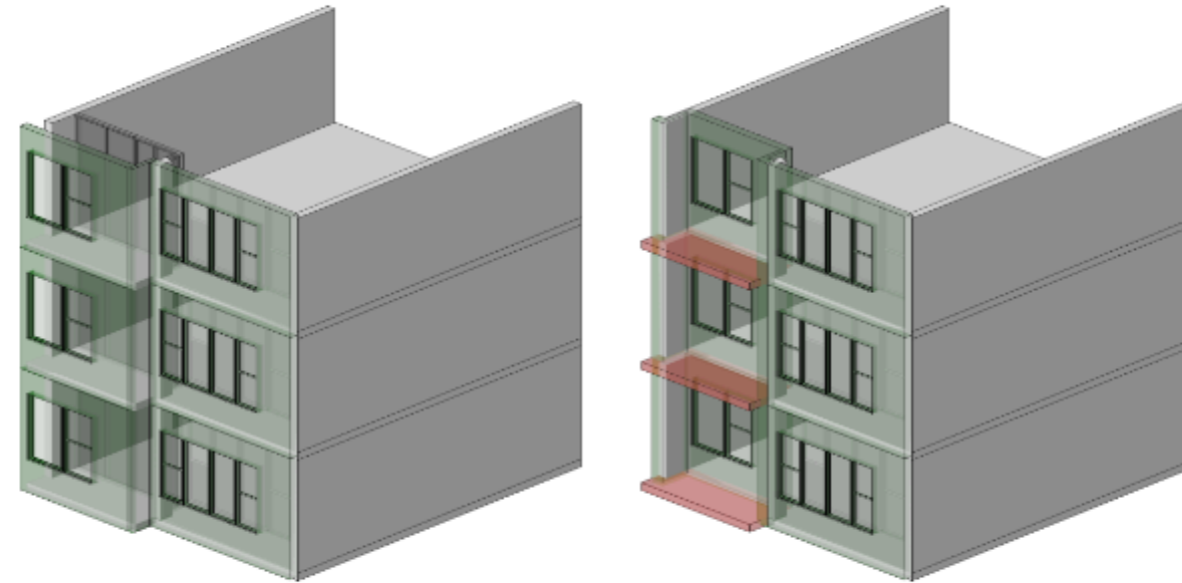
Mechslip - Baksteenstrips



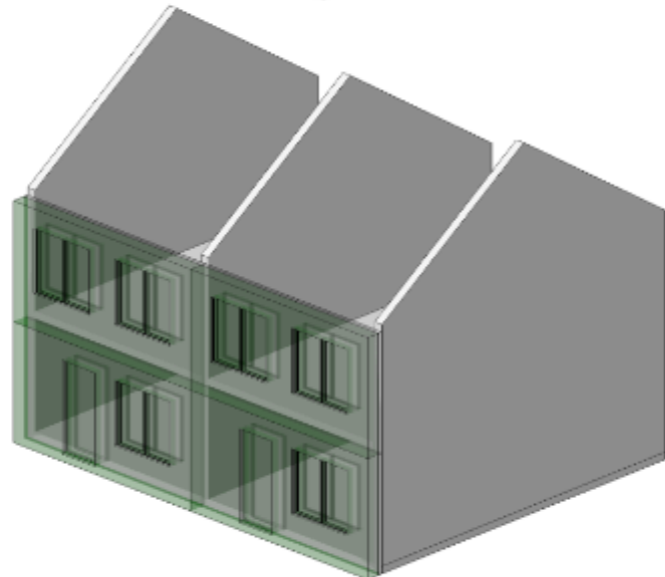
Gallerijwoning

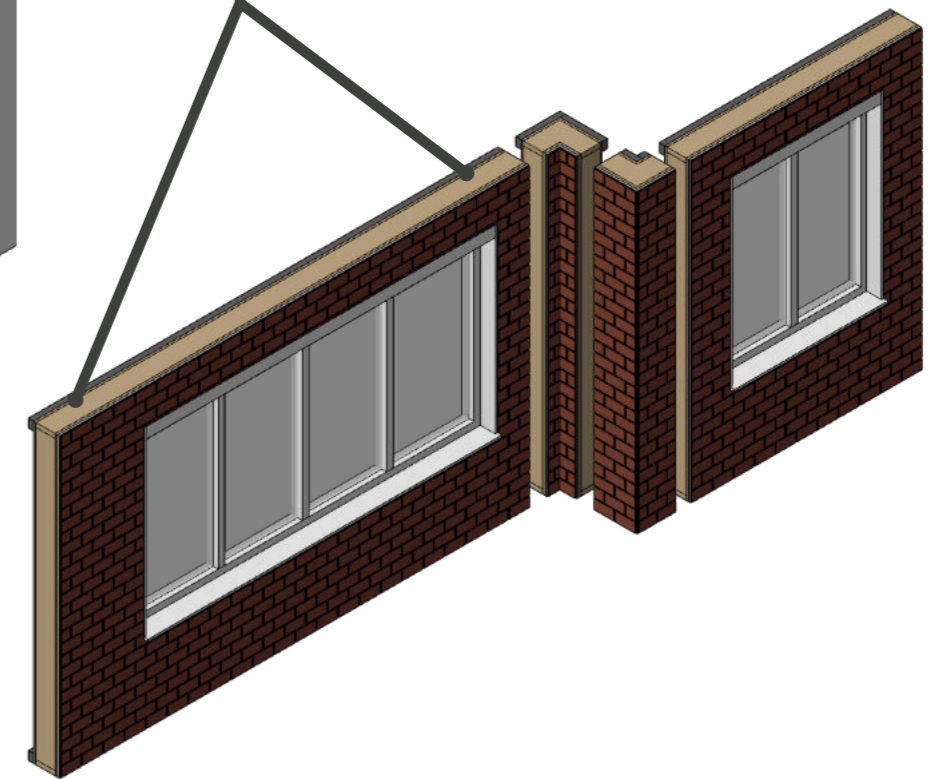
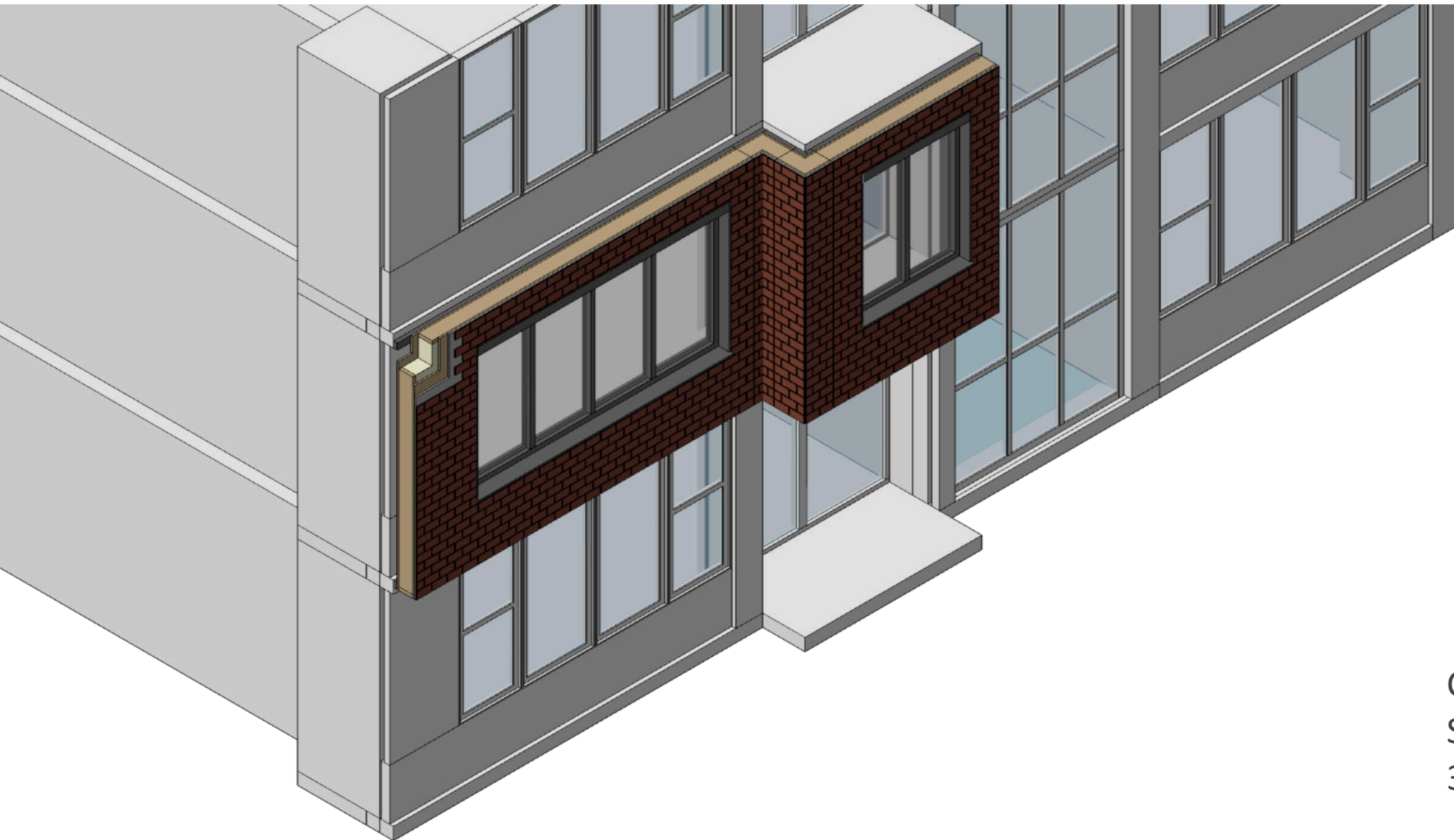


Portiekwoning

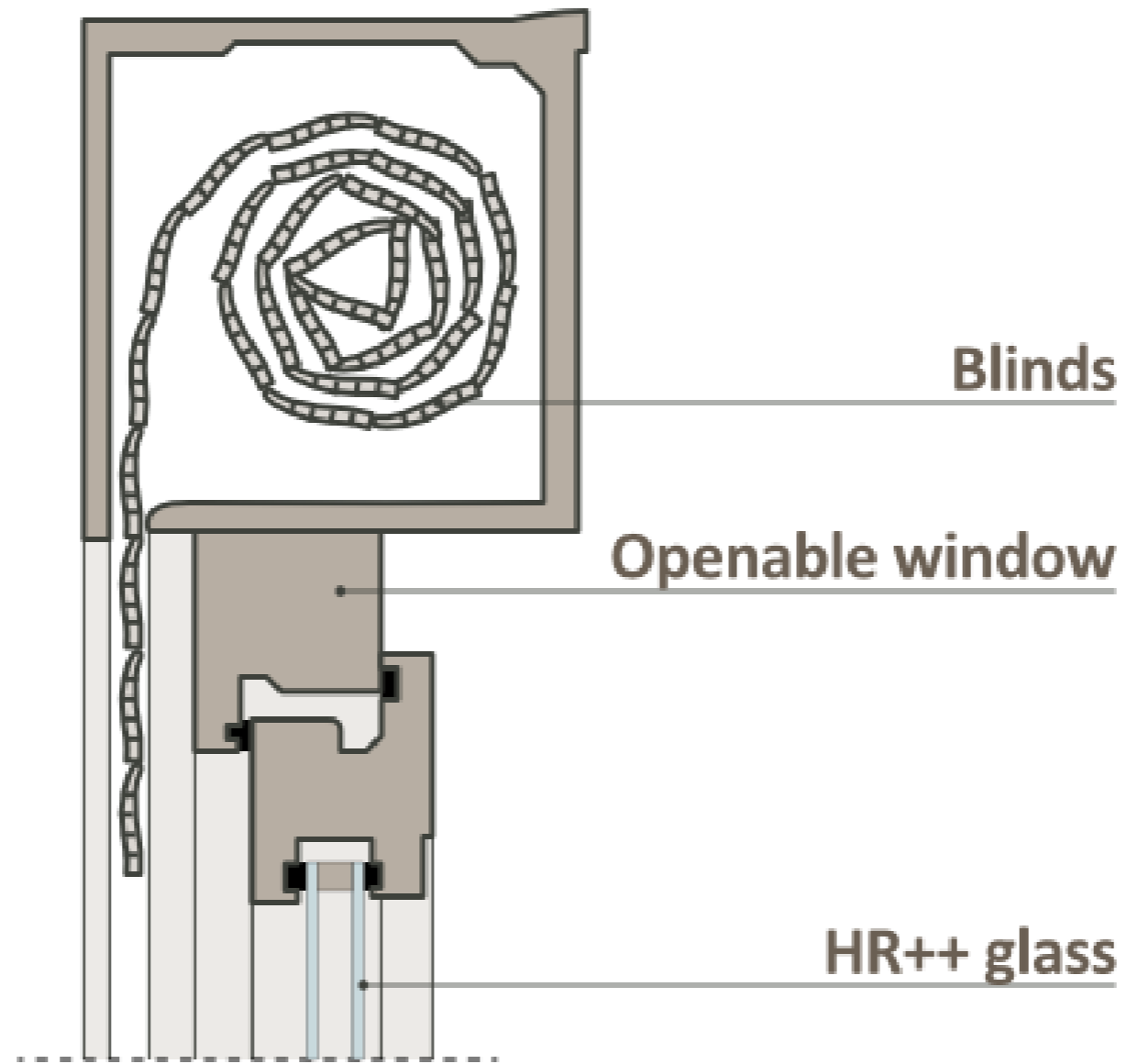


Rijteswoning

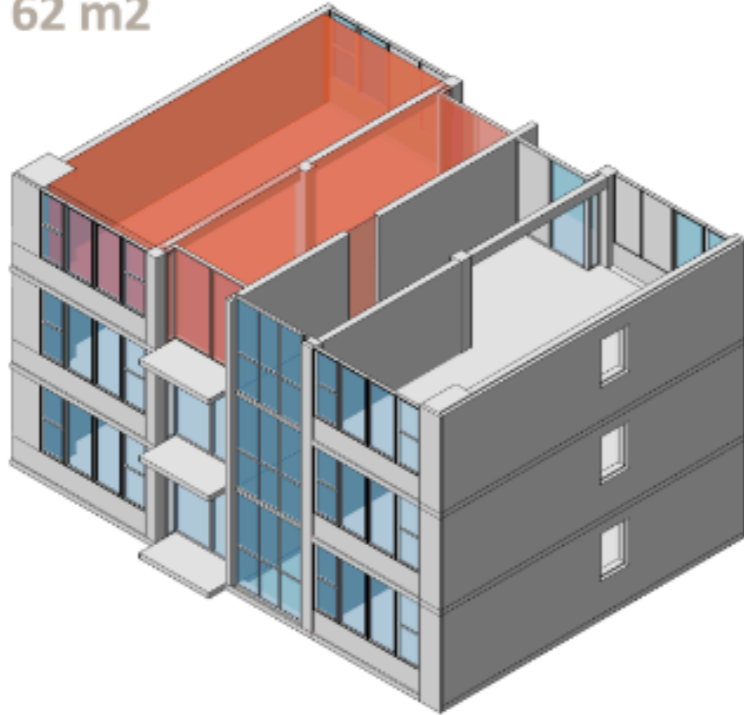




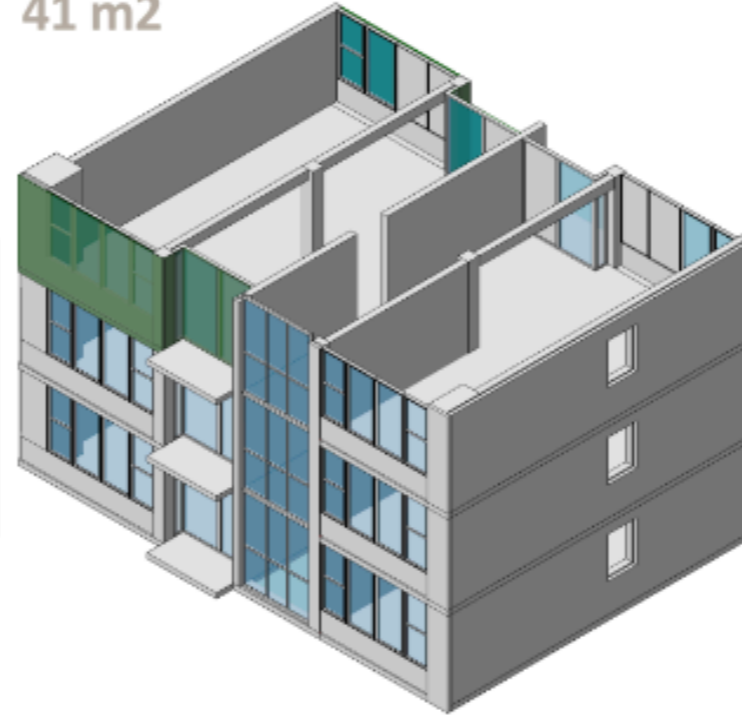
Connection on horizontal rails  
Stacking from bottom to top  
3 different elements



**GBO**  
62 m<sup>2</sup>



**Facade**  
41 m<sup>2</sup>



**Windows**  
22 m<sup>2</sup>

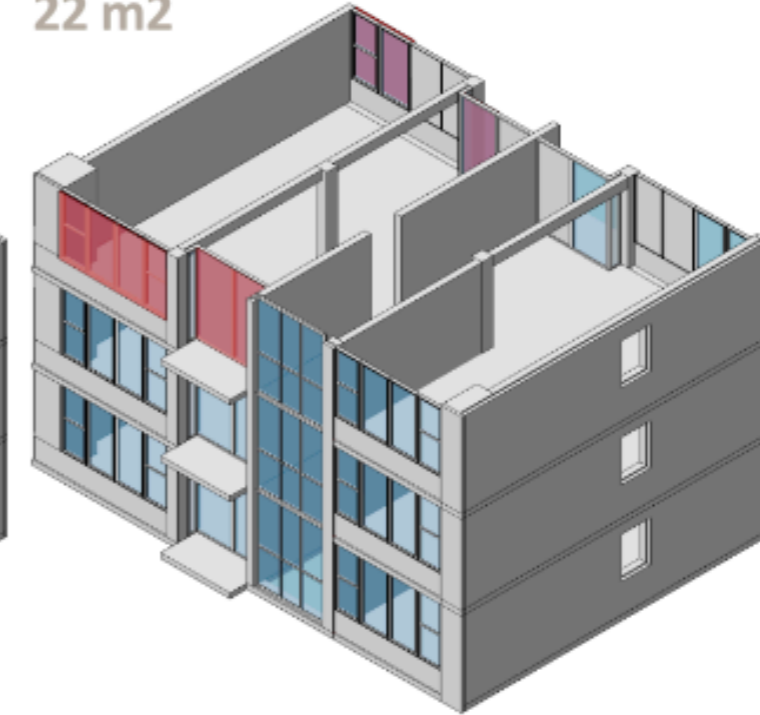


Table 8 Yearly operational energy demand for North-South orientation

	Total	/m <sup>2</sup>
Year space heating energy demand	2254 kWh	37,6
Year space cooling energy demand	780 kWh	13,0
Year hot water energy demand	5094 kWh	84,9
Year electricity demand	1094 kWh	18,2

Table 9 Yearly operational energy demand for East-West orientation

	Total	/m <sup>2</sup>
Year space heating energy demand	2293 kWh	38,2
Year space cooling energy demand	733 kWh	12,2
Year hot water energy demand	5094 kWh	84,9
Year electricity demand	1085 kWh	18,2



### **“How can a scalable and circular facade renovation system be designed for Dutch system-built houses from the post-war period?”**

- Diversity between system-built houses
- Several systems available, limited in terms of adaptability
- Limited circular solutions
- Mass-customization > specific solution preferred



- Analysis of existing systems on disassembly
- Hygrothermal performance of demountable joints
- Simulation with climate change



- No one-size-fits-all system
- Behavioral factors and occupant impact
- Interventions and changes during service life

Thank you

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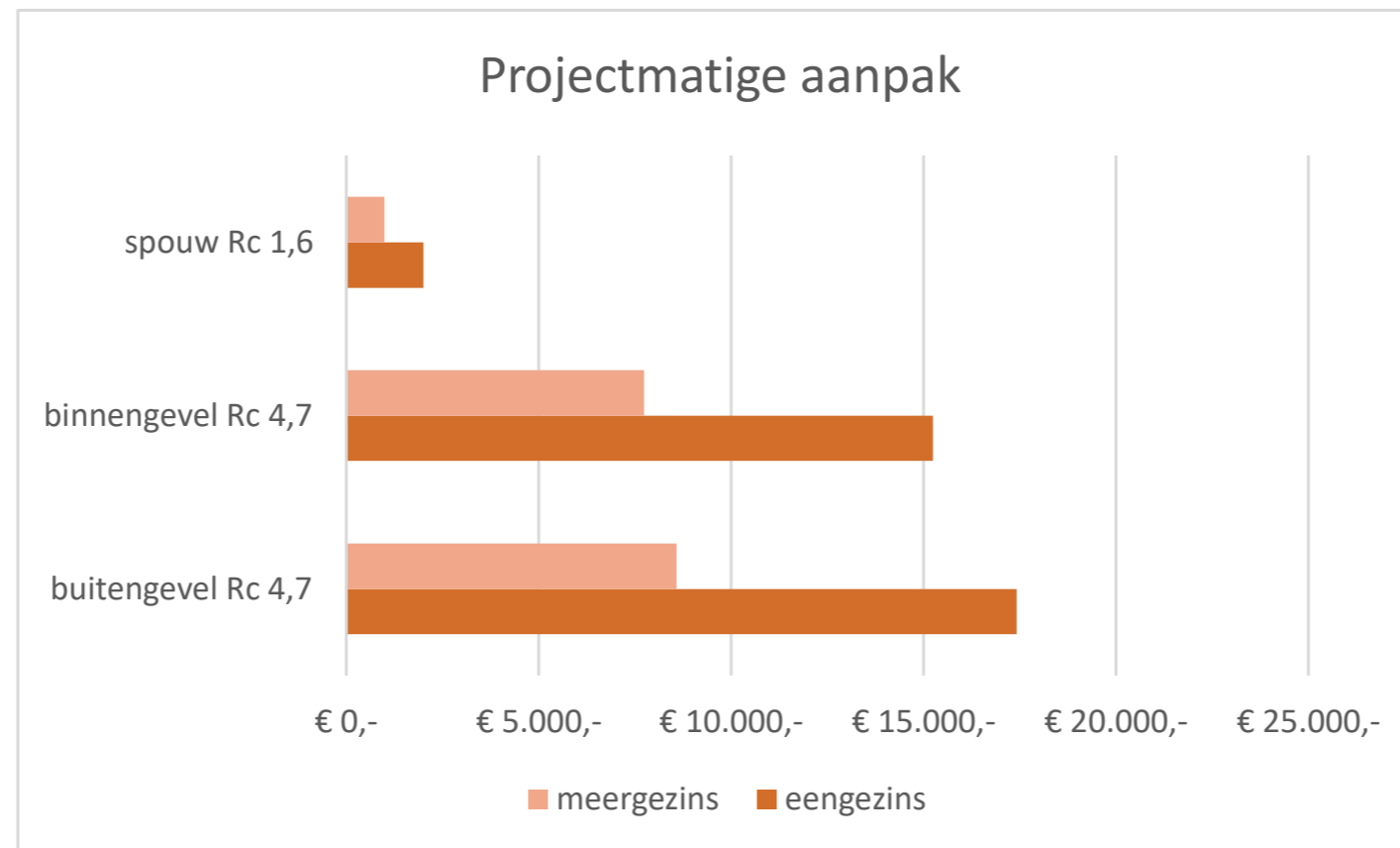
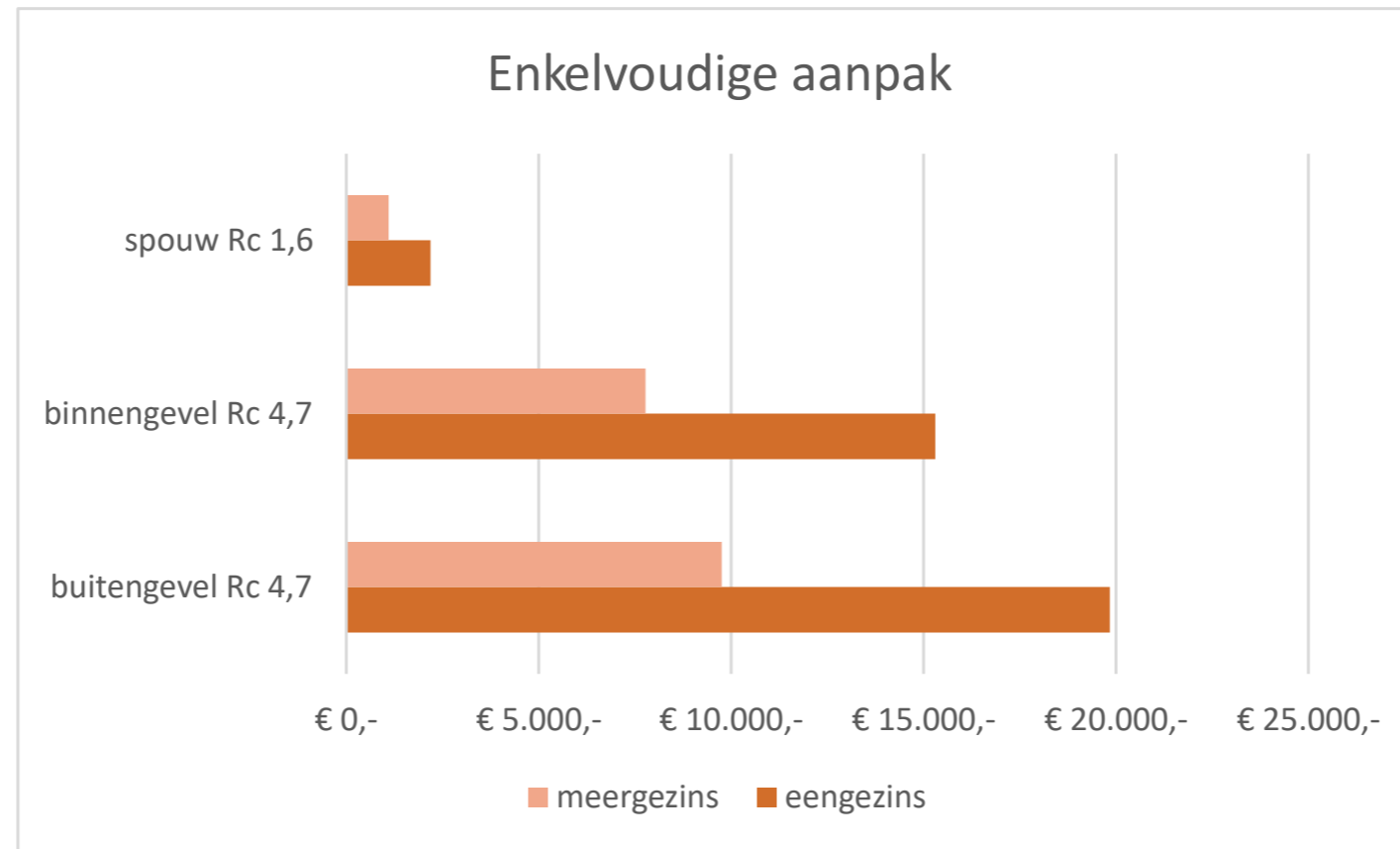
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# Costs of different insulation approaches for residential houses (RVO, 2023)

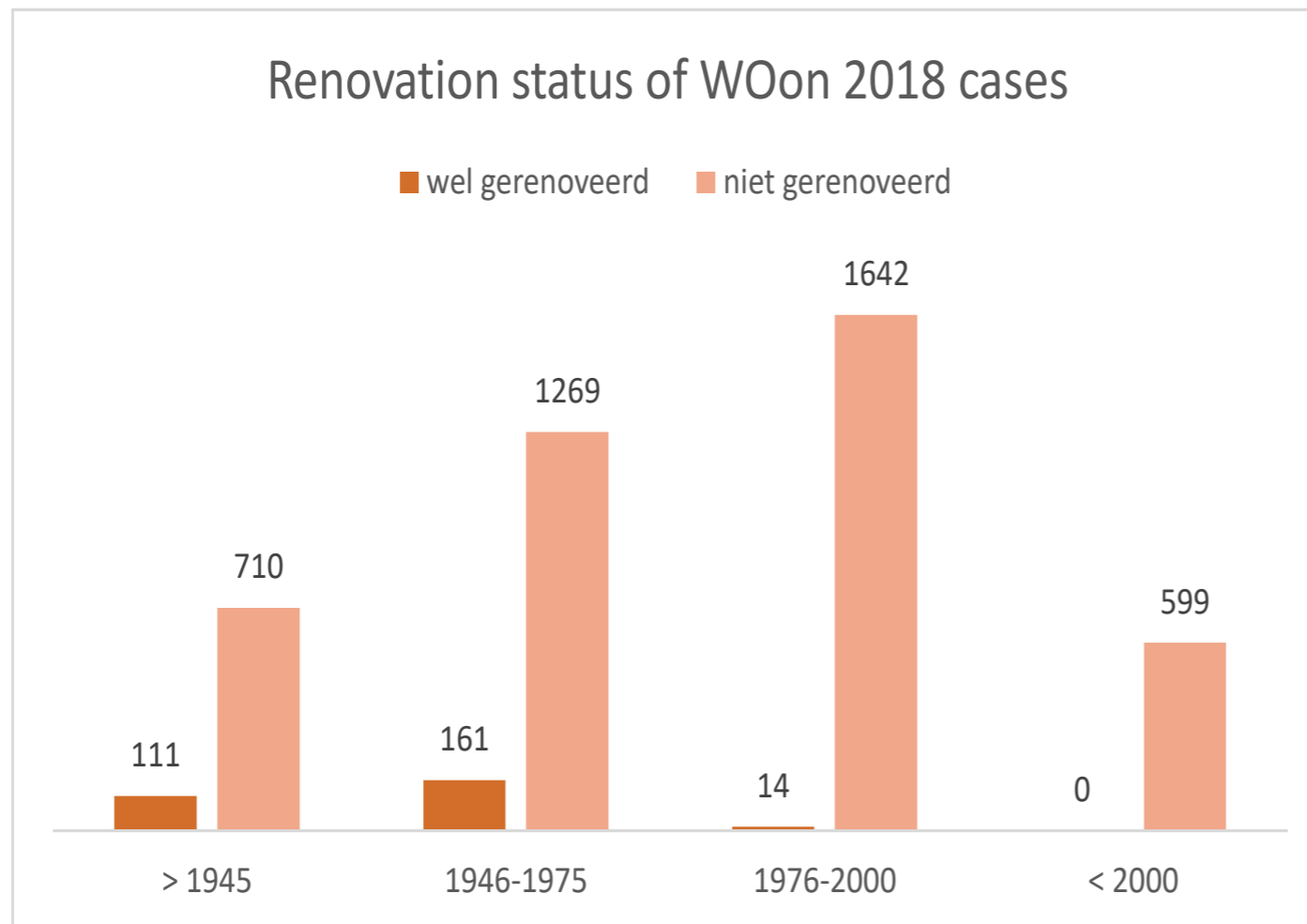


# Renovation status of Woon 2018 cases

**bouwjaar\_cat \* (Opname) Renovatiejaar Crosstabulation**

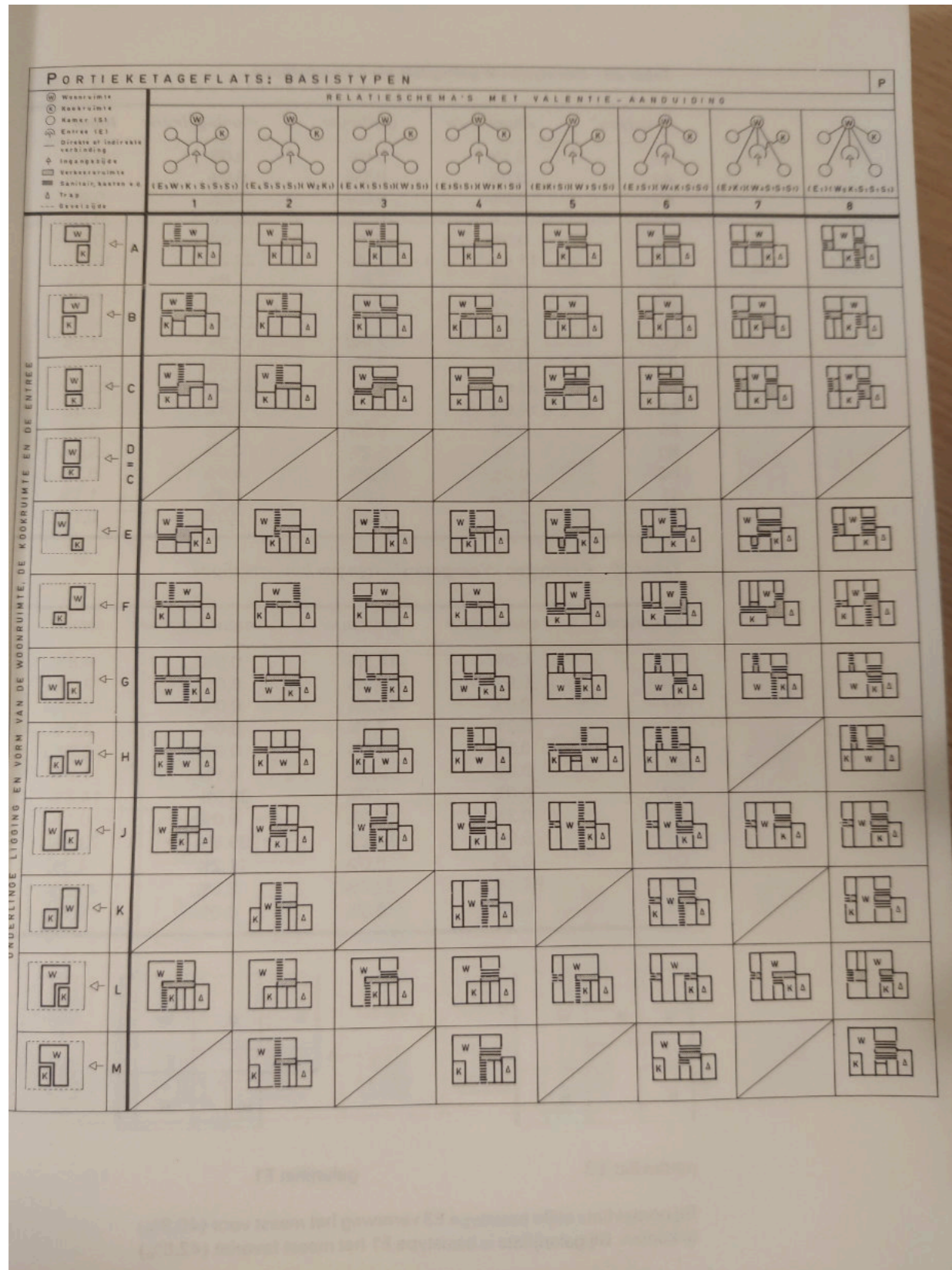
Count

		(Opname) Renovatiejaar						nvt	Total
		voor 1970	1970-1979	1980-1989	1990-1999	2000-2009	2010 en later		
bouwjaar_cat	>1945	2	7	8	22	32	40	710	821
	1946-1975	0	15	20	14	29	83	1269	1430
	1976-2000	0	0	1	0	4	9	1642	1656
	<2000	0	0	0	0	0	0	599	599
Total		2	22	29	36	65	132	4220	4506

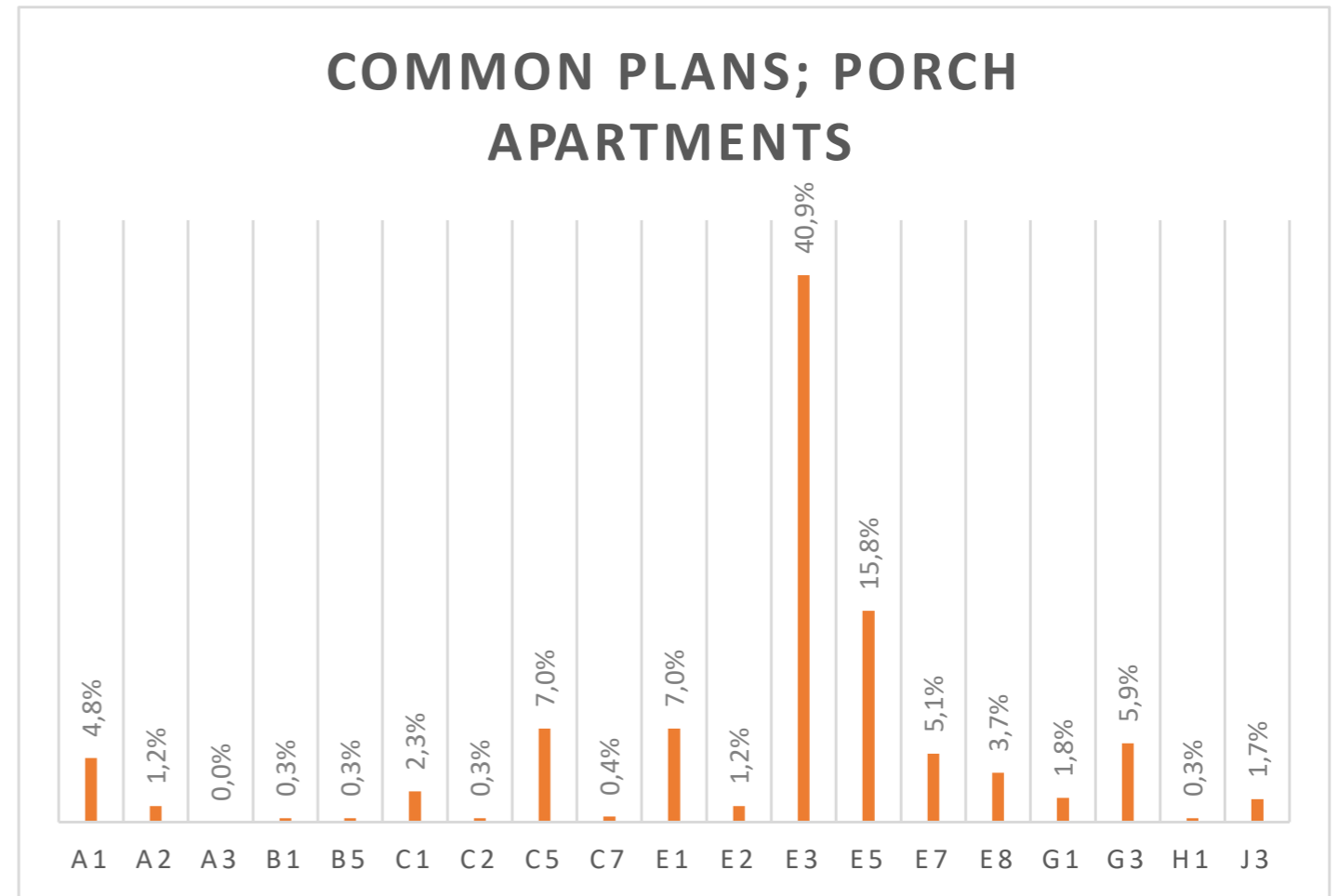


Modified from (Woon 2018)

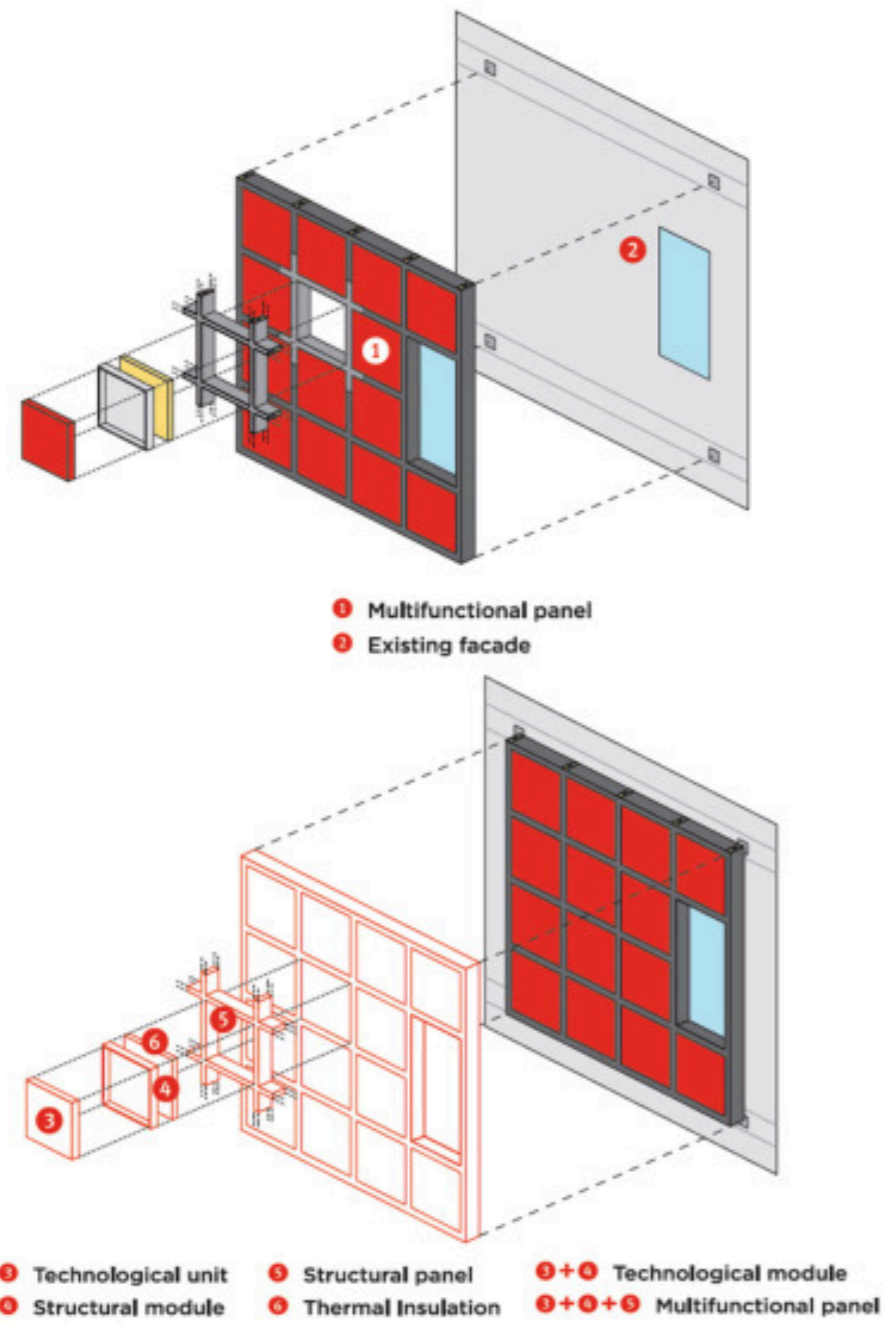
# Most common plans for portiek flats



(Priemus, 1971)



# Current systems



MEEFS system



RcPanels