The costs and benefits of deep retrofit – How does it stack up for $s and carbon?

Dr Gareth Gretton
Energy Efficiency and Conservation Authority
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ENERGY EFFICIENCY & CONSERVATION AUTHORITY

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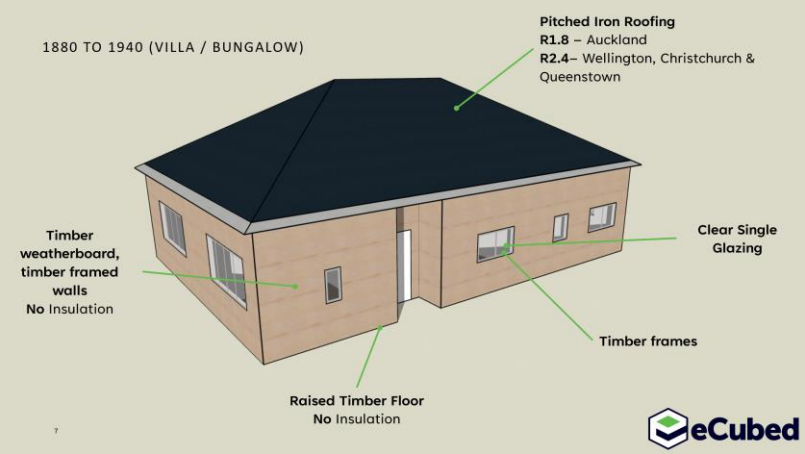
Part 1 – The buildings

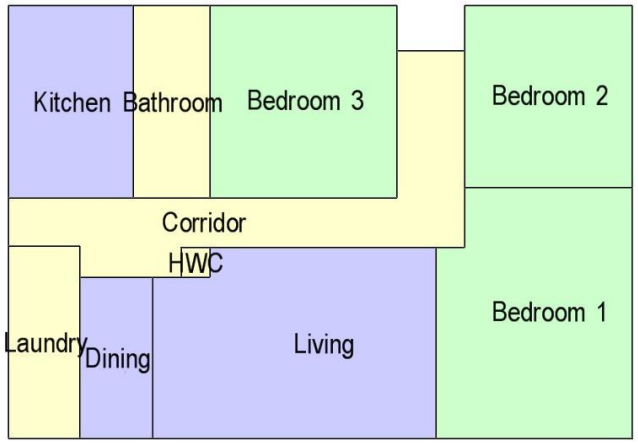
Methodology

192 deep retrofit scenarios

- **4 typologies – Specific buildings representing 4 eras**
- **4 climates – Auckland, Wellington, Christchurch, Queenstown**
- **4 thermal envelope standards – Baseline, H1, Homestar 6, EnerPHit**
- **3 heating schedules**

Methodology – Typologies





Number Bedrooms	3
Floor Area	115.7 m²
WWR	12%
Roof Construction	30° Pitched iron roofing over timber truss. Flat plasterboard ceiling
Floor to Ceiling Height	3000 mm
Roof Insulation	Average retrofitted insulation in place as follows: 70mm/R1.8 – (2007 H1 Climate Zone 1) * - Auckland 120mm/R2.4 - (2007 H1 Climate Zone 2 & 3) – Wellington, Christchurch & Queenstown
Floor Construction	Raised timber floor on piles
Floor Insulation	None
Floor Coverings	Carpet to bedrooms Bare wooden floor to living spaces. Bare wooden floor kitchen & bathrooms
Wall Construction	90mm Timber framing Timber weatherboards. Plasterboard lining
Wall Insulation	None
Window Construction	Clear single glazing in timber joinery
Air Tightness/Infiltration	0.9 ACH

HP in living areas (COP = 3.75 @ 8degC), electric resistance in bedrooms

Methodology – Thermal envelope standards

4 thermal envelope standards modelled

- **Baseline – different for each typology**
- **H1 – heating load for typology to H1/AS1**
- **Homestar 6 – 40-90 kWh/m^2 heating load**
- **EnerPHit – 20-25 kWh/m^2 heating load**

Methodology – Heating schedules

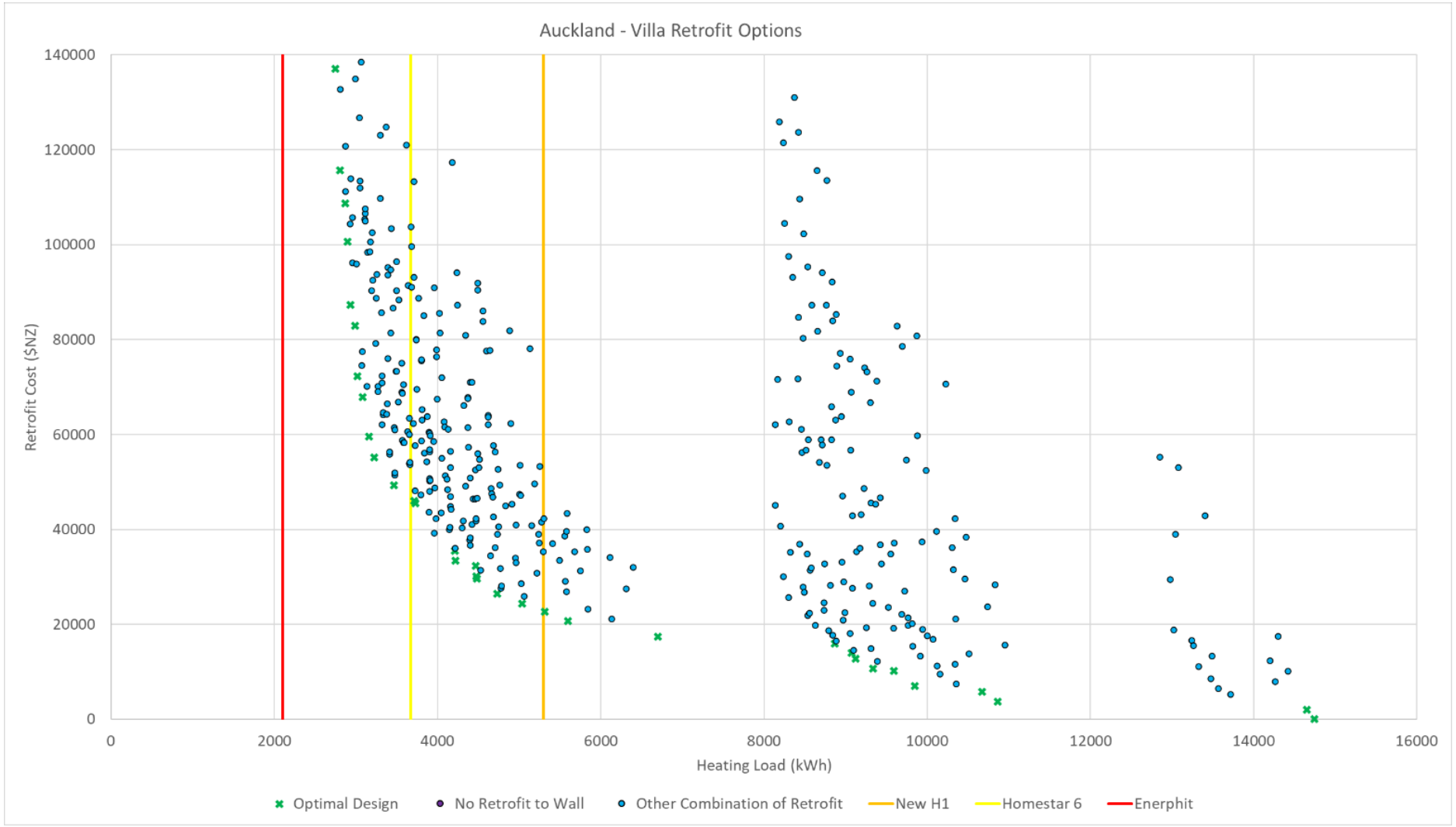
- **Heating schedules significantly influence economics**
- **‘Realistic’**
  - **Living areas: 20°C morning + evening + daytime at weekend**
  - **Bedrooms: 18°C morning + evening**
- **‘Idealistic’**
  - **As realistic + bedrooms 16°C overnight**
- **‘Underheated’**
  - **As realistic but 16°C for living areas and 14°C for bedrooms**
- **24/7 20°C for whole house when determining retrofit requirements to H1, Homestar 6 and EnerPHit standards**

Table 4 – Indicative Cost Estimate of Options: Villa / Bungalow (1880s to 1940s)

Ref.	Description	Element Qty	Unit	$/Element Qty	Total	$/m² GFA (116m²)	Indicative Split (NOTE: * = based on % split) Labour	Materials	*
	Wall Retrofits								
1	Drill & Fill Wall Insulation; installed from outside	138	m²	111	**15,312**	132	7,121	8,191	*
2	Drill & Fill Wall Insulation; installed from inside	138	m²	88	**12,108**	104	5,631	6,477	*
3	Exterior Wall Insulation (insulated cladding boards)	138	m²	240	**33,080**	285	15,384	17,696	*
4	Remove & replace wall linings and add insulation	138	m²	156	**21,595**	186	14,969	6,626	
4a	Remove & replace wall linings and add insulation with vapour control layer	138	m²	169	**23,368**	201	16,394	6,974	
5	Strap & line internal walls (existing concrete, masonry or timber walls)	138	m²	204	**28,198**	243	19,546	8,652	*
6	Insulated Wall Lining/Insulated Plasterboard	138	m²	230	**31,717**	273	16,512	15,205	
	Floor Retrofits								
7	Underfloor Insulation Blanket / Stapled polyester insulation	116	m²	16	**1,856**	16	757	1,099	
8	Underfloor Insulation Sections / Friction Fit Semi-rigid insulation	116	m²	28	**3,190**	28	870	2,320	
9	Underfloor Rigid Insulation / Friction Fit and Brackets	116	m²	25	**2,900**	25	812	2,088	
10	Slab edge insulation	46	m	178	**8,188**	71	3,808	4,380	*
11	Slab edge insulation + Skirt	46	m	260	**11,960**	103	5,562	6,398	*
	Windows/Glazing Retrofits								
12	Low-e window film	18	m²	115	**2,070**	18	963	1,107	*
13	Acrylic layer stick-on	18	m²	450	**8,100**	70	3,767	4,333	*
14	Double glazing retrofit into existing frames	18	m²	700	**12,600**	109	4,230	8,370	
15	Secondary Glazing	18	m²	575	**10,350**	89	4,813	5,537	*
16	Full Window replacement (Double glazed, low-e, thermally broken)	18	m²	993	**17,865**	154	8,308	9,557	*
	Roof Retrofits								
17	Ceiling Insulation Blankets / Fitted Bulk Ceiling Insulation	116	m²	28	**3,248**	28	2,251	997	*
18	Blown in Ceiling Insulation	116	m²	18	**2,047**	18	1,419	628	*
19	Remove & replace celling linings and add insulation (Skillion Roof)	N/A to this typology - refer to appendix							
20	Insulation (rigid or semi-rigid) between exposed rafters (Skillion Roof) with new ceiling lining below	N/A to this typology - refer to appendix							
21	Warm roof	134	m²	130	**17,420**	150	12,075	5,345	*
22	Insulated Ceiling Lining / Insulated Plasterboard	116	m²	193	**22,330**	193	15,478	6,852	*
23	Replace all downlights with rated LED downlights	10	No	97	**965**	8	615	350	
24	Replace all downlights with self-install retrofit Ecobulb LED	10	No	91	**905**	8	505	400	
	Draught Stopping Retrofits								
25	General Retrofit Airtightness gains (due to wall, floor, roof insulation additions)	N/A to this typology - refer to appendix							
26	Replace all downlights with rated LED downlights (New downlights are not vented)	N/A to this typology - refer to appendix							
27	Weather stripping around doors and windows	68	m	13	**897**	8	431	466	
28	Caulking of visible gaps & services penetrations	1	Sum	616	**616**	5	600	16	

NOTE: Refer to Appendix A for all related notes, assumptions, exclusions etc.

Results – Cost/performance optimisation



Results – Cost, carbon, and kWh

Table 9 – Total retrofit cost, embodied carbon, and annual heating electricity use for each combination of typology, climate, and performance standard.

Typology	Location	Standard	Cost $NZD	Minimum Embodied Carbon Range (kg CO2 eq)	Average Embodied Carbon (kg CO2 eq)	Maximum Embodied Carbon Range (kg CO2 eq)	Annual Heating Load/Demand "Realistic Schedule" kWh
1880-1940 Villa	Auckland	New H1	**$25,900**	2,280	**2,320**	2,350	**707**
		Homestar 6	**$50,800**	8,380	**8,930**	9,400	**291**
		EnerPHit	**$50,100**	3,060	**3,570**	4,190	**285**
	Wellington	New H1	**$25,900**	2,280	**2,320**	2,350	**1871**
		Homestar 6	**$69,400**	10,070	**10,680**	11,200	**560**
		EnerPHit	**$73,400**	9,180	**10,190**	11,220	**252**
	Christchurch	New H1	**$27,900**	2,400	**2,490**	2,550	**2657**
		Homestar 6	**$88,900**	10,050	**10,570**	11,000	**1153**
		EnerPHit	**$89,500**	9,310	**10,320**	11,350	**489**
	Queenstown	New H1	**$27,900**	2,400	**2,490**	2,550	**3512**
		Homestar 6	**$138,500**	11,100	**15,160**	19,220	**1504**
		EnerPHit	**$154,200**	15,150	**23,860**	31,920	**490**

Part 2 – Cost-benefit analysis

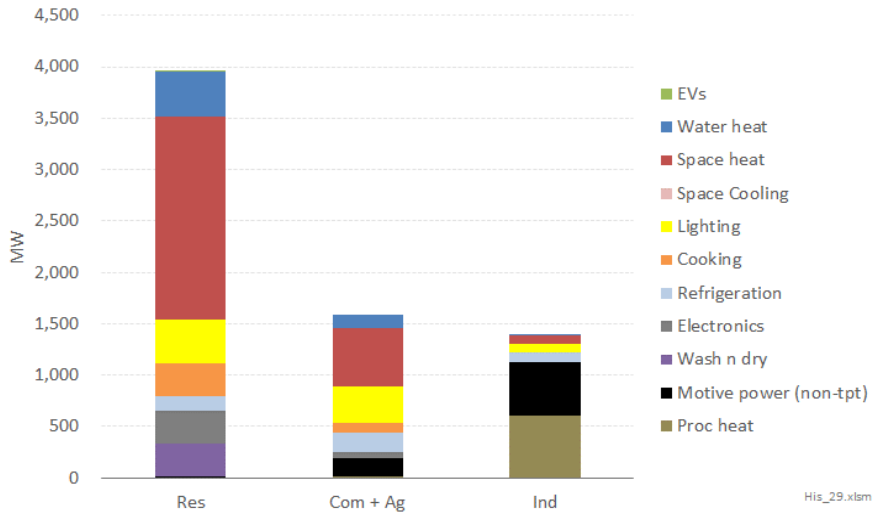
Methodology – CBA

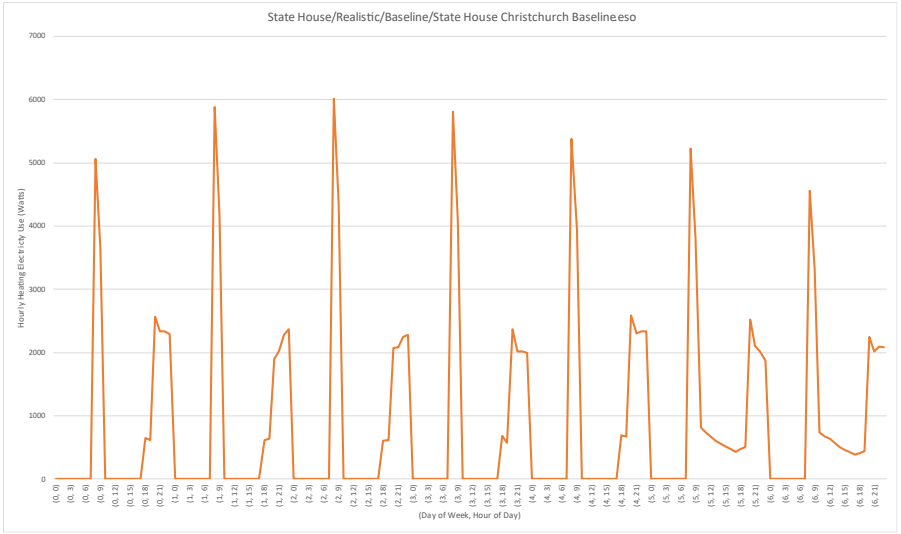
- **Detailed modelling of time of use electricity consumption ($ and carbon)**
- **Modelling of health benefits (via takeback)**

Methodology – ToU demand

- **Modelling matched to observed using MBIE, EECA and Transpower data**
  - **15% downscaling on annual**
  - **63% downscaling on peak (diversity)**

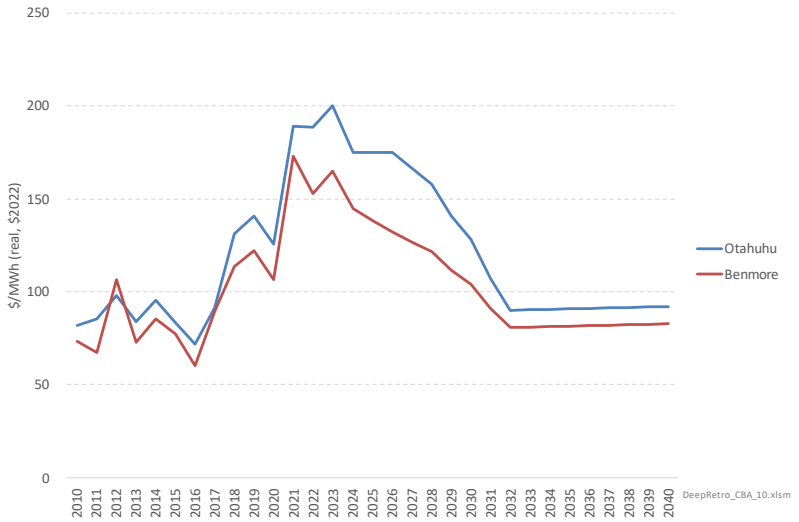
- **Average summer and winter week**





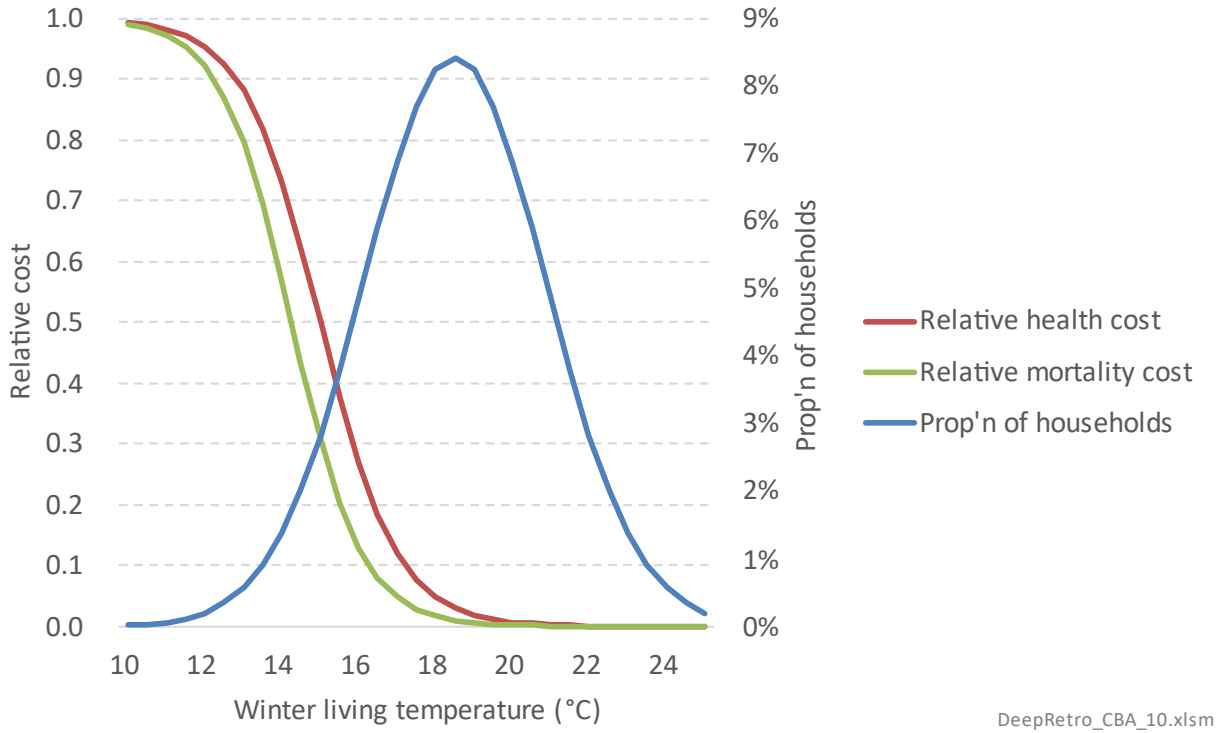
Methodology – ToU generation and network costs

- **Generation prices based on historic with future assumptions**
  - **Within-day and within-year ‘shapes’ applied**
- **Network costs as follows:**
  - **$125/kW/year for changes in peak demand**
  - **$6.5/MWh for changes in annual demand**



Methodology – Health benefits

- **Assumed distributions for health cost vs indoor temperature**
- **Indoor temperatures matched to heating schedules**
- **Takeback assumed up 22°C living temperature and current energy costs**



DeepRetro_CBA_10.xlsm

Caveats:

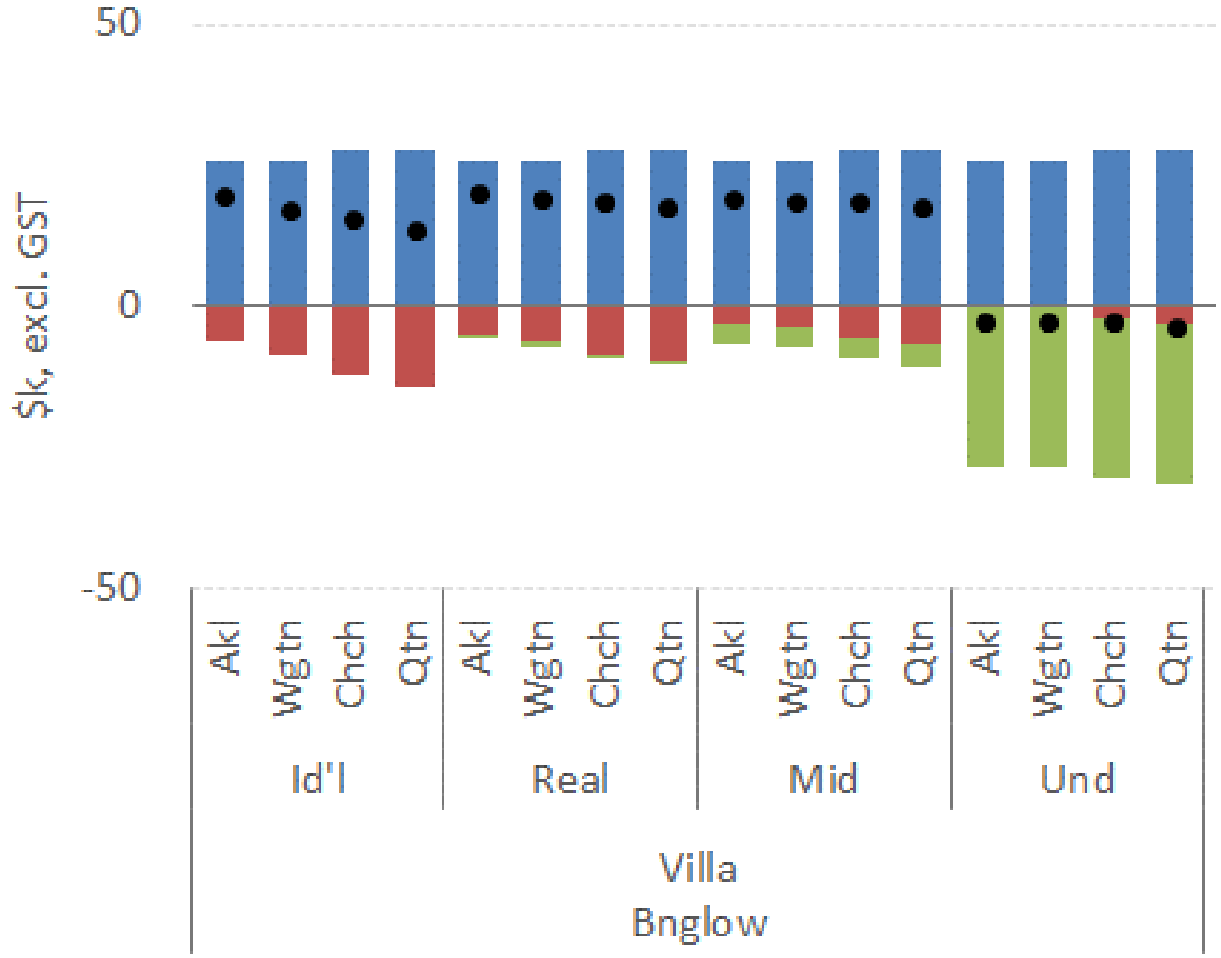
Costs as modelled do not consider ‘work happening anyway’

Benefits as modelled include health, but not wellbeing

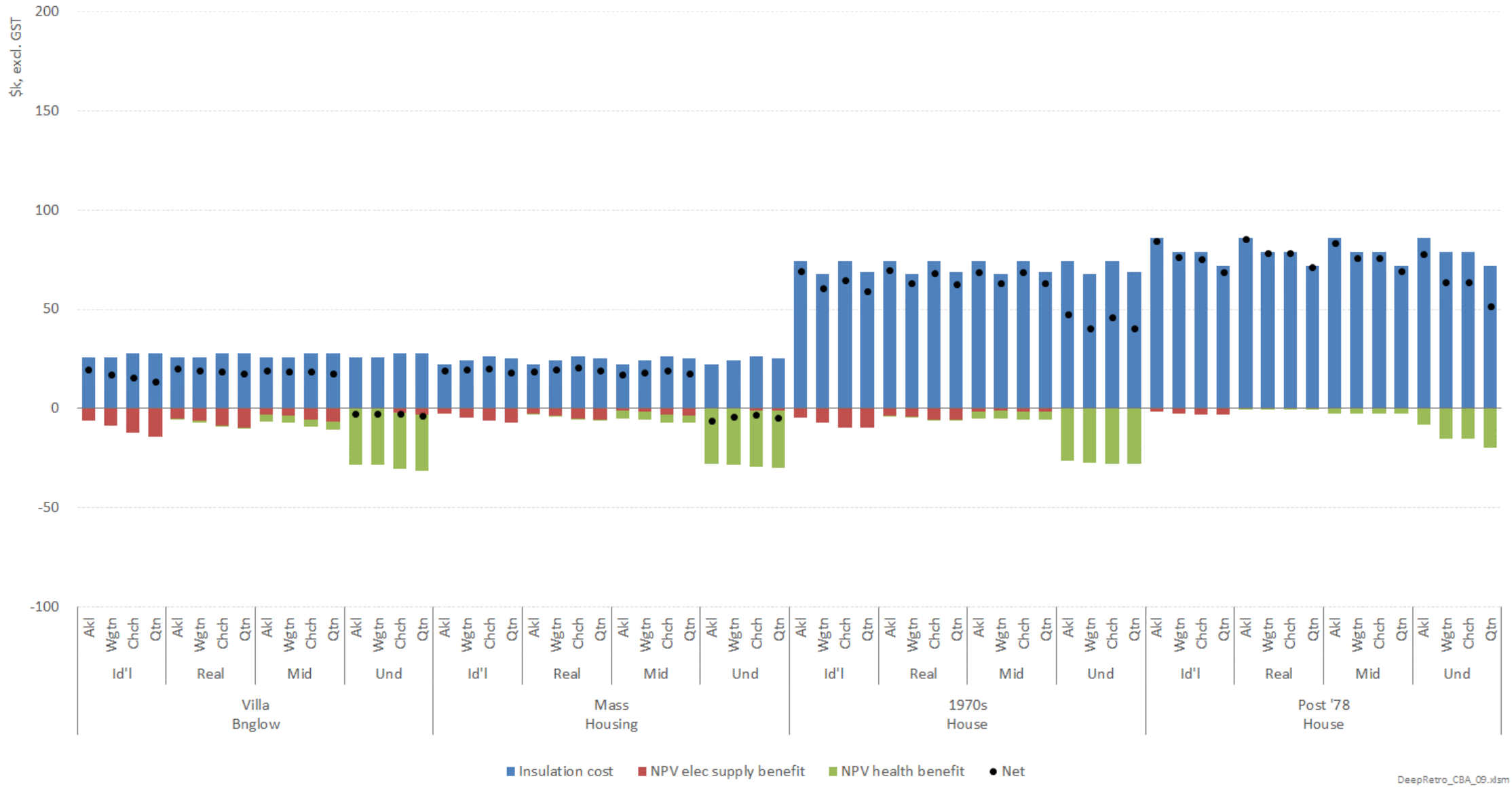
Net present value (5% discount)

- **Blue = cost of retrofit**
- **Red = NPV electricity supply benefit**
- **Green = NPV health benefit**
- **Black dot = net**

- **1 retrofit standard – H1**
- **1 typology**
- **4 heating schedules**
- **4 climates**



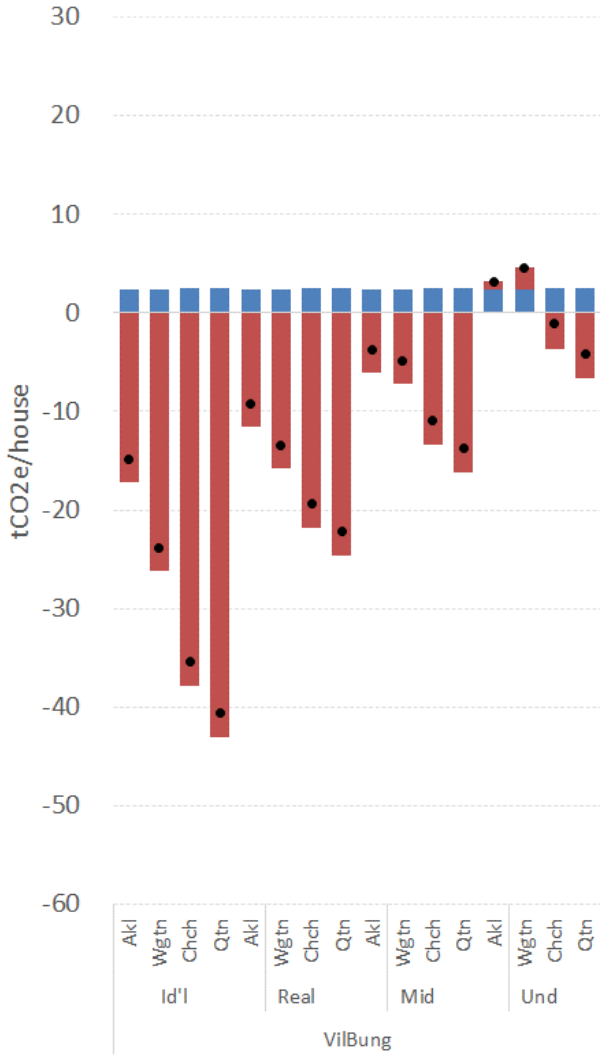
Net present value (5% discount)



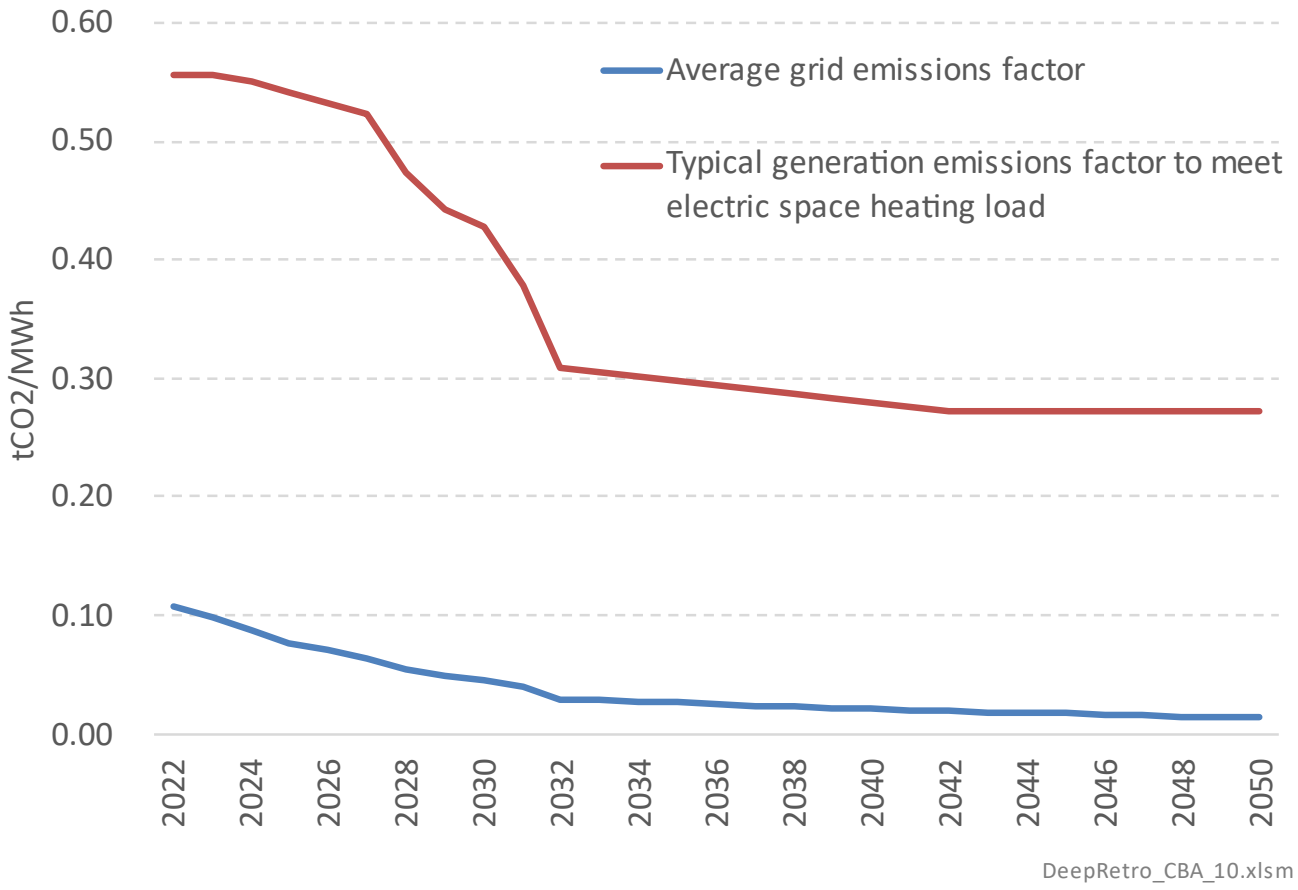
Carbon

- Blue = embodied carbon
- Red = electricity generation emissions
- Black dot = net

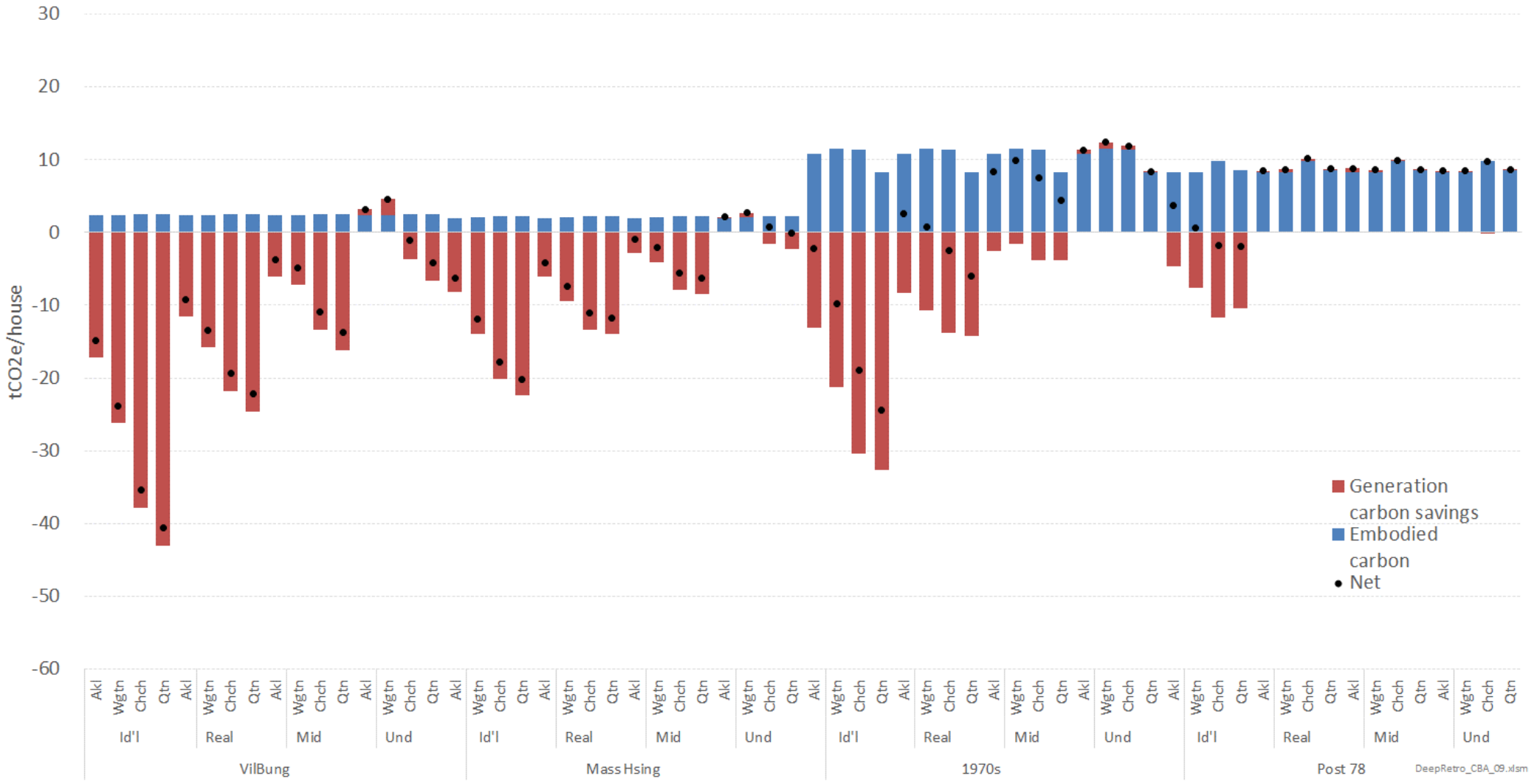
- 1 retrofit standard – H1
- 1 typology
- 4 heating schedules
- 4 climates



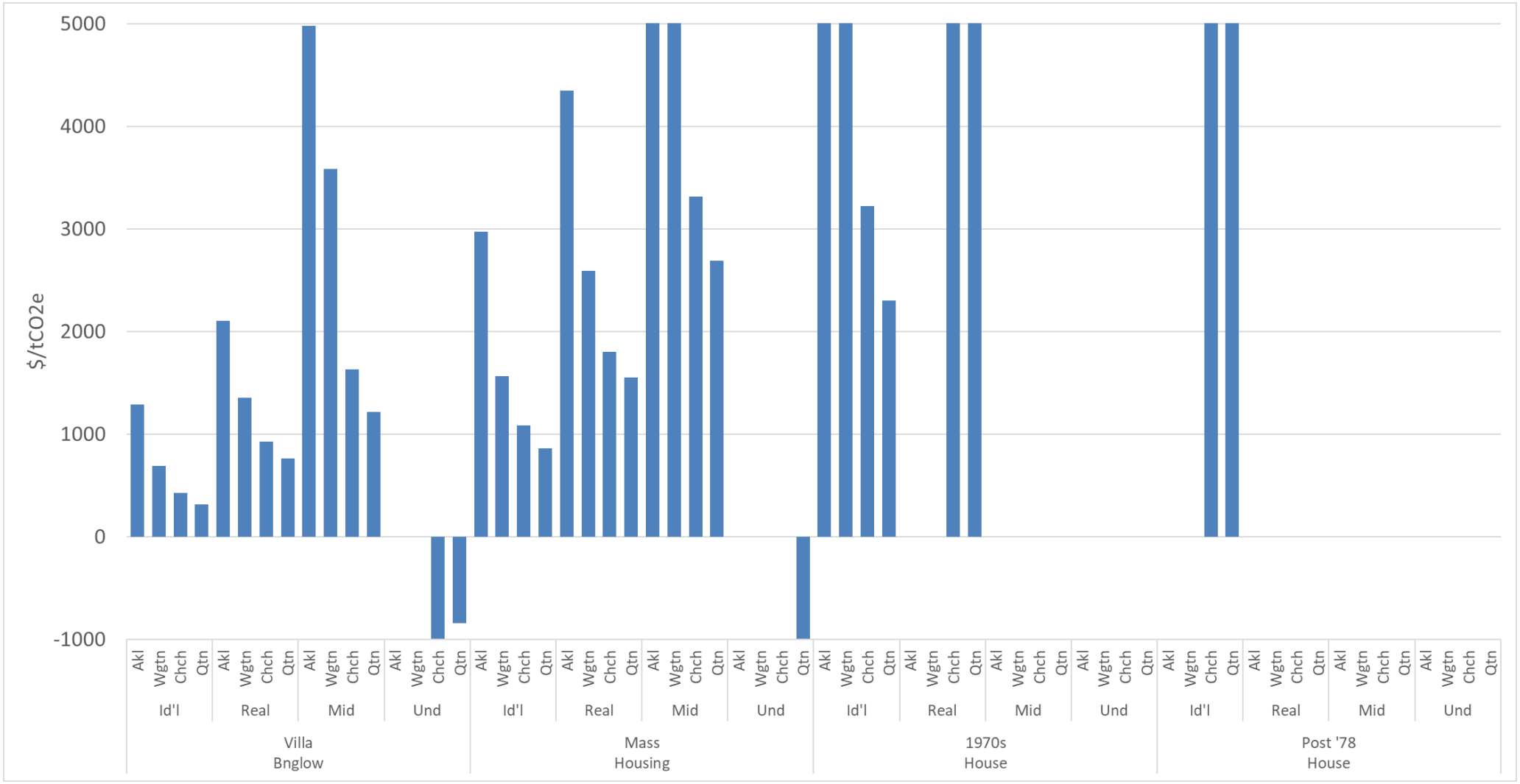
Carbon


0.60
0.50
0.40
0.30
0.20
0.10
0.00
tCO2/MWh
Average grid emissions factor
Typical generation emissions factor to meet electric space heating load
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
2048
2050
DeepRetro_CBA_10.xlsm

Carbon


30
20
10
0
-10
-20
-30
-40
-50
-60
tCO2e/house
Generation carbon savings
Embodied carbon
Net
Akl Wgtn Chch Qtn
Id'l Real Mid Und
VilBung
Mass Hsing
1970s
Post 78
DeepRetro_CBA_09.xlsm

Carbon – $/tCO2e (5% discount)



Part 3 – Conclusions

Conclusions

- **Results are strongly scenario-specific**
  - **Typology, climate, and heating schedule are all determinants**
  - **H1 generally the best, but MVHR on EnerPHit worthy of consideration**
- **Embodied carbon of some building products can annul carbon benefits in some situations**