Household energy use: How much and when, now and in the future

Dr Gareth Gretton
Energy Efficiency and Conservation Authority
20th February 2024

EECA
TE TARI TIAKI PŪNGAO
ENERGY EFFICIENCY & CONSERVATION AUTHORITY

Contents

Part 1

How much – 2022

Let's start from the top ...

MBIE Energy in NZ – Numbers are in PJ

1 kWh = 3.6 MJ
1 MWh = 3.6 GJ
1 GWh = 3.6 TJ
1 TWh = 3.6 PJ

1 house (ex. car) ~ 10,000 kWh = 36 GJ
1 PJ ~ 28,000 houses ~ Taupō / Timaru / Blenheim
2 million houses ~ 72 PJ

Energy Supply and Demand

Calendar Year

2022

Converted into Petajoules using Gross Calorific Values

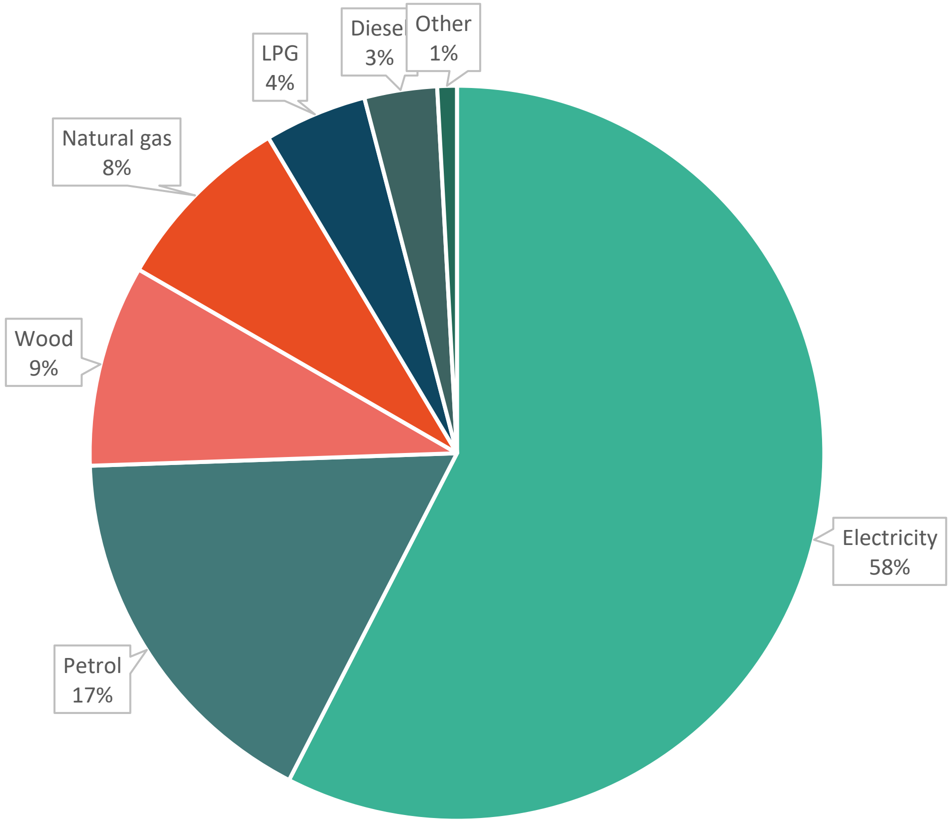
	Coal					Oil								Natural Gas	Renewables								Electricity	Waste Heat	TOTAL
	Bituminous	Sub-bitum.	Bituminous & Sub-bitum.	Lignite	Total	Crudes/ Feedstocks/ NGL	LPG	Petrol	Diesel	Fuel Oil	Av. Fuel/ Kero	Others	Total	Total	Hydro	Geothermal	Solar	Wind	Liquid Biofuels	Biogas	Solid Biofuels	Total	Total	Total	
SUPPLY																									
Indigenous Production	37.13	23.82	60.94	5.04	65.98	34.23	7.72	-	-	-	-	-	41.95	143.22	94.58	204.89	1.36	10.31	0.21	3.71	47.36	362.42		1.02	614.60
+ Imports	1.19	14.48	15.66	0.00	15.66	37.90	1.29	88.31	134.55	2.58	28.85	15.48	308.96	-	-	-	-	-	-	-	0.13	0.13		-	324.75
- Exports	37.19	0.97	38.15	-	38.15	35.34	1.53	4.36	1.96	3.38	0.80	0.54	47.92	-	-	-	-	-	-	-	(0.00)	(0.00)		-	86.07
- Stock Change	(1.27)	2.04	0.77	0.00	0.77	(9.52)	(0.01)	(1.98)	(0.87)	2.93	0.27	1.45	(7.73)	0.56	-	-	-	-	-	-	-	-		-	(6.39)
- International Transport	-	-	-	-	-	-	-	0.00	3.87	1.71	21.71	-	27.29	-	-	-	-	-	-	-	-	-		-	27.29
TOTAL PRIMARY ENERGY	**2.40**	**35.29**	**37.69**	**5.04**	**42.72**	**46.31**	**7.50**	**85.93**	**129.59**	**(5.44)**	**6.07**	**13.48**	**283.43**	**142.66**	**94.58**	**204.89**	**1.36**	**10.31**	**0.21**	**3.71**	**47.48**	**362.55**		**1.02**	**832.38**
ENERGY TRANSFORMATION	**(0.29)**	**(24.77)**	**(25.06)**	**(0.04)**	**(25.10)**	**(45.39)**	**-**	**14.79**	**19.73**	**5.30**	**5.85**	**0.39**	**0.67**	**(46.44)**	**(94.58)**	**(197.58)**	**(1.00)**	**(10.31)**	**(0.21)**	**(3.40)**	**(14.12)**	**(321.21)**	**143.72**	**(1.02)**	**(249.38)**
Electricity Generation	-	(7.71)	(7.71)	-	(7.71)	-	-	-	(0.09)	-	-	-	(0.09)	(29.56)	(94.58)	(196.33)	(1.00)	(10.31)	-	(2.61)	-	(304.84)	152.33	-	(189.87)
Cogeneration	-	(7.43)	(7.43)	(0.04)	(7.47)	-	-	-	-	-	-	-	-	(12.38)	-	(1.25)	-	-	-	(0.79)	(14.12)	(16.16)	7.55	(1.02)	(29.48)
Fuel Production	-	-	-	-	-	(45.39)	-	13.65	18.46	3.60	5.93	0.71	(3.03)	-	-	-	-	-	(0.21)	-	-	(0.21)	-	-	(3.24)
Other Transformation	-	(9.52)	(9.52)	-	(9.52)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(9.52)
Losses and Own Use	(0.29)	(0.12)	(0.41)	-	(0.41)	-	-	1.13	1.36	1.70	(0.08)	(0.32)	3.79	(4.50)	-	-	-	-	-	-	-	-	(16.15)	-	(17.27)
Non-energy Use	-	-	-	-		-	-	-	-	-	-	(13.62)	(13.62)	(35.26)	-	-	-	-	-	-	-		-	-	(48.88)
CONSUMER ENERGY (calculated)	**2.11**	**10.51**	**12.62**	**5.00**	**17.62**	**0.91**	**7.50**	**100.72**	**149.32**	**(0.13)**	**11.91**	**0.26**	**270.48**	**60.95**		**7.30**	**0.36**	**-**	**-**	**0.31**	**33.37**	**41.34**	**143.72**	**-**	**534.12**
DEMAND																									
Agriculture, Forestry and Fishi	**0.04**	**1.47**	**1.51**	**-**	**1.51**		**0.12**	**1.35**	**15.32**	**-**	**-**		**16.79**	**1.01**		**0.45**	**-**			**-**	**-**	**0.45**	**8.72**		**28.47**
Agriculture	0.04	1.47	1.51	0.00	1.51		0.12	1.29	11.32	-	-		12.73	1.01		0.45	-			-	-	0.45	8.29		23.99
Forestry and Logging	-	-	-	-	-		-	0.00	1.82	-	-		1.83	0.00		-	-			-	-	-	0.25		2.08
Fishing	-	-	-	-	-		-	0.05	2.18	-	-		2.23	-		-	-			-	-	-	0.18		2.41
Industrial	**2.26**	**11.48**	**13.74**	**4.85**	**18.59**		**3.74**	**0.09**	**19.27**	**0.59**	**-**		**23.69**	**47.92**		**4.27**	**-**			**0.05**	**25.80**	**30.12**	**50.59**		**170.90**
Mining	-	0.78	0.78	-	0.78		-	0.00	4.87	-	-		4.87	0.18		-	-			-	-	-	1.56		7.39
Food Processing	0.51	9.72	10.23	4.50	14.74		-	-	-	-	-		-	17.20		-	-			-	-	-	10.74		42.68
Textiles	0.15	0.05	0.20	-	0.20		-	-	-	-	-		-	0.38		-	-			-	-	-	0.33		0.90
Wood, Pulp, Paper and Printing	0.05	0.15	0.19	0.00	0.20		-	-	-	-	-		-	1.00		-	-			-	25.80	25.80	5.22		32.22
Chemicals	-	0.00	0.00	-	0.00		-	-	-	-	-		-	23.77		-	-			-	-	-	1.93		25.71
Non-metallic Minerals	1.19	0.76	1.94	0.13	2.07		-	-	-	-	-		-	2.29		-	-			-	-	-	0.90		5.26
Basic Metals	0.00	0.02	0.02	0.21	0.24		-	-	-	-	-		-	2.44		-	-			-	-	-	22.56		25.24
Mechanical/Electrical Equipmen	-	-	-	-	-		-	-	-	-	-		-	0.25		-	-			-	-	-	0.67		0.92
Building and Construction	-	-	-	-	-		-	0.02	7.48	-	-		7.50	0.31		-	-			-	-	-	1.63		9.44
Unallocated	0.37	-	0.37	-	0.37		3.74	0.07	6.92	0.59	-		11.32	0.09		4.27	-			0.05	-	4.32	5.06		21.15
Commercial	**0.15**	**0.32**	**0.46**	**0.07**	**0.53**		**1.78**	**2.22**	**8.27**	**0.47**	**-**		**12.73**	**7.45**		**2.38**	**-**			**0.26**	**-**	**2.64**	**33.66**		**57.01**
Transport	**-**	**-**	**-**	**-**	**-**		**0.14**	**84.23**	**102.10**	**0.71**	**15.03**		**202.20**	**-**		**-**	**-**			**-**	**-**	**-**	**0.70**		**202.90**
Residential	**0.01**	**0.11**	**0.12**	**0.03**	**0.15**		**3.79**	**14.18**	**2.68**	**-**	**-**		**20.65**	**6.79**		**0.21**	**0.36**			**-**	**7.44**	**8.01**	**48.28**		**83.88**
CONSUMER ENERGY (observed)	**2.46**	**13.37**	**15.83**	**4.95**	**20.78**		**9.56**	**102.07**	**147.64**	**1.77**	**15.03**		**276.06**	**63.16**		**7.30**	**0.36**			**0.31**	**33.24**	**41.21**	**141.94**		**543.17**
Statistical Differences			**(3.21)**	**0.05**	**(3.16)**	**0.91**	**(2.06)**	**(1.36)**	**1.68**	**(1.90)**	**(3.11)**	**0.26**	**(5.58)**	**(2.21)**	**-**	**0.00**	**0.00**	**-**	**-**	**0.00**	**0.13**	**0.13**	**1.78**	**-**	**(9.05)**

How much – 2022

- Indigenous production: **615 PJ** (coal, oil, gas, renewables)
  - Note 1:1 on hydro and wind to electricity, but 205 PJ of geothermal is net heat from fluid.
- Total primary energy supply: **832 PJ**
  - Includes 205 PJ as above. Excludes international transport (27 PJ).
- Total final energy consumption: **543 PJ**
  - What's used on the demand side. Excludes non-energy use (methanol, ammonia-urea), and after conversion losses in (thermal) electricity generation.
- Residential energy consumption: **84 PJ**

How much – 2022

Fuel	PJ
Electricity	48.3
Petrol	14.2
Wood	7.4
Natural gas	6.8
LPG	3.8
Diesel	2.7
Solar	0.4
Geothermal	0.2
Coal	0.1
Total	**83.9**

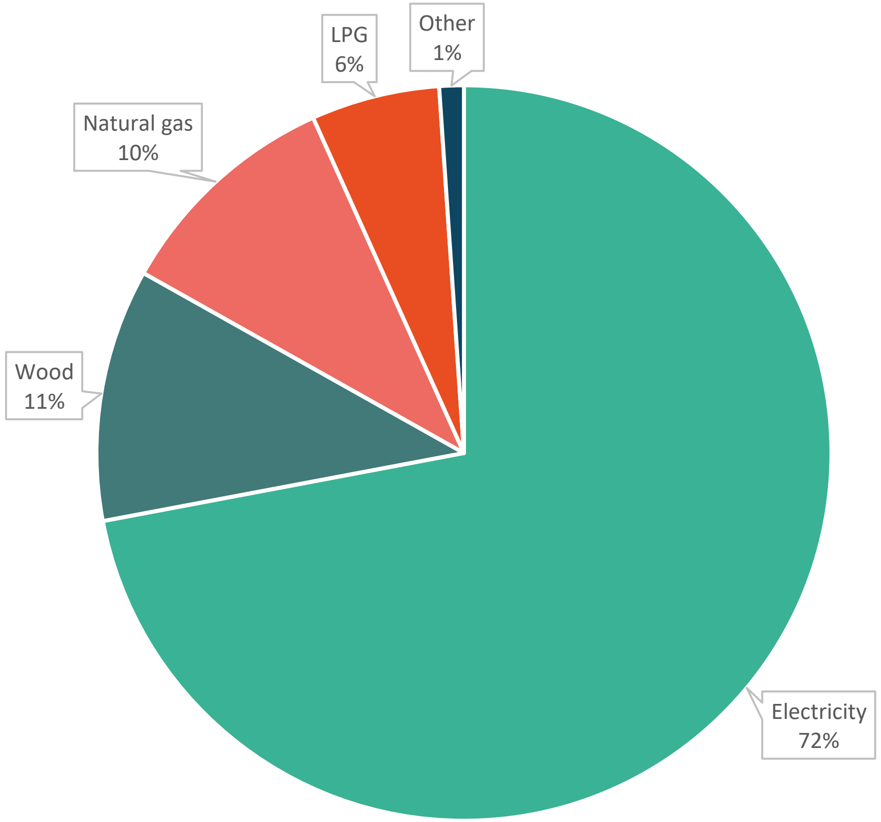


How much – some notes and caveats

- **Petrol and diesel use includes off-road vehicles and recreational marine**
  - Informed by EECA report on off-road liquid fuels
  - Probably an over-estimate? (Speaker's opinion!)
  - EECA EEUD attributes 100% to "mobile motive power"
  - Some diesel will be heating – number unknown, likely small

How much – 2022

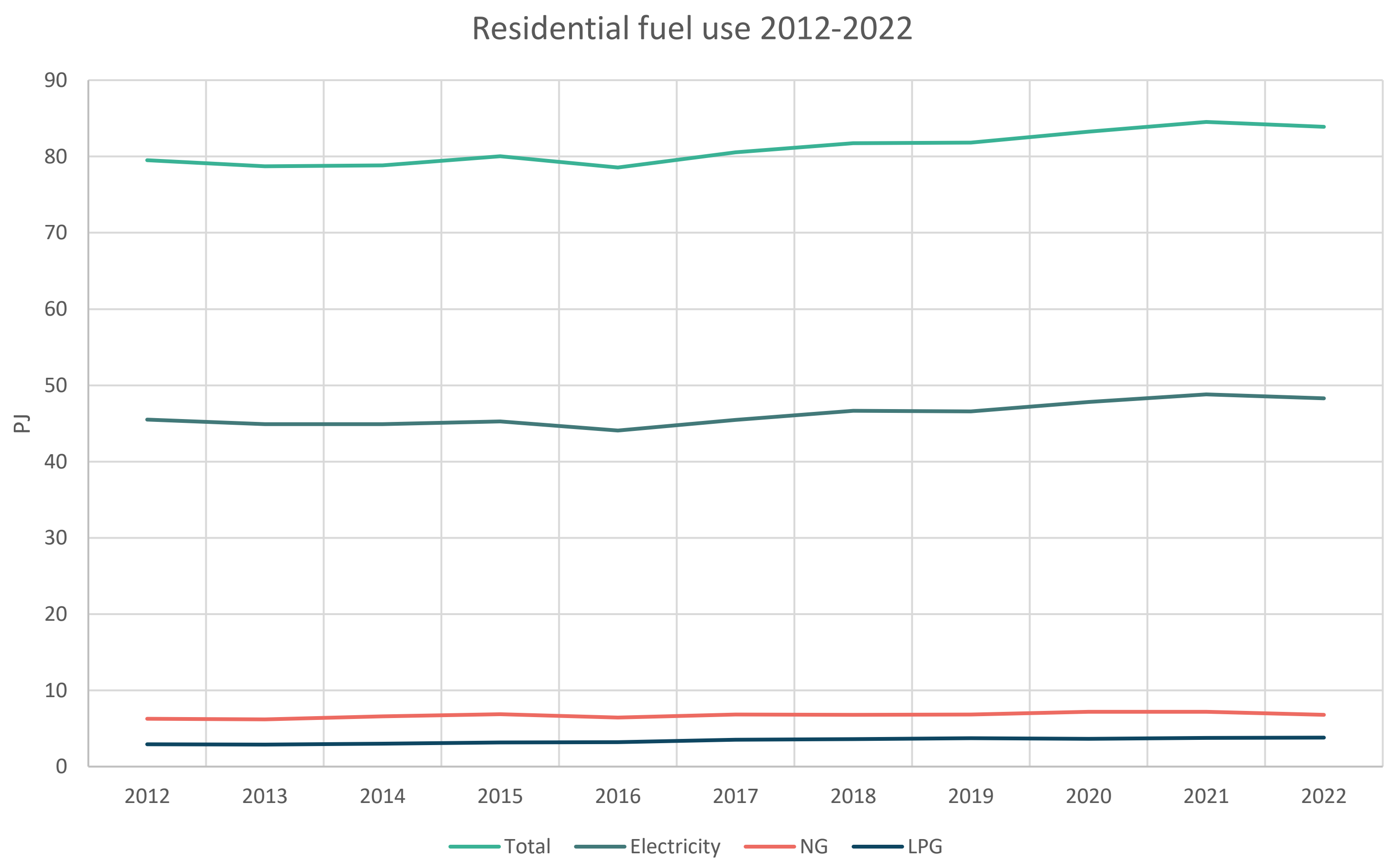
Fuel	**PJ**
Electricity	48.3
Wood	7.4
Natural gas	6.8
LPG	3.8
Solar	0.4
Geothermal	0.2
Coal	0.1
Total	**67.0**



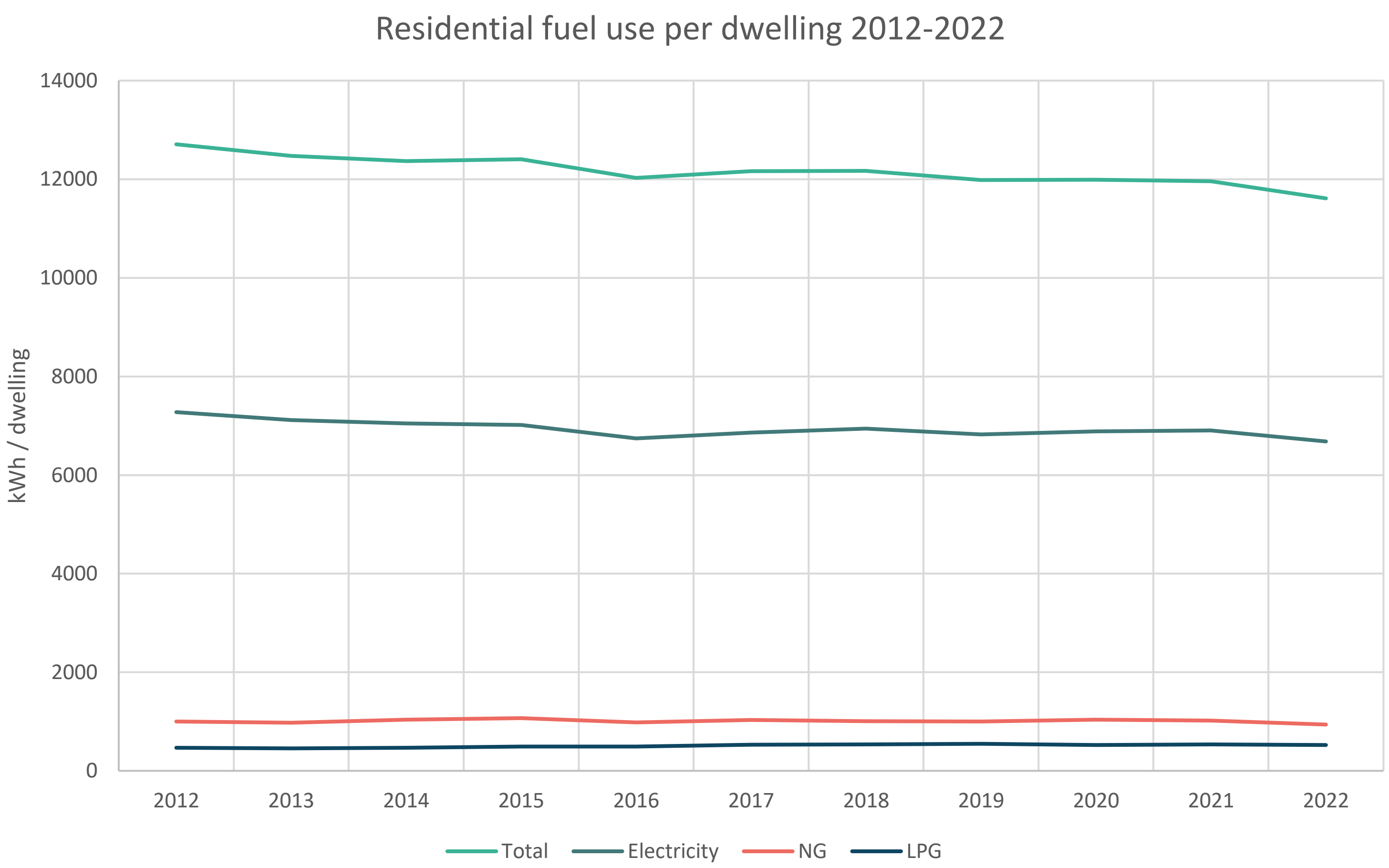
How much – 2022

Fuel	Residential [PJ]	Total [PJ]	Residential %
All	83.9	543.2	15%
All (ex. P & D for res)	67.0	543.2	12%
Electricity	48.3	141.9	34%
Natural gas	6.8	63.2	11%
LPG	3.8	9.6	40%

How much – Looking back
Residential total, electricity, NG, and LPG

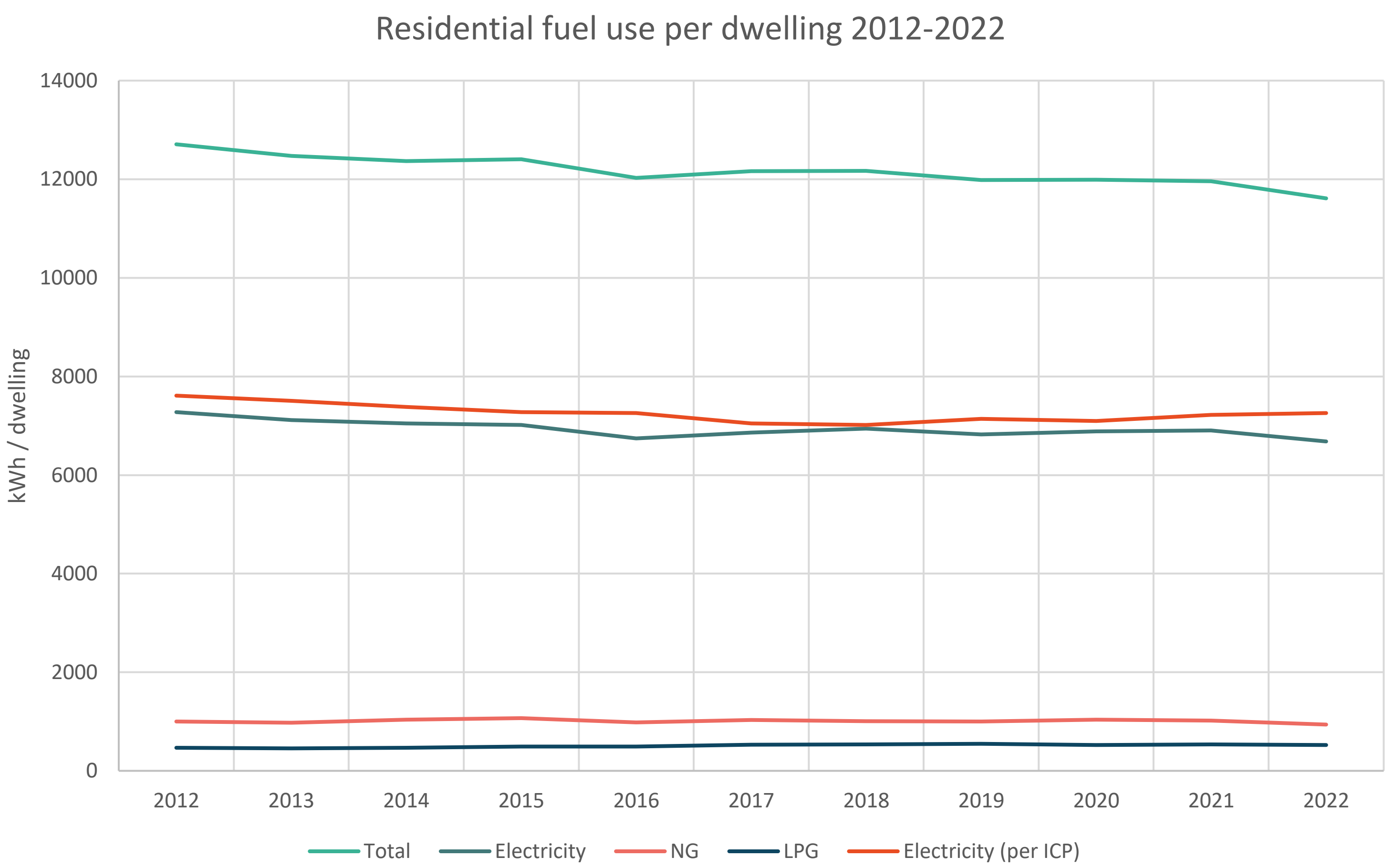


How much – Looking back
Residential total, electricity, NG, and LPG



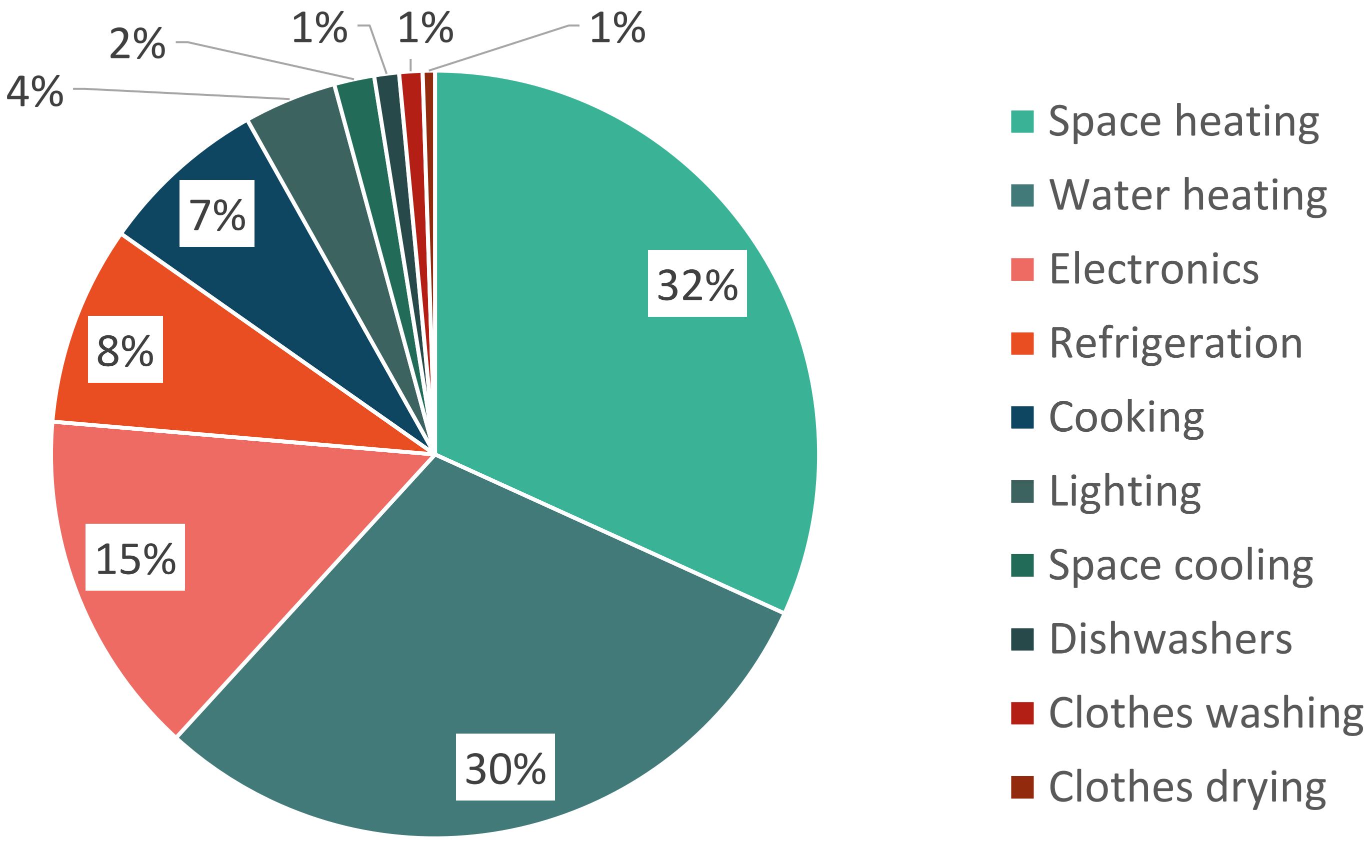
Data on private dwellings from [Stats NZ](#) / [Figure.NZ](#)

How much – Looking back
Residential total, electricity, NG, and LPG

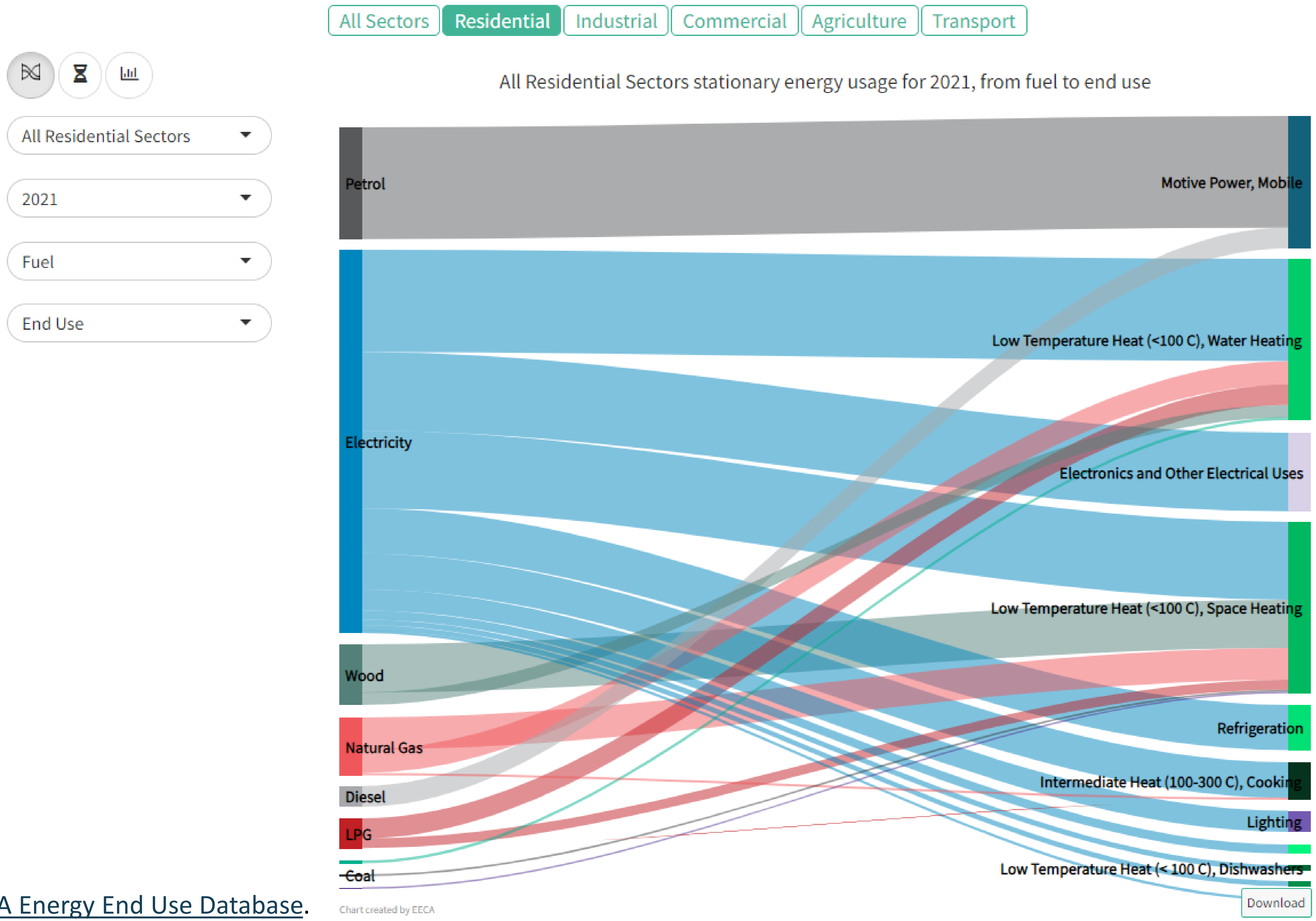


Data on electricity per ICP from MBIE / Figure.NZ

How much – End uses

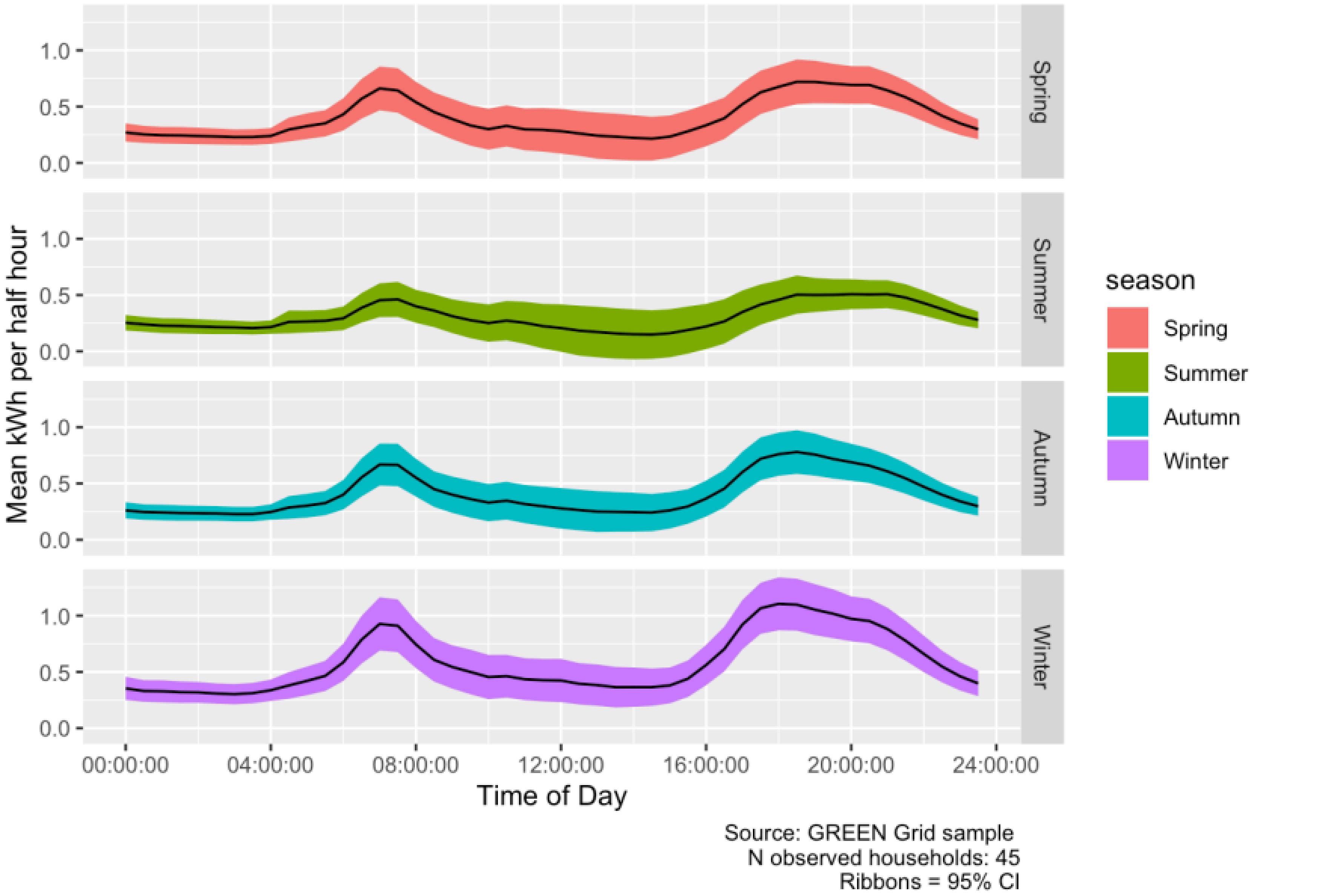


Data from EECA Energy End Use Database. Excludes “Mobile motive power”. “Water heating” includes hot water for clothes washing.



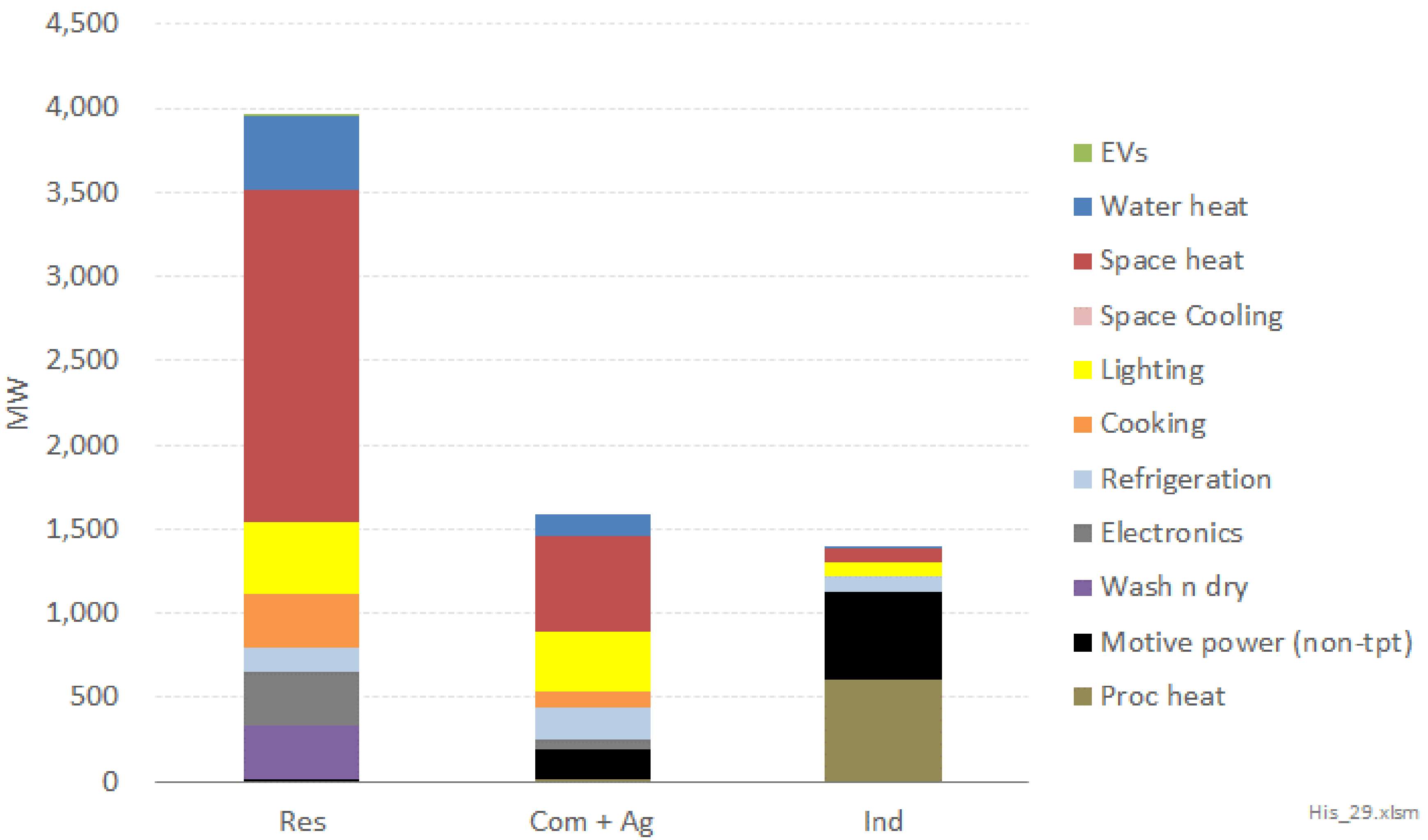
Data from EECA Energy End Use Database.

When



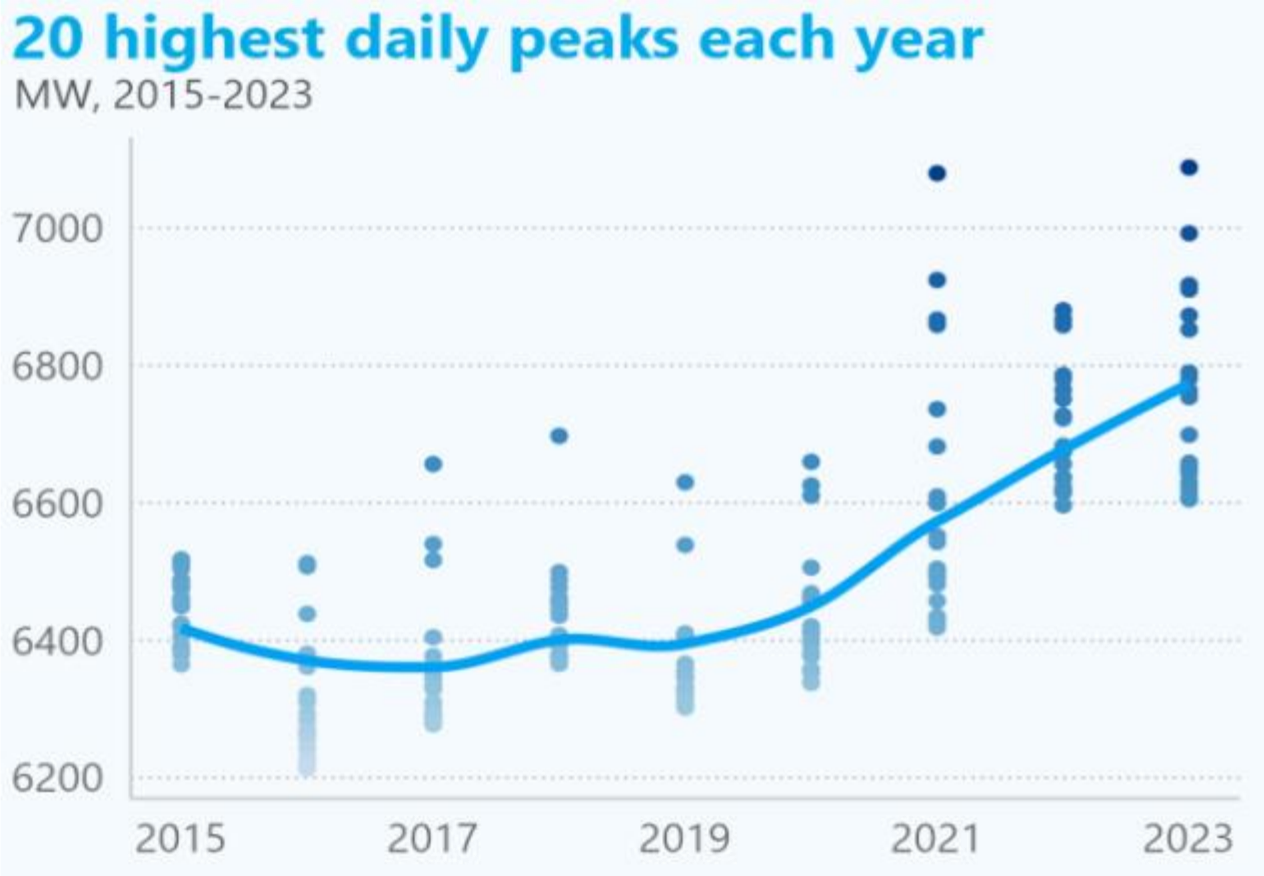
Source: [NZ GREEN Grid Household Electricity Demand Data]

When – Estimate of end use loads at peak



Source: eCubed/Concept Consulting/RDT deep retrofit study

When



“Peak electricity demand growth continues to raise concerns for potential capacity issues during peak demand periods. **Six of the highest peaks on record occurred in 2023**, with the maximum peak of 7122 MW on 2 August 2023 coming just 7 MW short of the record set on 9 August 2021.

“**Peak demand growth has risen 2% annually on average since 2021**, with another increase of 122 MW this winter. This rise in demand can be attributed to the growing electrification of **transport, process heat, and space heating**. It is also attributed to the removal of RCPD charges, with analysis published by the Electricity Authority confirming that this is associated with a 157 MW increase in average peaks – or 2.2% of national demand.”

Source: Transpower TMH Monitoring Report – October 2023

How much and when – In the future

- **Electrification**
- **Heat pumps**
- **Hot water cylinders**
- **EVs**
- **Solar and batteries**
- **Energy efficiency (of thermal envelope) – Part 2 of this talk**

Heat pumps

- Already (very) high penetration
  - 47% in 2018 census (Main types of heating used)
  - Over 1.1 million units sold in last 5 years (EECA data)
    - Note some will be used for commercial premises
    - Healthy Homes Standards (2021 onwards)
- Potential for demand management through pre-heating

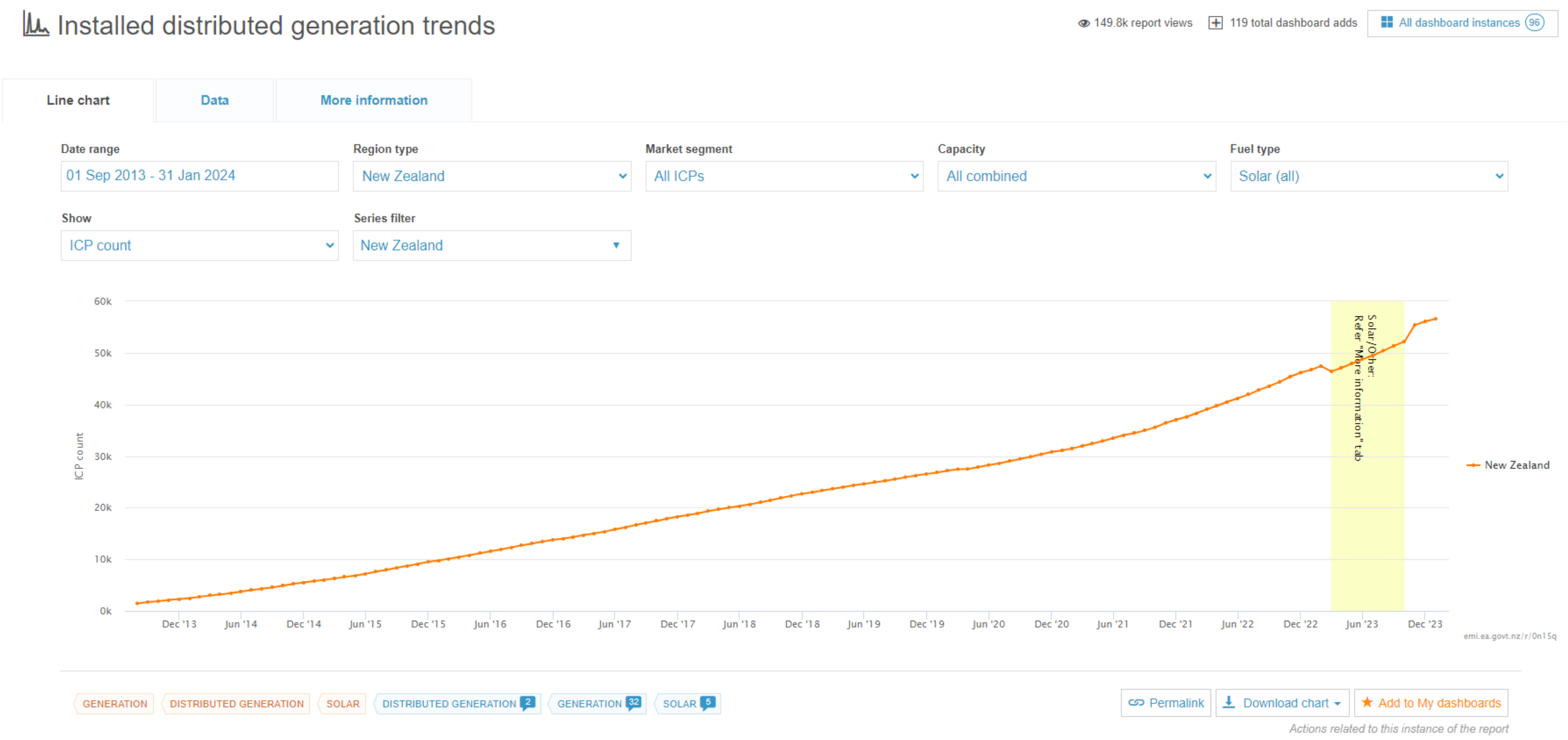
Hot water cylinders

- **Smart controls can anticipate usage and optimise temperatures**
- **Likely potential for greater demand response**
  - **Investigation into electricity supply interruptions of 9 August 2021**
  - **“Ripple (hot water) control and replacement technologies are envisaged as being at the heart of a transition to a richer demand side participation in the market over the next decade”**

EVs

- **Smart controls essential!**

Solar



Source: EA

Solar

- Costs continue to fall in real terms
  - (Flat-ish in nominal over last few years)
- Trend towards larger installations, and larger DC/AC ratio (all scales)
- $2.5/W for 4 kW, down to $2/W for 7 kW
- Cf. Genesis Lauriston (Canterbury) at $1.66/W for 62 MW

Batteries

- **TBC – Will leave to tomorrow’s speakers!**
- **Vehicle-to-grid represents huge opportunity to solve winter peaks for low (marginal) cost**

Part 2

Contents

Part 1

How much – Of different fuels, relative to national consumption

When – What's the pattern of time of use? How much does this matter?

Now – (And looking back)

In the future

Part 2

Insights from Warmer Kiwi Homes evaluation(s)

Insights on deep retrofit

Future work on life cycle carbon and energy

Insights from Warmer Kiwi Homes evaluation(s)

- **Q: What is Warmer Kiwi Homes?**
- **A: EECA's grant programme for insulation and heating**
  - **Targets low-income households (NZDep7-10 and CSC)**
  - **80-90% grant funding for insulation**
  - **80% grant funding for heating (capped at $3000)**
    - **Mostly heat pumps**
  - **Since 2009:**
    - **Around 400,000 insulation retrofits (~ ¼ of pre-2008 houses)**
    - **Around 75,000 heating retrofits**

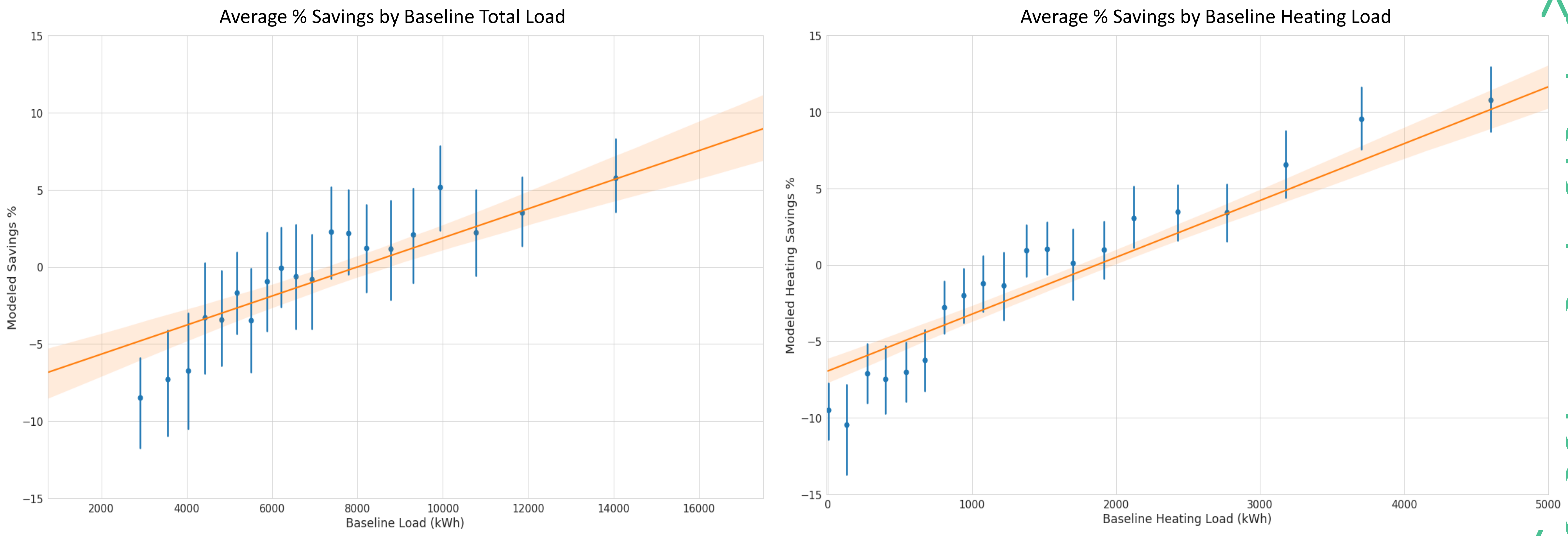
Insights from Warmer Kiwi Homes evaluation(s)

- **Smart meter data analysis by Vector**
- **Warmer Kiwi Homes Impact Evaluation: Phase 2: Warmer Kiwis Study by Motu**
- **... and more on EECA website**

Smart meter data analysis by Vector

- Some very clever analysis of 360,000 addresses in EECA database
- Matched to 2510 insulation jobs (and 492 heat pump jobs)
  - Vector Metering dataset + lots (and lots) of data cleaning!
- Key insights (on insulation):
  - Relatively low energy savings of 80-180 kWh (1-2%)
  - Saved more when cold (and at peak demand)
  - Saved more (%) if their electricity usage was higher before

Smart meter data analysis by Vector



Warmer Kiwis Study by Motu

- **Fieldwork study of impact of WKH heat pump retrofits – 164 households**
- **Key insights (on heat pumps):**
  - Households reported increases in warmth, comfort and satisfaction with their home, alongside a reduction in condensation and damp.
  - Living area temperatures increased, with the greatest gains when it was coldest outside, and at breakfast and dinner/evening time.
  - Household electricity use decreased at almost all times of day, and most significantly during the evening peak demand period.
  - **Overall electricity use decreased 16% over the winter months.**
  - Benefit cost ratios for the programme as a whole are **4.4** on a wellbeing and energy basis, and **1.9** on a health and energy basis.

Warmer Kiwis Study by Motu

Figure 4.3: Average temperature impact of heat pump by hour of day (*First winter*)

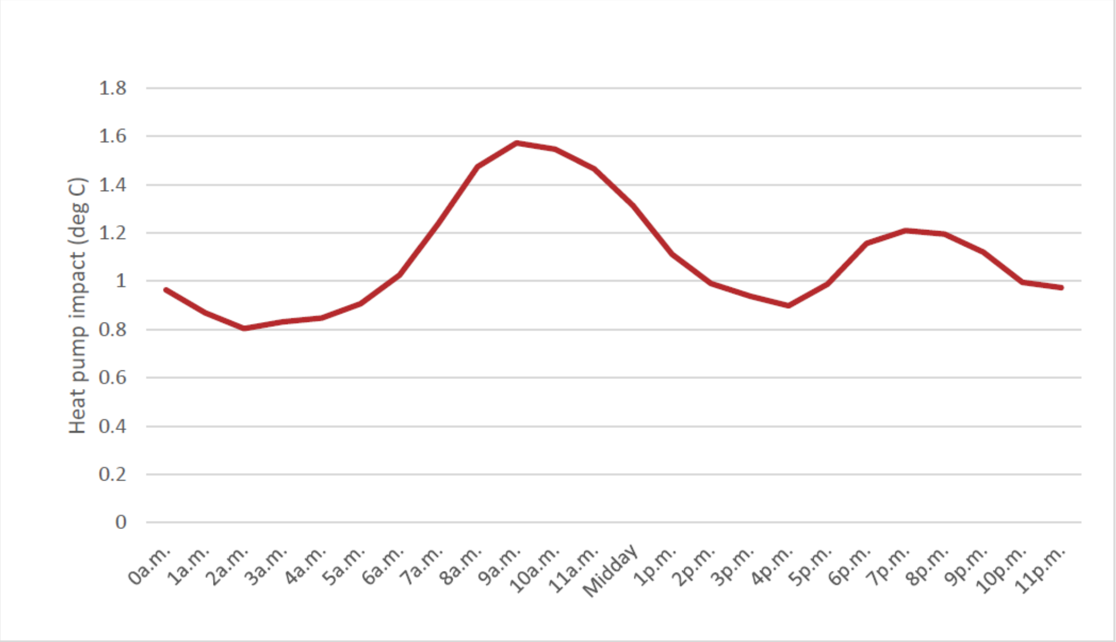
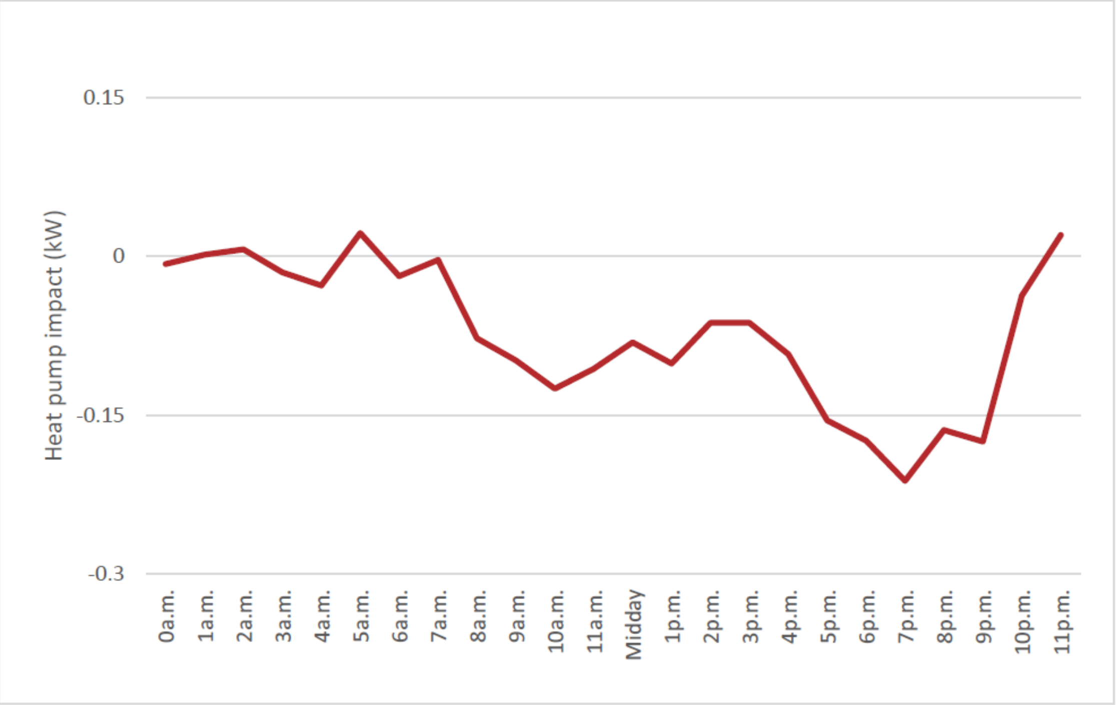


Figure 4.5: Electricity use impact of heat pump by hour of day (*First winter*)



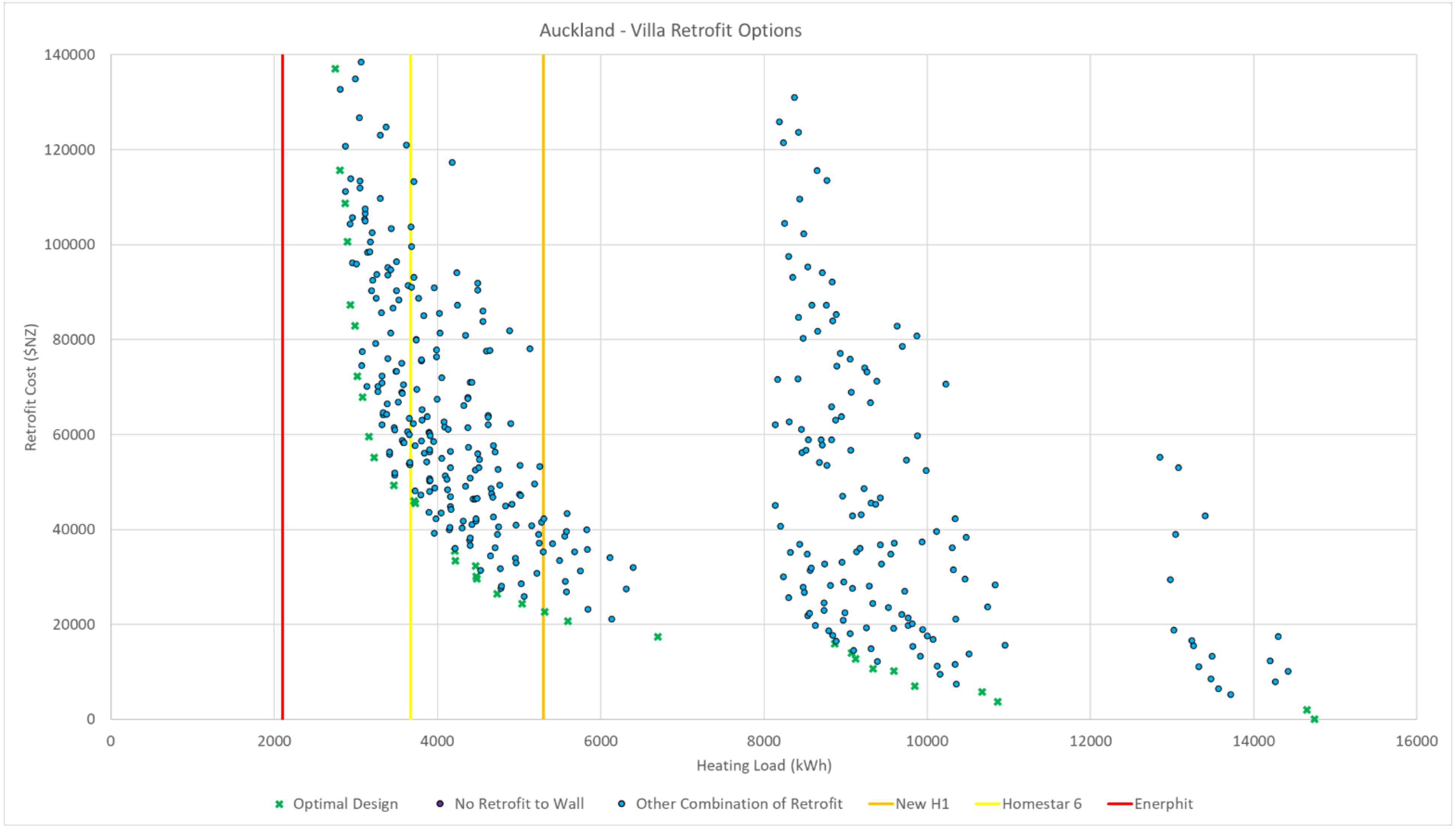
Insights on deep retrofit – Provisional subject to final QA

- Study commissioned by NZ Green Building Council and EECA
- Conducted by eCubed, Concept Consulting, and RDT
- Thermal modelling of 192 scenarios:
    - 4 typologies (specific buildings representing 4 eras)
    - 4 climates (Akl, Wgtn, ChCh, Qt)
    - 4 thermal envelope standards (baseline, H1, Homestar 6, EnerPhit)
    - 3 heating schedules
- Retrofit requirements determined by least-cost optimisation (additional to above 192)
- Full cost and carbon analysis

Insights on deep retrofit – 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 when determining retrofit requirements to H1, Homestar 6 and EnerPhit standards

Insights on deep retrofit - Optimisation



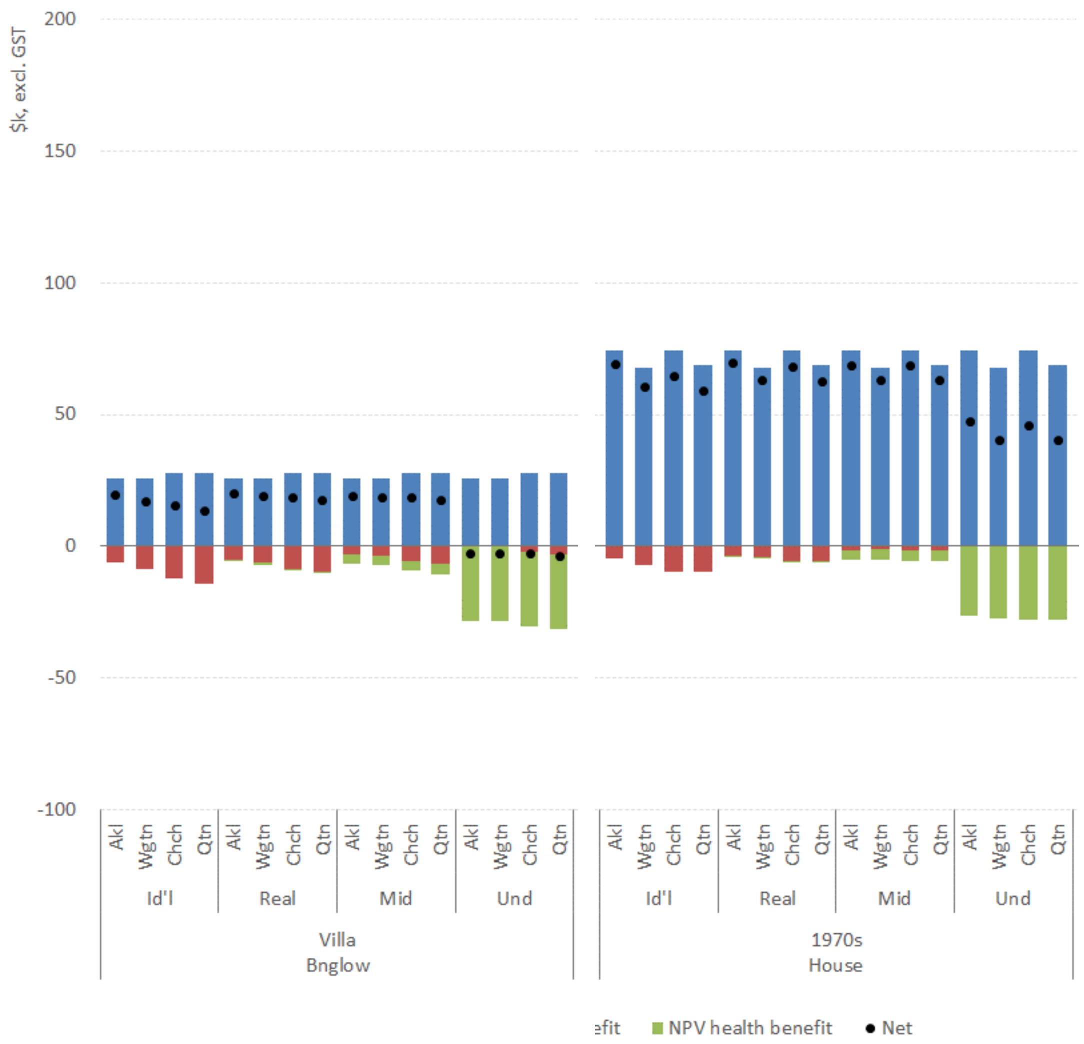
Insights on deep retrofit – Cost, carbon, and kWh

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**

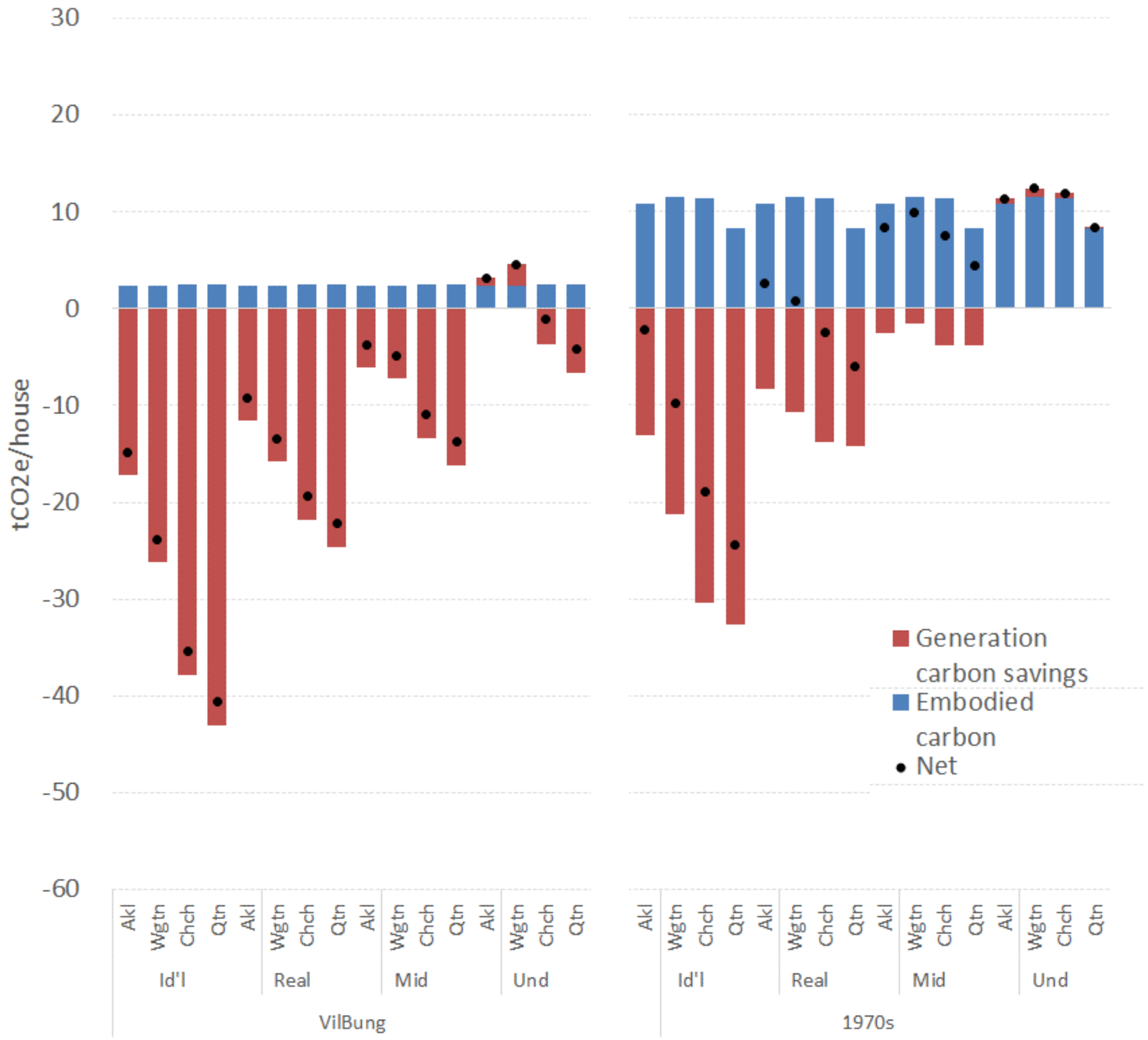
Insights on deep retrofit – Cost/benefit

- $ cost/saving for:
  - H1 retrofit standard
  - 4 climates
  - 4 heating schedules
  - 2 house typologies
- Note 'Mid-underheated' and 'underheated' assume takeback



Insights on deep retrofit – Carbon

- Carbon cost/saving for:
  - H1 retrofit standard
  - 4 climates
  - 4 heating schedules
  - 2 house typologies
- Note 'Mid-underheated' and 'underheated' assume takeback



Insights on deep retrofit – Time of use

- “An unexpected result is that, on average across New Zealand houses, the idealistic heating schedule has almost exactly the same space-heating-driven electricity supply costs as the realistic schedule, despite resulting in almost 40% more electricity consumption.”

- Reminder: Idealistic was realistic + bedrooms 16 °C overnight

Future work on life cycle carbon and energy

- **Heat pumps + less grid or …**
- **… resistance heaters + more grid**

- **Example in a nutshell is**
  - **Solar panels + hot water heat pump**
  - **More solar panels + resistance heater (element)**

Conclusions

- Is the residential sector a 'big player' in NZ's energy system?
  - Not 'huge' in overall PJs …
  - … but largest driver of peak electricity demand
  - … and generally lots of infrastructure with low(ish) capacity factor

- What can we do about it?
  - 'Shallow' retrofit cost-effective – Job mostly done?
  - Deep retrofit has big price range
    - Will likely be driven by general renovation cycle?
    - Can have net lifetime carbon cost depending on products