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# Examining the Factors affecting Household Energy Expenditures

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# Disclaimer

- Access to the data used in this study was provided by Stats NZ under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the authors, not Stats NZ or individual data suppliers.
- These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI) which is carefully managed by Stats NZ. For more information about the IDI please visit <https://www.stats.govt.nz/integrated-data/>.



# Background

- Interest in defining energy hardship
- Need better understanding of heating needs
  - What factors affect energy expenditures?
  - How much do expenditures vary seasonally? Can this be used to estimate heating costs?
  - Which household characteristics are associated with higher household energy expenditures?
  - Can we estimate “pent-up” demand?
- Work in progress



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# Lit Review – Building & Environmental Sciences

- Dwelling characteristics affect energy consumption
  - Dwelling size
  - Detached
  - Climate
  - Energy efficiency (appliances, insulation, design)
- Household characteristics
  - Income
  - Household size & composition
  - Housing tenure
  - Behaviours/energy literacy

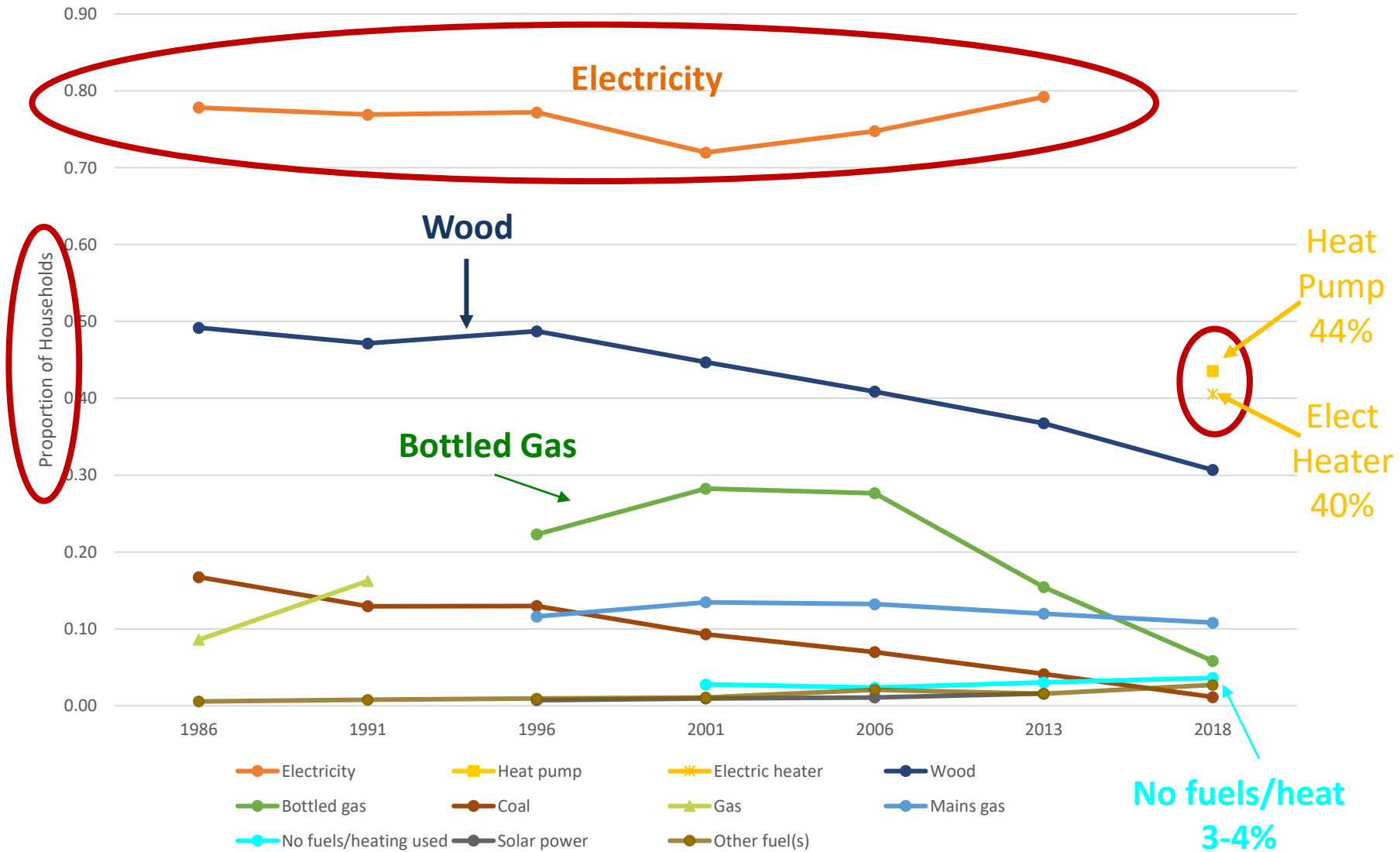


# Lit Review – Energy Hardship/Poverty/Health

- Energy poverty defined as inadequate levels of essential energy services in the home
  - Related to household factors like low income but also to energy inefficiency, energy supply, and cost
  - Capital expenditures required to improve energy efficiency
  - Increased income may be insufficient to reduce energy poverty if HH unable to improve efficiency (e.g., costs, renting)
  - Riva et al. 2021
- Energy poverty measures originally based on heating/energy **requirements** and not on actual expenditure
  - Grimes et al. (2011) find that HH used energy savings from insulation/heating improvements to increase temperatures
- Inadequate heating leads to cold/damp/mould which have been associated with health problems



# Heating Types 1986-2018



Source: Stats NZ Publicly Available Census Data (multiple types)

# Heating Type by Tenure, 2018



Source: Stats NZ, Census 2018 (publicly available)

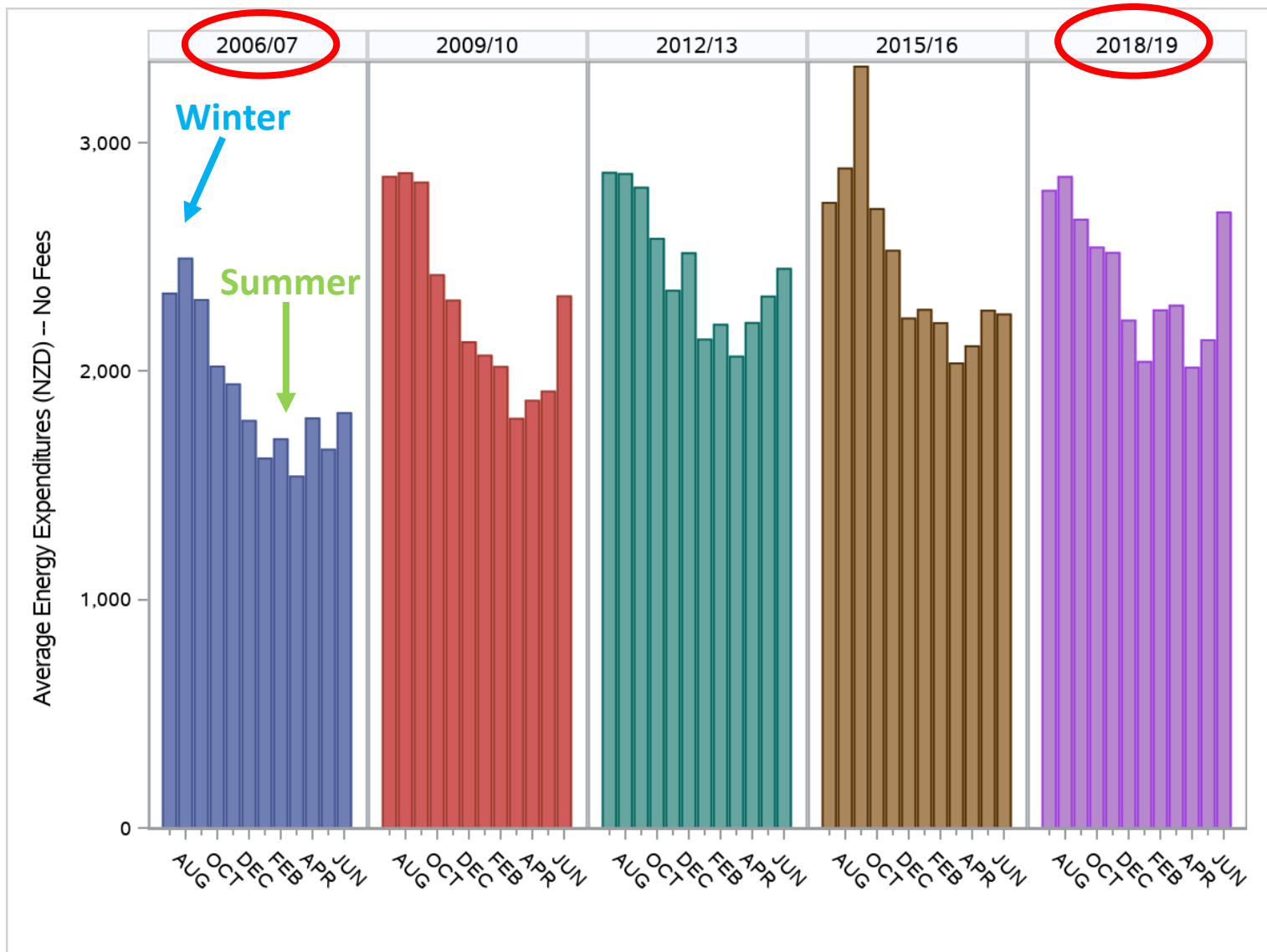
# Data for Main Analysis

- Use IDI HES Expenditure data (every 3 years)
  - 5 survey years (2006/07-2018/19)
  - July to June
  - “Power” Module -- household fuel expenditures **based on last bill** but annualised
    - electricity
    - mains gas
    - bottled (LPG) gas
    - home-heating oil
    - firewood
    - coal
    - other types of domestic fuels
  - Exclude 3% reporting no associated HH energy expenditures





# Average Annual Energy Expenditures by Interview Month



# Methodology

- Regression analysis

$$Y_i = \beta_0 + T' \beta_1 + D' \beta_2 + X' \beta_1 + \varepsilon_i$$

- $Y_i$  is **total energy expenditure** for  $i^{\text{th}}$  household
- $T$  is interview **time** characteristics
  - Interview year
  - Interview month
- $D$  is **dwelling** characteristics
  - Stand-alone home
  - Number of rooms
  - Auckland region
- $X$  is **household** characteristics
  - Housing tenure
  - Income
  - Housing costs

# Weighted Sample Sizes (HH)

<b><i>HES Year</i></b>	<b>All Months</b>	<b>Cold Months (June to Nov)</b>	<b>Low Income (Bottom 60%)</b>	<b>Dwelling ≤ 8 Rooms</b>
<b>2006/07</b>	1,467,000	749,000	846,000	1,308,000
<b>2009/10</b>	1,516,000	779,000	899,000	1,355,000
<b>2012/13</b>	1,552,000	783,000	886,000	1,393,000
<b>2015/16</b>	1,585,000	795,000	857,000	1,394,000
<b>2018/19</b>	1,580,000	723,000	946,000	1,408,000

# Sample Summary Statistics

<b>Summary Statistics</b>	<b>All Months</b>	<b>Cold Months</b>	<b>Low Income</b>	<b>Rooms ≤ 8</b>
<b><i>Dwelling Characteristics</i></b>				
Stand-alone Home	0.838	0.839	0.785	0.821
Public Rental	0.071	0.069	0.102	0.077
Private Rental	0.240	0.238	0.279	0.260
Owned	0.685	0.690	0.615	0.659
<b><i>Regions</i></b>				
Auckland/Northland Region	0.305	0.286	0.263	0.300
<b><i>Expenditure and Income</i></b>				
Electricity	1,958	2,169	1,757	1,894
Total Energy	2,328	2,589	2,026	2,230
Total Energy (No Fees)	2,314	2,573	2,012	2,217
Housing Costs	11,703	11,628	8,904	11,446
Total HH Expenditure	61,216	61,181	41,379	57,188
Total HH Income	65,259	65,101	37,943	61,536
<b><i>N</i></b>	<b>7,700,000</b>	<b>3,829,000</b>	<b>4,434,000</b>	<b>6,858,000</b>

# Rooms in Dwelling



# Results: Year Effects

Dependent Variable: Total HH Energy Expenditures (No Fees)	All Months	Cold Months	Low Income	Small Homes	Cold months, Small Homes	Small Homes, Low Income	
	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	
Survey Year*	2006/07	<b>-328.06</b>	<b>-337.68</b>	<b>-341.6</b>	<b>-308.16</b>	<b>-315.31</b>	<b>-320.24</b>
		(-10.43)	(-6.64)	(-9.46)	(-9.87)	(-6.27)	(-8.87)
	2009/10	2.72	67.17	<b>-73.59</b>	-7.38	46.02	-54.74
		(0.09)	(1.36)	(-2.10)	(-0.24)	(0.94)	(-1.57)
	2012/13	54.05	27.53	-43.35	56.67	51.33	-13.9
		(1.75)	(0.55)	(-1.23)	(1.85)	(1.03)	(-0.39)
	2015/16	50.28	37.67	12.67	52.48	36.67	23.16
		(1.69)	(0.79)	(0.37)	(1.77)	(0.78)	(0.68)

\*Results relative to 2018/19

# Results: Month Effects

Dependent Variable: <b>Annual Energy Expenditures (No Fees)</b>		All Months	Cold Months	Low Income	Small Homes	Cold months, Small Homes	Small Homes, Low Income
		$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)
Interview Month	January	<b>-134</b> (-2.66)		-37.99 (-0.66)	<b>-110.2</b> (-2.19)		-42.06 (-0.73)
	February	<b>-99.5</b> (-1.99)		-44.67 (-0.78)	-96.89 (-1.94)		-65.28 (-1.14)
	March	<b>-167.64</b> (-3.32)		-68.16 (-1.19)	<b>-160.36</b> (-3.19)		-74.87 (-1.31)
	April	<b>-196.71</b> (-4.00)		-83.78 (-1.51)	<b>-212.67</b> (-4.33)		<b>-111.93</b> (-2.01)
	May	-75.36 (-1.57)		-7.19 (-0.13)	-75.45 (-1.58)		-19.54 (-0.36)
	June	<b>169.85</b> (3.45)	-77.67 (-1.49)	<b>193.16</b> (3.48)	<b>160.12</b> (3.27)	-36.93 (-0.72)	<b>146.84</b> (2.65)
	July	<b>558.19</b> (11.03)	<b>311.92</b> (5.79)	<b>412.8</b> (7.26)	<b>536.24</b> (10.60)	<b>342.62</b> (6.44)	<b>407.56</b> (7.15)
	August	<b>605.93</b> (11.83)	<b>356.64</b> (6.53)	<b>615.7</b> (10.59)	<b>573.05</b> (11.17)	<b>374.16</b> (6.93)	<b>558.98</b> (9.56)
	September	<b>606.85</b> (12.19)	<b>369.79</b> (6.98)	<b>533.84</b> (9.48)	<b>562.9</b> (11.35)	<b>375.28</b> (7.21)	<b>503.28</b> (8.94)
	October	<b>356.25</b> (6.92)	<b>115.21</b> (2.10)	<b>300.87</b> (5.20)	<b>335.15</b> (6.55)	<b>142.23</b> (2.64)	<b>285.18</b> (4.94)
	November	<b>238.42</b> (4.83)	omitted	<b>252.84</b> (4.52)	<b>190.48</b> (3.89)	omitted	<b>212.49</b> (3.82)

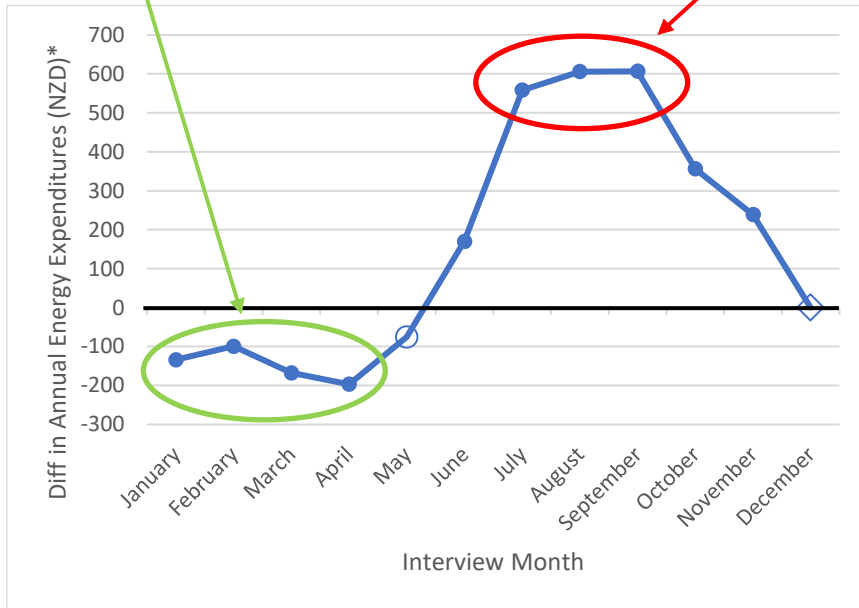
\*Results relative to December except for Cold Months sample (November)

# Monthly Regression Coefficients

~\$100-200 less annually than December interviewees

All Months

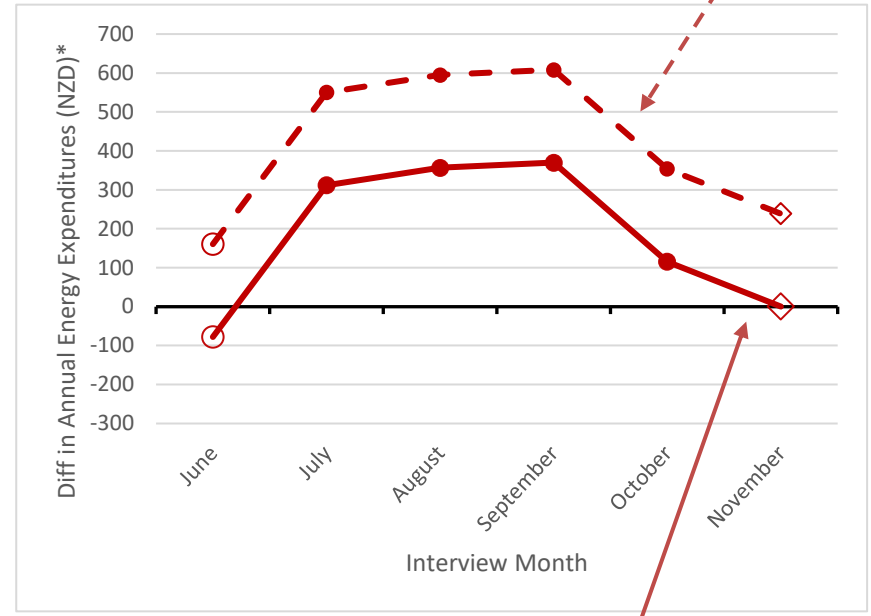
~\$600 more annually than December interviewees



\*Relative to December

\*Relative to December

Cold Months



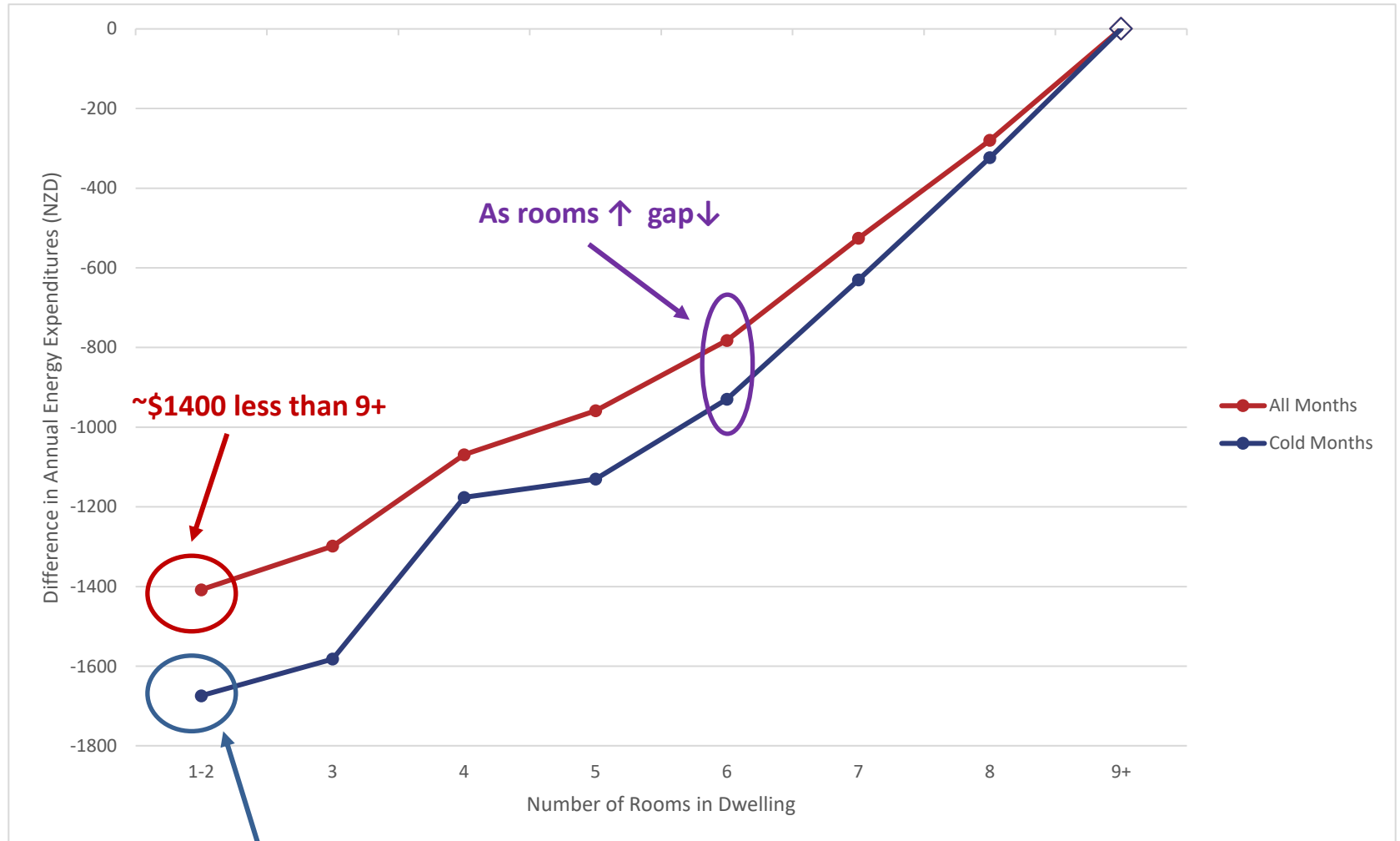
\*Relative to November



# Results: Dwelling and HH

Dependent Variable: Annual Energy Expenditures (No Fees)		All Months	Cold Months	Low Income	Small Homes	Small Homes, Cold Months	Small Homes, Low Income
		$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)
Number of Rooms	1-2	<b>-1408.27</b> (-9.59)	<b>-1674.13</b> (-6.93)	<b>-1327.4</b> (-9.64)	<b>-1172.89</b> (-8.48)	<b>-1394.67</b> (-6.17)	<b>-1094.57</b> (-8.34)
	3	<b>-1298.54</b> (-17.27)	<b>-1582.08</b> (-12.88)	<b>-1215.05</b> (-14.88)	<b>-1055.36</b> (-15.06)	<b>-1286.67</b> (-11.40)	<b>-983.55</b> (-13.19)
	4	<b>-1068.84</b> (-20.24)	<b>-1176.12</b> (-13.77)	<b>-928.37</b> (-14.55)	<b>-819.99</b> (-16.92)	<b>-881.38</b> (-11.48)	<b>-694.79</b> (-12.46)
	5	<b>-958.81</b> (-22.80)	<b>-1130.21</b> (-16.74)	<b>-794.84</b> (-14.16)	<b>-702.27</b> (-18.52)	<b>-825.94</b> (-13.94)	<b>-557.56</b> (-11.81)
	6	<b>-782.13</b> (-21.15)	<b>-929.4</b> (-15.54)	<b>-631.63</b> (-11.86)	<b>-515.66</b> (-15.64)	<b>-617.64</b> (-11.95)	<b>-391.55</b> (-8.91)
	7	<b>-525.61</b> (-13.53)	<b>-630.16</b> (-10.07)	<b>-410.74</b> (-7.27)	<b>-252.05</b> (-7.20)	<b>-312.08</b> (-5.70)	<b>-169.31</b> (-3.55)
	8	<b>-279.8</b> (-6.49)	<b>-323.31</b> (-4.69)	<b>-243.25</b> (-3.82)	<i>omitted</i>	<i>omitted</i>	<i>omitted</i>
	9+	<i>omitted</i>	<i>omitted</i>	<i>omitted</i>			
	Dwelling Characteristics	Stand-alone Home	<b>235.22</b> (7.52)	<b>193.62</b> (3.86)	<b>255.66</b> (7.84)	<b>232.55</b> (7.77)	<b>190.07</b> (4.00)
Public Rental		<b>196.14</b> (4.80)	<b>141.87</b> (2.17)	<b>215.7</b> (5.38)	<b>196.19</b> (5.00)	<b>137.4</b> (2.20)	<b>221.48</b> (5.64)
Private Rental		13.97 (0.55)	-8.06 (-0.20)	<b>95.84</b> (3.46)	31.25 (1.28)	7.87 (0.20)	<b>107.59</b> (3.94)
Auckland Region		<b>-229.69</b> (-9.87)	<b>-318.94</b> (-8.49)	<b>-173.11</b> (-6.18)	<b>-229.01</b> (-9.81)	<b>-331.49</b> (-8.85)	<b>-179.47</b> (-6.39)
HH Income (log)		<b>342.24</b> (26.60)	<b>428.69</b> (20.87)	<b>176.86</b> (9.80)	<b>315.38</b> (24.44)	<b>405.3</b> (19.87)	<b>170.59</b> (9.45)
N		7,700,000	3,829,000	4,434,000	6,858,000	3,414,000	4,115,000
Adj R <sup>2</sup>		0.2164	0.2023	0.1527	0.1964	0.183	0.1432

# Room Coefficients – All vs. Cold Months



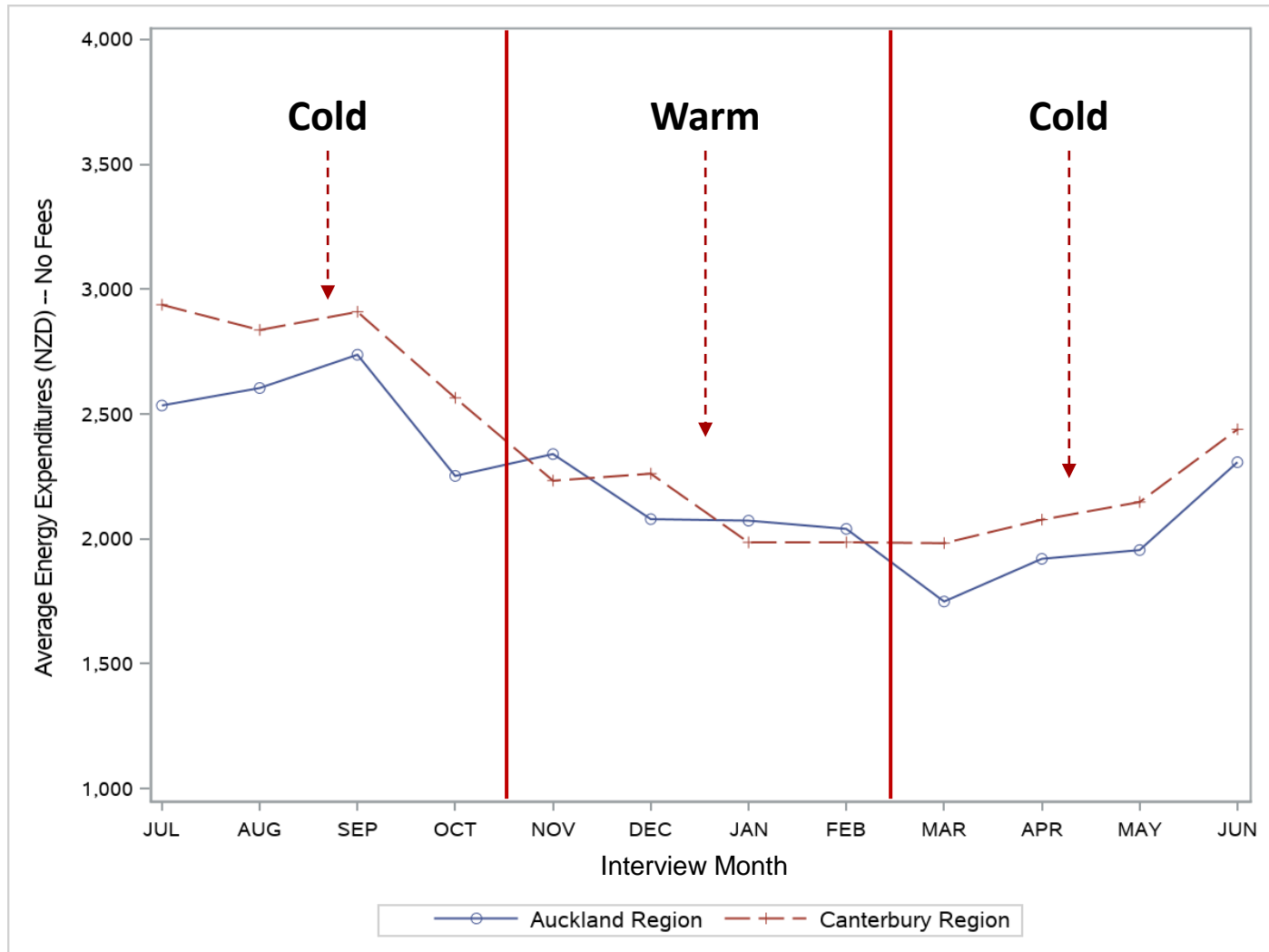
# Results: Dwelling and HH

Dependent Variable: Annual Energy Expenditures (No Fees)		All Months	Cold Months	Low Income	Small Homes	Cold months, Small Homes	Small Homes, Low Income
		$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)	$\beta$ (t-value)
Number of Rooms	1-2	-1408.27 (-9.59)	-1674.13 (-6.93)	-1327.4 (-9.64)	-1172.89 (-8.48)	-1394.67 (-6.17)	-1094.57 (-8.34)
	3	-1298.54 (-17.27)	-1582.08 (-12.88)	-1215.05 (-14.88)	-1055.36 (-15.06)	-1286.67 (-11.40)	-983.55 (-13.19)
	4	-1068.84 (-20.24)	-1176.12 (-13.77)	-928.37 (-14.55)	-819.99 (-16.92)	-881.38 (-11.48)	-694.79 (-12.46)
	5	-958.81 (-22.80)	-1130.21 (-16.74)	-794.84 (-14.16)	-702.27 (-18.52)	-825.94 (-13.94)	-557.56 (-11.81)
	6	-782.13 (-21.15)	-929.4 (-15.54)	-631.63 (-11.86)	-515.66 (-15.64)	-617.64 (-11.95)	-391.55 (-8.91)
	7	-525.61 (-13.53)	-630.16 (-10.07)	-410.74 (-7.27)	-252.05 (-7.20)	-312.08 (-5.70)	-169.31 (-3.55)
	8	-279.8 (-6.49)	-323.31 (-4.69)	-243.25 (-3.82)	omitted	omitted	omitted
	9+	omitted	omitted	omitted			
	Dwelling Characteristics	Stand-alone Home	235.22 (7.52)	193.62 (3.86)	255.66 (7.84)	232.55 (7.77)	190.07 (4.00)
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HH Income (log)		342.24 (26.60)	428.69 (20.87)	176.86 (9.80)	315.38 (24.44)	405.3 (19.87)	170.59 (9.45)
N		7,700,000	3,829,000	4,434,000	6,858,000	3,414,000	4,115,000
Adj R <sup>2</sup>		0.2164	0.2023	0.1527	0.1964	0.183	0.1432

# Key Results

- Survey design allows us to measure seasonality of energy expenditures
- Energy expenditures follow laws of physics
  - Stand-alone homes cost more than attached homes
  - Smaller homes cost less in general, but especially true in colder months
  - Homes in warmer regions spend less, primarily in colder months

# Average Annual Energy Expenditures Auckland vs. Canterbury



# Key Results – Income

- Energy expenditures increase with income
  - More so in colder months
  - Low-income sample showed differences
    - Coefficient on HH income about  $\frac{1}{2}$  the size of the coefficient in the all-months sample
    - No significant difference in spending in warmer months (Dec-May)

# Key Results – Rentals

- Private rentals
  - Energy expenditures not significantly different from owner-occupied dwellings
  - Exception: low-income samples
- Public rentals
  - Coefficient positive and significant for all samples compared to owner-occupied dwellings

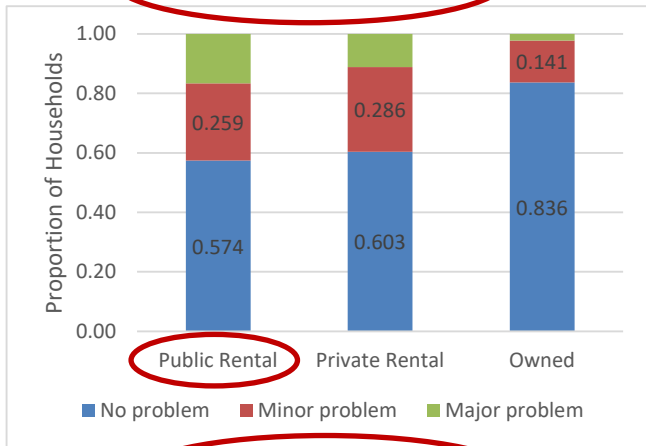
# Discussion – Public Rentals

- Potential reasons
  - Owner-occupiers may practice different energy-saving behaviours
    - Financial literacy and energy literacy literature evidence is limited
  - Lower housing costs allow for more income allocated to energy (all else equal)
    - Adding housing costs to the regression does not change the results
  - Dwellings less energy efficient
    - No measures of energy efficiency of dwelling
    - Self-reported quality of dwelling

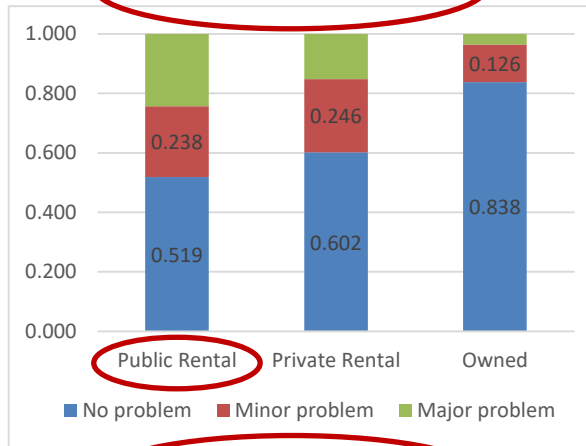


# Public Rentals Report More Housing-Related Issues

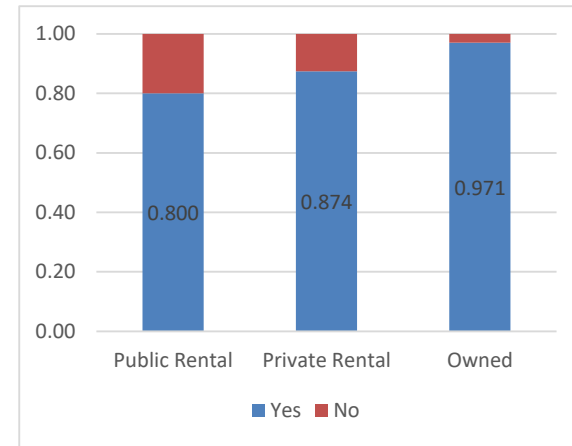
(a) Problem with Damp or Mould



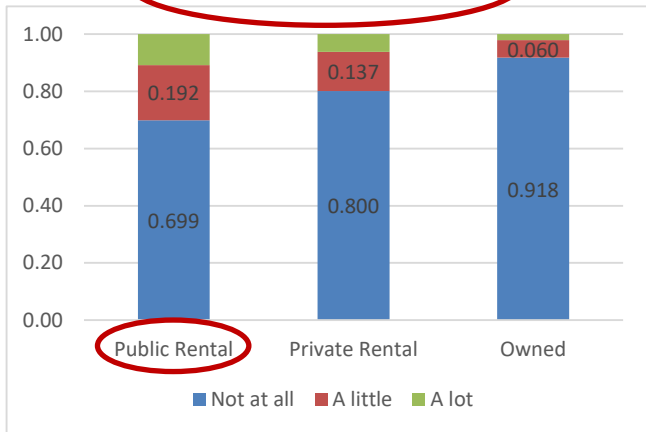
(b) Problem Keeping House Warm



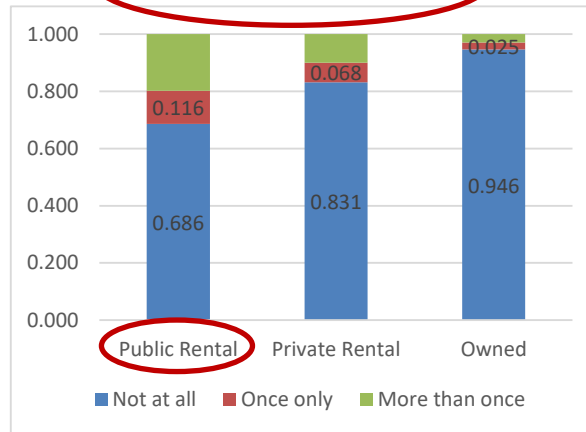
(c) Afford to Keep Accommodation Warm



(d) Feel Cold to Keep Costs Down



(e) Unable to Pay Utility Bill



# Concluding Discussion

- Energy hardship measures should account for seasonal and regional differences (at minimum)
  - Energy expenditures for HHs interviewed in summer are underestimated
  - Relative (distribution-based) measures will be particularly problematic w/no adjustment
- Measures should also distinguish actual vs. required expenditures

**THE END**