Warmer Kiwis Study: Final report

An impact evaluation of the Warmer Kiwi Homes programme

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EECA
TE TARI TIAKI PŪNGAO
ENERGY EFFICIENCY & CONSERVATION AUTHORITY

Warmer Kiwi Homes.

Motu economic & public policy research

Background

PHASE 1: Desk based review (2020)

Objectives:

- Benefit: Cost Ratio for Warmer Kiwi Homes estimated from similar programmes conducted in NZ and internationally.
- Summary of evidence gaps and outline of opportunities to use an evaluation of WKH to address these.

PHASE 2: Primary data collection from Warmer Kiwi Homes heat pump subsidy recipients (2021/22).

Objectives:

- Measure impacts on health and wellbeing, indoor environment, and change in electricity use.
- Accurate Benefit: Cost ratio for Warmer Kiwi Homes

Interim Report (December 2021)

- Initial findings from monitoring of 127 homes in the first winter after having a heat pump installed.
- Covers the monitoring period June-Sept. 2021.

Final Report (November 2022)

- Complete technical assessment of the effects of having a heat pump on a larger sample of homes over two winters.
- Cost benefit analysis of Warmer Kiwi Homes Programme.
- Covers the monitoring period June 2021 - Sept. 2022.

Study design

- Cohort study of 164 households that applied for a heat pump through Warmer Kiwi Homes (WKH) programme
- WKH eligibility: Homeowner in decile 8-10 area or with CSC
- Recruitment began April 2021; monitoring conducted over June 2021– Sep 2022 in Auckland, Waikato, Wellington, Christchurch

- **Cohort 2021** (Collected data starting June 2021; finishing Sep 2021)
  - N = 127
  - Collected from all four regions
  - 1 x winter
- **Cohort 2021 extension** (Collected data starting June 2021; finishing Sep 2022)
  - N = 85/127
  - Collected from all four regions
  - 2 x winters
  - 1 x summer
- **Cohort 2022** (Collected data starting June 2022; finishing Sep 2022)
  - N = 37
  - Collected from Wellington
  - 1 x winter

Study components

Data	2021 Cohort	2021 Cohort (ext)	2022 Cohort
IAQ monitor (Indoor)	✓	✓	✓
CliFlo (Weather)	✓	✓	✓
Electricity	✓	✓	✓
Survey 1 (before)	✓	✓	✓
Survey 2 (after)	✓	✓	✓
Survey 3 (subsequent)	✗	✓	✗
Efergy	✗	✗	✓

Sample

- 164 households (437 people) were recruited across the three clusters
  - 56 households (34%) in Climate Zone 1 (Auckland)
  - 82 households (50%) in Climate Zone 2 (Waikato and Wellington)
  - 26 households (16%) in Climate Zone 3 (Christchurch)

- 2021 recruitment suspended due to the community spread of COVID19 Delta variant
- Supply chain issues meant not all 2021 cohort households had heat pump installed by Sep 2021

Descriptive statistics (before survey, all cohorts)

Socio-demographic characteristic	N	Percentage of each variable
Pre-school (<5 years)	23	5.3
School age (5-17 years)	62	14.2
Adult (18-64 years)	246	56.3
Older adult (>65 years)	80	18.3
New Zealand European	173	39.6
Māori	73	16.7
Pacific peoples	65	14.8
Asian	120	27.5
Middle Eastern	2	0.5
Female	209	47.8
Gender neutral	5	1.1
Male	223	51.0

Descriptive statistics (before survey, all cohorts)

Socio-demographic characteristic	N	Percentage of each variable
Homemaker	14	3.2
Unable to work (medical)	8	1.8
Seeking work	14	3.2
Pre-schooler	23	5.3
Student	96	22.0
Working	197	45.1
Retired	81	18.5
Auckland	151	34.6
Waikato	22	5.0
Wellington	204	46.7
Christchurch	60	13.7

Results

Wellbeing transitions

After vs Before Surveys (DiD)

	Worsened	Constant	Improved
Life satisfaction	**26**	24	**40**
Cheerfulness	**18**	38	**30**
Self-reported health	**17**	53	**21**
Perceived cold	**4**	12	**76**

Each cell shows difference in number of responses between houses with heat pump fitted vs houses with no heat pump fitted

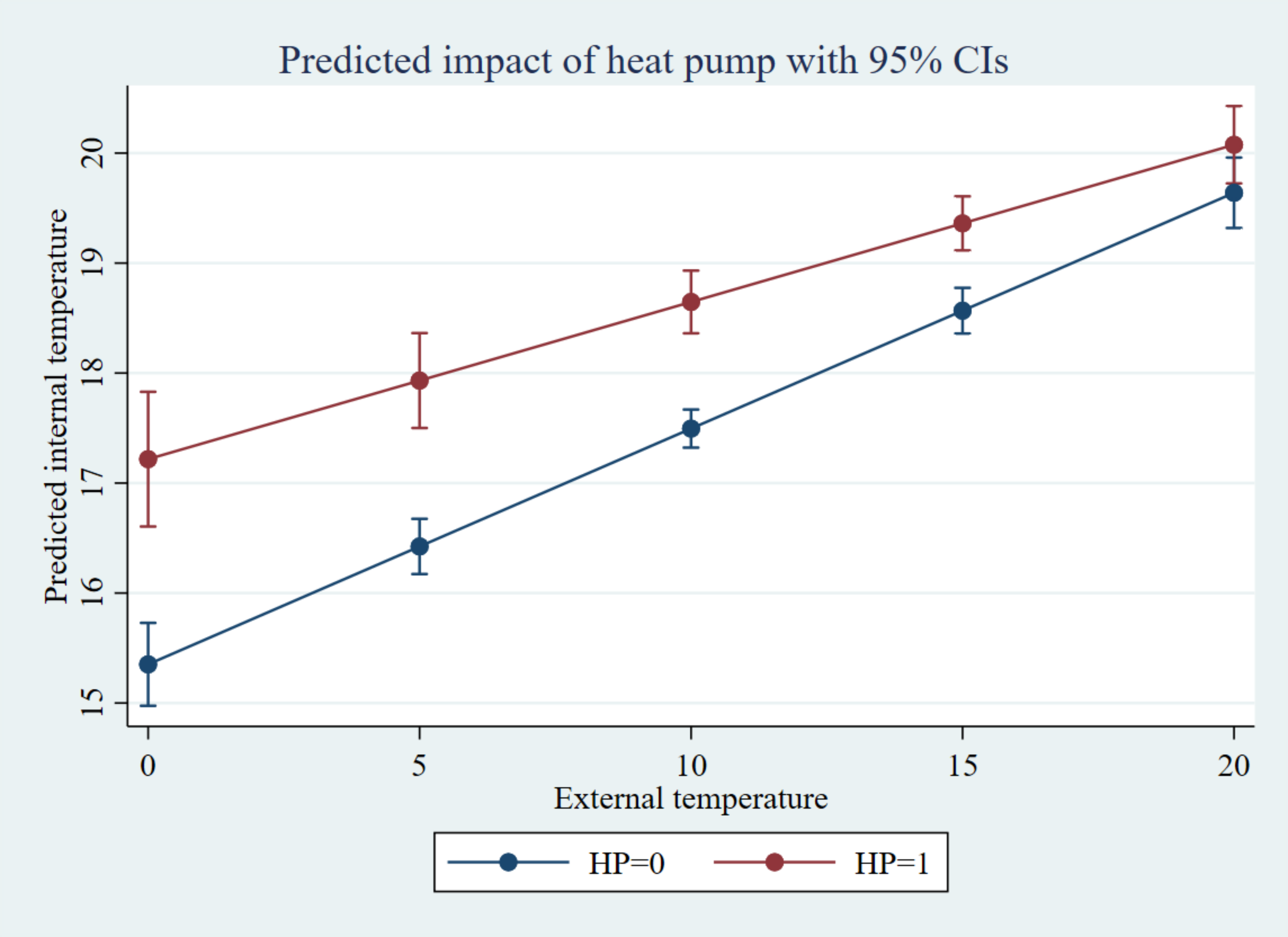
Subsequent vs Before survey shows stronger self-reported health benefit:

- 21 improved vs 11 worsened; 42 constant

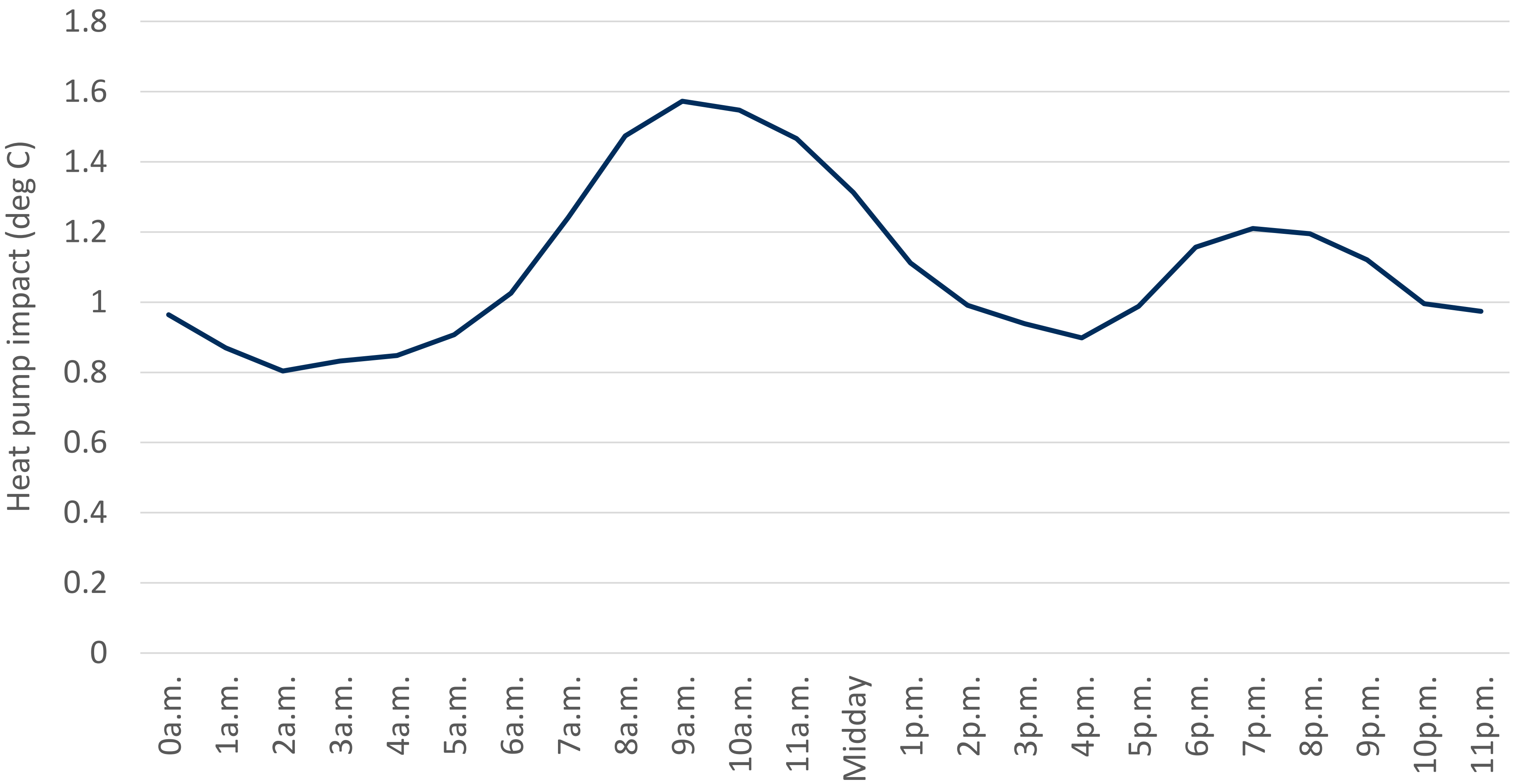
Regression evidence

- Strong impact of heat pump installation in reducing **perceived cold** (robust across multiple specifications) [included in CBA]
- Evidence ($p<0.1$) that time since heat pump installation positively impacts **life satisfaction**

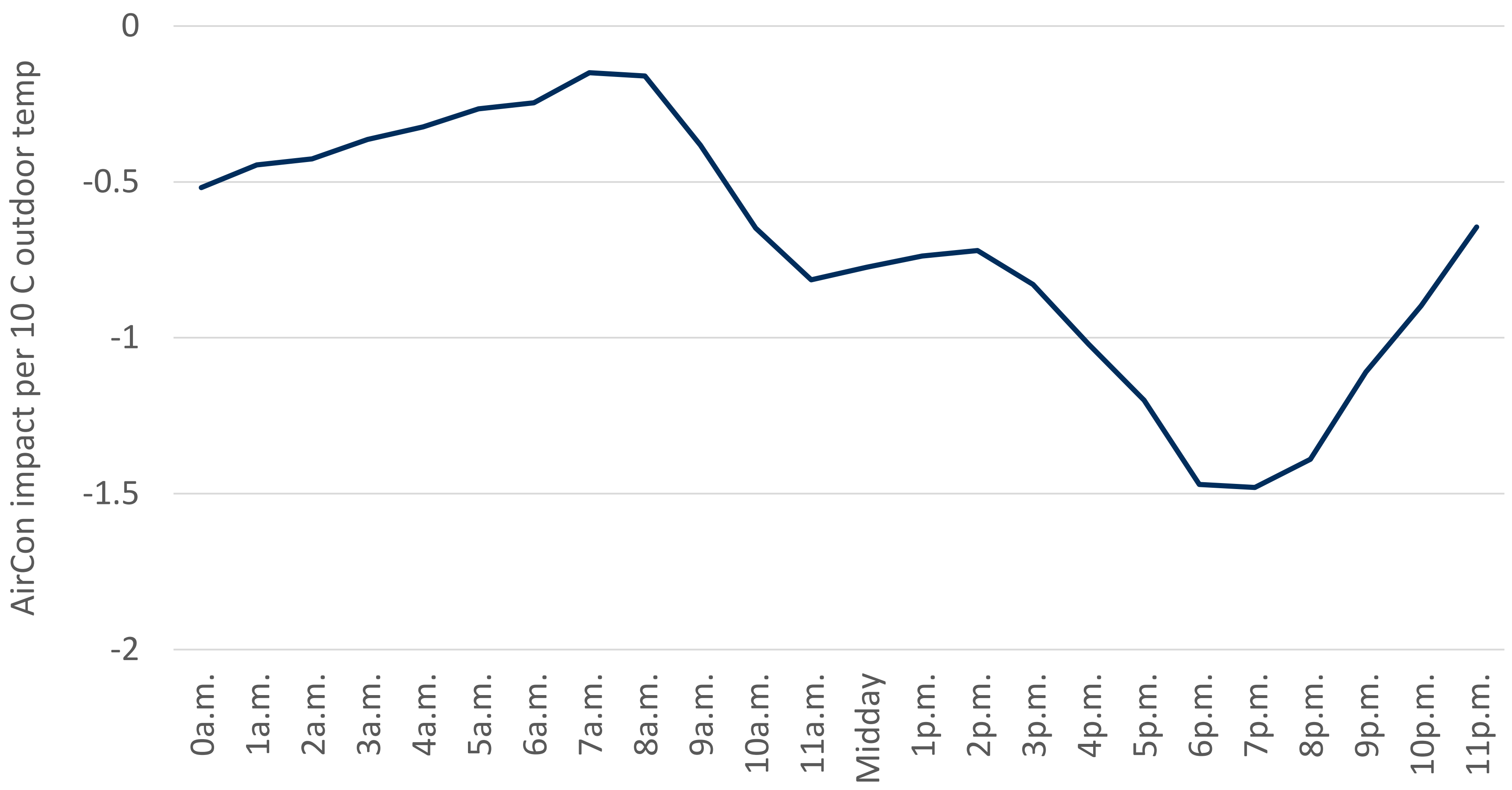
Modelled temperature impacts with & without heat pump (first winter)



Average temperature impact of heat pump by time of day (first winter) [all significant at p<0.01]



Average temp impact of air conditioner use per 10°C increase in outdoor temp ($p<0.05$ from 5pm – 11pm)



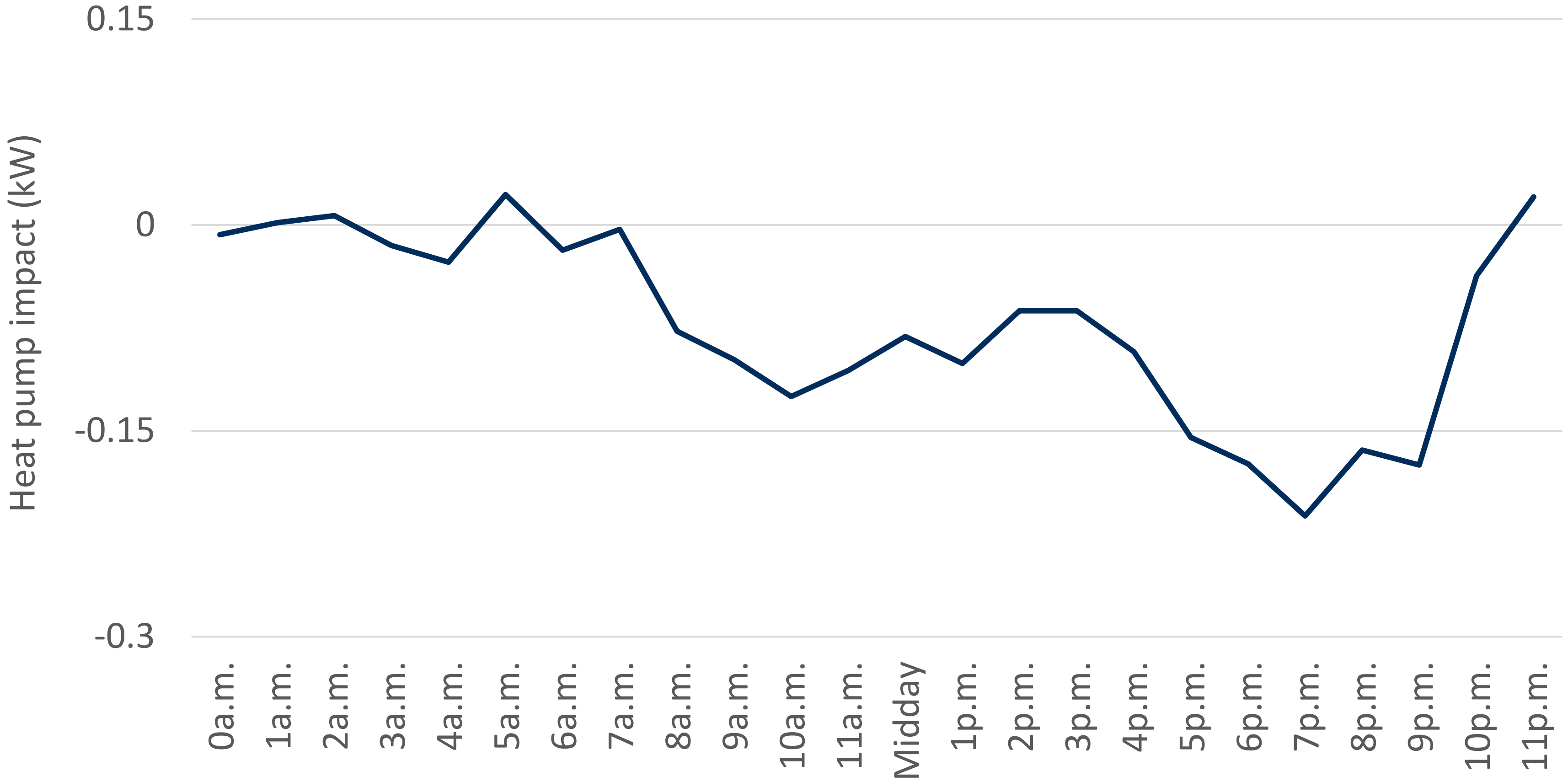
Relative humidity and CO_2 impacts of heat pump (first winter)

- Heat pump reduces indoor relative humidity ($p<0.01$) by:
  ~ 5% of its mean,
  ~ 30% of its standard deviation

  - Reduction in indoor humidity is greatest when outdoor humidity is high

- Heat pump installation also associated with reduction in indoor CO_2
  - Possibly due to greater ventilation if living area door left open

Electricity use impact of heat pump by hour of day (first winter) Overall impact is 16% reduction ($p<0.05$) across a full winter's day ($p<0.05$ for 7pm – 9pm)



Cost benefit analysis

Cost benefit analysis

- Cost benefit analysis of WKH programme was undertaken from:
  - a fiscal (government level) perspective
  - a societal (population level) perspective.

- 3 base case scenarios:

  (i) insulation component only

  (ii) heat pump component only

  (iii) whole programme (insulation + heat pump)

  Each with:
  - 5% discount rate to calculate NPV of future costs and benefits
  - 75% additionality,
  - fiscal multiplier of x1.2 on government expenditure

Costs

- Insulation (80% EECA) **fiscal**
- Insulation (20% householder) **societal**
- Administration insulation **fiscal**
- Insulation incentive **fiscal not societal**
- Heat pump (80% EECA) **fiscal**
- Heat pump (20% household) **societal**
- Heat pump servicing **societal**
- Administration heat pump **fiscal**
- Opportunity cost of next best alternative heater **societal** **negative cost**

Benefits

- Hospital admissions avoided **fiscal**
- Pharmaceutical prescriptions avoided **fiscal**
- Pharmaceutical prescriptions avoided **societal**
- Increase in survival **societal**
- Net change in wellbeing (perceived cold) **societal**
- Days off work due to sickness **societal**
- Days off work caregiving **societal**
- Days of school due to sickness **societal**
- GP visits avoided **societal**
- Net change in CO_2 from difference in kwh electricity consumed **societal**
- Average change in electricity consumption **societal**

Assumptions

- Costs and benefits based on 2021 prices
- The heat pump lasts 10 years (length of warranty) at 100% efficiency
- The next best alternative lasts 10 years at 100% efficiency
- Insulation lasts 30 years at 100% efficiency
- Heat pumps installed only in fully insulated houses
- Benefits remain consistent for the life of the heat pump and insulation
- No extra reduction in days off work/school from heat pump in addition to insulation
- Time off work to care for child only required if all adults in household work
- Survival increases only for those >65 years with pre-existing circulatory condition
- Number of GP visits required equals number of prescriptions dispensed

CBA Outcomes: Base case scenario

Base case BCR	Societal perspective	Fiscal perspective*
Whole programme: wellbeing/ energy benefits	4.36	
Whole programme: health/ energy benefits	1.89	0.80
Heat pump: wellbeing/energy benefits	7.49	
Heat pump: health/energy benefits	2.15	0.52
Insulation: wellbeing/energy benefits	3.51	
Insulation: health/energy benefits	1.78	0.98

CBA Outcomes: Sensitivity analysis

Societal BCR	2% discount rate	50% additionality	100% additionality	$150 p.a. service cost
Societal BCR				
Whole programme: wellbeing/energy	5.70	4.11	4.29	4.15
Whole programme: health/energy	2.44	1.78	1.96	1.80
Heat pump: wellbeing/energy	8.46	7.27	7.60	6.96
Heat pump: Health/ energy	2.43	2.09	2.18	2.00
Insulation: wellbeing/energy	4.97	3.48	3.52	3.51
Insulation: health/ energy expenses	2.42	1.77	1.79	1.78
Fiscal BCR				
Whole programme: health/energy	1.09	0.77	0.81	0.84
Heat pump: Health/ energy	0.59	0.51	0.52	0.52
Insulation: health/ energy expenses	1.39	0.95	1.00	0.98

Potential extensions

Data available now

House characteristics: window, roof, foundation type, glazing, shade, drainage, house age, size

Housing quality: Mould and damp, house condition, curtains, draughtiness

Indoor temperature, relative humidity, carbon dioxide, dew point, lux (half hourly)

Heating and ventilation behaviour, cold perception

Whole house electricity use (half-hourly) n=95

Heat pump electricity use (half-hourly linked and minute unlinked) n=20

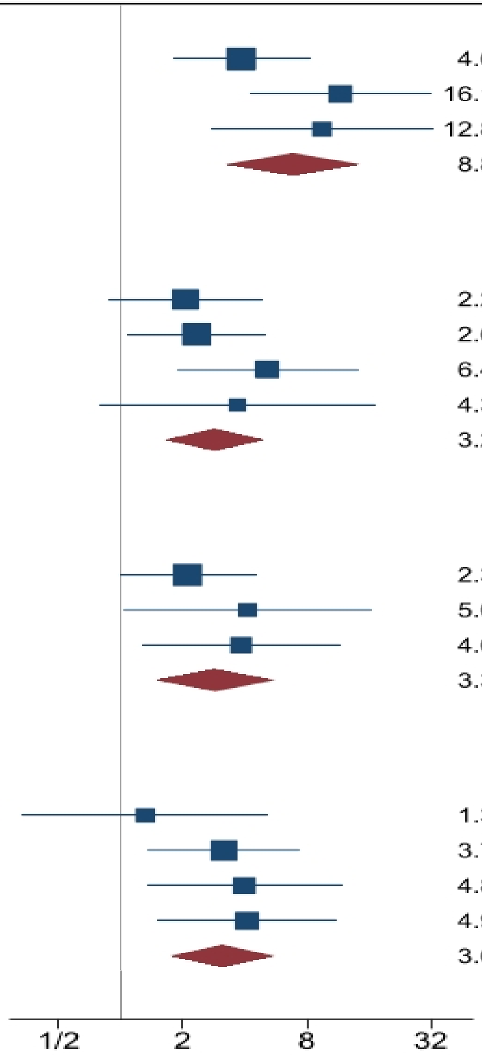
Outdoor temperature and humidity

Wellbeing: Life satisfaction, WHO5, health

Demographics: Age, work/study status, sufficient income

Univariate ordinal regression of Draughtiness

		OR with 95% CI	n
Dampness: whole house (vs Never)	Ref		52
Sometimes		4.62 (1.96, 10.86)	42
Often		16.12 (5.16, 50.40)	16
Always		12.81 (3.14, 52.20)	9
		8.88 (3.81, 20.71)	
Mould rooms: bed/living (vs None)	Ref		56
One room		2.27 (0.87, 5.90)	21
Some rooms		2.61 (1.09, 6.27)	26
Most rooms		6.42 (2.06, 19.99)	14
All rooms		4.39 (0.77, 24.90)	5
		3.29 (1.75, 6.16)	
MouldA4 (vs Never)	Ref		78
Sometimes		2.34 (1.00, 5.50)	25
Often		5.00 (1.06, 23.69)	6
Always		4.62 (1.34, 15.96)	9
		3.33 (1.57, 7.05)	
Restrict heating due to cost (vs Never)	Ref		24
Rarely		1.36 (0.29, 6.39)	8
Sometimes		3.71 (1.43, 9.58)	49
Often		4.81 (1.43, 16.20)	15
Always		4.95 (1.61, 15.26)	21
		3.63 (1.87, 7.04)	



Exploratory models for IOtemp18 (Indoor temp - outdoor temp, when outdoor temp <18C)

IOtemp18	Model 1	Model 2	Model 3	model 4
	R^2= 0.29	R^2= 0.36	R^2= 0.30	R^2= 0.32
hour	supp			
kwh	1.33 (1.30, 1.35)			
lux_1000	0.33 (0.31, 0.34)			
volume	-0.01(-0.02, -0.01)			
floor area (vs less than 100m2)	ref			
100-200m2	-1.01 (-1.07, -0.96)			
Larger than 200m2	-1.76 (-1.83, -1.69)			
HP (vs no)	ref			
Yes	1.54 (1.50, 1.58)			
Region_NS (vs Auckland)	ref			
Hamilton	1.56 (1.49, 1.62)			
Wellington	2.50 (2.44, 2.55)			
Christchurch	3.56 (3.50, 3.62)			
Draughty (vs Never)		ref	NA	NA
Sometimes		-1.11 (-1.15, -1.07)	NA	NA
Often		-1.26 (-1.32, -1.20)	NA	NA
Always		-3.80 (-3.86, -3.75)	NA	NA
draughty_alg			-0.11 (-0.12, -0.11)	NA
poor condition (vs 0-1)				ref
2-3 poor condition ratings				-1.08 (-1.12, -1.04)
4-5 poor condition ratings				-1.68 (-1.72, -1.64)

- Post grad projects: Masters and PhDs
- Data to support existing programmes
- Collaborations
- Housing system modelling
- Your ideas here

Houses are warmer

Even in winter and spring

Heat pumps are worth it

Appendix: Equation specifications

Perceived cold and life satisfaction

$$DepVar_i^{S2} = f\left(HPVar_i^{S2},\ \sum_{j=1}^{J} DepVar_i^{S1\_j}, Z_i\right)$$

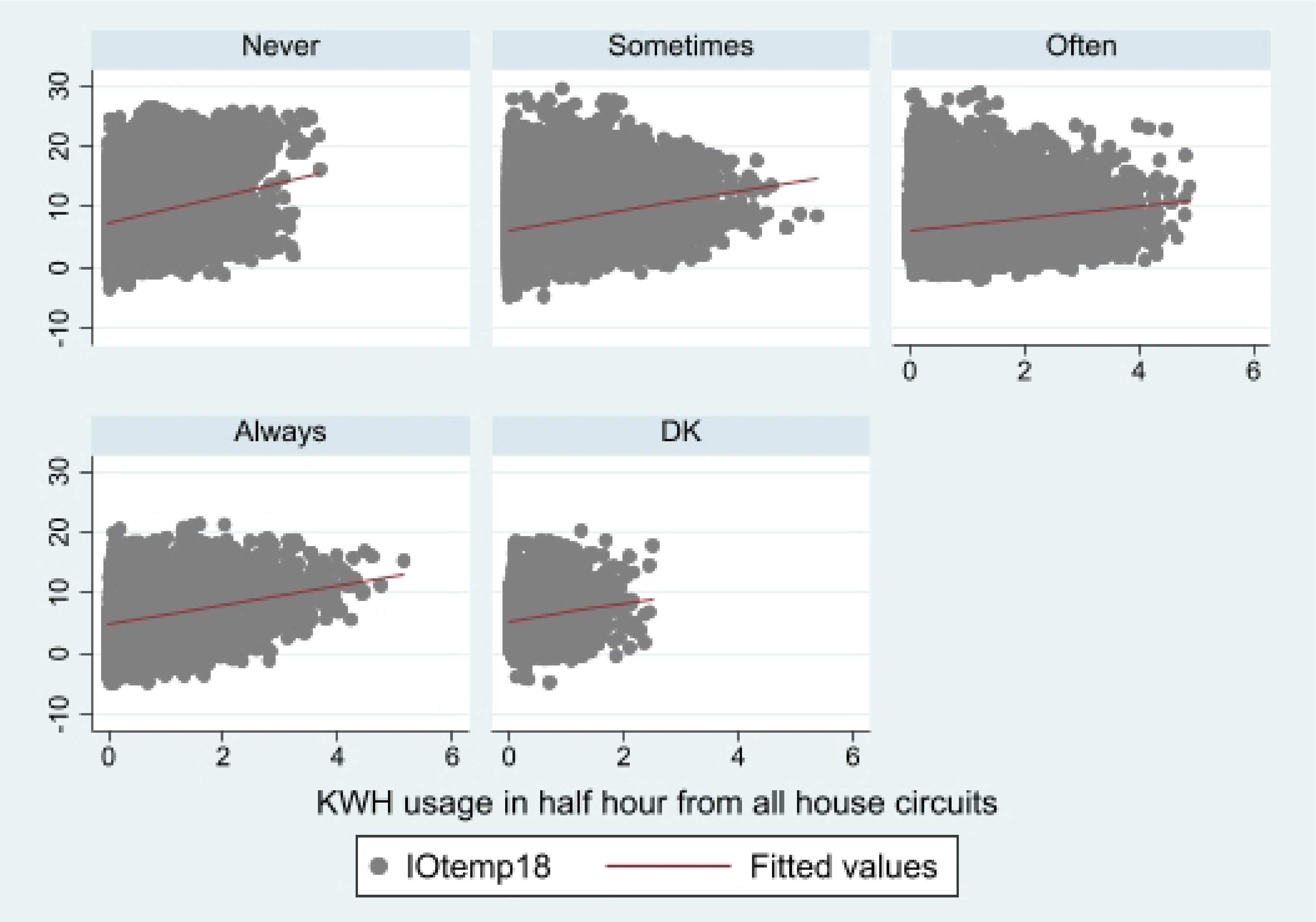
Temperature (also humidity and CO_2)

$$Temp_{iht}^{I} = \beta_0 + \beta_1 Temp_{iht}^{O} + \beta_2 HP_{iht} + \beta_3 HP_{iht} Temp_{iht}^{O} + \mu_{tc} + \mu_h + \mu_i + \varepsilon_{iht}$$

$$Temp_{iht}^{I} = \beta_0 + \beta_1 Temp_{iht}^{O} + \beta_2 AirCon_{iht} Temp_{iht}^{O} + \mu_{tc} + \mu_h + \mu_i + \varepsilon_{iht}$$

Electricity use

$$Electricity_{iht} = \beta_0 + \beta_1 Temp_{iht}^{O} + \beta_2 HP_{iht} + \beta_3 HP_{iht} Temp_{iht}^{O} + \mu_{tc} + \mu_h + \mu_i + \varepsilon_{iht}$$


Never
Sometimes
Often
Always
DK
-10
0
10
20
30
0
2
4
6
KWH usage in half hour from all house circuits
lOtemp18
Fitted values