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Measuring production and wellbeing outcomes of a public sector clean heat subsidy programme

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Abstract
Over a fifth of New Zealanders find their homes to be cold and damp. We consider how to evaluate the outcomes of a government programme – Warmer Kiwi Homes – which subsidises heat pumps for disadvantaged households. The programme aims to make homes warmer, drier, and healthier, while improving energy efficiency. Two companion studies show that the programme is successful in meeting these aims, and also in raising the subjective wellbeing of residents in treated homes. Here, we deal conceptually with how these outcomes are (or should be) measured when assessing the programme's contribution to welfare. The assessment contrasts the treatments of benefits and costs within a cost benefit analysis context relative to their treatment within a national accounts context (which may be used, for instance, for an economic impact assessment). The contrasting approaches have implications for the appropriate choice of evaluation framework for public sector programmes.

Keywords: Cost benefit analysis; national accounts; GDP; GNI; heat pump; public sector evaluation

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1. Introduction

A common criticism in the 'wellbeing economics' literature is that governments have traditionally prioritised the expansion of GDP over targeting outcomes that matter for people's wellbeing (Sen et al, 2009). While the extreme versions of this criticism are undoubtedly false (witness the large expenditures of many governments for healthcare of retired people), it does raise the issue of which metrics we should use to evaluate the consequences of government programmes. For instance, should a programme evaluation be in terms of wellbeing – a synonym for welfare (Deaton, 2016) – or in terms of its contribution to gross domestic product (GDP) or some other national accounts concept such as gross national income (GNI) – or, for that matter, any other concept?

In this short conceptual paper, we consider two different lenses to evaluate the outcomes of a government programme designed to improve the quality of existing houses. Specifically, the New Zealand government's Warmer Kiwi Homes (WKH) programme aims to make participating homes in more deprived situations warmer, drier and healthier while improving their energy efficiency. A key aspect of the programme is to fit heavily subsidised heat pumps in the living area of houses that do not currently have an efficient heater in the living area.

Details of the programme, and evaluation of outcomes over the first year of the study, are presented in Fyfe et al. (2022a). That paper examined the impacts that subsidised WKH heat pump provision has on household outcomes including comfort and wellbeing, indoor environmental outcomes and electricity use. The evaluation covered 127 households who applied for a heat pump through WKH in 2021. Evaluation methods included two qualitative household surveys, a house condition survey, hourly indoor environmental quality readings from a monitor in the living area, and hourly electricity use measured using smart meter data. Timing of heat pump installation for each house was partially randomised by the onset of COVID-19, so sharing some features of a natural experiment. Using a difference-in-difference design, the study provided estimates of the impact of heat pump installation on indoor temperature, relative humidity and CO_2 in the living area of treated and control houses and on treated and control households' electricity use. Fyfe et al. (2022b) provide estimates of the effects of heat pump treatment on subjective wellbeing outcomes; the study also includes consistency checks for householders' perceived cold and condensation in the living area.

Summarising the two sets of results briefly, living areas in treated (relative to control) houses are estimated to be warmer by an average of 1.4°C in winter accompanied by lower relative humidity and CO_2, while at the same time experiencing no increase (and likely some decrease) in electricity use.[1] Relative to control households, respondents in treated houses perceive their living area to become warmer with less condensation and they record a significant (and material) increase in life satisfaction.

The outcomes reported in these two prior studies will be used as inputs into a social cost-benefit analysis (CBA) of the programme, together with estimates of programme costs. The latter include resource costs associated with the heat pump itself, installation costs and administrative costs of the programme. Electricity is not included as a cost since the programme likely reduces electricity consumption of treated households as less efficient heaters are replaced by more efficient heat pumps. In keeping with standard CBA approaches, benefits and costs are considered at the societal

[1] To provide further context, the Appendix reproduces four figures from Fyfe et al. (2022a) detailing estimated internal living area temperature gains and household electricity use changes (for treated versus control houses), each in relation to (i) external temperature, and (ii) time of day; estimates are based on hourly data for June-September (winter to early spring) 2021.

level and the focus is on net social benefit, i.e. social benefits less social costs (Mishan & Quah, 2007).

Section 2 of this paper itemises the benefit and cost categories of the programme (without including monetary amounts) where benefits and costs are categorised in relation to the calculation of net present value (NPV) in a CBA.[2] Section 3 addresses how each of these costs and benefits would be accounted for, in a proximate sense, in GDP and GNI as might occur in a rudimentary economic impact analysis (EIA). That section also discusses general equilibrium effects of these contributions. In section 4, we contrast the benefits and costs derived from the CBA framework with those included in the GDP and GNI accounts. The concluding section uses these contrasts to illustrate why government programmes should not normally be evaluated through an EIA (e.g. within a national or regional accounts framework) if increasing welfare is the predominant purpose of the programme.

2. Programme benefits and costs (CBA perspective)

2.1 Benefits

Several studies have established the presence of objective benefits gained by upgrading the warmth of houses including through retrofitting heat pumps in living areas of houses in place of less efficient or non-existent heating. These benefits include improved health of the occupants, reduced electricity use and increased comfort in the home.

The health benefits can be further itemised as including benefits gained from: fewer hospital admissions, fewer GP (doctor) consultations, fewer pharmaceuticals prescribed, increased life expectancy and reduced days off work (both directly and because of caregiving duties) and off school (Milne & Boardman, 2000; Schweitzer, 2005; Howden-Chapman et al., 2008; Preval et al., 2010; Marmot Review Team, 2011; Maidment et al., 2014; Tonn et al., 2014; Preval et al., 2017; Fyfe et al, 2020).

Reduction in electricity consumption contributes to a direct reduction in resource use. It also contributes to a reduction in carbon emissions provided that some non-renewable generation is used in the electricity generation system (Grimes et al., 2012). (In New Zealand, approximately 20% of electricity is generated via non-renewables.) Furthermore, in some houses a heat pump will replace gas or solid fuel heaters, so replacing a direct emitter of carbon (Grimes et al., 2016).

Comfort benefits are classed as all non-health improvements to welfare that members of the household experience as a result of living in a warmer, drier home (Smith & Davies, 2020). These benefits may include the direct outcome of feeling warmer and also social benefits achieved by being more likely to invite others to the home now that it is warmer (Sharpe et al., 2022).

Cost wellbeing analysis (CWA) extends a conventional CBA to include not only aspects such as the value of increased comfort, but also any other impact of the programme on people's subjective wellbeing. Wellbeing, in this context, is generally measured by an evaluative subjective wellbeing (SWB) measure such as life satisfaction.[3] Life satisfaction may be affected by process factors as well as by outcomes (Frijters and Krekel, 2021). For instance, the manner in which the programme is

[2] We can equivalently consider the benefit: cost ratio (BCR) but the subsequent comparison of CBA methods with GDP and GNI accounts makes the NPV a more natural point of comparison.

[3] The relevant question in Statistics New Zealand's General Social Survey, which we also employ in our surveys is worded: *Please think about your life as a whole these days. This includes all areas of your life. Where zero is completely dissatisfied, and ten is completely satisfied, how do you feel about your life as a whole?*

implemented, rather than just the programme's objective outcomes, may impact on overall life satisfaction. It is important to note that an evaluative SWB measure conceptually captures all net benefits of a programme for the respondent, so should not be included as an extra benefit over and above other benefits. If some benefits are not captured in the detailed list of benefits (e.g. process-related net benefits), then we might expect the value derived from an SWB measure to exceed the total value of benefits summed from an itemised list of measured benefits.[4] Thus, in evaluating benefits of the programme, we might either include the aggregated listed net benefits or the value attributed to a change in life satisfaction, but not both to avoid double-counting.

2.2 Costs

A government subsidy programme such as Warmer Kiwi Homes entails a number of costs which must also be factored into the analysis. The most direct cost is the capital cost of the heat pump. Central heating is uncommon in New Zealand, so most New Zealand households heat their house with some form of room-specific electric, solid fuel or gas heater. These heaters need periodic replacement so the net capital cost is the cost of the heat pump less the expected replacement cost of an alternative heating source, both amortised over the life of the respective heating appliances after accounting for the expected timing of replacement.

In addition to the capital items, costs associated with the heat pump include installation costs (which require a professional installer, unlike the purchase and installation of a mobile electric heater), costs of regular servicing (which is required for a heat pump but not for portable electric heaters) and the administration costs of the programme.

3. National accounting

3.1 Proximate impacts on GDP and GNI

Rudimentary economic impact analysis focuses on the proximate (i.e. direct) impacts of a programme on measured economic activity of a region. In this case, the region is the nation, so GDP is the relevant measure of (gross) production (and expenditure). One might also consider the proximate effects on incomes in which case GNI is a more relevant national measure.

Some of the impacts discussed under Benefits above, have no counterpart impact on GDP or GNI, but some do. Of those benefits that do have an impact, some directly raise GDP and/or GNI while others directly reduce it.

For instance, increased comfort and reduced days off school have no direct counterpart in GDP or GNI measures. Reduced carbon emissions have no impact on GDP but may increase GNI if the reduced emissions reduce the cost of purchasing carbon credits offshore. Work-related health benefits (e.g. reduced days off work and increased survival of those in the workforce) lead to increases in GDP and GNI, but only for those in the workforce. Other health benefits have the opposite effect on GDP and GNI relative to their impact on net benefit within a CBA. For instance, each of reduced hospital visits, doctors' visits and pharmaceutical use (if manufactured domestically) are benefits under a CBA but lead to proximate reductions in GDP and GNI.

[4] Frijters and Krekel (2021) summarise methods for valuing subjective wellbeing gains, based on an assumption of cardinality of the life satisfaction measure together with some other methodological assumptions.

3.2 General equilibrium consequences: A comment

CBAs and EIAs are (initially at least) often formulated in a partial equilibrium context; i.e. focusing on proximate rather than general equilibrium effects. However, where (at least some) resources are fully employed, the general equilibrium outcomes of a programme may differ considerably from the proximate (partial equilibrium) effects. Neither conventional CBAs or EIAs are well equipped to deal with this issue.

However, the CBA approach in some respects comes closer to considering general equilibrium issues than does an EIA approach. As an example, take the cost category of 'heat pump installation'. Conventionally, (unless there are unemployed labour resources, when a shadow cost of labour may be used), a CBA will include the entire cost of the installer's labour as a resource cost and so deduct this input in the NPV calculation. This calculation reflects a general equilibrium perspective that the installer's labour would otherwise be used elsewhere for economic activity. By contrast, a rudimentary EIA treats the value added from the installer's input as a positive contribution to economic activity, reflecting a partial equilibrium, rather than general equilibrium, approach. To be consistent with the CBA approach (and with general equilibrium) a more nuanced EIA would have to disregard or deduct the value added due to the installer.

The distinctions between partial and general equilibrium approaches for the analysis are more nuanced for some other benefit categories. For instance, the benefit category 'Increase in comfort' may initially appear to be a full (i.e. general equilibrium) effect: a householder's comfort from increased warmth does not directly crowd out comfort elsewhere. However, if the resource put into installing a heat pump were instead used to install retrofitted double glazing there might also be an increase in comfort, so full crowding out may occur in this case. If, however, the heat pump resources were to be directed to some other public policy (especially one that gave a lower BCR than the heat pump programme) then full crowding out would not occur.

The contrasts shown between CBA versus national accounts approaches below rely solely on proximate effects in each case. The caveats above in relation to general equilibrium considerations should be borne in mind when interpreting the analysis in section 4.

4. Contrasts in consideration of benefits and costs

Table 1 lists 10 separate potential benefits (as viewed within a CBA) that may flow from the fitting of a heat pump to houses in the WKH programme. An 11th benefit category, increased SWB measured by life satisfaction (LS), is also listed but – as discussed above – should be considered as an alternative to the sum of the first 10 listed benefits. For each benefit, we have denoted whether that benefit would raise each of: (i) NPV in a CBA, (ii) GDP, and (iii) GNI when considered in a proximate sense. Brief comments are included to provide context where appropriate.

The first three benefits each represent a reduction in resource use due to improved health consequent on living in a warmer, drier home. The resource savings contribute positively to NPV within a CBA but – in a proximate sense – reduce production and expenditure, so reducing GDP, and also reduce incomes, so reducing GNI.

Benefit 4 represents the value (considered within a CBA) of extra life years, if living in a warmer home contributes to longevity.[5] The value of this benefit accrues in a GDP or GNI sense only if the

[5] Preval et al. (2017) find that the value of increased life years for those over 65 years with a pre-existing heart condition is the dominant benefit arising from a related house intervention, retrofitted insulation.

person concerned works extra years as a result of the increased longevity. (An assumption here is that the person's estate would otherwise be invested and/or spent in the same manner whether the person stayed alive or not.) Extra life years incurred by a retired person (or person not otherwise in the labour force) would be counted positively in a CBA but ignored in compiling GDP or GNI.

Benefits 5 and 6 accrue similarly in each of the three approaches. Fewer days off work increase the resources available for production (and hence expenditure and incomes), which is recognised in all three approaches. However, benefit 7 (fewer days off school), while recognised as a benefit in CBA, is not recognised in (current) GDP or GNI. However, to the extent that missed schooling results in lower school attainment (which underpins its positive valuation in a CBA), this benefit will be reflected in future GDP and GNI as a result of increased future resources (i.e. increased human capital) contributing to future production and incomes.

Fyfe et al (2022a) find that the WKH programme likely reduces electricity consumption (benefit 8). This resource saving contributes positively to NPV in a CBA but detracts from both GDP and GNI as electricity production (and income earned from it) declines. As a consequence of the reduction in electricity use (and also of gas use), carbon emissions will fall, representing a benefit at the national level when considered in a CBA context (benefit 9). If this fall in carbon emissions results in a fall in carbon permits bought from offshore to meet an emissions target, the benefit will also be reflected in GNI (though this might be regarded as a second round, rather than proximate, effect). The carbon saving will not be reflected in GDP.

Finally, improved comfort, net of any effects of improving health (benefit 10) is conceptually included as a non-monetary benefit in a CBA (though, in practice, may be missed because of quantification difficulties). This benefit is ignored entirely in both GDP and GNI.

Table 2 provides a similar break-down for costs (as viewed from a CBA perspective). The heat pump is a resource cost so is deducted from NPV within a CBA (cost 1). (Recall that the capital cost is considered net of the capital cost of replacement heaters that would otherwise be purchased over the lifetime of the heat pump.) If the heat pump (or some component of it) is manufactured domestically, the (proximate) effect of its installation is positive for GDP and GNI as domestic production and incomes increase.

Similarly, resource costs are incurred through heat pump installation and subsequent servicing,[6] and through programme administration (costs 2, 3 and 4). These resource costs are reflected as reductions in NPV in a CBA but as increases in both GDP and GNI.

Thus the majority of both benefits and costs are reflected in opposite directions when considered – in proximate terms – from a CBA as opposed to a national accounts (GDP and GNI) perspective. Implications of these different treatments are discussed in the concluding section.

[6] Heat pumps require regular servicing whereas the heating devices that they most commonly replace (convection or column heaters), are not normally serviced.

Table 1: Consideration of WKH heat pump benefits (as per CBA)

	Benefit description	CBA(NPV)	GDP	GNI	Comments
1	Hospital admissions avoided	+	-	-	
2	General practitioner (doctor's) visits avoided	+	-	-	
3	Pharmaceuticals avoided	+	-	-	GDP & GNI effects only if domestically produced
4	Increase in survival (value of extra life)	+	+	+	GDP & GNI effects only if respondent is in workforce
5	Reduced days off work due to sickness	+	+	+	
6	Reduced days off work for caregiving	+	+	+	
7	Reduced days off school due to sickness	+	0	0	Long-term GDP & GNI effects are positive
8	Reduced electricity use (net of old heating)	+	-	-	
9	Reduced CO_2 emissions from electricity reduction	+	0	+	GNI positive if carbon credits bought overseas reduce
10	Increase in comfort (excluding health benefits)	+	0	0	
	Increase in wellbeing (life satisfaction; LS)	+	*na*	*na*	*Do not double count in CBA (i.e. include either 1-10 or LS)*

Notes: + Heat pump leads to increase in category
- \- Heat pump leads to decrease in category
- 0 Heat pump leads to no change in category
- na Not applicable

Table 2: Consideration of WKH heat pump costs (as per CBA)

	Cost description	CBA(NPV)	GDP	GNI	Comments
1	Heat pump capital cost (net of next best heater)	-	+	+	GDP & GNI positive if heat pump made domestically
2	Heat pump installation	-	+	+	
3	Heat pump (future) servicing	-	+	+	
4	WKH programme administration	-	+	+	

Notes: + Heat pump leads to increase in category
- \- Heat pump leads to decrease in category

5. Conclusions

Tables 1 and 2 demonstrate how an economic evaluation of a government programme based on an EIA (as reflected in proximate movements in GDP or GNI) can produce very different results to one based on a CBA. A CBA is based on an economic definition of resource costs, treating extra resource use as a cost to society rather than as an (accounting) benefit. Conceptually at least, a CBA (and especially its extension, cost wellbeing analysis, or CWA) is based on an economic definition of benefit: benefits comprise any addition to utility, where the latter is proxied by subjective wellbeing in a CWA (Frijters and Krekel, 2021). GDP and GNI, by contrast, only consider benefits that flow through the market.

The listing of benefits and costs in Tables 1 and 2 show that an evaluation of a government programme based around an EIA has the potential to mislead policymakers when considering optimal allocation of resources across government programmes. At times, a government may wish – for political or other purposes – to raise GDP or GNI and hence to focus on these aggregates. This may be particularly the case during a recession when raising employment may also be a policy objective.[7] At these times, a properly constructed CBA will assign shadow prices to resources that lies below the market value to reflect lack of full resource employment. (For an example, see: Grimes et al., 2012). Nevertheless, some positive resource cost is likely still likely to be imputed in such cases (or, at the limit, the resource cost may be set to zero) so will still differ from the (positive) treatment accorded to the use of that resource in the national accounts.

No government aims to maximise GDP or GNI to the exclusion of other economic and non-economic aims. However, at times, public policies are adopted to boost GDP or GNI when other policies could be adopted instead (with the same fiscal resources) that would enhance societal net benefits. The illustration used here – the Warmer Kiwi Homes programme – shows how choosing a programme based on an evaluation within a CBA context is likely to lead to a better reflection of its impact on societal welfare (i.e. wellbeing) relative to an evaluation that focuses on boosting market activity. The analysis does not imply that GDP or GNI are irrelevant measures for policymakers; they do provide valuable descriptions of market economic activity. However, the analysis does illustrate why the focus of policymakers should be on choosing policies based on their welfare consequences rather than on their contributions to boosting gross domestic product.

[7] Note that increasing employment for a given set of outputs and other inputs results in reduced labour and multi-factor productivity; hence 'boosting employment', *ceteris paribus*, is a productivity-reducing policy aim.

References

Deaton A. 2016. Measuring and understanding behavior, welfare, and poverty. *American Economic Review*, 106, 1221–1243.

Frijters P, Krekel C. 2021. *A Handbook for Wellbeing Policy-Making: History, Theory, Measurement, Implementation, and Examples*. Oxford: Oxford University Press.

Fyfe C, Telfar-Barnard L, Howden-Chapman P, Douwes J. 2020. Association between home insulation and hospital admission rates: Retrospective cohort study using linked data from a national intervention programme. *BMJ* 2020;371:m4571.

Fyfe C, Grimes A, Minehan S, Taptiklis P. 2022a. *Warmer Kiwis Study: Interim Report. An impact evaluation of the Warmer Kiwi Homes programme.* Motu Working Paper 2022-02. Wellington: Motu Economic and Public Policy Research.

Fyfe C, Grimes A, Minehan S, Taptiklis P. 2022b. *"Snug, Warm, Coy and Dry": Assessing the contribution of a clean heat programme to householders' wellbeing*. Paper presented to International Society of Quality of Life Studies conference, Vermont.

Grimes A, Denne T, Howden-Chapman P, Arnold R, Telfar-Barnard L, Preval N, Young C. 2012. *Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme*. Prepared for MED (revised). https://www.motu.org.nz/assets/Documents/our-work/urban-and-regional/housing/Cost-Benefit-Analysis-of-the-Warm-Up-New-Zealand-Heat-Smart-Programme.pdf

Grimes A, Preval N, Young C, Arnold R, Denne T, Howden-Chapman P, Telfar-Barnard L. 2016. Does Retrofitted Insulation Reduce Household Energy Use? Theory and Practice. *The Energy Journal*, 37(4), 165-186.

Howden-Chapman P, Pierse N, Nicholls S, Gillespie-Bennett J, Viggers H, Cunningham M, Phipps R, Boulic M, Fjallstrom P, Free S. 2008. Effects of improved home heating on asthma in community dwelling children: Randomised controlled trial. *BMJ*, 337(a1411), 848–862.

Maidment CD, et al. 2014. The impact of household energy efficiency measures on health: A meta-analysis. *Energy Policy*, 65, 583-593.

Marmot Review Team. 2011. *The Health Impacts of Cold Homes and Fuel Poverty*, Friends of the Earth and the Marmot Review Team, London.

Milne G, Boardman B. 2000. Making cold homes warmer: The effect of energy efficiency improvements in low-income homes. *Energy Policy*, 28, 411-424.

Mishan EJ, Quah E. 2007. *Cost Benefit Analysis* (5th ed.). Abingdon: Allen & Unwin.

Preval N, Chapman R, Pierse N, Howden-Chapman P. 2010. Evaluating energy, health and carbon co-benefits from improved domestic space heating: A randomised community trial. *Energy Policy*, 38(8), 3965–3972.

Preval N, Keall M, Telfar-Barnard L, Grimes A, Howden-Chapman P. 2017. Impact of improved insulation and heating on mortality risk of older cohort members with prior cardiovascular or respiratory hospitalisations. *BMJ Open*, 7(11), e018079.

Schweitzer M. 2005. *Estimating the National Effects of the US Department of Energy's Weatherization Assistance Program with State-level Data: A Metaevaluation Using Studies from*

1993 to 2005. ORNL/CON-493. Washington, DC: US Department of Energy. http://dx.doi.org/10.1016/j.enpol.2010.03.020

Sen A, Stiglitz J, Fitoussi J. 2009. *Report of the Commission on the Measurement of Economic Performance and Social Progress*. https://ec.europa.eu/eurostat/documents/8131721/8131772/Stiglitz-Sen-Fitoussi-Commission-report.pdf.

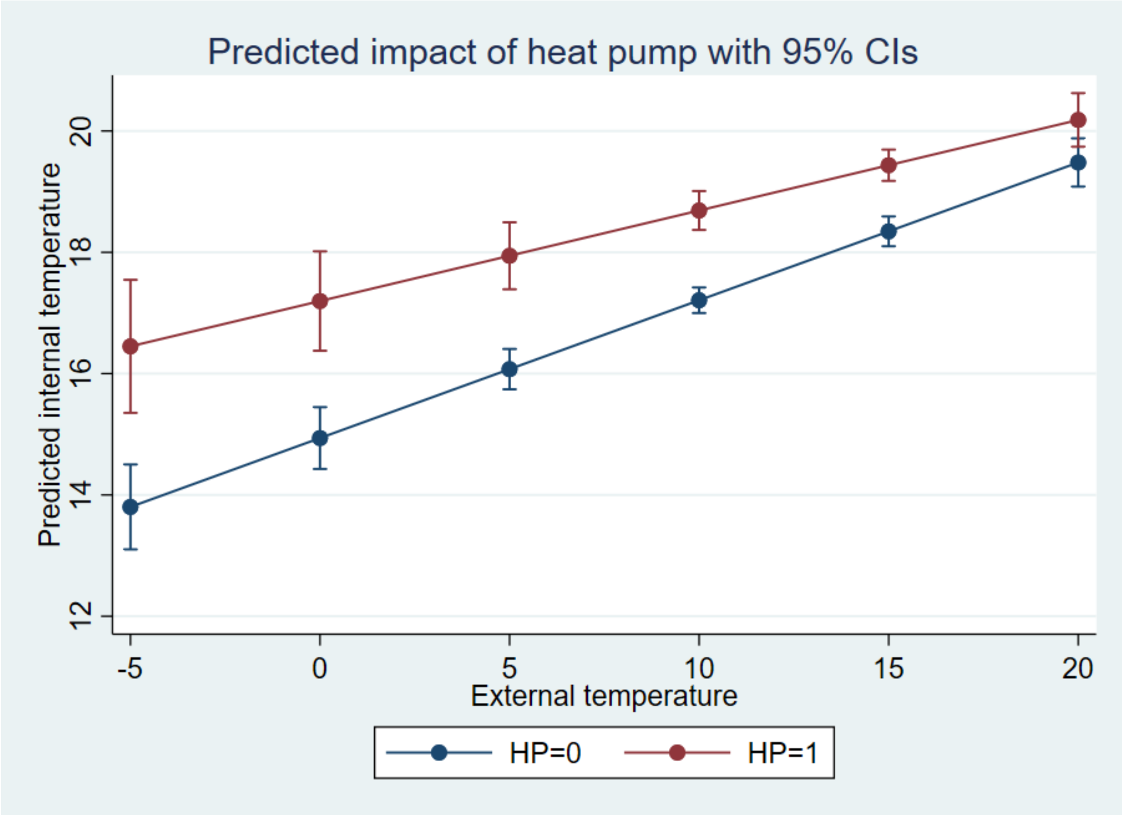
Sharpe R, Williams A, Simpson B, Finnegan G, Jones T. 2022. A pilot study on the impact of a first-time central heating intervention on resident mental wellbeing. *Indoor and Built Environment*, 31(1) 31–44.

Smith C, Davies C. 2020. *Cost-wellbeing analysis of housing outcomes in the New Zealand General Social Survey*. Kotata Insight. https://kaingaora.govt.nz/assets/Publications/Housing-wellbeing-valuation_final-paper_2020.pdf

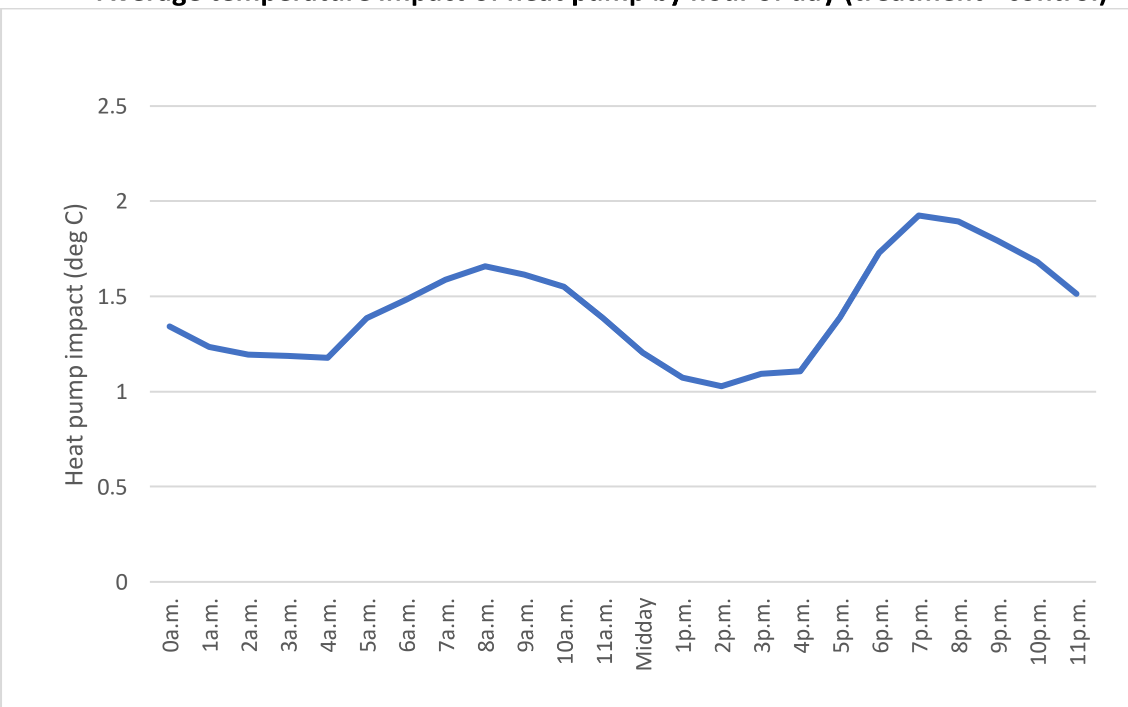
Tonn B., et al. 2014. *Health and Household-Related Benefits Attributable to the Weatherization Assistance Program*, ORNL/TM-2014/345. Oak Ridge National Laboratory, Oak Ridge.

Appendix: Temperature and Electricity Use Impacts of Heat Pump Installation
Source for all figures: Fyfe et al. (2022a)

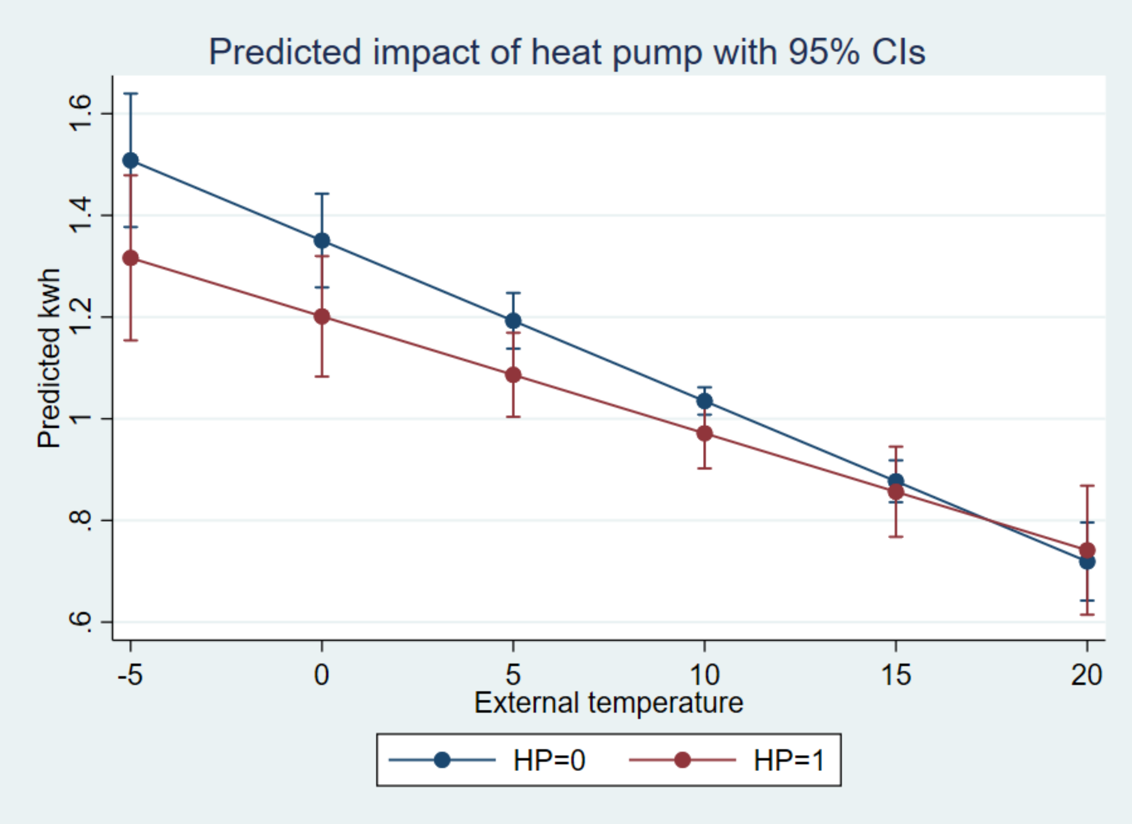
Modelled temperature with (HP=1) and without (HP=0) a WKH heat pump



Average temperature impact of heat pump by hour of day (treatment - control)



Modelled electricity use with (HP=1) and without (HP=0) a WKH heat pump



Average electricity use impact of heat pump by hour of day (treatment - control)