6 Cost-effectiveness and cost benefit analysis

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Summary of results

OGW was engaged to carry out a cost-effectiveness (C-E) analysis and a cost-benefit analysis (CBA) of the Home Energy Efficiency Upgrade Program as a whole, based on the four cost levels set out in the Low Energy Efficiency Program (LIEEP) Guidelines.

Data illustrating the installation cost and timing, household characteristics and subsidy payments was collected throughout the program by Brotherhood of St Laurence (BSL) staff for each individual household while the Monash Sustainability Institute (MSI) estimated the energy savings and the daily and annual cost savings for eight relevant upgrade pathways.

MSI estimates indicate a decrease in energy consumption of 25 percent and 7 percent for electricity and gas respectively. These savings amount to 762 kWh ($216.13)[21] for average annual electricity consumption and 2,787MJ ($55.64) for gas consumption.

The energy savings estimated by MSI were compared with deemed energy savings estimated for the VEET scheme.

The most cost-effective pathway for electric HWS was upgrade pathway 1 – switching from electric storage to a heat pump. The most cost-effective gas pathway was upgrade pathway 8, switching from gas to a heat pump.

The analysis did not conclude a benefit cost ratio > 1 for any of the eight pathways, when estimating the cost and benefits based on the four cost level framework and the HEEUP energy savings estimates. However, pathway 1 estimated a result closest to 1 compared to the other pathways.

[21] In 2015 dollars residential tariff

The result for the C-E and the CBA was in line with the result based on the VEET electricity savings data by indicating that these are the most cost efficient pathways as the pathways with the highest BCRs.

Four-cost level analysis

The four cost level analysis[22] shows total costs per capita ranging from $2,063 at level 1 (direct costs of delivering the trial to a participant) to $4,649 at level 4 (total trial costs). Program wide costs range from $1,575,908 to $3,552,007. These costs exclude the co-contributions by householders. The C-E and CBA also consider a scenario with the inclusion of the household contributions; these results are presented in Table 23 and in Appendix H9: CBA results – scenario 2.

Table 20: Total annual cost by cost level 1, 2, 3 and 4 – cumulative

	Jul 13 – Jun 14	Jul 14 – Jun 15	Jul 15 – Jun 16	Total cost by cost level	Per capita
Cost level 1	$ 175,466	$ 962,496	$ 437,946	$ 1,575,908	$ 2,063
Cost level 1, 2	$ 239,776	$ 1,164,290	$ 607,965	$ 2,012,032	$ 2,634
Cost level 1, 2, 3	$ 374,640	$ 1,570,429	$ 893,995	$ 2,839,063	$ 3,716
Cost level 1, 2, 3, 4	$ 547,340	$ 2,021,168	$ 983,499	$3,552,007	$ 4,649

Cost-effectiveness analysis

The most cost-effective pathway for an upgrade from an electric hot water system (instant or storage) was to a heat pump ($0.36/kWh), the pathway with the lowest cost/energy savings ratio is the pathway that is considered to be the most cost-effective.

Table 21 Cost-effectiveness results: electricity pathways ($/kWh)

Cost level	Electric (instant or storage) to heat pump ($/kWh)	Electric (instant or storage) to gas instant or storage ($/kWh)	Electric (instant or storage) to solar electric ($/kWh)	Electric (instant or storage) to solar gas ($/kWh)
Level 1	0.16	(4.05)	1.08	0.82
Level 2	0.20	(5.17)	1.38	1.05
Level 3	0.28	(7.30)	1.94	1.47
Level 4	0.36	(9.13)	2.43	1.84
Total program effectiveness	**0.36**	**(9.13)**	**2.43**	**1.84**
Proportion of participants by pathway	12%	8%	3%	3%

[22] Due to time and contract constraints the cost benefit and cost effectiveness analysis were undertaken before program expenditure was finalised. As a result there are some differences between the figures used in the CBA and CEA and the final expenditure.

The most cost-effective pathway for an upgrade of a gas hot water system was gas instant or storage to heat pump ($0.04/MJ).

Table 22 Cost-effectiveness results: gas pathways

Cost level	Gas instant or storage to solar gas($/MJ)	Gas instant to solar gas ($/MJ)	Gas storage to Instant gas ($/MJ)	Gas instant or storage to heat pump ($/MJ)
Level 1	0.027	0.026	0.024	0.019
Level 2	0.034	0.033	0.031	0.024
Level 3	0.049	0.046	0.043	0.034
Level 4	0.061	0.058	0.054	0.043
Total program effectiveness	**0.061**	**0.058**	**0.054**	**0.043**
Proportion of participants by pathway	46%	7%	6%	16%

Cost-effectiveness results: electricity and gas pathways inclusive of all contributions

When all contributions are taken into account, the most cost-effective pathway for an upgrade from an electric hot water system (instant or storage) was still to a heat pump ($0.45/kWh), since that is the pathway with the lowest cost/energy savings ratio.

Table 23 Cost-effectiveness results: electricity pathways – all contributions

Cost level	Electric (instant or storage) to heat pump ($/kWh)	Electric (instant or storage) to gas instant or storage ($/kWh)	Electric (instant or storage) to solar electric ($/kWh)	Electric (instant or storage) to solar gas ($/kWh)
Level 1	0.25	(6.49)	1.73	1.31
Level 2	0.30	(7.61)	2.03	1.54
Level 3	0.38	(9.74)	2.59	1.97
Level 4	0.45	(11.57)	3.08	2.34
Total program effectiveness	**0.45**	**(11.57)**	**3.09**	**2.34**
Proportion of participants by pathway	12%	8%	3%	3%

When all contributions are taken into account, the most cost-effective pathway for an upgrade from a gas hot water system (instant or storage) was from a gas instant system to new gas instant system ($0.054/MJ).

Table 24 Cost-effectiveness results: gas pathways – all contributions

Cost level	Gas instant or storage to solar gas ($/MJ)	Gas storage to instant gas ($/MJ)	Gas instant or storage to heat pump ($/MJ)	Gas instant to gas Instant ($/MJ)
Level 1	0.043	0.041	0.039	0.031
Level 2	0.051	0.048	0.045	0.036
Level 3	0.065	0.062	0.058	0.046
Level 4	0.077	0.073	0.069	0.054
Total program effectiveness	**0.077**	**0.073**	**0.069**	**0.054**
Proportion of participants by pathway	46%	7%	6%	16%

Cost benefit analysis

The cost benefit analysis (whole of program, excluding co-contribution) found a benefit cost ratio (BCR) of 0.48 (NPV = $(2,397)) for electric (instant or storage) to heat pump to be the pathway that provided the largest benefits, although no pathway achieved a BCR > 1, meaning that there was no pathway that had benefits that exceeded its cost.

Table 25 CBA results based on total program cost: cumulated four-level cost analysis (excl. co-contribution)

	Pathway	NPV (residential tariff)	BCR (residential tariff)	NPV (controlled load tariff)	BCR (controlled load tariff)
1	Electric (instant or storage) to heat pump	$ (2,397)	0.48	$ (3,133)	0.33
2	Electric (instant or storage) to gas instant or storage	$ (2,580)	0.45	$ (3,406)	0.27
3	Electric (instant or storage) to solar electric	$ (4,321)	0.07	$ (4,389)	0.06
4	Electric (instant or storage) to solar gas	$ (2,504)	0.46	$ (3,319)	0.29
5	Gas instant or storage to solar gas	$ (3,721)	0.20	n/a	n/a
6	Gas instant to solar gas	$ (3,674)	0.21	n/a	n/a
7	Gas storage to instant gas	$ (3,607)	0.22	n/a	n/a
8	Gas instant or storage to heat pump	$ (3,670)	0.21	n/a	n/a

Cost-benefit analysis: electricity and gas pathways inclusive of all contributions

The cost-benefit analysis (whole of program, including co-contributions) found a benefit cost ratio (BCR) of 0.38 (NPV = $(3,640)) for electric (instant or storage) to heat pump, which was the pathway that provided the largest benefits, although no pathway achieved a BCR > 1, meaning that there was no pathway that had benefits that exceeded its cost.

Table 26 CBA results based on total program cost: cumulated four-level cost analysis incl. co-contributions (see Appendix H8).

	Pathway	NPV (residential tariff)	BCR (residential tariff)	NPV (controlled load tariff)	BCR (controlled load tariff)
1	Electric (instant or storage) to heat pump	$ (3,640)	0.38	$ (4,376)	0.26
2	Electric (instant or storage) to gas instant or storage	$ (3,823)	0.35	$ (4,650)	0.21
3	Electric (instant or storage) to solar electric	$ (5,564)	0.06	$ (5,632)	0.064
4	Electric (instant or storage) to solar gas	$ (3,747)	0.36	$ (4,563)	0.23
5	Gas (instant or storage) to solar gas	$ (4,964)	0.16	n/a	n/a
6	Gas instant to solar gas	$ (4,917)	0.17	n/a	n/a
7	Gas storage to instant gas	$ (4,850)	0.18	n/a	n/a
8	Gas (instant or storage) to heat pump	$ (4,914)	0.17	n/a	n/a

Introduction to cost-effectiveness and cost-benefit analysis

Background

The Home Energy Efficiency Upgrade Program (HEEUP) was a trial project that assisted low-income households across Victoria in upgrading their hot water systems (HWS). The trial ran from April 2013 to January 2016 and was funded by the Department of Industry, Innovation and Science (DIIS) through the Low Income Energy Efficiency Program (LIEEP)[23]. It was delivered by the Brotherhood of St Laurence (BSL) in partnership with the Monash Sustainability Institute, AGL Energy Ltd., the NSW Office of Environment and Heritage, and the Alternative Technology Association.

The high level objectives and intended benefits of the LIEEP as outlined in the Guidelines are as follow:

- Objectives:
    - Trial and evaluate a number of different approaches in various locations to assist low-income households to become more energy efficient.
    - Capture and analyse data and information for future energy efficiency policy and program approaches.
- Benefits:
    - Assist low-income households to implement sustainable energy efficiency practices to help manage the impacts of increasing energy prices and improve the health, social welfare and livelihood of low-income households.
    - Build the knowledge and capacity of consortium members to encourage long-term energy efficiency among their customers or clients.
    - Build capacity of Australia's energy efficiency technology and equipment companies by maximising the opportunities for Australian Industries to participate in the projects.

Households were recruited to the program via direct mail (from AGL) or through community-based channels. The program distributed letters progressively to over 120,000 households. In total, 2,400 households expressed interest in the program and home visits were conducted with 1,291 of them. During the home visits an energy engagement officer discussed the costs and benefits of different upgrade options with the householder. These home visits resulted in upgrades of the hot water systems (HWS) of 764 households.

Participants had the choice of upgrading their HWS to:

- Solar with gas booster

[23] The LIEEP was a competitive merit-based grant program established by the Commonwealth Government to provide grants to consortia of government, business and community organisations to trial approaches to improve the energy efficiency of low income households and enable them to better manage their energy use.

- Solar with electric booster
- Heat pump
- Instant gas
  or
- Gas storage.

The cost of each upgrade option was subsidised by BSL (using DIIS funding). Households were also offered an interest-free loan for the unsubsidised portion of the HWS upgrade. Depending on the fuel type before and after intervention, the total cost of the new HWS could also receive additional financial assistance through the VEET[24] and/or via STCs[25], thereby reducing the initial installation cost even further. The BSL made subsidies either directly to the householder, or provided a flat subsidy of $1,200 per upgrade to participating Community Housing Associations, regardless of the chosen upgrade. The Community Housing Associations (rather than the occupant) also paid for the unsubsidised portion of the upgrades in these instances.

The subsidies made available to individual participating households (i.e., participants not located in Community Housing) by BSL varied over the course of the program, as shown in Table 27 below.

Table 27: Time frame and type of subsidy

Jul 13 – Jun 14	Jul 14 – 8 Feb 15	9 Feb 15 – April 15	May 15 – Dec 15	Jun 15 – Mar 16
BSL HESS: all available systems attracted a $1,200 cost to the householder	**BSL**, all subsidies were fixed at $2,000 for solar	**BSL 1**, all subsidies were fixed at $2,500 for solar	**BSL 2,** fluctuating subsidy, with a maximum out of pocket expense of $2,000	**Community Housing,** received a flat subsidy of $1,200 for each upgrade irrespective of the system and fuel type.

Purpose

OGW was engaged to provide advice to carry out a cost-effectiveness and benefit-cost analysis of the program as a whole using the methodology specified in the LIEEP Guidelines (discussed in the LIEEP contribution allocation methodology section below). Data on the cost of the program was provided by BSL. Data on the energy savings achieved in the program were provided by the Monash Sustainability Institute (MSI).

Data

Data regarding the installation cost and timing, as well as subsidy payments was collected throughout the program by Brotherhood of St Laurence (BSL) staff for each

[24] The Victorian Energy Efficiency Target provided additional financial assistance for upgrades to solar and heat pump HWS.
[25] Only gas or electric solar HWS were eligible for STCs.

individual household while MSI estimated the energy savings and the resultant daily and annual cost savings for eight relevant upgrade pathways.

The data set maintained by BSL included the following information for 764 individual participants:

- Pre-intervention type of HWS
- Post-intervention type of HWS
- Type and amount of subsidy and participant co-contribution
- Cost of installation
- Date of installation
- LIEEP contributions and non-LIEEP contributions (i.e. VEET and STC co-contributions).

The data on uptake was provided on an aggregate level across all households. As a result, we were not able to analyze the uptake rate by subsidy or by technology relative to all householders that expressed an interest in participating in the program[26].

MSI analysis

MSI provided pre-/post intervention consumption comparisons for participants by pre-intervention HWS energy source and technology pathway[27]. This data set allows comparison of different upgrade pathways, with the resultant average daily energy saving and average daily monetary savings resulting from the upgrade[28].

The MSI study results indicate a significant decrease in average daily pre-intervention energy consumption of 25 percent and 7 percent for electricity and gas respectively. These savings account for 762 kWh for average annual electricity consumption and 2,787MJ for gas consumption.

This translates into an annual average saving per household of $216.13 for electricity consumption and $55.64 for gas consumption, based on an average marginal market offer retail electricity price of $0.28/kWh (January 2015[29]) and an average marginal gas retail tariff of $0.02/MJ (January 2015).

[26] Where information was available on individual participating households, we were able to use it to adjust for missing data. For example, information was available on whether the household received VEET and/or STC co-contributions. Averages from this data were used to assign VEET and STC values to the 24% of the records for which data on these items was missing.

[27] The term 'technology pathway' is used to indicate each of the combinations or pre-intervention and post-intervention pairs of HWS equipment that occurred under the program.

[28] Full details of the MSI consumption analysis is provided by Byrne et al. What was the effect of the HEEUP on household electricity and gas consumption? in Chapter 2 of this report.

[29] Adjusted by CPI Mar 2014 – Mar 2015 http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/32044F411E5ACC79CA257E89001B226A?opendocument

MSI compared their estimated energy savings with published energy savings from DEDJTR (2015), Sustainable Victoria (2015) and EnergyConsult (2012). The publicly available estimates from past trials and engineering approaches appear to be higher compared to the results from the HEEUP trial. Possible reasons for the size of the difference between the MSI results and these other studies include:

- The other studies were all engineering analyses, while the MSI study is a bill analysis. Engineering analyses can focus on the thermodynamic changes within an end use, and may not account for behavioural change. Bill analyses, by their very nature, reflect customer usage changes – for example, changes in family composition, changes in non-hot water usage, or the possibility that the customer, having had energy efficient measures installed, may decide that they can now 'afford' longer showers.
- For a whole-house billing analysis to accurately capture water heating energy consumption changes, the amount of energy consumed for all other end uses must remain relatively constant. Otherwise, changes in the energy consumed in those end uses will 'appear' as hot water savings. This sort of effect can be particularly pronounced if weather conditions change markedly across the pre- and post-intervention timeframes.

Data limitations and application of MSI data

There are issues with the representation of the data in the MSI report that limited our ability to answer some of the originally intended questions. The MSI report provides cost-savings on:

- four electricity pathways, three of which are deemed to have statistically significant results but all of which are deemed to be at a level of 'practical' statistical significance (the electric storage to electric solar is deemed non-significant due to the small sample size[30])
- six gas pathways, three of which are deemed to have statistically significant results and another two of which are deemed to be at a level of 'practical' statistical significance (gas instant to gas instant and gas instant to gas solar); and one is marginally not statistically significant (gas storage to heat pump) [31]

[30] For completeness, we still used the results and compared them with the outcomes of the VEET study.

[31] MSI estimated that the four upgrade pathways have a significant impact on electricity consumption, meaning that there is enough evidence to infer that these results would occur in a larger population. Practically significant results mean that these changes are real for the sampled households but there is not enough evidence to infer that these results would occur in larger populations. The marginally non-significant pathway, gas storage to heat pump, was based on a low participation rate and the heat pumps were installed between April and October, and did not operate during summer months. This may underestimate the potential savings.

- There is no information on the energy and monetary savings by subsidy type or technology; the savings are calculated by pathway and were aggregated across subsidy types
- The MSI study results do not include households that participated in the last months of the HEEUP and thus, the HEEUP encompasses a larger total sample size
- The MSI study accounted for 63[32] households in the electricity pathways and 210 households[33] in the gas pathways that are deemed to be of statistical significance.
- We extrapolated these results for our entire sample, resulting in estimating the benefits obtained by 725 out of a total of 764 households, accounting for 187 in the electricity pathways and 538 households in the gas pathways.
- The electricity savings in the upgrade pathways that involve a switch to gas are net of the increase in gas consumption.
- The dollar savings are based on the average retail offer price, but it is our understanding that most of the program participants that use electric hot water are on controlled load tariffs. There is only limited information in the program dataset to distinguish between households on controlled load tariffs versus households on continuous tariffs. We made some high level inferences to account for the lack of information by accounting for the proportion of the population that was on controlled load tariffs for each pathway (see Cost-benefit analysis of HEEUP below), and assuming that there were no changes in the householder's tariff choice after the intervention[34]

As a result of the above mentioned limitations:

- We could only perform a cost-effectiveness analysis and cost benefit analysis for the pathways for which savings data are available.[35] We also assumed that the useful life of all of the HWS upgrades is 15 years and that the maintenance costs of the new HWS were essentially no different from those of the pre-intervention technologies and therefore could be ignored.
- Cost-effectiveness and cost-benefit results were calculated using two sets of energy savings inputs: the MSI results and the savings as calculated by the Victoria Department of Economic Development, Jobs, Tourism and Resources (DEDJTR)[36]. This was undertaken as a means of assessing the potential savings that could be

[32] We note that the sample sizes for the electricity pathways in the MSI study are small. MSI used a step-wedge design to account for the lack of control groups and small sample sizes. The results were considered significant, meaning that there is enough evidence to infer that these results apply to larger sample sizes.
[33] See Tables 9 and 10, in Chapter 2 of this report.
[34] Unlike the MSI study, however, we did not account for household sizes, due to insufficient data.
[35] And assume use of the average tariff that is provided in table 10 of the MSI report (see Chapter 4), and an estimated proportion of households on controlled load tariff.
[36] DEDJTR: 'Modelling the future VEET certificate market for residential-type measures'. Savings estimates available from Sustainability Victoria report were investigated but not used for the purpose of this report as they have not been published.

masked by the limitations of a whole-load billing analysis as discussed in MSI analysis above.

The available sample size to estimate the energy efficiency savings was N = 63 for electricity pathways, and N = 210 for gas pathways[37]. We extrapolated these results to the complete sample size for the C-E and CBA, which is 764.

Application of Monash data for the cost-effectiveness and cost-benefit analyses

The C-E and CBA applied a 28 c/kWh peak tariff and an 18 c/kWh off-peak tariff, in line with the Monash study and their referenced estimates from Sustainability Victoria (2015). The peak tariff was CPI adjusted to align the electricity price with the gas price.

We applied sensitivities to allow variations in energy savings estimates by applying DEDJTR's (2015) energy savings data. In addition, we applied sensitivities to the cost of electricity by assuming that the entire population is on peak tariffs, compared to a weighted approach that assumes that a proportion of the population in each pathway is on a controlled-load tariff. This is detailed below (Cost-benefit analysis of HEEUP).

The MSI data uses upgrade pathways that only comprise electricity storage to relevant upgrade technologies. However, the HEEUP data set also includes electricity instantaneous technologies as the original, pre-intervention HWS. In these cases, we assumed that the savings from electric storage and electric instantaneous HWS would be the same for each post-intervention HWS. It should be recognised that this is likely to over-estimate the savings for the instantaneous pre-intervention segment of the sample.

We applied the following aggregations for pathways:

- *Our modelling:* electric (instant or storage) to gas instant or storage – *MSI modelling*: this is only electric storage to instant gas, assuming the energy savings from the Monash pathway and extrapolating it to the entire population in the respective pathway.
- *Our modelling:* electric (instant or storage) to solar electric – *MSI modelling*: electric (storage) to solar electric. This pathway was considered by MSI to be statistically non-significant, although previous trials reported decreases in electricity consumption of 16.7 and 22 per cent[38], hence can be considered to be practically significant.
- Like to like gas upgrades such as gas storage with gas storage and instant gas with instant gas, did not deliver statistically significant decreases in consumption. In fact, upgrading an existing gas storage unit to a new one resulted in 16 percent increase in consumption. Possible explanation may include that the replacement unit was

[37] See Tables 9 and 10, Chapter 2 of this report
[38] Lynch et al. (2013), Alice Springs Solar City trial.

larger, allowing some households to use more hot water than they would otherwise have done.

The DEDJTR 2015 (VEET) approach

The MSI report (2016)[39] compares the estimated HEEUP energy savings with the savings that were estimated by Sustainable Victoria (2015)[40] and DEDJTR (2015)[41]. It was acknowledged that the reductions in electricity and gas consumption and subsequent estimate of financial savings based on the HEEUP model results were not completely consistent with either one of these sources. The HEEUP results suggest that the intervention achieved lower energy reductions compared to either of these studies. These differences may be due to the sample households and study context having different characteristics (i.e. low income households, older residents, small number of residents, relatively cooler climate, etc.) to those on which the Sustainable Victoria and DEDJTR studies were based on.

Sustainability Victoria developed a spreadsheet model to predict the future behavior of the VEET certificate market for residential-type measures under a range of scenarios. The modelling for this data set was initiated by DEDJTR. These VEET results estimated four upgrade pathways, which were comparable with the upgrade pathways estimated by MSI.[42]

It is worth noting, that there are stark differences in the methodologies to estimate the energy savings from upgrading the HWS between the HEEUP/Monash estimates compared to the VEET estimates.

The HEEUP data is based on full-bill energy savings estimates, while the VEET estimates use an engineering approach. The full-bill energy savings estimate accounts for the entire energy usage across the whole household, not just the HWS. As such, a change in the usage of other appliances may cause changes in energy consumptions that could not be accounted for in MSI's estimates, such as:

- Changes in the usage of other appliances,
- Changes in the composition of the household, i.e. the number of occupants in the household might have increased after the intervention. For example, the house was occupied by a couple before the intervention and was replaced by a family with two children afterwards.

[39] see Chapter 4
[40] Sustainability Victoria (2015) Hot water running costs. Accessed May 17, 2016 http://www.sustainability.vic.gov.au/services-and-advice/households/energy-efficiency/at-home/hot-water-systems/hot-water-running-costs
[41] DEDJTR: 'Modelling the future VEET certificate market for residential-type measures',
[42] It was recognized that the underlying algorithms that estimate the energy savings overstate these savings and that VEET certificate creation algorithms will be updated from 2017. DEDJTR: 'Modelling the future VEET certificate market for residential-type measures', p. 9.

As such, there is a possibility that the real savings that could have been achieved through the HWS only, may have been underestimated.

To provide a comparison (likely upper energy savings estimate), we compared the HEEUP results with the deemed approach based on engineering estimates that was available from the VEET analysis. This approach applies engineering data to estimate the changes in energy usage as a result of only the differences in the thermodynamic properties of the pre- and post-intervention HWS technologies (i.e. behaviour is excluded except where an explicit assumption is made about its impact). These estimates are often a slight overstatement, as they do not take environmental factors and possible behavioral changes in the household into account.

Despite these drawbacks with both approaches, the results provide useful upper and lower bound estimates of the energy savings as a result of the HEEUP.

Organisation of the report

The report is organised as follows. The first section provides an overview of the four cost-level analysis framework specified by DIIS. The next section presents how the costs applicable to each of the four cost levels were derived. This is followed by the Cost-effectiveness analysis and then the cost-benefit analysis of HEEUP.

HEEUP four cost-level analysis

The LIEEP provided the primary funding source for the HEEUP, but this was supplemented by various sources of co-contributions. The C-E analysis and CBA include costs only attributable to the LIEEP funding and exclude any co-contributions. The analysis was also undertaken for all contributions (see summary and Appendix H)

The *LIEEP* contribution was used for:

- Staff costs, i.e. salaries to BSL staff for administration, recruitment and home visits
- Associated on-costs
- Subsidies for the purchase of HWS upgrades i.e. BSL and community housing (see LIEEP allocation methodology below for a description of the treatment of subsidies)

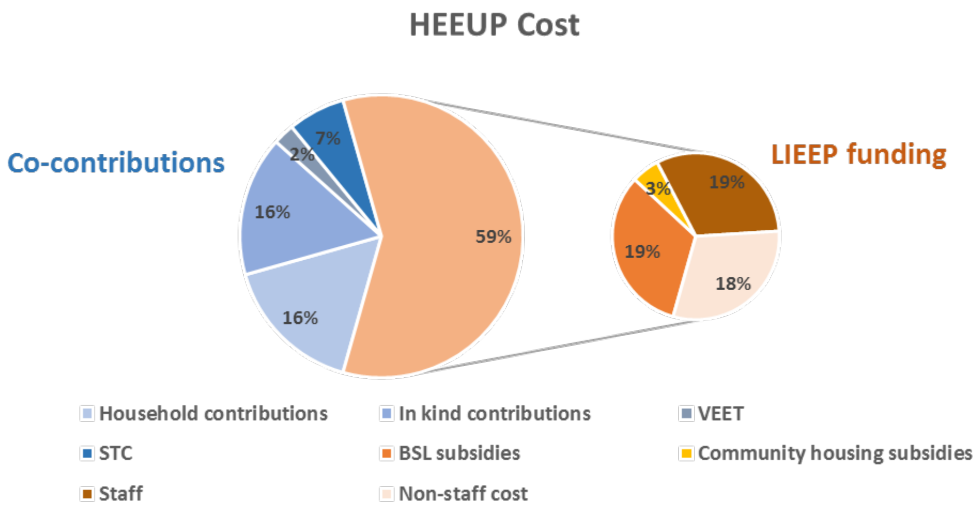
Non-LIEEP contributions are referred to as *co-contributions* and include:

- Contributions made by households to fill the gap between subsidies by BSL to the household for the HWS
- In-kind contributions by external stakeholders (see below)
- VEET[43] and STC[44] payments, which reduce the cost of the HWS at the time of installation.

[43] Under the VEET scheme, accredited businesses can offer discounts and special offers on HWS (and other selected energy saving products). The level of discount is dependent on the Victorian energy efficiency certificates (VEEC) the upgrade attracts.

Figure 22 provides an overview of the contributions by source.

Figure 22: HEEUP cost allocations



HEEUP funding was allocated according to the four cost-level analysis framework based on the LIEEP guidelines and outlined in Table 28 below, which provides an overview of the LIEEP framework and the allocation of costs as defined by DIIS. The table provides a high level description of the cost data that is relevant for conducting each level of the analysis. Appendix H1: LIEEP framework application for HEEUP presents further information on the application of this framework to the analysis of the HEEUP program.

The cost-effectiveness and cost benefits of co-contributions were calculated separately and the results are presented below and in Appendix H4: Non-LIEEP contributions – co-contributions by households, VEET and STC, in-kind contributions.

Table 28: Four levels of analysis – LIEEP framework

Cost level	Cost data analysed
Direct Trial approach (Level 1)	**a. Cost of delivering the trial approach to a participant** • The calculated cost of delivering: o The retrofit hardware and install cost per participant o The home energy audit and coaching cost per participant o The education program per person • Staff costs o Percentage of: energy engagement officers, admin, loan, management • Non-staff costs

[44] Small scale technology certificates (STC) are created per system, based on the MWh that are generated by the system (solar, wind or hydro; in the HEEUP case, only solar was available) or displaced by the solar HWS over the life of the system.

Cost level	Cost data analysed
	o OEH o Cars • May include: Household contribution/Total cost of hot water system, STC/VEET
Trial Component (Level 2)	a) Cost of delivering the trial approach to a participant, **and** **b) Costs associated with:** **i. Recruiting a participant, and** **ii. Maintaining a participant** **iii. Delivery** • For example, media and advertising, staff time, conducting interviews, screening applicants, maintaining resources to support ongoing participation etc.) • Staff cost i. Percentage of: EEO (engaging follow up), admin (higher maintenance/intake), loans admin, management (partner relations) • Non-staff costs i. Percentage of AGL (recruitment), loans
Total Business (Level 3)	The delivery of an outcome for: a) Cost of delivering the trial approach to a participant, **and** b) Costs associated with: i. Recruiting a participant, and ii. Maintaining a participant, **and** **c) Cost of running an organisation to do the above** • For example, renting office space, IT infrastructure, energy costs, running costs, over-heads, etc.) • Staff cost i. Percentage of Management overheads, loans • Indirect staff costs i. Percentage of Rent, IT Energy
Total Trial (Level 4)	The delivery of an outcome for: a) Cost of delivering the trial approach to a participant, **and** b) Costs associated with: i. Recruiting a participant, and ii. Maintaining a participant, **and** c) Cost of running an organisation to do the above, **and** **d) Cost of participating in a government funded trial**[45] • For example, total cost of the trial, including funding, and administrative and compliance costs associated with participating in a government funded trial - e.g. Costs associated with preparing milestone and financial reports)

[45] Although stated in the guidelines, we excluded co-contributions from the cost analyses as we only considered costs that were directly funded through LIEEP payments. However, co-contributions were considered as an additional calculation in the section Non-LIEEP contributions

Cost level	Cost data analysed

	• Staff cost
	  i. Percentage of management
	• Non-staff costs
	  i. All research costs (BSL, MSI), AGL
	• Non-staff costs

Source: LIEEP

LIEEP contribution allocation methodology

The *LIEEP* contribution was used for:

- Staff costs, i.e. salaries to BSL staff for administration, recruitment and home visits
- Associated on-costs
- Subsidies for the purchase of HWS upgrades, i.e. BSL and community housing

Staff costs and associated on-cost

The staff costs were accounted for in an accounting staffing expenses format. The cost allocations for staff expenses in this format needed to be disaggregated and aligned with the relevant cost levels for the four-cost analysis.[46]

Thus, these proportions represent the relative degree of participation in the delivery of the program. The program is divided into the three financial years it ran for (FY 2013/14, FY 2014/15 and FY 2015/16).

The allocated proportions account for the time spent by staff at different levels for the delivery of the program. The annual four program costs are allocated across staff levels in this fashion. In the first year of HEEUP, only the program and technical manager, EEO and admin loan staff were involved in the delivery of the program. Year 2 involved administration and data processing. In the last year, all staff levels (i.e. program manager, EEO, admin loan, technical manager, EEO & recruitment, admin and data processing) were involved in the delivery of the program. Appendix H5: Weighting for direct and indirect staff costs provides a comprehensive presentation of the allocation matrix for step 1 as well as step 2.

Direct program delivery cost – BSL subsidies and Community Housing subsidies

Cost level 1 also includes the cost of subsidies. Subsidies help the householder with the initial investment cost of the upgrade and were either paid directly to the householder (BSL subsidies) or as a $1,200 flat rate for each HWS upgrade through community housing providers. BSL subsidies differed in delivery mode across the program's life span, depending on the timing as described in Table 27 above.

[46] BSL staff provided approximate costs for each staff level and percentage allocations for the participation of each staff level across the four cost levels.

Both BSL and community housing subsidies are included in the cost allocation for cost level 1. Due to the different treatment of community housing during the HEEUP trial period, it was deemed appropriate to separate the community housing and BSL subsidies. Appendix H3: Direct staff cost – subsidies, BSL and Community Housing shows that from a total of $1,316,147 in subsidies, $188,100 were related to subsidies made through community housing providers and $1,128,047 were made directly through BSL. Community housing subsidies were only delivered during the last year of the program (FY 2015/16).

The calculations for BSL subsidies and community housing subsidies contain two cost parts:

- The monetary value of the subsidies
- The BSL staff costs necessary to administer these subsidies to the participants and to community housing providers

The direct staff costs for the FY 2015/16 were weighted to apportion the amount of time spent on BSL subsidies and community housing subsidies.

The costs for both subsidies are allocated based on the same allocation matrix. This matrix is also the same allocation matrix that is used to allocate direct and indirect staff costs.[47]

For comparison, Table 29 illustrates the total cost by cost Level, cumulatively, inclusive of the BSL and community housing subsidies, added to cost Level 1. Appendix H2 shows the disaggregated allocations of the incremental and cumulative annual costs, inclusive of subsidies, as well as a separate estimate showing results inclusive of household contributions (see Tables 37–39).

Table 29: Total annual cost by cost Level 1, 2, 3 and 4 - cumulative

Staff cost FY	Total cost excl. household-contributions	Total cost incl. household contributions
Cost level 1	$ 1,575,908	$ 2,533,669
Cost level 1, 2	$ 2,012,032	$ 2,969,793
Cost level 1, 2, 3	$ 2,839,063	$ 3,796,824
Cost level 1, 2, 3, 4	$3,552,007	$4,509,768

Non-LIEEP contributions – household co-contributions, in-kind co-contributions, VEET and STC

Co-contributions include:

- Contributions made by households to fill the gap between subsidies by BSL to the household for the HWS
- In-kind contributions by external stakeholders

[47] The allocation matrix was provided to OGW by BSL staff.

- VEET and STC payments, which reduce the cost of the HWS at the time of installation.

The total sum of all co-contribution was $2,048,286[48]. These are costs that are not financed through the LIEEP and represent costs that are additional to the cost of the LIEEP funding.

These costs are not included in the four-cost-level analysis and are presented separately[49]. Table 30 and Table 31 present the co-contributions by household, VEET + STC and in-kind contributions, as well the percentage of its contribution within the total amount of co-contributions. The cumulative in-kind co-contributions are presented in Table 31. In-kind co-contributions were allocated according to the LIEEP guidelines.

In-kind contributions were allocated using a matrix that apportioned them based on time spent by the co-contributor on activities associated with each of the four cost levels[50]. A detailed list of co-contribution costs is presented in the Appendix.

Table 30: Co-contributions – Total households' co-contribution and VEET + STC

Co-contributions	Total non-LIEPP funded co-contributions	Percentage of total co-contributions
Household contributions	$ 957,761	47%
VEET + STC	$ 145,160	7%

Table 31 Total annual in-kind contributions by cost Level 1, 2, 3 and 4 – cumulative

Staff cost	Total cost by cost level	Percentage of total co-contributions
Cost level 1	$0	
Cost level 1, 2	$282,217	
Cost level 1, 2, 3	$570,262	
Cost level 1, 2, 3, 4	$945,366	46%

Cost-effectiveness analysis and cost-benefit analysis

Overview

The cost-effectiveness (C-E) analysis measures the cost for each unit of energy saved under each of the various technology pathways and for the program as a whole. This is in contrast to the cost benefit analysis, which also accounts for monetized benefits in dollar terms, but does so in terms of the either or both (a) the degree to which the

[48] Note: due to time and contractual constraints, the cost benefit and cost effectiveness analysis were undertaken prior to the finalisation of the program budget. As a result there are some differences between the figures used in the CBA and CEA and the program final budget.
[49] We only included funding that could be directly associated with money coming from LIEEP. However, we do recognize the importance of co-contributions to the successful delivery of the program; therefore, we undertook separate analysis of the non-LIEEP contributions.
[50] The matrix for the allocation of in-kind contributions was provided by BSL staff.

present value of the benefits of the program (primarily the stream of dollar savings over the life of the post-intervention technology) exceed the applicable program costs associated with those benefits), and/or the ratio of those savings to those costs.

At a minimum, BSL is obliged under the funding provided by DIIS, to provide a cost-effectiveness analysis of the HEEUP, based on the four cost-level approach as outlined in the LIEEP Guidelines.

The LIEEP Guidelines state that both analyses should only include quantifiable benefits and costs that can be directly attributed to the HEEUP. Thus, both analyses take those subsidies into account that were provided directly from LIEEP funding, but exclude co-contributions (i.e. householder's co-contributions for the purchase of a HWS, in-kind contributions and VEET and STCs).

In addition, we estimated an upper and lower bound based on different estimates for household energy savings before and after the intervention. As discussed above, the lower bound was estimated based on the HEEUP data that was collected throughout the course of the program and estimated by MSI. In contrast, the upper bound savings are based on a deemed approach using estimates developed by DEDJTR for the VEET data. The objective is to provide a robust range for the C-E and CBA results, given the uncertainties surrounding the different estimation methodologies as outlined in the data section above.

Thus, the two analyses outlined below and in the cost-benefit analysis of HEEUP, were undertaken for both data sets, the MSI estimates of energy saving based on the HEEUP data and the VEET savings.

The C-E is performed based on the following assumptions:

- The total cost-effectiveness for each upgrade pathway is weighted for each cost level.
- The costs are based on the full cumulated cost of the HEEUP, including the subsidies (i.e. BSL and community housing subsidies)[51].

The CBA is performed for each of the eight pathways, based on two scenarios.

- Firstly, based on total cumulative program cost, including the subsidies (i.e. BSL and community housing subsidies). The cost of the HWS upgrade is included in the form of the subsidies. The following scenarios were considered:
  - Cost and benefits based on residential tariff
  - Cost and benefits based on controlled-load tariff
- Secondly, the CBA was performed based on the cost of the technology only. Here, the costs were represented by the subsidies to upgrade the HWS, exclusive of

[51] Appendix H2 provides a comparison of the program cost based on the full cost of the upgrade, inclusive of contributions by the householder.

program on-cost. The purpose was to answer the question as to what the cost and benefits of the technology itself were, based on the energy and the dollar-value of the savings that can be achieved by that technology[52]. We analyzed the following scenarios:

- *HWS costs[53]:* the technological upgrade costs as invoiced, including contributions made by households towards the purchase of the HWS, but excluding VEET and STC[54]
- *LIEEP contribution to HWS costs:* the technological upgrade costs exclusive of contributions made by households. The costs are based on the BSL and community housing (i.e. subsidies paid directly through LIEEP funding) only, representing the cost/benefits of the technology pathway to DIIS.
- *Household contribution to HWS costs:* the technological upgrade costs based only on the contributions by the householder (excluding VEET + STC and BSL and community housing subsidies). This represents a technology analysis from the householder's perspective after government's policy impacts.

Lower-bound energy savings – MSI data

Table 32 and Table 33 show the energy savings used in the cost-effectiveness and cost-benefit analyses for the eight pathways whose results were statistically or practically significant[55]. The tables show the average pre- and post-intervention daily consumption (in either kWh or MJ, depending on the pathway) for the households that participated in each of the pathways, as well as the average total savings calculated to accrue for households over a 15-year period, which was taken as the likely useful lifetime of the measures installed under the HEEUP.[56]

Table 32: Daily energy-savings for electricity pathways by household (MSI)[57]

	Pathway	Pre-intervention (kWh)	Post-intervention (kWh)	Net daily saving (kWh)	Total savings (kWh) after 15 years
1	Electric (storage) to heat	8.21	5.82	2.39	13,080

[52] The energy savings as well as the $-value savings were provided to BSL by Monash for the lower bound energy savings estimate and based on VEET for the upper bound estimates.
[53] These costs reflect the invoice cost after adjustment for VEET and STC
[54] Total HWS costs = Invoice costs = BSL/community housing subsidies + contributions by households
[55] We considered the pathways storage to electric heat pump and gas instant to solar gas to be practically significant. The reason was that the results for the switch to heat pump were considered by MSI to be only marginally non-significant, due to a small sample size, and the switch to solar gas was one of the VEET pathways that were used for comparison. Again, the reason for non-significant outcome was a small sample size in the MSI study.
[56] MSI estimated the upgrade pathway gas storage to gas storage with a significant increase in consumption of 16 percent. We did not include this pathway in the analysis as the reasons for this increase are unknown and may relate to a change in the size of the new HWS or some other reason that we could not account for within the timeframe and scope of this analysis.
[57] Pathways 2, 4 and 8 account for increased gas/electricity consumption after the fuel switch

	Pathway	Pre-intervention (kWh)	Post-intervention (kWh)	Net daily saving (kWh)	Total savings (kWh) after 15 years
	pump				
2	Electric (instant or storage) to gas instant or storage (net)	7.11	7.20	(0.09)	(509)
3	Electric (instant or storage) to solar electric	9.11	8.76	0.348	1,912
4	Electric (instant or storage) to solar gas (net)	7.11	5.33	0.46	2,520

Table 33: Daily energy-savings for gas pathways by household (MSI)

	Pathway	Pre-intervention (MJ)	Post-intervention (MJ)	Net daily saving (MJ)	Total net savings (MJ) after 15 years
5	Gas instant or storage to solar gas	106.91	92.94	13.97	76,469
6	Gas instant to solar gas	123	108.3	14.67	80,302
7	Gas storage to gas instant	105.43	89.75	15.68	85,837
8	Gas instant or storage to heat pump	99	79.22	19.76	108,208

The largest daily savings for the electricity pathway per household were achieved by upgrading from electric (instant or storage) to heat pump. The largest savings in the gas pathways were achieved through an upgrade from instant or storage gas to heat pumps.

Upper-bound energy savings – VEET data

Pathways 1, 2, 3 and 5 in the MSI study were found to be comparable with the pathways estimated for the VEET scheme. Table 34 shows the annual net savings and the total savings at the end of the useful life of the HWS. The useful life for the solar electric upgrade (pathway 3) was considered to be 6.5 years in the VEET analysis, compared to 15 years in our analysis. For comparison, we reported both (pathway 3a = savings after 6.5 years, and pathway 3b = savings after 15 years).

Table 34: Annual energy-savings for electricity and gas pathways by household (VEET)

	Pathway	MSI: Net saving (annually)	VEET: Net saving (annually)	MSI: Total savings (kWh) after 15 years	VEET: Total savings (kWh) after 15 years
1	Electric (storage) to heat pump (kWh)	872	2,381	13,080	35,721
2	Electric (instant or storage) to gas instant or storage (net) (kWh)	(34)	(2,74)	(509)	(24,888)
3a	Electric (instant or storage) to solar electric (kWh) (6.5 years' useful life)	n/a	3,403	n/a	22,122

3b	Electric (instant or storage) to Solar electric (kWh) (15 years' useful life)	127	3,403	1,912	51,050
5	Gas instant or storage to solar gas (MJ)	5,098	9,601	76,469	144,015

Results

The upper and lower bound energy savings range is considerably large. The reason for such wide differences in energy savings data may include:

- Overstatement of energy savings in the VEET analysis[58]
- Understatement of the household energy savings in the HEEUP data set, due to the small sample size
- Changes in household composition before and after the intervention
- Difference in the energy savings estimation methodology – the HEEUP estimate was based on the total energy bill, not limited to HWS consumption changes. In contrast, the VEET analysis bases its algorithms on engineering data related to the HWS only.

Cost-effectiveness analysis

The cost-effectiveness analysis asks the question: how much did each unit of energy save under the HEEUP cost in LIEEP funding (i.e. $LIEEP/kWh saved). The lower the cost, the more cost-effective the program.

Table 35 and Table 36 show the lower and upper bound results of the cost-effectiveness analysis for each of the four cost levels specified in the LIEEP Guidelines for each of the upgrade pathways (Table 35 shows the results for the electricity upgrade pathways, and Table 36 for the gas upgrade pathways).

These tables also show the proportion of participants in each pathway[59]. These proportions are used to weight the cost-effectiveness of each pathway in the calculation of the cost-effectiveness of the program overall.

Table 37 compares the results of the cost-effectiveness analysis based on HEEUP vs VEET energy savings estimates.

Specific assumptions for the cost-effectiveness analysis are the following:

- The cost-effectiveness analysis by cost-level assumes that the technology costs are already included in cost level 1 in the form of BSL and community housing subsidies (co-contributions are excluded). Appendix H7 provides a sensitivity analysis to show the implications for the cost-effectiveness of the program, if contributions from households are included within cost level 1.

[58] DEDJTR, 'Modelling the future VEET certificate market for residential-type measures', p. 9.
[59] Most participants did not have a 'free choice' of upgrade pathway, and rather chose what was suitable for their given circumstances, current HWS and housing situation.

- The cost-effectiveness analysis by cost-level is performed based on the cumulative cost levels as outlined in the LIEEP Guidelines.
- The daily consumption data pre-and post-intervention is an average across participants in each pathway.

Table 35 Cost-effectiveness results: electricity pathways

Cost level	Electric (instant or storage) to heat pump ($/kWh)	Electric (instant or storage) to gas instant or storage ($/kWh)	Electric (instant or storage) to solar electric ($/kWh)	Electric (instant or storage) to solar gas ($/kWh)
Level 1	0.16	(4.05)	1.08	0.82
Level 2	0.20	(5.17)	1.38	1.05
Level 3	0.28	(7.30)	1.94	1.47
Level 4	0.36	(9.13)	2.43	1.84
Total program effectiveness	**0.36**	**(9.13)**	**2.43**	**1.84**
Proportion of participants by pathway	12%	8%	3%	3%

Table 36 Cost-effectiveness results: gas pathways

Cost level	Gas instant or storage to solar gas($/MJ)	Gas instant to solar gas ($/MJ)	Gas storage to instant gas ($/MJ)	Gas instant or storage to heat pump ($/MJ)
Level 1	0.027	0.026	0.024	0.019
Level 2	0.034	0.033	0.031	0.024
Level 3	0.049	0.046	0.043	0.034
Level 4	0.061	0.058	0.054	0.043
Total program effectiveness	**0.061**	**0.058**	**0.054**	**0.043**
% of participants by pathway	46%	7%	6%	16%

Table 37 HEEUP C-E comparing MSI and VEET savings data

	Electric (storage) to heat pump ($/kWh)		Electric (instant or storage) to gas instant or storage (net) ($/kWh))2		Electric (instant or storage) to solar electric ($/kWh)) (6.5 years' useful life)		Gas instant or storage to solar gas (net) ($/MJ)	
Cost level	MSI	VEET	MSI	VEET	MSI	VEET	MSI	VEET
Level1	0.16	0.06	(4.05)	(0.08)	1.08	0.04	0.03	0.01
Level2	0.20	0.07	(5.17)	(0.11)	1.38	0.05	0.03	0.02
Level3	0.28	0.10	(7.30)	(0.15)	1.94	0.07	0.05	0.03
Level4	0.36	0.13	(9.13)	(0.19)	2.43	0.09	0.06	0.03
Program effectiveness	0.36	0.13	(9.13)	(0.19)	2.43	0.09	0.06	0.03

Results

The HEEUP results show that within the electricity pathways, switching from electricity to heat pump (pathway 1) is the most cost-effective pathway. This is because in comparison with the other pathways, it exhibits the lowest cost/energy savings ratio. This pathway also accounts for the largest proportion of participants among the electricity pathways.

Pathway 2 produces a negative result in terms of energy consumption (for both HEEUP and VEET). The reason for this is that the decrease in kWh due to the switch from electricity to gas results in a net increase in energy consumption. The household is still able to achieve a cost saving as a result of the upgrade, as (at the moment) gas prices are lower than electricity prices.

Within the gas pathways in the HEEUP results, the most cost-effective pathway is the upgrade from instant gas or storage to solar gas. This means that this pathway achieves one more unit of energy savings (here, one more MJ) for the least cost.

This is also the most common pathway used in the program. The greatest electricity savings are achieved through the electricity (instant to storage) to heat pump pathway.

The results from HEEUP and VEET reveal that switching from electric instantaneous or storage HWS to a solar storage system is the most cost-effective electricity pathway, with the lowest cost/energy savings ratios.

Cost-benefit analysis of HEEUP

For the cost-benefit analysis we applied the average daily $-savings by household as estimated by MSI and VEET and distinguished between the following two scenarios, as described below:

- **Scenario 1:** Analysis based on total program cost (this analyses the costs and benefits of the LIEEP funding for HEEUP), this scenario analyzed the following two categories:
    - **A)** Total program cost by cost level (cumulatively), this analysis is inclusive of BSL and Community Housing subsidies to account for the cost of the upgrade, based on residential tariff
    - **B)** As above based on the assumption that a proportion of the population is on controlled-load tariff
- **Scenario 2:** Analysis based on the cost and benefits of the technology only, exclusive of any other program costs, this scenario analyzed the following four categories:
    - **A)** Cost of technology assumed to be HEEUP subsidies (through BSL and community housing) and the benefits were estimated based on the $-savings using the residential tariff
    - **B)** Cost of technology assumed to be HEEUP subsidies (through BSL and community housing) and the benefits were estimated using $-savings assumed to represent a proportion of the population being on controlled tariffs
    - **C)** Cost of technology based on household's contributions and the benefits were estimated based on the $-savings using the residential tariff
    - **D)** Cost of technology based on household's contributions and the benefits were estimated using $-savings assumed to represent a proportion of the population being on controlled tariffs
    - **E)** Cost of technology is based on invoice costs[60] (after the application of any applicable VEET and STC subsidies) and the benefits were estimated based on the $-savings using the residential tariff
    - **F)** Cost of technology is based on invoice costs (after the application of any applicable VEET and STC subsidies) and the benefits were estimated using $-savings assumed to represent a proportion of the population being on controlled tariffs

The technology costs were estimated for two sets of daily savings, (a) all households were assumed to be on a residential tariff, (b) the daily savings were based on a weighted average, reflecting the proportion of households on controlled-loads. We made the following specific assumptions:[61]

- We calculated a weighted daily saving based on the average household unit savings (i.e. kWh, MJ) with the assumed controlled-load tariff

[60] In this case, it represents the cost of the technology, inclusive of subsidies and household contributions, after VEET and STC subsidies are applied.
[61] This adjustment did not need to be made for the gas pathways, as there are no controlled load gas tariffs.

- We weighted the new daily savings with the proportion of participants on controlled-load tariff vs. residential tariff
- We assume that the new daily savings are based on the controlled-load tariff, reducing the cost of electricity to run the HWS from $0.28/kWh (average estimated electricity tariff) to $0.18[62].
- We assume that the savings were achieved through the HWS upgrade only and applied the controlled load tariff to the daily savings

A more holistic estimate would include changes in water consumption after the intervention, where increases in water use would indicate a possible benefit in comfort and possibly hygiene at the expense of additional water use. But because hot water is now relatively cheaper, householders may have been more likely to use more of it.

The following sections present the results of the cost-benefit analysis by pathway, based on the two scenarios as outlined above.

The CBAs are based on the following technical assumptions:

- A 7 percent[63] discount rate for the NPV was applied, based on a 15-year useful life of the upgraded technology.
- The benefits represent the annual discounted savings to the household over the 15-year life of the asset.
- The savings are calculated based on the average daily household savings as represented in the Monash analysis.
- Households did not change tariffs after the intervention. This means that households on off-peak tariffs before the intervention continued to be on off-peak tariffs after the intervention[64]

CBA results

The cost benefit analysis answers the question of how much benefit (in dollar terms) each of the pathways produces per dollar of money spent that is directly attributable to the program. A cost-benefit analysis compares the outcomes with the counterfactual base case. In this case, the counterfactual or base case would be a scenario that accounts for business as usual, i.e. energy consumption if the householder kept the current (pre-intervention) HWS. The results of the CBA express the implied changes from the base case. A CBA result greater than 1 means the benefits of the program exceed its costs.

For robustness, we also compared these results with the results of the four comparable pathways in the VEET analysis. The objective is to provide an upper and lower bound as

[62] MSI report, see Chapter 4 of this report
[63] DTF ‘Economic evaluation for business cases: technical guidelines’, August 2013.
[64] The allocations are estimated for each pathway and presented in Appendix H6: Households on controlled load tariffs.

well as high level confirmation of the most cost-effective pathway. For example, if both estimates point to the same pathway to create the highest benefit/cost ratio, our conclusion will be more robust.

RESULTS FOR SCENARIO 1 – ANALYSIS BASED ON LIEEP PROGRAM COST

The analysis is based on the cost of the program, using the four-cost level framework. It includes only costs that are directly attributable to LIEEP funding and excludes any non-LIEEP funding such as householder's co-contributions, VEET+STCs and in-kind contributions. The cost of the technology is accounted for by applying the subsidy that was paid through the LIEEP funding (either BSL subsidies or subsidies through Community Housing) to the cost of Level 1. Appendix H8 shows the results of the CBA based on the total program cost, taking the full cost of the HWS into account, applying the invoice cost to the cost of Level 1 and as such including householder's co-contributions.

The benefits are based on the net energy savings and the residential tariff, and account for the daily saving by pathways. For example, electric (instant or storage) to heat pump generates a daily saving of $0.66. In contrast the benefits for the controlled load tariff are based on the net energy savings and the controlled load tariff. Here, the daily savings for the same pathway account for $0.40.

The results account for an increase in the consumption and hence cost of gas and electricity, when switching fuel. The savings for residential and controlled-load as provided by MSI for each pathway are presented in Table 38. The highest monetary savings can be achieved through upgrading from electric (instant or storage.) to heat pump. This is in line with the results of the C-E.

Table 38 daily saving by pathway (residential and controlled-load tariff)

	Pathway	Daily savings ($) (residential tariff)	Daily savings ($) (controlled load tariff)
1	Electric (instant or storage.) to heat pump	$0.68	$0.43
2	Electric (instant or storage.) to gas instant or storage	$0.62	$0.31
3	Electric (instant or storage.) to solar electric	$0.10	$0.06
4	Electric (instant or storage) to solar gas	$0.65	$0.35
5	Gas instant or storage to solar gas	$0.28	n/a
6	Gas instant to solar gas	$0.29	n/a
7	Gas storage to instant gas	$0.31	n/a
8	Gas instant or storage to heat pump	$0.40	n/a

Table 39 compares the NPVs and Benefit Cost Ratios (BCR) by pathway based on the savings presented in Table 38. The costs are based on the cumulative program costs, excluding non-LIEEP co-contributions. The costs for the technology are incorporated into cost Level 1, in form of BSL and Community Housing subsidies.

Table 39 CBA results based on total program cost: cumulated four-level cost analysis (excl. co-contribution)

	Pathway	NPV (residential tariff)	BCR (residential tariff)	NPV (controlled load tariff)	BCR (controlled load tariff)
1	Electric (instant or storage.) to heat pump	$ (2,397)	0.48	$ (3,133)	0.33
2	Electric (instant or storage.) to gas instant or storage	$ (2,580)	0.45	$ (3,406)	0.27
3	Electric (instant or storage.) to solar electric	$ (4,321)	0.07	$ (4,389)	0.06
4	Electric (instant or storage) to solar gas	$ (2,504)	0.46	$ (3,319)	0.29
5	Gas instant or storage to solar gas	$ (3,721)	0.20	n/a	n/a
6	Gas instant to solar gas	$ (3,674)	0.21	n/a	n/a
7	Gas storage to instant gas	$ (3,607)	0.22	n/a	n/a
8	Gas instant or storage to heat pump	$ (3,670)	0.21	n/a	n/a

The results show that none of the pathways produce a positive NPV or BCR > 1, even if we assume that all electricity participants are on the more expensive full residential tariff.

However, it is worth noting that the benefits above are based on energy savings only. There may be other, flow-on benefits from the program. These benefits are challenging to measure and there is a lack of data to do so. However, potential additional benefits that may result as a consequence of this program include (but are not limited to):

- Improved comfort, health and well-being (hygiene) benefits because householders may have longer showers/baths due to less expensive hot water and/ have increased their energy consumption overall
- Employment benefits, due to a large influx of demand for HWS during the delivery of the program
- Increased money in householder’s pockets, which may be spent to improve individual’s wellbeing.

Because of the uncertainties related to the energy saving estimates, we compared our results with results based on energy savings data from the VEET analysis.

Table 40 on the following page compares the CBA results in NPV and BCR terms for each of the technology pathways based on both the MSI and VEET energy savings estimates.

Table 40 CBA results based on total program cost: cumulative four level cost analysis comparing results based on HEEUP and VEET data

		HEEUP				VEET			
		residential tariff		controlled load tariff		residential tariff		controlled load tariff	
	Pathway	NPV	BCR	NPV	BCR	NPV	BCR	NPV	BCR
1	Electric (instant or storage.) to heat pump	($2,397)	0.48	($3,133)	0.33	$1,503	1.32	($895)	0.81
2	Electric (instant or storage.) to gas instant or storage	($2,580)	0.45	($3,406)	0.27	$874	1.19	($2,542)	0.45
3a	Electric (instant or storage.) to solar electric 15 years	($4,321)	0.07	($4,389)	0.06	$4,143	1.89	$1,977	1.43
3b	Electric (instant or storage.) to solar electric 6.5 years	n/a	n/a	n/a	n/a	$253	1.05	($955)	0.79
5	Gas instant or storage to solar gas (MJ)	($2,504)	0.46	n/a	n/a	($2,904)	0.38	n/a	n/a

Based on the higher energy savings in the VEET analysis, the results are more favorable compared to the HEEUP results. The highest BCR (and the only pathway with BCR>1 under both the controlled and non-controlled tariffs) is achieved when switching from electric (instant or storage.) to solar electric, assuming a 15-year useful life of the HWS. However, if assuming a useful life of 6.5 years, as reported in the VEET analysis, pathway 1, switching from electric to heat pump becomes the most beneficial upgrade pathway (but is only cost-beneficial on the non-controlled tariff). This is in line with the previous C-E, and also with the HEEUP data. Although the HEEUP results do not produce a positive BCR, the closest BCR (and thus the most beneficial) is the pathway 1.

Results for scenario 2 – Analysis based on the cost and benefits of the technology only

This scenario answers the question whether the dollar savings create a large enough benefit to cover the cost of the initial investment of the HWS, either in full (i.e. invoice cost), or in reduced form, based on subsidies (i.e. BSL and Community Housing) or based on contributions by householders to the initial investment.

Therefore, we analyzed this question from three different view-points:

- The LIEEP, here the costs are based on only the BSL and Community Housing subsidies

- The householder, here the costs are based on only the co-contribution that the householder made to purchase the HWS
- The total cost of the technology (excl. VEET + STC), which considers the full cost of the technology as invoiced (i.e., LIEEP and householder costs)

This analysis was also conducted based on controlled and non-controlled electricity tariffs.

The results show again that the benefits are greater when the $-savings are based on the residential tariff. The results show, that considering the view point of the LIEEP program, the electric (instant or storage) to heat pump and electric (instant or storage) to gas (instant or storage) generate a positive NPV and a BCR > 1 for $-savings based on the residential tariff. In addition, the pathway electric (instant or storage) to gas (instant or storage) also shows a positive NPV and a BCR > 1, based on the controlled-load tariff.

These two pathways also generate a positive outcome based on the residential tariff when considering co-contributions by households while VEET+STC[65] generate a BCR of 1.02 for the electric (instant or storage) to gas (instant or storage).

All other pathways fail to generate enough dollar savings for a BCR > 1.

Table 41, Table 42, and Table 43 present the CBA results for scenario 2.

Table 41 Technology cost only: based on BSL and community housing subsidies only

	Pathway	NPV (residential tariff)	BCR (residential tariff)	NPV (controlled load tariff)	BCR (controlled load tariff)
1	Electric (instant or storage.) to heat pump	$492	1.28	($244)	0.86
2	Electric (instant or storage.) to gas instant or storage	$1,107	2.15	$377	1.39
3	Electric (instant or storage.) to solar electric	($1,798)	0.15	($1,918)	0.10
4	Electric (instant or storage) to solar gas	($425)	0.83	($1,422)	0.45
5	Gas instant or storage to solar gas	($1,977)	0.32	n/a	n/a
6	Gas instant to solar gas	($1,810)	0.35	n/a	n/a
7	Gas storage to instant gas	($43)	0.96	n/a	n/a
8	Gas instant or storage to heat pump	($1,529)	0.39	n/a	n/a

[65] See Appendix I, Table 80 Total cost of the technology (excl. VEET + STC).

Table 42 Technology cost only: Based on contributions by households only

	Pathway	NPV (residential tariff)	BCR (residential tariff)	NPV (controlled load tariff)	BCR (controlled load tariff)
1	Electric (instant or storage.) to heat pump	$357	1.19	($379)	0.80
2	Electric (instant or storage.) to gas instant or storage	$803	1.63	($563)	0.70
3	Electric (instant or storage.) to solar electric	($1,711)	0.16	($1,831)	0.10
4	Electric (instant or storage) to solar gas	$206	1.11	($791)	0.59
5	Gas instant or storage to solar gas	($963)	0.49	n/a	n/a
6	Gas instant to solar gas	($1,033)	0.49	n/a	n/a
7	Gas storage to instant gas	($672)	0.61	n/a	n/a
8	Gas instant or storage to heat pump	($787)	0.55	n/a	n/a

Table 43 Technology cost only: Based on BSL and community housing subsidies + contributions by households = invoice costs (excl. of VEET and STC)

	Pathway	NPV (residential tariff)	BCR (residential tariff)	NPV (controlled load tariff)	BCR (controlled load tariff)
1	Electric (instant or storage.) to heat pump	($1,404)	0.62	($2,227)	0.39
2	Electric (instant or storage.) to gas instant or storage	($118)	0.95	($851)	0.61
3	Electric (instant or storage.) to solar electric	($3,837)	0.08	($3,905)	0.06
4	Electric (instant or storage) to solar gas	($2,368)	0.48	($3,184)	0.29
5	Gas instant or storage to solar gas	($3,869)	0.19	n/a	n/a
6	Gas instant to solar gas	($3,818)	0.20	n/a	n/a
7	Gas storage to instant gas	($1,777)	0.37	n/a	n/a
8	Gas instant or storage to heat pump	($3,295)	0.23	n/a	n/a