Renovation Pathways: Method and assumptions

TECHNICAL REPORT

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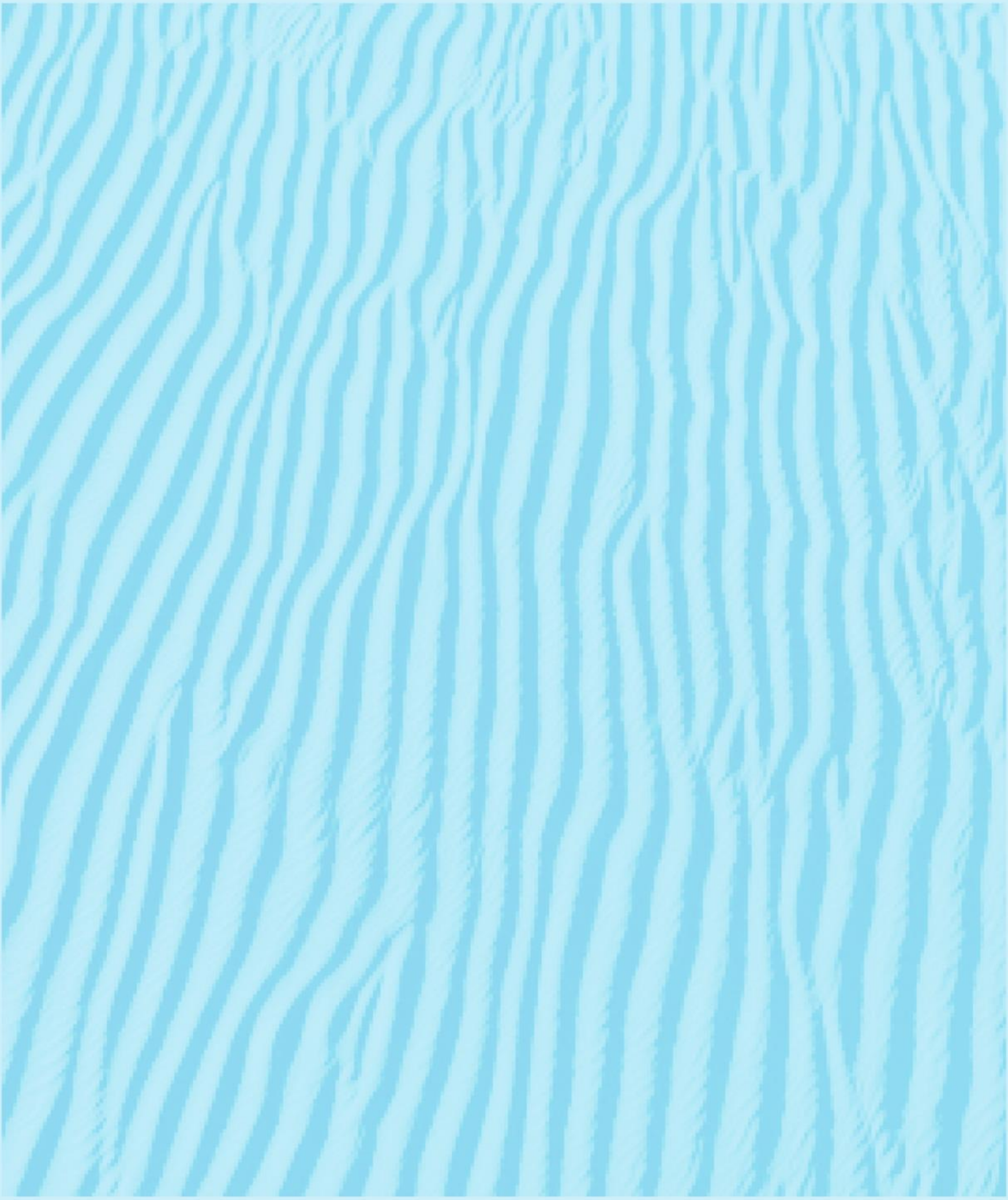

ACKNOWLEDGEMENT OF COUNTRY

We acknowledge and pay respect to the Traditional Custodians and Elders – past and present – of the lands and waters of the Wurundjeri people of the Kulin Nation on which the Climateworks Centre head office is located, and acknowledge that sovereignty has never been ceded.
We extend our respect to all Traditional Custodians and Elders of the lands and waters where Climateworks operates. More information.

ABOUT US

Climateworks Centre bridges the gap between research and climate action. We are climate transition specialists, working in Australia, Southeast Asia and the Pacific with decision-makers who have the power to reduce emissions at scale. Climateworks develops evidence-based solutions to accelerate emissions reduction in line with the global 1.5°C temperature goal and shared climate safety.

Co-founded by philanthropy and Monash University, Climateworks is an independent not-for-profit working within the Monash Sustainable Development Institute.

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Introduction

The Renovation Pathways research focuses on opportunities for improving the energy and emissions performance of Australia's 11 million existing homes across all climate zones. The overall aim of the research is to identify ways the government and the private sector can enable home energy performance upgrades in a coordinated manner.

1. This research involves the construction and analysis of a residential building stock model to define the most prevalent home archetypes.We determined the most prevalent archetypes by analysing quantitative data from a national sample of 102,000 Australian homes from CSIRO's Australian Housing Data (AHD) portal. The dataset detailed homes located across all 69 Nationwide House Energy Rating Scheme (NatHERS) climate zones (CSIRO 2019). We then undertook economic and impact analysis of the most prevalent archetypes in Australia.

Our research findings are detailed in our published national report, titled, *Climate-ready homes: building the case for a renovation wave in Australia (Climatework Centre, 2023)*. This report accompanies these findings, providing further high level detail of the research method, assumptions and values relied upon, and the limitations of the research.

Data sources

The project uses two main data sources to identify the archetypes within Australian building stock, and to examine the economic and impact analysis of renovating these residential buildings. The data sources and their contribution to the method are as follows:

The Australian Housing Data (AHD) **portal**, managed by CSIRO, was used to identify the dominant archetypes and the archetype mix in each jurisdiction to Statistical Area 2 (SA2) and to NatHERS climate zones (CZ). The AHD data is also used to undertake our economic/impact analysis.

Housing Census (2021) published by Australian Bureau of Statistics (ABS)**,** was used to account for the distribution of residential dwelling types across Australia and weightings were applied to the Race for 2030 subset of the AHD dataset.

Other data sources used to undertake the economic/impact analysis are detailed in what follows, including a number of data sources for gas and electricity prices, emissions intensity estimates, plug and other loads, and costings for upgrades, using Cordell's Cost Guide.

The AHD dataset

The AHD dataset was used to identify the archetypes, and for economic/impact analysis. The dataset is managed by CSIRO. It was chosen by Climateworks as the best dataset available at the time of analysis as it covers houses in all states and mainland territories of Australia. It contains information from residential buildings that have undergone a NatHERs assessment rating. The dataset, therefore, includes energy efficiency metrics, and other information about the dwellings types relevant to energy performance, such as: construction technologies, materials, and floor areas.

The dwellings in the dataset are identified by location, and mapped to the NatHERS climate zones. The dataset included dwellings for most of the 69 NatHERS CZs are covered (64 out of the total 69). The AHD portal has very fine spatial resolution, down to postcodes.

Method for understanding the Australian housing stock

The following steps were taken to construct a building stock model using the largest, reliable national data available. Firstly, the dwelling types were categorised by class defined in Australian building regulations. Then dwelling types were selected for analysis on the basis of their energy performance and construction technologies referred to as 'archetypes'. The archetypes were then weighted in a housing stock model.

Step 01: Categorising the homes by Class

To identify the dominant housing archetypes in Australia, we used the whole AHD dataset.

Dwelling types were categorised in terms of their residential dwelling classes. The NCC recognises three residential dwelling Classes – houses (Class 1ai), townhouses (Class 1aii), and apartments (Class 2). However, the AHD data only distinguishes between Class 1 and 2, therefore rolling houses and townhouses together. To distinguish between houses and townhouses for this project, it was assumed that Class 1 dwellings with at least one façade that has no glazing are likely to be townhouses – see Table 1.

TABLE 1: DWELLING TYPES IN THE RENOVATION PATHWAYS RESEARCH AND METHODOLOGY FOR DISTINGUISHING BETWEEN CLASS 1 DWELLINGS – HOUSES AND TOWNHOUSES.

Dwelling types in Renovation Pathways	NCC Class	Information used to differentiate Class 1 dwellings from the AHD
House: Detached dwellings	Class 1(ai)	Number of storeys = 1
Townhouse: Two or more storey, semi-detached dwellings	Class 1(aii)	Number of storeys = 2+ No. of façades with glazing = at least one without
Apartment	Class 2	n/a - already separated in dataset

Step 02: identifying archetypes

To categorise residential buildings by archetype, the data on construction technologies for thermal shells were compiled and examined from an energy performance perspective. A list of construction technology categories derived from this exploration of the data is detailed in Appendix A.

Construction technologies for external walls, ground floors and roofs, were grouped together according to their influence on the energy performance of the thermal shell, as follows:

1. **External walls**: lightweight (LW), concrete (C), cavity brick (CavB)
2. **Floors**: concrete slab on ground (CSOG), suspended concrete (SC), suspended timber (ST), other
3. **Roofs**: concrete (C), framed (F), other

There are 18 different combinations for external walls + floors + roofs for each residential building type (house, townhouse, apartments - e.g. LW_CSOG_F) – see Appendix B.

Step 03: Selecting the archetypes

We undertook steps to identify the number of archetypes that represented the majority of homes across Australia. From the different combinations of construction technologies, a frequency analysis determined the most prevalent archetypes.

We selected the most common archetypes for the three residential building types, totalling 16 archetypes. These are summarised as:

1. **Houses:** 5 archetypes (H1-5)
2. **Townhouses:** 6 archetypes (TH1-6)
3. **Apartments:** 5 archetypes (A1-5)

A summary of the 16 archetypes can be seen in Appendix C.

Archetypes H1-H5 and TH1 - TH6 represent over 80 per cent of the dwellings in the data sample for houses and townhouses. Archetypes A1-A5 represent over 50 per cent of apartments. The exploration of the construction technologies for apartments showed there is higher variability in the construction of apartments, with no clear dominant archetypes for apartments after 50 per cent of the housing stock is represented.

Step 04: Weighting the archetypes

Residential buildings are not evenly distributed across Australia's geography. There are higher densities of residential buildings in particular areas, for example cities such as Brisbane and Sydney. However, the sampling used to produce the CSIRO dataset, which Renovation Pathways uses, does not reflect this distribution. As such, using an average of the CSIRO dataset to present results may be misleading.

Weighted averages have been used with the intention of making results more accurately reflect the distribution of residential buildings across Australia. This weighting is based on Australian Bureau of Statistics data on the location of different archetypes across Australia.

The total number of dwellings constructed in each SA2 over the sample period (2016-22) was sourced from the **ABS**. The ABS data provided the end-of-year stocks, annual additions, and annual demolitions; however, it does not provide information on the archetypes of residential buildings. Therefore, the **AHD** data was used to determine the shares (per cent) of each archetype in each Class and CZ. The shares of archetypes were applied to the ABS total, providing the estimated totals of each archetype in each Class/SA2/CZ.

Understanding energy efficiency modelling

The economic/impact analysis in this research relies on the thermal modelling originated from previous research by CSIRO and RMIT (Rajagopalan et al. 2023). A summary of the key relevant information from Rajagopalan *et al.* (2023) is detailed next.

DEFINING OLDER, 'LOW-PERFORMANCE' HOMES

The source of the original data was from newly built residential buildings, as there is a lack of data representing the performance of older housing stock. This available dataset details all residential buildings constructed between 2016-2022.

To represent older residential buildings, earlier research (Rajagopalan *et al.,* 2023) removed the features of the dwellings in the dataset which are not typical of older dwellings. These features were based on the requirements of minimum energy efficiency standards, introduced in the National Construction Code in 2002/3. They included removing wall, floor and ceiling insulation, replacing all windows with single glazing, and reducing the air-tightness of the models of the dwellings.

The software 'AccuRate' Sustainability V2.4.3.21 SP1' was used to effectively 'regress' the models to represent older dwellings. These are referred to as 'low-performance homes' in our report and 'base' in Rajagopalan *et al.* (2023).

The performance of the 'low-performance' home is equivalent to under 3.5 NatHERS stars depending on the CZ and dwelling type (Class 1 and 2).

The 'low-performance' residential buildings have:

+ no wall and floor insulation. A ceiling R=0.25 is used as a small proportion of existing residential buildings have ceiling insulation (Rajagopalan et al. 2023)
+ poor airtightness
+ single-pane, clear, untreated glazed windows with aluminium frames
+ connected to gas for heating, cooking and hot water heating appliances
+ A date of construction over 20 years old, built before energy efficiency standards were introduced in the NCC (i.e. pre-2003), and have not undergone any upgrades.

AccuRate was used to re-rate these models for three upgrade levels: 'Rehab', 'Refurb', 'Renov' (Rajagopalan *et al.*, 2023).

DEFINING THERMAL UPGRADES 'QUICK-FIX', 'MODEST', 'CLIMATE-READY'

Three thermal upgrade levels are defined in research by RACE for 2030 (Rajagopalan et al. 2023). These upgrades were applied to the 'low-performance' case – see Appendix D. These scenarios are referred to as:

1. **Quick-fix** (referred to as 'Rehab' in Rajagopalan *et al.* 2023)
2. **Modest** (referred to as 'Refurb' in Rajagopalan *et al.* 2023)
3. **Climate-ready** (referred to as 'Renov' in Rajagopalan *et al.* 2023).

All three thermal upgrades include a space conditioning (heating and cooling) change from a gas appliance to an efficient electric heat pump. Space conditioning was included in the thermal upgrades to demonstrate the impact of electrification and efficiency upgrades.

ELECTRIFICATION AND ROOFTOP SOLAR

The impact of electrifying cooking and hot water heating services were modelled, along with rooftop photovoltaic (or 'rooftop solar'):

+ **Domestic hot water** was upgraded from gas powered hot water (at 'low-performance') to heat pump hot water units (above 'low-performance')
+ **Cooktops** were upgraded from gas cooking (at 'low-performance') to electric induction hobs (above 'low-performance')
+ **Rooftop solar** installation was modelled as a further upgrade after thermal upgrades and electrification of appliances to match the energy consumption of the residential building.

The **total domestic electricity consumption** of the residential building was used to determine the capacity of rooftop solar required. The total consumption included the appliances upgraded in this research, including space conditioning, electrified cooking and hot water. Other sources of residential electricity consumption were also examined – electric ovens, lighting and plug loads – which provided a total estimate of electricity consumption. The figures for plug and other loads were sourced from the 2021 Residential Baseline Study (Energy Consult 2020). Note: rooftop solar would only be able to offset a dwelling's energy consumption if households use load shaping behaviours and smart controls, i.e. shift the time of day when energy is used, to when rooftop solar is generating energy.

Economic and impact analysis

We calculated the cost-effectiveness of the renovations (thermal upgrades, electrification, rooftop solar), and the potential impact in terms of emissions, peak demand reduction, and energy savings for the 397 unique combinations of archetypes across the Australian climate zones. These were derived from a sample of 102,000 residential buildings from the AHD dataset.

BENEFIT COST ANALYSIS (BCA)

The BCA was undertaken at the household and societal levels.

- **Household** level considers the costs and benefits directly afforded by the household.
  - **Benefits:** the reduction in energy bills due to renovation
  - **Costs:** incremental upgrade costs of thermal upgrades, electrification and rooftop solar.
- **Societal** level considers the broader benefits and costs to society. This includes:
  - **Benefits:** value of energy savings calculated via the 'marginal cost of energy' method, avoided electricity network infrastructure investment costs and climate costs (estimated using social cost of carbon)
  - **Costs:** incremental upgrade costs of thermal upgrades, electrification and rooftop solar.

The net present value (NPV) and benefit-cost ratio (BCR) were calculated for each upgrade level.

- The **NPV** demonstrates the cost-effectiveness of an investment over its lifetime, in dollars (FY2023).
  - Upgrades to residential buildings cost money today, however the benefits are spread over the dwelling's lifetime. The NPV reflects the time value of money for the cash flow (future benefits of bill savings) and the time value of cost of the initial investment (current costs). This is done to account for the opportunity cost of foregoing the alternative use of those funds in another investment by committing it to the chosen investment.
  - The future benefits are discounted because people are aware of their cash flows today and in the future, yet these values cannot be directly compared (Office of Best Practice Regulation 2020). We have assumed a **7 per cent real discount rate** for all of our analysis as recommended by the Australian Government Office of Impact Analysis (previously the Office of Best Practice Regulation).
- The BCR also demonstrates the cost-effectiveness of an investment over its lifetime, as a ratio.
  - The BCR is calculated as the discounted present value of benefits divided by the discounted present value of costs.
  - A ratio above 1 is likely to be cost effective over the life of the asset, indicating that the present value of the benefits (e.g. bill savings) exceeds the present value of the upgrade cost.
  - The lifetime of the upgrades is over 40 years for thermal shell upgrades and 15 years for appliances.
  - Discounting factors in how the value of money decreases over time to compare between current costs and future benefits.

IMPACT ANALYSIS

For the thermal upgrades, we compared each upgrade to the 'low-performance' case, determining:

- Annual space conditioning energy savings (GJ/dwelling)
- Annual GHG emissions savings (tCO2-e/dwelling, 2023)
- Average reductions in peak electricity demand (kW/dwelling)

+ Avoided electrical network infrastructure and maintenance costs ($/dwelling)

For the appliance electrification upgrades, we compared each upgrade to the 'low-performance' case, determining:

+ Energy consumption savings (GJ/dwelling)
+ Annual GHG emissions savings (tCO2-e/dwelling, 2023)
+ Estimated average annual energy bill savings ($2023/dwelling)

Assumptions and values

The economic/impact analysis uses a set of values and assumptions from a range of sources, including those set with NatHERS assessments, Canstar Blue, Australian Competition and Consumer Commission (ACCC), and Cordell's price book.

ROOM TEMPERATURE VALUES

The comfort band used in calculations differs between living spaces and the time of day. , including kitchens (min. 20ºC 7am - 12am and bedrooms (min 18ºC 7am - 9am, and 4pm - 12am; 15ºC 12am - 7am). These parameters are used to calculate the heating and cooling loads relied on from the RMIT and CSIRO for RACE for 2030 (Rajagopalan et al. 2023). The loadings use thermal modelling via the NatHERS rating tool, which calculates the theoretical energy required to maintain a building within a defined comfort band. It should be noted, this did not calculate the actual energy required for heating/cooling appliances.

GAS AND ELECTRICITY COSTS USED IN THE BENEFIT-COST ANALYSIS

Gas prices were sourced primarily from Canstar Blue, as summarised in Table 2. As prices are regulated in WA and TAS, these were sourced from alternative websites (Household Gas Pricing 2023; Tasmania Price Change 2023, *n.d.*). The pricing of NT gas is not covered in either source, so it has been estimated as an average of other jurisdictions.

TABLE 2: GAS PRICES BY JURISDICTION, EXCLUDING SUPPLY CHARGES

City	Source, Date	$/GJ
Sydney	Canstar, 2023[1]	$41.40
Melbourne	Canstar, 2023[1]	$38.40
Brisbane	Canstar, 2023[1]	$62.00
Adelaide	Canstar, 2023[1]	$48.10
Perth gas	WA Govt, 2022-23[1]	$44.81
Hobart gas	TasGas, 2023[1]	$46.06
Darwin gas	Estimate as average of other regions	$46.07
Canberra gas	Canstar, 2023[1]	$41.70

*Prices from Canstar Blue were sourced on 03/05/2023, and used the central postcode for each state (2000, 3000, 4000 etc). The price is the standard tariff rate of the plan with the highest value score out of 10.

Electricity prices are primarily derived from the ACCC, Inquiry into the National Electricity Market - November 2022 report, Supplementary Table D10.1A, as summarised in Table 3 (Australian Competition and Consumer Commission 2022). This publication does not cover WA and NT. As such, pricing for WA and NT were sourced from their respective government websites ("Household Electricity Pricing" 2023; Office of the Parliamentary Counsel 2021).

For benefit-cost analysis at household level, the full retail price of electricity was used (see Table 3), i.e. the full total cost stack.

For benefit-cost analysis at the societal level, the marginal cost of electricity was calculated by excluding network costs from the total cost stack, using the data provided by ACCC (2022). This is important, to avoid double counting network costs in the analysis. To explain this further two formula are important:

Societal electricity prices = total cost stack - ***network costs***

and

total cost stack = ***network costs*** *+ wholesale costs + environmental costs + retail & other costs + retail margin + retail component*

As environmental costs were included in both the household and societal electricity price inputs, there is still a risk of double-counting the cost of carbon. This is a limitation as the extent that environmental costs refer to climate-related costs relative to other environmental regulatory costs is not known.

TABLE 3: ELECTRICITY PRICES BY JURISDICTION (FULL RETAIL PRICE)

State / Territory	Source, Date	c/kWh
NSW	ACCC, 2021-22	25.3
VIC	ACCC, 2021-22	28.4
QLD	ACCC, 2021-22	23.4
SA	ACCC, 2021-22	31.2
WA	WA Govt, 2021-22	29.3
TAS	ACCC, 2021-22	24.4
NT	NT Govt, Jul 2022	26.7
ACT	ACCC, 2021-22	25.3

RENOVATION COSTS

Incremental cost of the thermal upgrades are displayed in Table 4. The costing used are calculated using unit costs provided in *Cordell Housing Building Cost Guide* (2017). The costings are deflated to FY2023 assuming an average of 2 per cent real cost inflation per year. For items not included in Cordells (2017), the average of three prices are used, sources from national retailers. It is assumed that renovations would be managed by the owner-occupier. It is assumed that the renovations are undertaken at the time of other work, such as maintenance or deeper renovations.

To calculate the cost-benefit of electrification, the costing and assumptions used are displayed in Table 5. As this analysis looks at determining the most cost effective pathway, we intentionally selected quotes on the lower end of the spectrum. If households opt for more expensive options with additional features, the economic will alter. Table 6. gives the non-monetary assumptions used to calculate the benefit cost ratios.

TABLE 4: THERMAL UPGRADE COSTS AT THE TIME OF DEEPER RENOVATIONS

The Incremental costs of upgrades (the upfront cost of performing each of the upgrades detailed, weighted by dwelling)									
	Thermal upgrade			Full electrification			PV installation		
Dwelling	Quick -fix	Modest	Climate -ready	Quick -fix	Modest	Climate -ready	Quick -fix	Modest	Climate -ready
Apartment	$9,197	$13,260	$25,355	$1,693	$1,693	$1,693	$4,947	$4,876	$4,475
House	$13,115	$18,916	$38,677	$1,693	$1,693	$1,693	$5,801	$5,688	$4,772
Townhouse	$7,723	$11,141	$23,697	$1,693	$1,693	$1,693	$5,088	$5,036	$4,497
National average	$12,038	$17,362	$35,439	$1,693	$1,693	$1,693	$5,622	$5,522	$4,706

TABLE 5: APPLIANCE COSTS AND ASSUMPTIONS

Metric	**Source**
Space conditioning energy consumption estimates	Coefficients of performance (COPs) of 0.8 for gas and 3.5 for heat pumps (heating and cooling) and ‘constraint factors’ of 75 per cent. Constraint factor of 75 per cent means that we assume that 75 per cent of the NatHERS modelled thermal load is space conditioned. This allows for lower occupancy and energy service levels (zoning behaviours, thermostat settings) than NatHERS assumes.
Space heating/ cooling costs	$264/kW plus a $750 installation fee (based on internet searches and quotes).
Gas space heating costs for 'low-performance'	Assumptions for costs of gas space heating capacity for the 'low-performance' home are dependent on CZ. + In CZs where heating loads are **significant** (≥30 MJ/sqm.a), assumed to have whole of home (e.g. ducted) gas heating. These are estimated to have an average installed cost of $7,500/dwelling. + In CZs where heating loads are **modest** (>10<30 MJ/sqm.a), assumed to have single room ducted gas heater (flued). These have an average installed cost of $2,300. + In CZs with **low** heating loads (<10 MJ/sqm.a) we assume no fixed space heating - effectively meaning portable heaters are used.
Dwelling lifecycle	40 years
Space heater lifecycle	20 years
Appliance lifecycle (cooktop, hot water)	15 years

TABLE 6: ASSUMPTIONS TO CALCULATE THE SOCIETAL AND HOUSEHOLD BENEFIT-COST RATIOS

Real discount rates for present value calculations	**7 per cent real discount rate** is assumed for all present value calculations – the default as used by the Australian Government (Office of Best Practice Regulation 2020).
Peak loads, avoided peak loads, and network capacity	Since network costs are subtracted from retail prices for the purposes of valuing energy savings (or ‘directly avoidable energy costs’ – that is, the part of the bill that varies with energy consumption), we use the **Conservation Load Factor (CLF) method to estimate peak loads and avoided peak loads and associated costs**. These costs also vary, or are ‘avoidable’, but not directly. This is because certain costs (e.g. providing network infrastructure) may be avoided by one party (the network), but are imposed on the householder as a fixed daily charge. Therefore, these costs are not avoidable by the householder (until and unless the daily charge is adjusted). For the purpose of this CLF methodology, we assume an **average space conditioning CLF of 0.25**, and **cost of network capacity by state ($/kW)** (University of Technology Sydney 2010). The figures were deflated to $FY2023 real (average value across states: $813/kW). These were used to calculate peak demand and electricity network costs, respectively.
Social cost of carbon	Interagency Working Group on Social Cost of Carbon, US Government (February 2021), rebased to real $FY2023 and converted to AUD assuming 1 AUD = 0.75 USD. **‘Mid’ series** used as default, which assumes a **3 per cent discount rate**.
Inflation	**2 per cent per annum**. This rate is applied to electricity and gas prices for 40 years in the future, at the private and societal level.

Limitations

General limitations of this research have been described in the report 'Climate-ready homes: Building the case for a renovation wave'. The list in this document describes further limitations specific to the dataset and analysis:

Best available data

While the dataset used in this study is the most comprehensive to date, limitations still exist and these include:

- The dataset is limited to **new residential buildings built between 2016-2022**. We are unaware of any comprehensive data source that would definitively identify new housing archetypes or archetype distribution of residential buildings across the whole of Australia for the pre-2016 period.
    - The impact of this limitation is low, as the development of the dataset to re-rate residential buildings to be 'low-performance' makes the sample data relevant for the whole building stock. It is however important to understand that this is the result of modelling, rather than real data for residential buildings built pre-2016.
- The **estimated plug and other loads were not used for impact or benefit cost analysis**. Therefore, the modelled energy performance of residential buildings relates to the thermal shell and certain fixed appliances (hot water, cooking, space conditioning). It therefore **does not provide insight into the whole-of-home energy consumption.**
    - The **percentages** presented in the report and calculations for the **amount of rooftop solar required** account for the **total domestic consumption** – meaning that these figures include plug and other loads. The plug and other loads included in this calculation are plug loads (e.g. TVs, computers, battery/device chargers), electric ovens and lighting.
    - The majority of energy consumption is from space conditioning, hot water and cooking combined (71 per cent)[2]. Additionally, the plug and other loads do not affect the impact and benefit cost analysis, as these loads stay constant pre- and post-upgrade. As a result, the impact of this limitation is deemed to be negligible for the purposes of this study.
- **Not all NatHERS CZs are represented in the data – 64 out of 69 are**. The lack of data in certain climate zones can be explained by a lack of residential building construction during the 2016-2022. This has been cross checked with the ABS data. As we sought to identify the dominant archetypes across Australia, this should not significantly impact the findings.
- **Not all archetypes are represented in every climate zone.** This may be due to no construction of that specific archetype in a given CZ, or even no residential construction at all in a given region of Australia over the 2016-2022 period.
- The dataset **excludes dwellings constructed under the 'deemed to satisfy' (DTS) code compliance verification pathway.** NatHERS ratings account for approximately 90 per cent of new dwellings constructed in Australia, however this varies by state. The distribution of archetypes may differ between the different compliance pathways (DTS vs NatHERS). While there is generally good coverage of residential buildings across our sample, some areas have missing data for certain dwelling types due to bypassing the NatHERS rating system (e.g. apartments in SA, which are underrepresented).

[2] Using 2023 figures from the 2021 Residential Baseline Study

Scope of the analysis

When interpreting and applying this research, caution should be applied due to the following limitations:

+ This analysis describes the most common archetypes in Australia, representative of 80 per cent of Class 1 buildings (houses) and 50 per cent of Class 2 buildings (apartments). As such, it may not capture the dominant archetypes in local regions if this archetype falls outside of those selected for this analysis.
+ The analysis does not yet identify specific portions of the housing stock such as social housing. Social housing is currently being explored by Climateworks as a potential area for future research, due to its significance in housing some of the most vulnerable households. Climateworks would welcome any support in characterising and mapping social housing stocks against our dataset.
+ The modelling and analysis in this research improves the performance of residential buildings and models achievement of a 'net zero' home, from the perspective of operational emissions (emissions related to the use of the building). The analysis does not cover embodied emissions as embodied energy and lifecycle analysis was not within the scope of this project. However, we acknowledge that upgrading existing residential buildings can be a sustainable alternative to demolition and new builds, if the majority of the existing structure and materials are retained, thus reducing the overall carbon footprint.
+ The findings of this study cannot be applied to every dwelling in Australia, due to the diversity of the existing building stock – in star ratings, renovation levels, current appliance types, fuel mix and rooftop solar size.
+ Temporal limitations apply to the methodology used for this project. The findings are based on upgrades made to households in 2023. Future costs and savings are discounted to compare at a single point in time using net present values. The methodology does not explore the costs and savings of renovations that might take place in future years, and does not investigate the sequencing of upgrades for all of the Australian housing stock.

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For further information please contact:

DR GILL ARMSTRONG
Project Impact Manager – Buildings
gill.armstrong@climateworkscentre.org

TIM GRAHAM
Business Analyst – Research And Modelling
tim.graham@climateworkscentre.org

WINNIE PANCZEL
Project Officer - Buildings
winnie.panczel@climateworkscentre.org

Climateworks Centre
Level 27, 35 Collins Street
Melbourne Victoria 3000
Wurundjeri Country

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