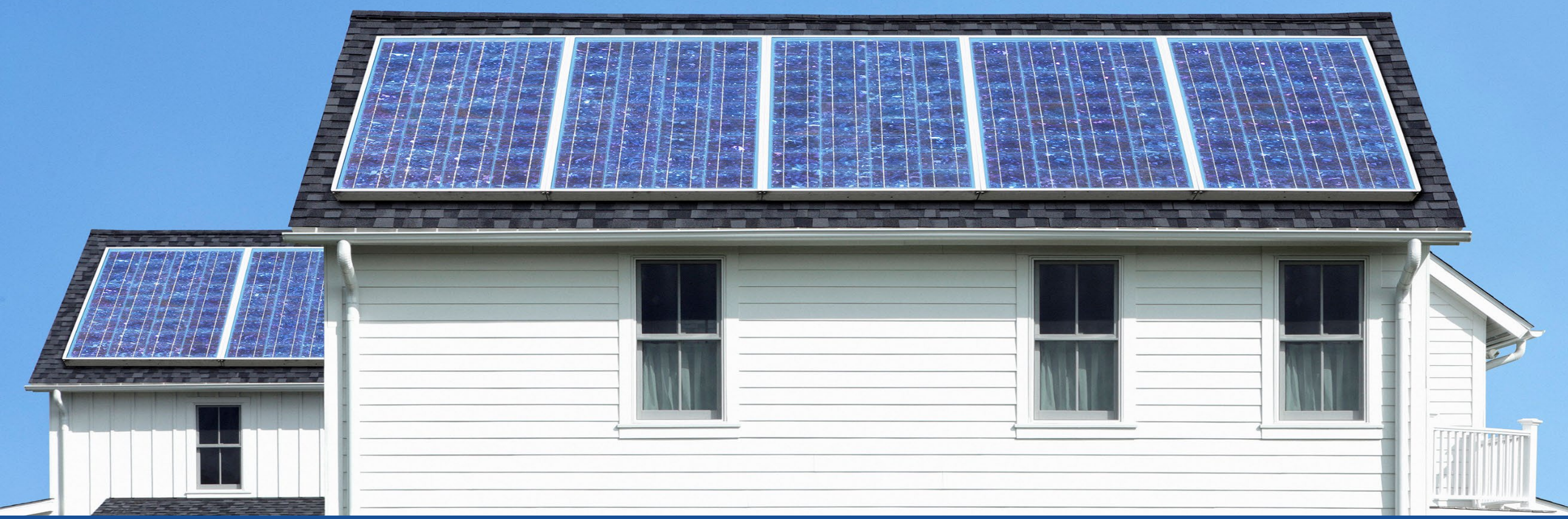

Impact Analysis of CSIRO Residential Energy Efficiency Services

Prepared for

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Executive Summary

As rising home prices have become a major concern in Australia, the building industry needs to prepare for a rapid expansion in home construction. At the same time, energy use is an important focus throughout Australia, with the government setting the National Energy Productivity Target to improve Australia's energy productivity by 40% between 2015 and 2030 (COAG Energy Council, 2015). To meet both the need for more housing and reduced energy use, there is an increased emphasis on residential energy efficiency.

Australia has been aggressively pursuing improved residential energy efficiency over the last 20 years, implementing the Nationwide House Energy Rating Scheme (NatHERS) in 2003 and increasing thermal performance requirements for new homes since then. The Building Code of Australia was updated in 2010 (BCA 2010) to include a 6-star rating for residential building thermal performance, and the National Construction Code was updated in 2022 (NCC 2022) to include a 7-star rating for residential building thermal performance.

CSIRO's residential energy efficiency services have played a significant role in supporting these approaches to increased residential energy efficiency throughout Australia. CSIRO has over 60 years of experience in energy efficiency research, modelling and dissemination of information that has made it a knowledge leader in the area. CSIRO has used this position to create software and provide analyses that support industry research and the development of building standards and regulations. There have been several outcomes from CSIRO's work that support energy efficiency in the residential sector:

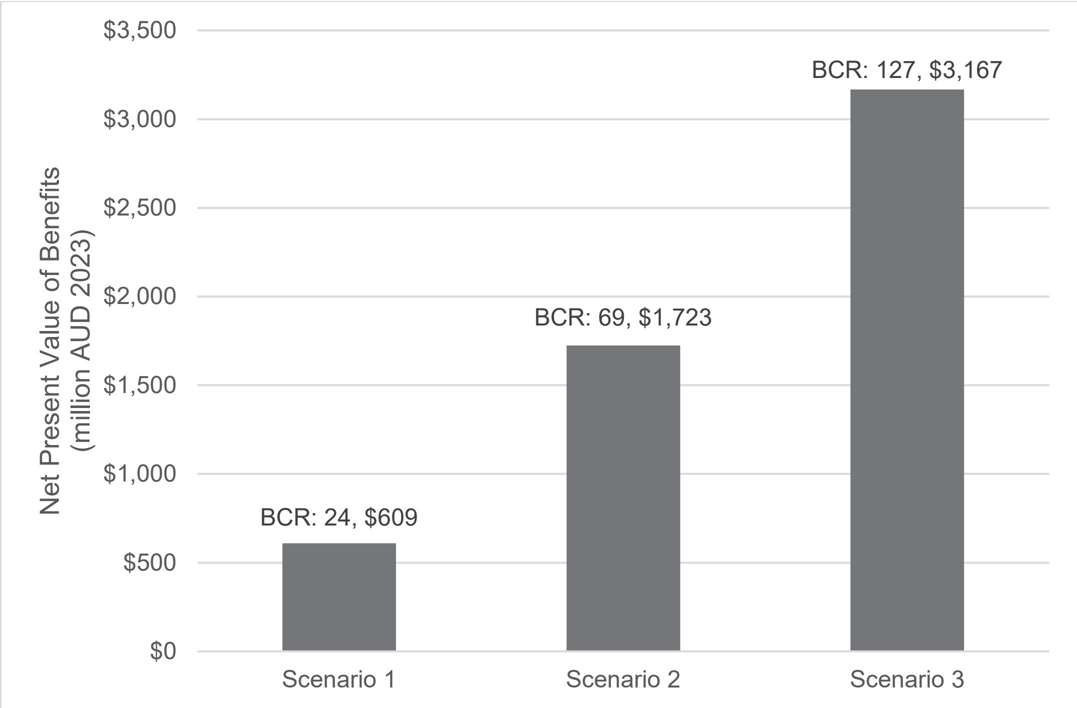
- an acceleration of the implementation of BCA 2010 and NCC 2022 due to CSIRO's research support and analysis tools like AccuRate
- an agreement on information, analysis methods and modelling techniques and assumptions among a wide array of industry stakeholders providing confidence in regulatory analysis of new policy
- greater access to information on home energy performance on new and existing housing stock with the support of NatHERS and the future release of RapidRate

CSIRO has decades of experience with residential energy efficiency, but this study focuses on the services CSIRO has offered from 2003 through today. This study offers a prospective cost–benefit analysis (CBA) over two periods of time. The first is 2003 through 2033 to analyse the benefits of CSIRO's residential energy efficiency services from the implementation of NatHERS through a 10-year prospective period aligning with CSIRO's evaluation guidelines. The second is 2003 through 2050 to analyse the benefits of CSIRO's residential energy efficiency services from the implementation of NatHERS through an extended period so that the long-term benefits of reduced energy use can be realised by residents after the initial costs were incurred by homebuilders. This period is a more accurate representation of the benefits of CSIRO's services.

This study shows that from 2003 through 2050 CSIRO's energy efficiency services have provided a median present value estimate of $1.72 billion in net benefits (within a range of $609 million to $3.17 billion). We estimate a median benefit-cost ratio of 69, with a range of 24 to 127. This means that for every $1 invested, around $69 in benefits accrue. Figure ES.1

shows the range of estimated benefits from CSIRO's residential energy efficiency services in the modelled scenarios. The wide range of benefits shows the magnitude of the impact of each year that building regulations are delayed.

Figure ES.1. Estimated Net Present Value of Benefits from CSIRO's Residential Energy Efficiency Services in Modelled Scenarios, 2003–2050



Note: BCR denotes benefit-cost ratio

1. Introduction and Background

In 2015 the Australian Government set a National Energy Productivity Target to improve Australia's energy productivity by 40% between 2015 and 2030 (COAG Energy Council, 2015). The residential sector is a crucial area to target when working to achieve this goal. Residential buildings account for 24% of electricity use and 10% of carbon emissions in Australia (Department of Climate Change, Energy, the Environment and Water, 2024).

The residential building sector is an extremely important part of Australia's economy. Like many other countries, Australia is facing housing affordability challenges that require an influx of new housing stock. The new residential building industry was almost $70 billion in 2023 (Australian Bureau of Statistics, 2023) and may grow further with residential building stock expected to double by 2050. With the expected influx of new housing, it is important to ensure that the new housing stock is built to high energy efficiency standards. Buildings have a long life expectancy, so housing stock that is energy intensive will take a long time, around 40–50 years, to turn over to newer, more efficient generation.

Energy efficiency standards play a key role in reducing energy consumption from the residential sector. However, builders have a greater incentive to save money on upfront building costs as the economic benefits from a reduction in energy use are instead realised by residents over the long term.

It is important to have a neutral arbiter of information who can conduct research, build modelling tools and disseminate information to stakeholders in order to facilitate the development of standards and regulations. In Australia's residential building sector, CSIRO plays this role for residential energy efficiency. CSIRO has over 60 years of experience conducting research and developing building thermal performance algorithms and software used across the industry.

This report presents a case study of CSIRO's residential energy efficiency services. These services include conducting research on thermal performance of building materials and design in different climate areas throughout Australia, developing research reports on innovative topics in building energy efficiency, developing algorithms to model building energy efficiency and creating software to analyse building energy performance that is used to benchmark national tools and regulations. The case study evaluates the economic, social and environmental impacts of CSIRO's residential energy efficiency services throughout Australia on newly built homes, as well as potential impact on existing housing stock and related infrastructure investment. It describes the team's contribution to improved residential building energy performance, as well as the benefits CSIRO's expertise lends to various stakeholders. The report also presents a cost–benefit analysis (CBA) that assesses how CSIRO's residential energy efficiency services generate economic and social value for Australians over a 21-year period from 2003 to 2033, and a 48-year period from 2003 to 2050.

1.1 Australian Residential Energy Efficiency Policy

For nearly 60 years, Australia has maintained a uniform national building code to ensure that buildings meet the basic standards for sustainable resource use, through the collaboration of the Australian States. The first entity responsible for publishing this set of standards was the

Interstate Standing Committee Uniform Building Regulations (ISCUBR), which was formed in 1965 to bring uniformity to Australia's building standards. The ISCUBR published the first edition of Australia's building code, the Australian Model Uniform Building Code (AMUBC), in the early 1970s.

A decade after the AMUBC was first published, the Australian Building Regulations Coordinating Council (AUBRCC) was formed to replace the ISCUBR. The AUBRCC was tasked to continue development of the AMUBC, with more consideration for regional variations. In 1988, the AUBRCC published the newly titled Building Code of Australia (BCA), which was refined in 1990 and then adopted by States and Territories over the next few years.

Just one year after the release of the refined BCA, the Building Regulation Review Task Force made a recommendation to the Council of Australian Governments (COAG) stating that the country needed a governmental body dedicated to achieving nationwide reform. As a result, the Australian Building Codes Board (ABCB) was established in 1994 and tasked with converting the BCA into a "more fully performance-based document".

Additionally, in 1993 the Australian and New Zealand Minerals and Energy Council (later the Ministerial Council on Energy) initiated the Nationwide House Energy Rating Scheme (NatHERS). NatHERS provided a standardised approach to assessing the energy rating for new residential buildings in Australia. CSIRO supported development of NatHERS through their energy modelling tools to test and validate the NatHERS approach.

The ABCB released this new, performance-based BCA in 1996 and it was adopted by all States and Territories by 1998. The new BCA introduced the residential building star rating system from NatHERS. Between 2003 and 2006, energy efficiency provisions for houses were added to the BCA and gradually increased. The AccuRate tool developed by CSIRO supported the regulatory analysis for these initial energy efficiency provisions. The BCA moved to an annual amendment cycle starting in 2004 and during this same year, the Plumbing Code of Australia (PCA) was published as a performance-based code that was compatible with the existing BCA.

In 2010, the BCA was updated to include a 6-star residential building thermal performance standard in NatHERS. This standard was adopted as a regulation by Australian states at various times over the next several years.

In 2011, the BCA and PCA were later combined into a single code, presently known as the National Construction Code (NCC). From this point forward, standards for residential buildings and structures were covered within Volume Two of the NCC. Additional enhancements were made to the NCC between 2011 and 2015, and the NCC process moved to a 3-year amendment schedule in 2016. In 2022, the improved NCC usability initiative called for larger enhancements to make the NCC more accessible and user-friendly. The NCC 2022 also included the first major update to the residential building energy efficiency standards. The updated code included a minimum thermal performance standard of 7-stars in NatHERS. The updated NCC 2022 code for residential energy efficiency is set to be adopted as a regulation in states across Australia at various times throughout 2024.

1.2 CSIRO Residential Energy Efficiency Services

CSIRO has played a key role in Australian energy efficiency and energy modelling research since the 1950s. The most prominent output of CSIRO's residential energy efficiency research and modelling work has been the AccuRate tool. The AccuRate tool is built using a the Chenath simulation engine. The Chenath engine is the culmination of decades of development of different methodologies, rules and algorithms that were the foundation of preceding models that CSIRO developed.

CSIRO has also played a key role in the development and deployment of NatHERS, the residential home building rating system. NatHERS was first developed in 1993 in collaboration with CSIRO and other government agencies using the Chenath engine as the underlying tool for the rating system. In 2004 NatHERS was adopted as the nationwide approach for rating building energy efficiency. NatHERS is currently used to assess about 90% of new home designs (Department of Climate Change, Energy, the Environment and Water, 2022), creating a thorough inventory of newer Australian housing stock and allowing the energy efficiency regulations in the BCA and NCC to be implemented. AccuRate is still used as the benchmarking tool for NatHERS, providing the industry with confidence in the data and methodology underlying the energy efficiency rating system and requirements for new Australian homes.

While 90% of Australian homes built currently are included in NatHERS, there is still a substantial portion of Australian building stock that was built prior to NatHERS implementation. Energy use characteristics of these homes would be useful for targeting efficiency investments, system upgrades and retrofits or infrastructure updates. CSIRO is working to address this issue through the development of RapidRate. RapidRate is an Artificial Intelligence model that uses data from approximately 1.1 million homes rated under the NatHERS to train and evaluate the model and estimate home energy use characteristics for the existing housing stock[1].

The tools developed along with the research and industry outreach has made CSIRO the knowledge leader in the Australian residential energy efficiency sector. CSIRO is seen throughout the industry as a knowledgeable, unbiased broker of information. This allows CSIRO to play a key role in supporting energy efficiency regulations that shape the multibillion-dollar residential real estate industry.

1.3 Case Study Purpose

Case studies are included as a key component of CSIRO's evaluation and performance measurement program for the purpose of evaluating the outcomes and impact of CSIRO research and innovation activities. As outlined in CSIRO's impact evaluation framework, case studies must clearly describe the rationale behind CSIRO's investment, action and participation in the research, as well as the actual or projected outcomes and impact across social, environmental and economic dimensions. CSIRO's preferred method for case study evaluation is CBA.

[1] The RapidRate tool is under development and has not been widely implemented, therefore it has not been included in the BCA in this study.

The purpose of this study Is to evaluate the impacts of CSIRO's residential building energy efficiency services, including a CBA of the quantitative social benefits of these services and a discussion of the qualitative benefits. This report uses interviews with industry experts and secondary research from literature on the social benefits of energy efficiency to describe the potential economic benefits under three scenarios based on the impact of the services. The overall goal is to provide an assessment of how the energy efficiency modelling and software has generated social value for Australians over the previous 20-year period from 2003 through 2023 and the prospective value for both the next 10 years through 2033 and through 2050, the target for many climate goals. RTI International, an independent, nonprofit research institute, was commissioned to conduct this case study.

This report presents a prospective impact analysis using CBA to quantify the net potential benefits of CSIRO's energy efficiency software and technical expertise from 2003 to 2033 and 2003 to 2050. To account for uncertainty, the case study includes three costing scenarios (low, medium and high). The results of this analysis are intended to inform CSIRO performance management, accountability, communications and continual improvement.

2. Impact Pathway

CSIRO's decades of experience with residential energy modelling put the organisation in a unique position to develop the energy modelling software tool AccuRate. The AccuRate tool incorporates up-to-date research in energy efficiency and the growing dataset of the Nationwide House Energy Rating Scheme program. The AccuRate software enables strong data collection that allows regulators to analyse the impacts of energy regulations that support the justification of more stringent building codes.

The AccuRate tool is widely recognised to be backed by proper data, research and energy efficiency expertise, giving it the legitimacy to be used by multiple stakeholders in the industry. The legitimacy of AccuRate and CSIRO's backing gives industry stakeholders a straightforward tool to support building designs and regulators a tool to support regulations. While regulations would be in place without AccuRate, the regulations may be delayed or less stringent if there was not an industry-recognised tool to support data collection and analysis.

Implementation of energy efficiency regulations are meant to meet several objectives:

- reduce energy consumption and energy peak demand
- reduce greenhouse gas emissions
- improve occupant health and amenity
- reduce energy costs for households and businesses
- maintain Australia's competitiveness and grow the economy
- reduce carbon emissions and improve sustainability

The regulations are key for addressing several market failures:

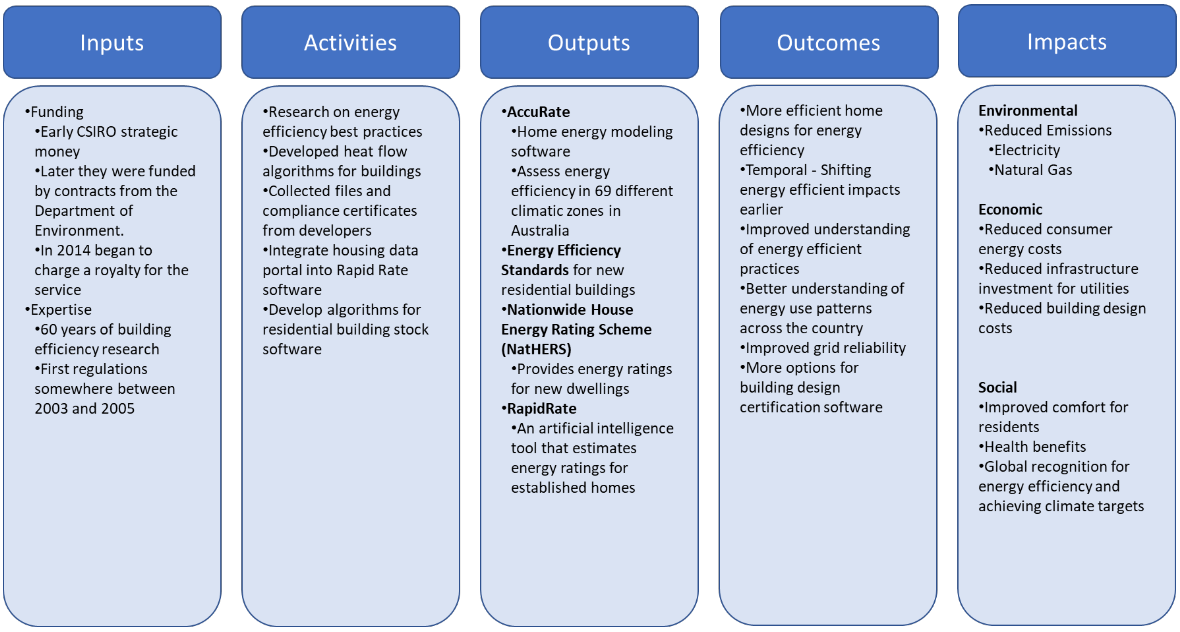
- unpriced negative effects—externalities (greenhouse gasses, environment, peak demand infrastructure)

- information problems—understanding consumer behaviour
- split incentives—builders vs home buyers (upfront vs continuing costs)

CSIRO has built a reputation as a trusted advisor in the residential energy efficiency space. The AccuRate tool's key value is building consensus among disparate stakeholders in the industry because CSIRO is a trusted arbiter of information and the AccuRate tool is well understood. The validation of AccuRate throughout the industry allows it to be the framework for the regulatory environment. The use of AccuRate removes friction in the regulatory process as there is agreement on data sources and analysis methodology. Removing the uncertainties and knowledge gaps allows the regulatory process to proceed quickly and without delays due to a common agreement on methods throughout the industry.

Figure 1 shows the logic model supporting the theory of change for CSIRO's energy efficiency activities.

Figure 1. Logic Model for CSIRO's Energy Efficiency Activities



2.1 Inputs

The main inputs to CSIRO's energy efficiency work are the time, talent and expertise of the CSIRO staff working on the tools. The CSIRO staff has over five decades of experience studying building energy use behaviour and designing simulation tools and software modelling energy performance in residential buildings. The CSIRO staff has also built strong relationships with industry stakeholders and regulatory agencies that allows the transfer of knowledge of best practices throughout the industry.

2.2 Activities and Outputs

The CSIRO staff uses their expertise and industry connections to offer a variety of tools that support energy efficiency in Australia. These tools include:

- AccuRate—novel energy use modelling tool developed using decades of modelling and simulation work

- NatHERS—national energy rating scheme using the AccuRate software as the benchmarking tool
- RapidRate—new software tool that will model the existing Australian housing stock that is not included in the NatHERS program

Additionally, CSIRO has produced extensive documentation and reports on their energy efficiency work to disseminate to industry stakeholders. CSIRO has built strong relationships with other government and industry organisations through collaboration on research and the development of software tools.

2.3 Outcomes and Impacts

CSIRO's residential energy efficiency services have been crucial to disseminating information on residential energy use and energy efficiency strategies and establishing building codes for energy efficiency in new residential buildings over the past 20 years. The outcomes of CSIRO's residential energy efficiency services have been increased efficiency in the new residential building stock and the resulting decrease in energy consumption in the residential sector. The key impacts from CSIRO's work fall into three impact categories: environmental, economic and social.

The main environmental benefit is the prevention of adverse environmental conditions due to the reduction of energy use in the residential sector. These include reduced emissions from electricity generation and from natural gas combustion. Additionally, there is a reduction in other environmental disturbances due to avoided generation and transmission capacity additions from a decline in peak demand from the residential sector.

Economically, home builders experience both cost increases and reductions from CSIRO's services. While the accelerated implementation of energy efficiency in building codes places additional compliance costs on home builders, the AccuRate software gives builders a straightforward tool to use and to provide evidence of compliance with the building codes. For home owners, they see benefits in the increased value of homes due to the enhanced thermal performance, which reduces energy bills.

Additionally, there are broad social benefits resulting from improved energy efficiency in the housing stock. The reduction in criteria pollutant emissions from the electricity sector associated with reduced energy use decreases the adverse health impacts on surrounding populations, such as risks of asthma and heart disease. The improved building envelope performance also leads to a more comfortable environment for residents, an important aspect of quality of life. The improved energy efficiency in the residential sector also helps Australia meet energy use reduction goals and show progress to the international community.

Table 1 summarizes the impact pathways and associated benefits.

Table 1. Summary of Impact Pathways

Impact Category	Impact	Impact Pathway
Environmental	Emission reductions	Acceleration of energy efficiency building codes will reduce energy use, and therefor reduce emissions from electricity generation and fuel combustion.
Economic	Cost changes for builders	Builders have a streamlined and efficient tool to use to collect data and certify building designs. Updated EE building codes could increase costs but may also increase home values due to better EE characteristics.
	Reduced infrastructure investment	Improved EE in homes could reduce total energy use and peak demand, which could reduce investment needed from utilities in supporting infrastructure such as transmission lines and substations.
	Reduced energy bills	Residential energy consumers will have lower bills and long-term cost savings due to reduced energy usage. May have higher upfront costs for homes and appliances.
Social	Improved home comfort	Improved understanding of building and climate characteristics allows consumers to better control the climate and energy use characteristics of their homes.
	Health benefits	A reduction in energy use reduces emissions and indoor fuel combustion, which can improve community and indoor air quality.
	Global recognition of climate change mitigation	Climate action is an important objective for the Australian government, and tools that help reduce energy use for people within their homes can be an innovative way to show progress.

3. Approach for Analysing Benefits

As discussed in the Impact Pathway section, the major benefit that this report analyses is the impact of CSIRO's services, specifically the AccuRate software, on accelerating the implementation of updated residential building energy efficiency regulations. This report analyses the benefits of implementing the previous two iterations of building energy efficiency requirements relative to a set of counterfactual scenarios where the AccuRate software was not available. In the counterfactual scenarios, regulators had to conduct analysis without AccuRate and industry had to use another tool to conform to reporting requirements. Under the counterfactual scenarios, the regulations are delayed by 1 to 6 years, and a set of residential homes are built to the previous energy efficiency standards.

The two regulations that were considered for the quantification of benefits in this report were the BCA 2010, moving the minimum NatHERS thermal performance standard from 5-star to 6-star, and the NCC 2022, updating the NatHERS thermal performance standard from 6-star to 7-star. The BCA 2010 was widely implemented throughout 2011 while the NCC 2022 is in the process of being widely implemented through 2024.

We modelled the following three scenarios based on survey responses and interviews with subject matter experts (SMEs) who indicated what they thought the regulatory process would look like without the support of CSIRO's services:

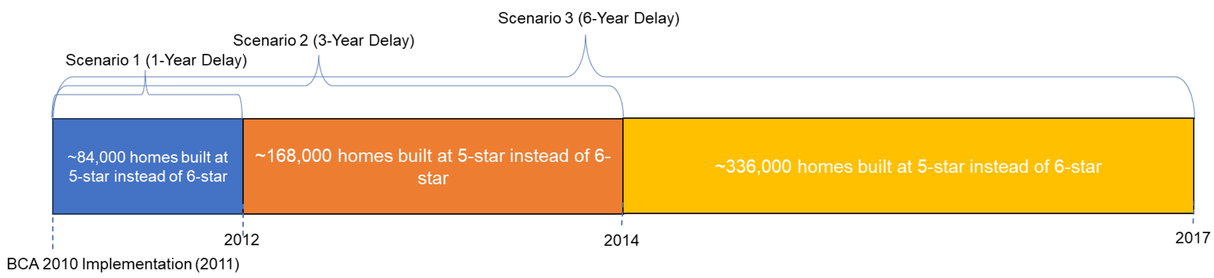
- Scenario 1–Low-end Estimate: BCA 2010 and NCC 2022 implementation was delayed by 1 year (states extend delays in implementation).

- **Scenario 2–Median Estimate: BCA 2010 and NCC 2022 implementation was delayed by 3 years (one regulatory cycle).**
- Scenario 3–High-end Estimate: BCA 2010 and NCC 2022 implementation was delayed by 6 years (two regulatory cycles).

SME discussions and survey responses indicated that a delay of one 3-year regulatory cycle **(Scenario 2)** was the most likely outcome if the CSIRO services were not available to support the regulatory process.

The benefits that we quantify for the accelerated implementation of the building energy efficiency regulations are the benefits for the stock of buildings that were built between the actual implementation of the updated thermal performance regulation and the implementation of the regulation in our counterfactual scenarios. Figure 2 shows the home stock that is impacted under each scenario for implementation of BCA 2010.

Figure 2. Schematic Display of Residential Homes Impacted in the Three Scenarios – BCA 2010



3.1 Economic Model Design

The economic model designed to support this analysis quantified the benefits of the reduction in energy use for homes built during each of the implementation delay periods represented in the scenarios. The economic benefits for the homes built over the potential delay periods are calculated as the reduction in energy bills for consumers over the period of the study minus the compliance costs for the builders to meet the minimum requirements for the regulations. Equation 3.1 shows the formula used to calculate the benefits for each scenario.

Equation 3.1. Calculation of Economic Benefits

$$
\begin{aligned}
&\mathit{Economic\ Benefits} \\
&= \left[\sum_{i=build\ year}^{n=End\ of\ study\ Period} (\mathit{Annual\ Reduction\ in\ Electricity\ Use}\ (kWh) \right. \\
&\times \mathit{Electricity\ tariff\ rate} \\
&+ \mathit{Annual\ reduction\ in\ natural\ gas\ use}\ (MJ) \times \mathit{Natural\ gas\ tariff\ rate}) \\
&\left. \times \mathit{Number\ of\ Impacted\ building\ stock} \right] \\
&- (\mathit{Building\ compliance\ costs} \times \mathit{Buildings\ built\ during\ delay\ period})
\end{aligned}
$$

The quantification of the benefits of accelerated implementation of the two energy efficiency regulations is specific to the regulation, building class, state and NatHERS climate zone. The study quantifies the benefits for class 1 and class 2 buildings. Class 1 buildings are single homes or homes horizontally attached to other class 1 homes. Class 2 buildings are residential buildings containing two or more sole-occupancy units.

The annual reduction in electricity use, annual reduction in natural gas use and building compliance costs are all pulled from the recommended policy options in the BCA 2010 Regulatory Impact Statement (Centre for International Economics, 2009) and the NCC 2022 Regulatory Impact Statement (Acil Allen, 2022). The annual reduction in energy use (both electricity and natural gas) represents the annual change in energy use in a home built to the 6-star thermal performance requirements versus the 5-star thermal performance requirement for the BCA 2010 regulation, and the annual change in energy use in a home built to the 7-star thermal performance requirements versus the 6-star thermal performance requirements for the NCC 2022 regulation.

The compliance costs are the additional design, material and construction costs required to meet the 6-star requirement versus the 5-star requirement for thermal efficiency for the BCA 2010 regulation, and the additional costs required to meet the 7-star requirement versus the 6-star requirement for thermal efficiency for the NCC 2022 regulation. The reduction in energy use (both electricity and natural gas) and the compliance costs are specific to the regulation, building class, state and NatHERS climate region.

To monetise the economic benefits of the reduction in electricity and natural gas consumption by home occupants, we multiplied the reduction in electricity and natural gas use by the retail residential tariff rates for electricity or natural gas in each state. For electricity and natural gas rates we used the projected retail rates from 2022 through 2050 from the NCC 2022 Regulatory Impact Statement (Acil Allen, 2022). Prior to 2022 we used the same retail rates but adjusted them for inflation. There was not a consolidated source with a time series of electricity or natural gas tariff rates by state, but checking historical rates showed that the historic rates used in the economic benefit model were very close to the actual retail rates for the utilities.

The number of buildings Impacted by the accelerated implementation of the BCA 2010 and NCC 2022 regulations is calculated using data from the States and Territories NatHERS Dashboard managed by CSIRO (CSIRO, 2024). For the implementation of the BCA 2010 regulation the model assumed that buildings that were built to the 6-star thermal performance requirements during the period of the potential regulation delay would have been built to the 5-star thermal performance standard to save builders money. The count of residentials buildings built each year to the 6-star thermal performance standard was estimated to be the average of the annual buildings awarded 6- and 6.5-star certificates in the NatHERS from 2016 through 2023, the data available on the CSIRO dashboard.

We estimated the count of buildings impacted by a delay in implementing the NCC 2022 regulation by assuming that the buildings currently built with below a 7-star NatHERS thermal performance rating would be built to a 7-star rating after the NCC 2022 was implemented. The annual count of buildings built below the 7-star thermal performance rating was estimated based on the average annual count of buildings awarded NatHERS certificates below seven stars from 2016 through 2023. The percentage of homes in each state that were built in each climate zone was based on the breakdown in residential homes by climate zone provided by the NCC 2022 Regulatory Impact Statement.

Table 2. Residential Buildings Built to Higher Thermal Performance Standards Each Year Due to the Implementation of Updated Regulations

State	BCA 2010 – Annual homes built to 6-star standard due to regulation		NCC 2022 – Annual homes built to 7-star standard due to regulation	
	Class 1	Class 2	Class 1	Class 2
NSW	8,748	10,531	25,571	25,790
VIC	43,602	2,898	43,944	4,239
QLD	7,795	715	11,423	2,175
SA	2,856	97	3,226	161
WA	3,417	106	3,920	169
TAS	2,345	40	2,345	40
NT	270	15	443	23
ACT	717	96	734	123
Total	69,750	14,497	91,606	32,720

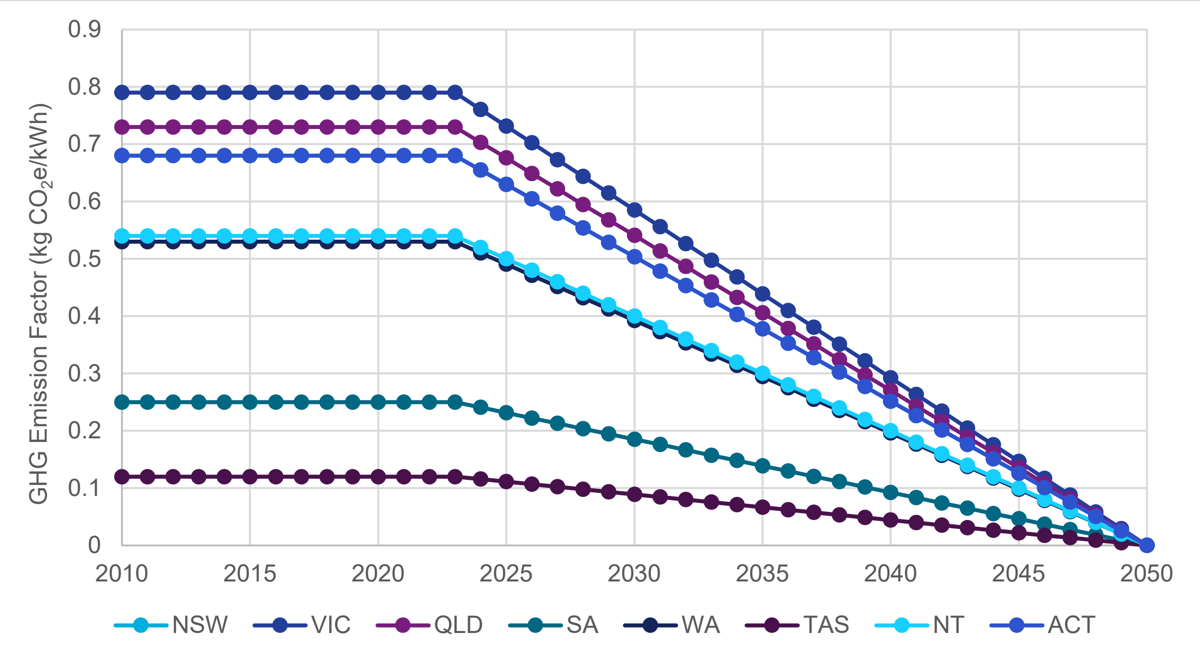
The economic impact model calculates both the economic benefits realised for a prospective period of 10 years (through 2033) to align with economic impact assessment standards, and through 2050 to encompass a greater portion of the building lifespan. Buildings impacted by the implementation of BCA 2010 may only be approximately 20 years old by 2033, and buildings impacted by NCC 2022 will be less than 10 years old in 2033. Many Australian and international climate goals are set with a target date of 2050, and buildings impacted by BCA 2010 will be near 40 years old at this point. Benefits from improved thermal performance are expected to continue through the lifespan of the home, and although some homes would have had upgrades to achieve higher efficiency in the future, other homes may accrue benefits past 2050 as they have expected lifespans of more than 40 years.

All the results of the CBA are presented as the net present value of the benefits in 2023 AUD. A 7% discount rate was used in the analysis to align with the Australian standard. The costs and benefits were adjusted to 2023 AUD using the Australian national consumer price index (CPI) from the Australian Bureau of Statistics (December CPI is used as a proxy for each year). An internal rate of return and payback period were not calculated in this study because there was not a major upfront investment, but rather a prolonged investment in developing tools, technical expertise and research that has spanned the period of this study.

3.2 Greenhouse Gas Emissions Impacts

In addition to the economic benefits of the reduced energy use for the home occupants, there are additional benefits quantified in this study due to the reduction in greenhouse gas (GHG) emissions from both electricity generation and natural gas combustion. The reduction in both natural gas and electricity usage was calculated in the economic impact model as described in the previous section. The reduction in electricity emissions in each state was multiplied by an emissions factor specific to the electricity grid in each state. The state-specific emission factors were based on the 2023 GHG emissions factors from the Australian National Greenhouse Accounts Factors Workbook (Department of Climate Change, Energy, the Environment and Water, 2023). We assumed that the GHG emissions from the grid would reach net zero by 2050 and we modelled a linear reduction in GHG emissions from 2023–2050. Prior to 2023 we assumed a constant rate of GHG emissions from the electricity grid in each state. Figure 3 shows the GHG emission factors from the electricity grid by state used to calculate the GHG emissions benefits.

Figure 3. GHG Emission Factors for the Electricity Grid in Each State



The emission factors for natural gas consumption were based on the scope 1 and scope 3 emission factors for natural gas consumption that were used in the NCC 2022 Regulatory Impact Statement (Acil Allen, 2022). These factors are constant throughout the entire time period, although there may be slight variations based on updates to the natural gas supply chain and combustion technology in the homes.

The GHG emission benefits were monetised using the social cost of carbon from the updated United States (US) Government's Interagency Working Group's (IWG) guidance on Social Cost of Greenhouse Gases (2021). The guidance document provides values on the social cost of carbon using a 5% discount rate and a 3% discount rate. Since this study uses a 7% discount rate for the CBA, the 5% discount rate values were used for the social cost of carbon calculation.

3.3 CSIRO Costs

The CSIRO costs for the CBA analysis were the costs associated with developing the AccuRate tool and integrating it with NatHERS for use as the benchmarking tool. Based on discussions with CSIRO personnel and background research using technical reports and journal and news articles we estimated that the effort to develop these tools and integrate them with NatHERS was approximately four full-time employees (FTEs) working at a schedule 7 salary from the CSIRO enterprise agreement. The costs for this study are the labour for the period of 2003–2023. Equipment costs and other costs for server space were excluded as they were very small compared to the salary costs. As with the benefits, the costs are presented as a net present value in 2023 AUD. A 7% discount rate was used in the analysis to align with Australian standard. The costs and benefits were adjusted to 2023 AUD using the Australian national CPI from the Australian Bureau of Statistics (December CPI is used as a proxy for each year).

4. Results

The benefits of CSIRO's residential energy efficiency services are presented over two time periods. First, 2003 through 2033 is used to start a year before NatHERS was adopted as the nationwide approach for rating building energy efficiency and extending through a 10-year prospective study to align with the CSIRO guidelines for CBA. Second, 2003 through 2050 is used to include more of the benefits due to the long lifespan of the homes being built that are impacted by the updated energy efficiency regulations. While the results for 2003 through 2033 are reported in this study to show the near-term benefits, the benefits through 2050 more accurately represent the economic impact of CSIRO's residential energy efficiency services.

4.1 Summary of Economic Benefits

This report quantifies the benefits of three scenarios to present a range of economic benefits that result from the use of CSIRO's services, specifically the use of AccuRate as the benchmarking tool to support NatHERS and the regulatory process for the Australian government. The scenarios represent counterfactuals where the implementation of thermal performance standards for residential buildings is delayed by a period of 1 to 6 years in the absence of AccuRate and CSIRO support in the regulatory decision-making process. Table 3 shows the economic benefits due to a reduction in energy use in new residential homes from 2003–2033.

Table 3. Economic Benefits, 2003–2033

Scenario	Avoided Implementation Delay	Compliance Costs ($M)	Benefits ($M)	Net Benefits ($M)
Low-end	1 Year	$375	$529	$153
Median	**3 Years**	**$1,079**	**$1,444**	**$365**
High-end	6 Years	$2,016	$2,490	$474

While the economic benefits are positive through 2033, a large portion of benefits have not been realised within that period because residential homes are a long-lived asset. Table 4 shows the economic benefits from 2003 through 2050 with expected economic benefits of over $1.5 billion in AUD 2023.

Table 4. Economic Benefits, 2003–2050

Scenario	Avoided Implementation Delay	Compliance Costs ($M)	Benefits ($M)	Net Benefits ($M)
Low-end	1 Year	$375	$911	$535
Median	**3 Years**	**$1,079**	**$2,590**	**$1,511**
High-end	6 Years	$2,016	$4,783	$2,767

4.2 Summary of Emissions Impacts and Monetised Benefits

In addition to the economic benefits from a reduction in energy usage, the benefits from reduced GHG emissions due to avoided energy use are substantial. Almost half of the benefits of reduced GHG emissions are realised by 2033 because the electricity grid is expected to have lower emission moving forward, leading to a net zero grid by 2050. Table 5 shows the monetised GHG benefits from accelerating the implementation of residential energy efficiency standards through 2033.

Table 5. GHG Emissions Impacts, 2003–2033

Scenario	Avoided Implementation Delay	Reduced Emissions Electricity Sector (tonnes CO_2e)	Reduced Emissions Gas (tonnes CO_2e)	Monetised GHG Benefits ($M)
Low-end	1 Year	643,801	622,404	$34
Median	**3 Years**	**1,747,116**	**1,744,461**	**$95**
High-end	6 Years	2,970,164	3,120,672	$167

Although there is an expected reduction in GHG emissions from the electricity grid through 2050, the majority of the benefits of reduced GHG emissions still occur from 2033 through 2050 due to reductions in natural gas consumption. As the grid becomes less carbon intensive towards 2050, the reduction in electricity consumption yields less GHG benefits, but reducing natural gas consumption continues to have substantial GHG emissions benefits. Table 6 shows the expected GHG benefits from accelerated implementation of residential energy efficiency standards through 2050.

Table 6. GHG Emissions Impacts, 2003–2050

Scenario	Avoided Implementation Delay	Reduced Emissions Electricity Sector (tonnes CO_2e)	Reduced Emissions Gas (tonnes CO_2e)	Monetised GHG Benefits ($M)
Low-end	1 Year	975,787	1,317,986	$73
Median	**3 Years**	**2,743,073**	**3,831,207**	**$212**
High-end	6Years	4,962,079	7,294,165	$401

4.3 Additional Health and Economic Impacts

In addition to the economic impacts quantified in the previous section, several other important economic, social and environmental impacts were not quantified in this study. The first is the human health impact from the reduction in residential energy use. We did not qualify this in the economic model but the NCC 2022 Regulatory Impact Statement estimated approximately $190 M in human health impacts through 2060. This value is based on an Australian study monetising health benefits of air pollution reduction from electricity generation. Estimates of gas electricity generation for NCC 2022 and the generation profile for BCA 2010 were not provided, so we could not back calculate the portion of health impacts that would be associated with each scenario. Health benefits would be front loaded due to a reduction in fossil fuel electricity generation in the future. Additionally, there are health impacts associated with enhanced thermal performance of the home. Vulnerable populations can be susceptible to extreme temperatures, and homes with poor thermal performance increase the risk of exposure to extreme temperatures for vulnerable populations.

There are also broader economic impacts that Australians would be exposed to through energy bills in the future. Energy can be a major economic burden for vulnerable populations, and reducing long-term electricity bills can alleviate economic distress. Reduction in energy consumption, both in total energy use and peak load, can decrease infrastructure expenses for utilities that are passed to consumers. Addition of generation sources and transmission infrastructure to service incremental load can be expensive causing rates to increase, and in many cases the additional generation sources can be more environmentally detrimental in the short term as they may require natural gas or coal facilities to be added.

4.4 Summary of CSIRO Costs

The main cost associated with CSIRO's residential energy efficiency services is salaries for the staff conducting research and developing tools to support industry. CSIRO's residential energy efficiency services staff has been six personnel for many years but has recently increased to almost 20 people. The focus of this CBA is the impact of the AccuRate tool on accelerating implementation of energy efficiency standards, therefor the costs are for the CSIRO services associated with the development and maintenance of AccuRate. Recent hires have been supporting other tools and research, including RapidRate. Based on research of reports produced by CSIRO, interviews and news articles, we assumed that the costs associated with this study were for four FTEs at the CSIRO level 7 salary schedule rate over the study period from 2003 through 2023. The estimated total salary expenditure, in real terms assuming a 7% discount rate and adjusting for inflation was about $25 million.

4.5 CBA Summary (Economic and Environmental Benefits)

Table 7 summarises the total present value of the costs and benefits of CSIRO's residential energy efficiency services over both periods analysed in this report.

Table 7. Summary of CBA for CSIRO Residential Energy Efficiency Services

Scenario	Avoided Implementation Delay	CSIRO Costs ($M)	Economic Net Benefits (2003–2033) ($M)	BCR (2003–2033)	Economic Net Benefits (2003–2050) ($M)	BCR (2003–2050)
Low-end	1 Year	$25	$153	6	$535	22
Median	**3 Years**	**$25**	$365	15	**$1,511**	**61**
High-end	6 Years	$25	$474	19	$2,767	111

BCR = Benefit-Cost ratio

Table 8 summarises the total present value of the costs and benefits of CSIRO's residential energy efficiency services over both periods analysed in this report with the monetised benefits of the reduction in GHG emissions included.

Table 8. Summary of CBA for CSIRO Residential Energy Efficiency Services Including Monetised GHG Benefits

Scenario	Avoided Implementation Delay	CSIRO Costs ($M)	Economic Net Benefits (2003–2033) ($M)	BCR (2003–2033)	Economic Net Benefits (2003–2050) ($M)	BCR (2003–2050)
Low-end	1 Year	$25	$187	8	$609	24
Median	**3 Years**	**$25**	$460	18	**$1,723**	**69**
High-end	6 Years	$25	$641	26	$3,167	127

BCR = Benefit-Cost ratio

5. Qualitative Findings

In addition to the benefits quantified in the previous section, CSIRO's residential energy efficiency services have provided other large and intangible benefits that we are not able to show within the confines of a CBA but were emphasised by industry stakeholders during the interview process. During each interview, stakeholders were asked about the following items:

- their background and role pertaining to residential energy efficiency
- the relevant CSIRO services they have experience with
- how CSIRO services have affected their work process and decisions
- how CSIRO's services have impacted the energy use and energy intensity in the residential sector
- without CSIRO's services, what alternatives were available and how would that impact their work

The main finding from our interviews was that AccuRate is a unique tool that does not presently have alternatives. There are other approved NatHERS software tools, but they all rely on AccuRate validation. Other industry tools do not have the Australian-focused building fabric, ventilation, or climate detail that AccuRate offers, nor do they offer the responsiveness to Australian industry and Government needs provided by CSIRO which creates limitations for their use supporting regulatory development.

Another key piece of feedback was the importance of information, especially for existing housing stock. CSIRO is addressing this issue through the development of the RapidRate tool, scheduled for release in 2024, and adapting AccuRate for use in existing dwellings. AccuRate, NatHERS and RapidRate are important tools for understanding the current landscape of energy use in the residential sector to develop a more accurate baseline for future energy policy. Targeting future investment is hard without a common set of data for stakeholders to agree on. RapidRate can provide a benchmarking tool leading to an agreement on information that is required to advance major energy policies.

One key gap that was brought up was the need for verification and validation across the industry. CSIRO has played an important role in advancing science and theory around building energy efficiency, but more data validation and onsite testing is needed to ensure that standards are achieving the intended goals. The energy rating scheme can be more effective if it is not just a prescriptive path for builders but guidelines that facilitate improved performance throughout the residential home building industry.

6. Discussion

CSIRO's residential energy efficiency services have provided strong economic benefits for Australian residents. The benefits of improved home thermal performance also flow through Australian society due to improved energy utilisation and the broader benefits that provides. This section summarises these benefits and the broader impact.

There are substantial economic benefits that result from accelerating the implementation of thermal performance standards for new residential buildings. The BCA 2010 thermal performance standards impacted over 70 000 new buildings per year and the NCC 2022 thermal performance standards are expected to impact over 100 000 new residential buildings annually. Through 2033 we project that there will be $460 million (net present value (NPV) in 2023 AUD) in net benefits due to CSIRO's residential energy efficiency services. The benefit-cost ratio for this period is 18, meaning that for every $1 invested in these services, there are economic and environmental benefits of $18. Table 9 shows the range of CBA results for the period of 2003 through 2033.

Table 9. CBA Results, 2003–2033

Scenario	Avoided Implementation Delay	CSIRO Costs ($M)	Economic Net Benefits (2003–2033) ($M)	BCR (2003–2033)
Low-end	1 Year	$25	$187	8
Median	**3 Years**	**$25**	**$460**	**18**
High-end	6 Years	$25	$641	26

BCR = Benefit-Cost ratio

Since residential homes are an asset with a lifespan that extends far beyond the standard prospective CBA period of 10 years, an extended study period accurately incorporates the benefits of CSIRO's residential energy efficiency services. Therefor we calculated the NPV and a benefit-cost ratio for the period of 2003–2050. The net benefits of CSIRO's residential energy efficiency services over the extended period through 2050 was over $1.72 billion for a benefit-cost ratio of 69 over that period meaning that for every $1 invested in these services, there are economic, environmental benefits of $69. Since most benefits of reduced energy consumption are realised past 2033 (the majority of the impacted housing stock will only be 10–20 years old in 2033), RTI recommends using 69 as the benefit-cost ratio. Table 10 shows the range of CBA results for the period of 2003 through 2050.

Table 10. CBA Results, 2003–2050

Scenario	Avoided Implementation Delay	CSIRO Costs ($M)	Economic Net Benefits (2003–2050) ($M)	BCR (2003–2050)
Low-end	1 Year	$25	$609	24
Median	**3 Years**	**$25**	**$1723**	**69**
High-end	6 Years	$25	$3167	127

BCR = Benefit-Cost ratio

The benefits of CSIRO's residential energy efficiency services can vary greatly by region as improved energy efficiency performance can have various results by region, depending mostly on climate but also other social and economic characteristics of the population. While some homes may invest in energy efficiency upgrades in the future that would reduce benefits attributable to the updated building standards (the reduction in energy use from that point forward would be attributed to the customers actions), other homes may see benefits extending further into the future as the building lifespan extends beyond 2050.

The results show the importance of stringent energy efficiency requirements for new homes. With so many homes being built each year, over 100,000 per year moving forward, the impacts of a delay in energy efficiency requirements will apply to a large number of Australians and last for an exceptionally long time. Energy efficiency upgrades are expensive and have long payback periods, so many residents do not make these investments unless there is an urgent need.

While more aggressive energy efficiency standards can save consumers money over a long period, they do add costs for residential home builders upfront. Without a widely trusted source to be an impartial arbiter of information and analysis, receiving buy-in from key stakeholders would be a much more difficult process. Developing regulations that can disrupt a $70 billion per year industry is a slow and laborious process that cannot be done without widespread agreement in key data, information and analysis methods.

7. Conclusion

CSIRO's residential energy efficiency services are crucial for Australia's goals in improving energy productivity because they support regulations that correct areas where incentives for residential builders and residents do not align. CSIRO is a well-respected arbiter of information that is needed to support the development of regulations in an industry with a diverse set of stakeholders and a large amount of investment annually. With more than 100 000 homes built annually, the compliance costs of new regulations to builders need to have a sound economic, social and environmental rationale to be widely accepted.

The improved building energy efficiency standards have a major economic, social and environmental impact across the population. They lower energy bills for consumers, improve home comfort, reduce environmental and health impacts associated with electricity production and fuel use and reduce the need for expensive expansion of energy infrastructure. The expansive impacts of improved energy efficiency create an urgency to ensure that improved standards for homes are not delayed. Delays can impact a large number of homes for many years, as shown by the poor energy performance in Australia's legacy building stock.

Additionally, a better understanding of the energy performance characteristics of Australia's legacy building stock is important for future policy decisions to improve energy efficiency throughout the country. A tool like RapidRate has a unique ability to provide this information to key industry stakeholders to develop a path forward that alights with Australia's energy roadmap.

CSIRO is in a unique position in Australia to offer energy efficiency services due to their extensive 60-year history in research and energy modelling and the relationships they have built throughout the industry. The development of the AccuRate tool and its use as the benchmarking tool for NatHERS has created a framework for past and continued rigorous energy policy measures and innovations in residential energy efficiency technology that can make Australia a leader in residential energy efficiency. With the expected expansion of home building, it will be crucial to ensure that Australia can continue to meet its housing needs while not sacrificing the country's need to improve energy productivity.

References

Acil Allen. (2022). *National Construction Code 2022: Decision Regulation Impact Statement for a proposal to increase residential building energy efficiency requirements.* Australian Building Codes Board.

Australian Bureau of Statistics. (2023). *Building Activity, Australia.* Retrieved from https://www.abs.gov.au/statistics/industry/building-and-construction/building-activity-australia/latest-release#data-downloads

Centre for International Economics. (2009). *Final Regulation Impact Statement for residential buildings (Class 1, 2, 4 and 10 buildings) - Proposal to revise energy efficiency requirements of the Building Code of Australia for residential buildings.* Australian Building Codes Board.

Chen, D. (2016, September). *AccuRate Chenath Repository.* Retrieved from AccuRate and the Chenath Engine for Residential House Energy Rating: https://www.hstar.com.au/Chenath/AccuRateChenathRepository.htm

COAG Energy Council. (2015). *National Energy Productivity Plan 2015-2030.* Commonwealth of Australia.

CSIRO. (2024). *Australian Energy Rating Dashboard – States and Territories*. Retrieved from https://ahd.csiro.au/dashboards/energy-rating/states/

Department of Climate Change, Energy, the Environment and Water. (2022). *About NatHERS*. Retrieved from Nationwide House Energy Rating Scheme: https://www.nathers.gov.au/

Department of Climate Change, Energy, the Environment and Water. (2022). *Australian energy consumption, by state and territory, by industry, energy units table E1.* Retrieved from Australian Energy Statistics.

Department of Climate Change, Energy, the Environment and Water. (2023). *Australian National Greenhouse Accounts Factors Workbook 2023.* Commonwealth of Australia.

Department of Climate Change, Energy, the Environment and Water. (2024, June). *Energy Efficiency – Residential Buildings*. Retrieved from https://www.dcceew.gov.au/energy/energy-efficiency/buildings/residential-buildings

Interagency Working Group on Social Cost of Greenhouse Gases, United States Government. (2021). *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990.*