Aligning Queensland's Energy Efficiency Requirements for Residential Dwellings with National Standards, and Associated Measures – Cost-Benefit Analysis

Final Report

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Executive Summary

This report investigates the societal benefits and costs associated with three potential regulatory changes in Queensland (QLD):

1. Alignment of QLD's current energy efficiency provisions for new residential buildings (houses and units) with the minimum mandatory provisions required by the National Construction Code (NCC 2019)
2. Improved building compliance by requiring the accreditation of house energy assessors and that energy efficiency features are documented on residential dwelling plans
3. Mandating a minimum standard that significant roof replacement or repair works must comply with additional work to improve resilience through structural and thermal performance measures.

A detailed description of our overall methodology and key assumptions is provided in Chapter 2, with further details in the subsequent chapters. The study adopts best practices as applied by the Australian Building Codes Board and Australian Government benefit cost analyses. It accesses high quality data from CSIRO's *Australian Housing Data* portal and Geoscience Australia's *NEXIS* database amongst other sources. For analytical purposes only, the measures are assumed to commence in FY2024 (that is, from 1 July 2023) and to persist for 10 years (until the end of FY2033).

Incremental costs are estimated by Brisbane-based quantity surveyors, Steele Wrobel, with cost assumptions for reroofing and storm damage also drawing on work by the Cyclone Testing Station associated with James Cook University. In this study, Ecolateral and RED Sustainability Consultants undertake the technical analysis and simulation modelling, while SPR undertakes the benefit cost analysis. Further details on the analysis team are in Chapter 1. The analysis uses QLD-specific or adapted designs – each of which feature an outdoor living area – and the analysis is resolved by building class, archetype (or building type/design), climate zone and, as appropriate, wall- and floor-construction-methods and wind-zones. By assumption, the base designs are not changed in order to help achieve compliance with higher standards, even though, in practice, this routinely occurs and would generally provide a least-cost solution. Also, we do not assume that designs are optimally oriented, even if this also can in some circumstances offer a least cost solution. For some designs, we found at least 1 star difference between the best and worst oriented layouts.

Summary of Key Findings

1. The overall package of measures would be highly cost-effective if implemented jointly, generating a net economic benefit for QLD of at least $620 million at a benefit cost ratio (BCR) of 2.3. It would also avoid more than 3.5 million tonnes of greenhouse gas emissions, and reduce peak electrical demand by almost 26 MW, reducing electricity infrastructure costs.

2. The net benefits could be as high as $686 million (with a BCR of 2.6) if home-owners/builders consistently chose the NatHERS compliance pathway over the elemental/DTS pathway, as we find that incremental construction costs under the NatHERS pathway are close to one-third, on average, of those under the elemental/DTS. In some cases, however, the elemental/DTS approach could offer a least-cost solution. We recommend that the QLD Government raises awareness of the potential cost savings associated with the NatHERS pathway, as it is likely that most home-buyers, and some builders, would not be aware of the cost savings available.
3. Considering the major elements of the package, a move from QDC 4.1 to NCC2019 would, on its own, be highly cost-effective and generate large net benefits for QLD households on average, and for society more generally. These include net societal benefits of at least $595 million at a BCR of 3.2, on current compliance verification trends, or up to $664 million at a BCR of 4.0 if the NatHERS pathway were used consistently. The benefits also include avoided greenhouse gas emissions of just over 3 million t CO_2-e and reduced peak electrical demand in QLD of at least 9 MW.
4. On average at the household level – setting aside societal benefits such as avoided climate damage and network costs – new house/townhouse owners would be significantly better off under NCC2019. In total, they would save over $4,500 in energy costs over the life of the dwelling.[1] With the weighted average incremental cost of upgrades being only $383 for Class 1 dwellngs, and $1,684 for heat pump vs electric storage hot water, the benefit cost ratio for individual households is 2.3. For new apartments, the weighted average savings are much less than for houses/townhouses, in particular because the change in hot water provisions, that contributes much to the house/townhouse results, does not apply to apartments. Indeed, the average new apartment owner would experience a small net cost (less than $29)[1] over the life of the apartment. See Table 3 and Table 4 below.
5. The proposal to improve building compliance by requiring the accreditation of house energy assessors and energy efficiency features to be documented on residential dwelling plans would be expected to have numerous benefits, including early attention to energy efficiency in the development process, leading to lower-cost building solutions being identified by accredited and trained professionals; greater incentive for builders to consistently install the required efficiency features that home-owners are paying for; lower energy bills for home-owners over the whole life-span of homes; and greater comfort for occupants.
    - Quantifying these benefits is difficult, due to limited information on current compliance outcomes, but costs are relatively low at $2.2 million in present value terms, compared to the net benefit of the overall package of measures at over $620 million.

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[1] Present value at 7% real discount rate.

   - This measure would also be consistent with nationally-agreed policy directions to strengthen compliance with building codes.

6. The measures to increase building resilience, taken together, are cost-effective, with an expected net societal benefit of just over $25 million at a BCR of 1.1. However, the insulation measure is much more cost-effective, with a net benefit of $88 million at a BCR of 1.7, in its own right, while the roof strengthening measure is not expected to be cost-effective in its own right. However, this finding could change if there is an increasing risk of storm-related damage in SE QLD due to climate change. Quantifying this risk is outside our scope and expertise, but we recommend it be investigated by suitably-qualified parties.

Summary Tables

Table 1 summarises expected impacts for each measure, and for the overall package, assuming that current compliance verification trends continue into the future, while Table 2 indicates the potential outcomes if the NatHERS verification pathway were consistently preferred.

Note that, throughout this report, all present values are calculated at 7% real discount rate, and all financial values are expressed in real FY2023 dollars.

Table 1: Summary of Benefit Cost and Impact Analysis by Measure (current compliance verification trends)

Measure	Present Value of Benefits	Present Value of Costs	Net Present Value	Benefit Cost Ratio	Cumulative Emissions Savings (t CO2-e)	Avoided Peak Electrical Demand (MW)
QDC4.1 - NCC 2019 (NatHERS)	$84,672,304	$17,368,291	$67,304,013	4.9	221,058	7.0
QDC4.1 - NCC 2019 (Elemental)	$23,513,079	$59,180,368	-$35,667,290	0.4	61,388	1.9
Hot Water	$761,883,512	$198,538,009	$563,345,503	3.8	2,723,395	-
Sub-total NCC2019	***$870,068,894***	***$275,086,668***	***$594,982,226***	***3.2***	***3,005,841***	***9.0***
Accreditation	*Not quantified*	$1,358,166	*Not quantified*	*Not quantified*	*Not quantified*	*Not quantified*
Documentation	*Not quantified*	$835,046	*Not quantified*	*Not quantified*	*Not quantified*	*Not quantified*
Roof strengthening	$24,741,263	$87,765,346	-$63,024,083	0.3	-	-
Roof insulation	$208,808,531	$120,636,967	$88,171,563	1.7	540,563	16.8
Totals	**$1,103,618,688**	**$483,488,981**	**$620,129,706**	**2.3**	**3,546,403**	**25.8**

NB: All present values are calculated at 7% real discount rate and expressed in real $FY2023.

Table 2: Summary of Benefit Cost and Impact Analysis by Measure (100% NatHERS compliance verification scenario)

Measure	Present Value of Benefits	Present Value of Costs	Net Present Value	Benefit Cost Ratio	Cumulative Emissions Savings (t CO2-e)	Avoided Peak Electrical Demand (MW)
QDC4.1 - NCC 2019 (NatHERS)	$126,376,573	$25,922,822	$100,453,751	4.9	329,937	10.5
QDC4.1 - NCC 2019 (Elemental)	-	-	-	-	-	-
Hot Water	$761,883,512	$198,538,009	$563,345,503	3.8	2,723,395	-
Sub-total NCC2019	***$888,260,085***	***$224,460,831***	***$663,799,254***	***4.0***	***3,053,332***	***10.5***
Accreditation	*Not quantified*	$1,358,166	*Not quantified*	*Not quantified*	*Not quantified*	*Not quantified*
Documentation	*Not quantified*	$835,046	*Not quantified*	*Not quantified*	*Not quantified*	*Not quantified*
Roof strengthening	$24,741,263	$87,765,346	-$63,024,083	0.3	-	-
Roof insulation	$208,808,531	$120,636,967	$88,171,563	1.7	540,563	16.8
Totals	**$1,121,809,878**	**$435,056,356**	**$686,753,522**	**2.6**	**3,593,895**	**27.3**

Tables 3 and 4 below summarise the average private per-dwelling costs and benefits, both for the potential change fromQDC4.1 to NCC2019, and also for the potential change from NCC2019 to NCC2022, as reported in Table ES5 in the Final Decision RIS for NCC2022 by ACIL Allen Pty Ltd.[2] These include the average incremental capital costs (which include incremental costs for hot water upgrades for the Class 1 dwelling), present value of energy bill savings, and other private benefits as appropriate, for Class 1 and Class 2 dwelling respectively. Societal benefits are not included in this analysis, in order to highlight just the direct costs and benefits expected to be experienced by households. Net benefits would accrue, on average, to owners of Class 1 dwellings from both the potential change from QDC4.1 to NCC2019 and from the potential change from NCC2019 to NCC2022 (Table 3). The average household would be better off by nearly $2,700 if both changes were implemented.

Table 3: Average Per-Dwelling Costs and Benefits: QDC4.1 – NCC2019 and NCC2019 – NCC2022 (from Decision RIS) – Class 1 Dwellings

	Class 1 Dwellings	**Capital Costs ($)**	**Energy Savings ($)**	**Other Benefits ($)**	**Net Impact ($, NPV)**	**BCR**
QDC4.1 to NCC2019	QLD	$2,010.54	$4,540.74		$2,530.20	2.3
NCC2019 to NCC2022 (from DRIS, Table ES5)	QLD	$710.00	$790.00	$86.00	$166.00	1.2
Total	QLD	**$2,720.54**	**$5,330.74**	**$86.00**	**$2,696.20**	**2.0**

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[2] Note that this study relates to FY2024 and the ACIL Allen table referenced relates to FY2022, but this is unlikely to affect the comparability of the results significantly.

Small net costs would accrue to owners of Class 2 dwellings, if both changes were implemented, averaging $65 per dwelling (Table 4).[3]

Table 4: Average Per-Dwelling Costs and Benefits: QDC4.1 – NCC2019 and NCC2019 – NCC2022 (from Decision RIS) – Class 2 Dwellings

	Class 2 Dwellings	Capital Costs ($)	Energy Savings ($)	Other Benefits ($)	Net Impact ($, NPV)	BCR
QDC4.1 to NCC2019	QLD	$99.17	$70.37		-$28.80	0.7
NCC2019 to NCC2022 (from DRIS, Table ES5)	QLD	$764.00	$655.00	$73.00	-$36.00	1.0
Total	**QLD**	**$863.17**	**$725.37**	**$73.00**	**-$64.80**	**0.9**

Detailed Findings

Table 1 above highlights that if all the potential measures were implemented simultaneously, taking effect in FY2024, and remaining in place until FY2033, then there would be a net benefit for Queensland of at least $620 million at a benefit cost ratio of 2.3. We note ‘at least’ because, as discussed further below, this net benefit would be higher if more home-owners/builders chose to use the NatHERS verification pathway rather than the elemental (or deemed-to-satisfy (DTS)) pathway.

As an overall package, this set of measures would be highly cost-effective. However, there is no presumption that all measures considered must proceed together and, in this report, each measure is also considered in isolation. Table 1 also indicates that some measures, or components of measures, are not expected to be cost-effective on their own, while in other cases, incremental costs could be quantified with confidence but not so the benefits, which have been treated more qualitatively. The following sections address each of the measures in more detail.

QDC4.1 to NCC2019

It would be highly cost-effective, and generate large net benefits for QLD, if NCC2019 energy performance requirements were adopted in place of those in QDC 4.1. The net societal benefit is expected to be at least $595 million, with benefits 3.2 times larger than costs – see Table 1.

As noted above, this estimate assumes that past practices, under which up to one third of new housing construction in QLD follows the elemental or DTS verification pathway, continue into the

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[3] Class 2 dwellings are shown to be cost-effective to upgrade to NCC2019 when the additional benefits from avoided carbon and network infrastructure costs are taken into account.

future. Builders/home-owners are free to choose between NatHERS, the elemental (DTS) pathway, or indeed other verification pathways – there is no compulsion about which one should be chosen. In practice, very few new home-buyers will be aware of this choice, let alone of its potentially significant consequences for the costs of their home. However, Table 2 highlights that the net benefit could be as high as $664 million if new home-owners/builders consistently chose the NatHERS verification pathway. This is because construction costs are, on average, much lower when NatHERS is used – almost one-third, on average. However, results will vary depending upon the design and other factors, and there may be designs for which DTS offers a lower-cost compliance pathway.

Overall, the incremental construction costs attributable to NCC2019 would be more than $50 million lower, and the net benefit for QLD some $70 million higher, if NatHERS were used consistently in place of elemental/DTS. We therefore suggest that the QLD Government could assist new home-owners to avoid significant costs by promoting awareness of and a positive preference for the NatHERS pathway.

Tables 1 and 2 also highlight that the largest part of the net benefit associated with NCC2019 would be generated by the hot water provisions. NCC2019 would effectively restore the quasi-ban[4] on large electric storage hot water systems that applies in most states, and which also applied in QLD until 2014. This ban was introduced (as part of BCA2010) due to the low energy efficiency and high greenhouse gas intensity of this hot water technology.

Restoring this provision of NCC2019 would create large and highly cost-effective net benefits for new home buyers and for QLD. This reflects the fact that heat pump hot water systems (which would be expected to be the dominant technology replacing large electric storage systems under this regulatory change) are at least 3.5 times more energy efficient, on average, than the systems they would replace, while the incremental capital costs of these systems have fallen significantly over time. On average, lower-cost heat pumps would have a payback of less than 3 years and would save each house more than $2,400 in present value terms over the 10-year (warranted) life of the systems. With an estimated 59% of new houses in QLD currently choosing electric storage systems, a switch to heat pumps (or other compliant hot water technologies) would generate large net benefits, including cumulative avoided greenhouse gas emissions of over 2.7 million t CO_2-e.

For those new buildings that, on current trends, would be expected to use the NatHERS verification pathway, we find a change from QDC4.1 to NCC2019 would be:

- cost-effective or negative cost for all housing classes
- cost-effective or negative cost in all climate zones

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[4] There are exceptions, such as where the system is connected to a renewable (or reclaimed) energy source and for small (less than 50 l) systems.

- highly cost effective for Class 1s with concrete slab on ground construction, cost-effective (but less so) for those with suspended timber floors, but not cost effective for the 'Queenslander' archetype modelled
    - This is due to the significant combination of upgrades required to the 'Queenslander' archetype and in particular due to the glazing improvements necessary to counter the lack of thermal mass in the lightweight structure.
- cost-effective or negative cost for all archetypes, with the exception that the BCR for the Class 1, 2-storey archetype, is just under 1, at 0.9.

Indeed, for those choosing the NatHERS pathway:

- more than 58% of all new dwellings impacted by this measure (ie, those using the NatHERS verification pathway and not already achieving or exceeding 6 stars) show an absolute reduction in construction costs under NCC2019, compared with QDC4.1
- These 58% of new dwellings that experience a reduction in construction costs also generate gross benefits (fuel cost savings, avoided infrastructure costs, avoided emissions costs) with a present value of more than $70 million
- A second group is those dwellings that achieve cost effective, but not negative cost, savings (that is, they have a BCR > 1). These represent a construction-weighted share of just under 33% of all new dwellings constructed, and together they achieve a net benefit of $8.8 million.
- Finally, some 8.7% of new dwellings (choosing the NatHERS pathway) would experience a BCR less than 1 (that is, that are assessed as not cost-effective), and these would experience a combined net social loss of $11.9 million
    - Some of these *may* be able to achieve lower costs under the elemental (DTS) pathway, as discussed below.

For those choosing the elemental (DTS) pathway, the incremental cost of compliance with NCC2019 is estimated to average $3,790/dwelling, across all archetypes and orientations, cf only $1,360 under the NatHERS pathway – ie, almost three times higher. These findings are consistent with the purpose and function of NatHERS being to provide for lower cost and more cost-effective performance-based solutions than are possible under the prescriptive elemental (DTS) approach. As a result, less than 35% of the 52 combinations of building class, archetype, climate zone and construction method considered have a positive NPV (note: there is no elemental (DTS) solution for Class 2 apartments). As a group, these 35% would experience net benefits of $6.1 million. This underscores that the elemental (DTS) pathway *can* be cost-effective in some circumstances – although, even in these cases, NatHERS could be *more* cost-effective. In practice, the least cost pathway should be assessed on a case-by-case basis. However, these benefits are more than offset by the more than 65% of elemental (DTS) combinations that have negative NPVs. Together these amount to -$41.8 million, with the total of these two equalling the overall negative net benefit for the elemental (DTS) pathway of -$35.7 million. These values assume that past trends, under which

~33% of new construction occurs under the elemental (DTS) pathway, are perpetuated into the future. We conclude that homeowners in QLD would benefit from efforts to increase awareness that they may be able to avoid significant costs by selecting the NatHERS verification pathway.

Overall, we conclude that a move to NCC2019 would be beneficial for QLD from an economic perspective, with *at least* $595 million in net societal benefit and benefit cost ratio of at least 3.2. In addition, this regulatory change would realise:

- avoided cumulative greenhouse gas emissions of just over 3 million t CO_2-e
- peak electrical demand in QLD would be around 9 MW lower than otherwise each year.

At the household level – setting aside societal benefits such as avoided climate damage and network costs – new house/townhouse owners would be significantly better off, on average, under NCC2019. They would use over 2,000 kWh less electricity per year (weighted average of all the Class 1 dwellings), and some houses (of the relatively few that use gas) would also use less gas. In total, the average new house owner would save over $4,500 in energy costs over the life of the dwelling.[5] With the weighted average incremental cost of upgrades being only $383, the benefit cost ratio for individual households is almost 12:1. By definition, within these averages, some households will experience either higher costs and/or lower savings, and some will experience lower costs and/or higher savings.[6] For apartments, the weighted average savings are much less than for houses/townhouses, because the change in hot water provisions that contribute much to the house/townhouse results do not apply to apartments. Indeed, the average new apartment owner would experience a small net cost (less than $29)[4] over the life of the apartment.

Accreditation and Documentation

The proposal to improve building compliance by requiring the accreditation of house energy assessors and energy efficiency features to be documented on residential dwelling plans would be expected to have numerous benefits:

- home-owners and builders being better informed as to the expected energy performance of their designs
- lower-cost building solutions being identified by accredited and trained professionals
- lower energy bills for home-owners over the 50 or more years life of new homes
- better value for money, with greater incentive and accountability for builders to consistently install the required efficiency features that home-owners expect and are paying for
- increased greenhouse gas emissions savings
- reduced peak loads on QLD's electrical grid

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[5] Present value at 7% real discount rate.

[6] As noted, households that use the NatHERS compliance verification pathway on average experience significantly higher benefits and lower costs than those that use the DTS compliance verification pathway.

- more comfortable homes.

However, quantifying the *extent* to which these benefits are likely to occur is challenging, primarily because there is little clarity about the extent to which new homes in QLD do or do not fully comply currently with energy performance requirements at present. Nationally, serious concerns have been expressed about this in at least the Shergold & Wier Report, *Building Confidence: improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia* (February 2018) and pitt&sherry, *National Energy Efficient Building Project – Phase 1 Report*, December 2014. However, neither report provides data that would enable us to value the extent of likely benefits with confidence.

We provide estimates of the expected costs, and also indicators of how much benefit would be required to offset these costs. Decision-makers and other stakeholders can then form their own views about how likely it is that sufficient benefits would accrue.

With respect to accreditation for NatHERS assessors, the NatHERS Administrator estimates that there are already some 50 accredited assessors based in QLD, and accredited assessors based in other states may also provide services in QLD. CSIRO's Australian Housing Data portal indicates that of the 22,277 NatHERS certificates issued in Queensland between June 2021 and July 2022, 36% were issued to non-accredited assessors. While it is not certain, we estimate there may be up to 250 unaccredited assessors in QLD, many of whom may undertake very few assessments per year.

If mandatory, accreditation will be an issue for the industry and will play a part in keeping them in these roles or seeing them depart. The issue of 'recognised prior learning' (RPL) is a significant selling point for experienced practitioners, however the extent of RPL is determined by the Certificate IV course provider based on the merits of the applicant.

The costs of accreditation are estimated at between $3,960 and $4,700 for the Certificate IV coursework, but discounts of up to 50% are available for practitioners with extensive experience and 'prior learning'. We estimate an average, one-off training cost, after discounts, of around $3,150. Annual costs of around $870 are estimated, which cover association membership fees, accreditation fees (incl. audits) and continuous professional development costs. It is likely that some smaller-volume builders could avoid costs by not seeking accreditation, and therefore avoid all of these costs, and instead obtain their required assessments from an accredited assessor. This means that not all currently unaccredited assessors may seek accreditation if it became a legal requirement, and this would tend to reduce the total costs incurred. Overall, we estimate the present value of costs, for those assessors not already accredited and that do seek (and retain) accreditation, at just under $1.4 million over a 10-year period.

To illustrate the scale of benefits required to offset these costs, if the effect of accreditation were to increase the actual, as-built performance of at least some new homes by up to 1 star, then if 1,480 homes were improved to this degree each year, this would fully offset the cost of accreditation. If the average improvement were only 0.5 stars, around 3,100 homes would need to be improved by this amount each year to offset the costs.

With respect to documentation, a key uncertainty is the extent to which plans are already appropriately documented. If all plans were appropriately documented already, the proposed measure would generate no incremental costs (or benefits) at all. Short of conducting a sample of audits, we can only rely on informal advice that such documentation is far from commonplace in QLD, although practices are understood to vary widely, and it is likely that larger-volume construction firms tend to provide more complete documentation.

The cost of adding appropriate documentation of energy efficiency features is likely to be small, and negligible once drawing software templates, or standard design drawings, are adjusted to include this feature. This may require a one-off cost to be incurred in some cases. We estimate the likely upper-bound of costs by assuming that up to 25% of existing plans are already appropriately documented, and then allow up to 15 minutes (at an hourly cost of $130/hr) for the balance of 75% of the ~34,000 plans expected to be utilised in QLD in FY2024. Of course, some of the plans may be virtual or complete duplicates of others, so this may overstate actual costs. In present value terms, these one-off costs would have a present value of around $835,000.

Using the same approach as for accreditation, if the effect of improved documentation were that some houses had their as-built performance improved by 1 star, then ~910 houses per year would be sufficient to offset these costs. If the improvement were only 0.5 stars on average, some 1,900 houses would need to be improved per year to offset this cost.

Roof Strengthening

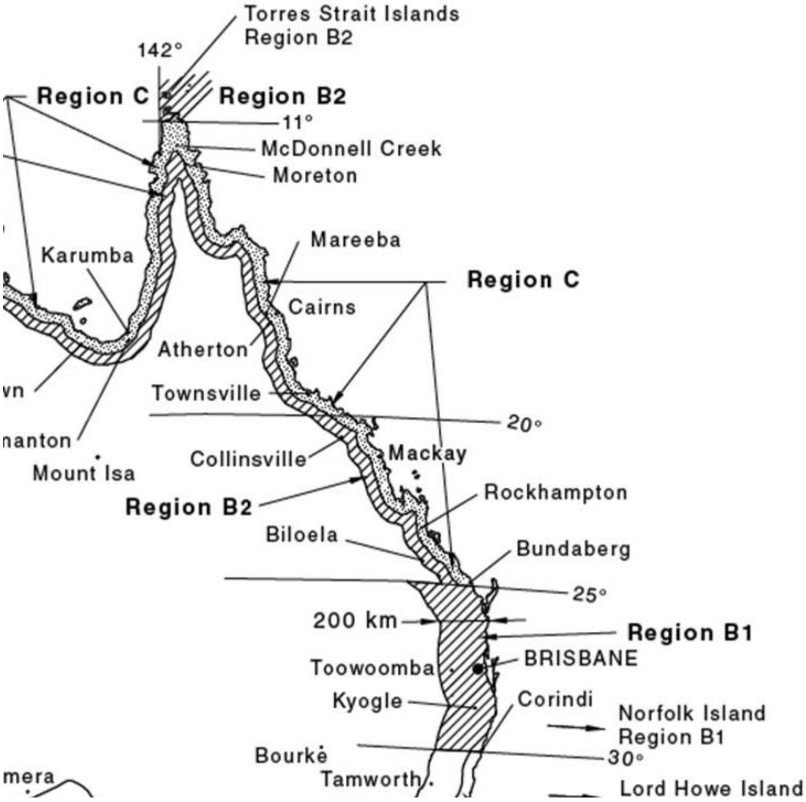
The first resilience case tested is strengthening roofs (eg, tying battens and rafters down to slabs) at a time when the roof is being replaced in any case, with potential application in wind zones B1, B2 and C (see Figure 1), but only to houses completed prior to 1982 (as improved strength requirements have applied since that date, at least in wind zone C).

We note that this analysis was adversely affected by the availability of data, for example on the number of houses deroofed annually in QLD, whether due to storm damage or at the end of economic life (EOEL) of the existing roof, and on the distribution of these events by wind/climate zone. Given the risk of increasing storm-related damage to QLD housing in future due to climate change, it would be valuable for future policy development if a reporting regime could be established, potentially triggered by relevant insurance claims, so that future governments could better understand and respond to the underlying risks.

We estimate the total stock of pre-1982 houses in QLD in FY2024 will be around 268,000 – noting that the most recent of these will already be at least 42 years old by then. Due to their age, it is likely that EOEL replacements will become relatively common – we estimate around 1,300 per year but falling due to the falling stock of these older houses over time (due to demolitions, fires, conversions, etc).

The average annual rate of roof replacement due to storm damage in QLD may be known to the insurance industry, but as noted above, this information is not in the public domain. Reports from the Cyclone Testing Station provide data that relates to individual cyclone events, but these do not provide an overall and annual picture. Further, the distribution of these reroofing events by wind region is not known, but it is likely that most occur in the highest wind zone (in QLD) – Wind Zone C. For this exercise, and based on informal advice only, we assume that the total number of houses deroofed due to storm/cyclone damage in QLD is around the same of the number reroofed due to EOEL replacement. This estimate may be able to be improved by further research undertaken by more specialised bodies.

Figure 1: Wind Regions Map, QLD[7]



Also based on informal advice and the knowledge of the review team, it likely that most (pre-1982) houses in Wind Region C that are deroofed (whether due to storm/cyclone damage or EOEL) are mostly strengthened as a matter of course. This is because the risk of deroofing is much higher in this Wind Region, and because there has been increasing attention paid to this risk, including wide circulation of advisory materials that have helped to inform the building industry as to appropriate strengthening practices. This means the measure would not be expected to have any incremental impacts (costs or benefits) in Wind Region C. Wind Region A (the lowest wind strength region) was excluded from the strengthening measure, so the incremental impact of this measure would be felt

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[7] Note: Wind regions B1 and B2 are depicted from AS 168:2021 and AS 4055:2021.

only in Wind Regions B2 (coastal hinterland) and B1 (SE QLD). We estimate a total of around 1,000 pre-1982 houses, mostly in Wind Region B1 (SE QLD) would be affected per year.

Based on the Cyclone Testing Station's analysis, we estimate that the total cost of strengthening these roofs would be around $87.8 million in present value terms, assuming the measure applied from FY2024 to FY2033, based on an average cost per house of a little over $10,000. Given the BCRs noted by the Cyclone Testing Station (in the range of 0.3 – 0.4), the total present value of benefits would be less than $25 million. The benefits considered include avoided:

- damage costs to houses
- water ingress costs (eg, damage to home contents)
- temporary accommodation costs.

Not included as potential benefits are avoided:

- health system and loss of life costs
- damage to ancillary items, such as roof ventilators, gutters and TV aerials, impacts from fallen trees
- damage to the dwelling structures due to severely degraded elements due to lack of maintenance.

Overall, this measure is not expected to be cost-effective on its own, given the data and parameters available to the study team. However, whether or not this measure may be *worthwhile* is a separate question. It is possible, for example, that climate change will lead to more frequent and more severe storms and cyclone occurring further south, including potentially in SE QLD. If even one such event were to occur, the potential impacts, including loss of life, could be very significant, given the high density of housing in this region. Also, we note that research by the Cyclone Testing Station suggests that there may be significant benefits associated with strengthening doors and/or windows, in addition to roofs. If the risk of deroofing could be significantly reduced by strengthening doors and windows, for example, this could prove a more cost-effective solution than strengthening roofs. Indeed, there could also be a case for strengthening both roofs and doors/windows, but these questions would need to be examined by more specialised parties.

Also, as set out below, the second resilience measure (insulation) is expected to be highly cost-effective, and if both measures were implemented as a joint package, then the package would be cost-effective, with an NPV of over $25 million, albeit with a modest BCR of 1.1.

Table 5: Roof Strengthening and Insulation – Joint BCA Indicators

Parameter	Values
PV of benefits:	$233,549,793
PV of costs:	$208,402,313
NPV:	$25,147,480

Parameter	Values
BCR:	1.1

Roof Insulation

This measure would require that when replacing a roof on an existing house (class 1 building) and unit building (class 2), that has a building approval before 1 September 2003, the replacement roof must include a total level of insulation installed consistent with the relevant acceptable solutions under NCC 2019.

To analyse this measure, we remodelled the housing archetypes used in other parts of the analysis, essentially stripped out the energy efficiency measures that have been introduced since 1 September 2003, and then compared their energy performance in this condition with that after NCC2019 elemental (DTS) pathway levels of insulation were installed (as this proposed measure specifically references NCC2019 DTS). Note that there is no elemental (DTS) solution for Class 2s in NCC2019, so we assumed that the same insulation requirements as for Class 1 would apply. We then modelled the stock of pre-September 2003 housing stock, which we estimate to be around 780,000 buildings in FY2024, reducing to around 650,000 in FY2033. We assume lower rates of both EOEL and storm-related reroofing for this younger cohort of housing, compared to the pre-1982 housing above. On this basis, we estimate that around 3,900 roof replacements would occur in the pre-2003 stock in FY2024, falling to around 3,250 in FY2033. The reduction is due to the declining stock over time. We assume that only a small proportion of these (around 5%) are likely to already be insulated to NCC2019 standards.

Overall, we found that installing insulation to NCC2019 standards in these cases is cost-effective and this holds true for all climate zones and for all residential building types. This is broadly explained by the significant energy savings that occur when uninsulated houses are insulated, even in the absence of any other complementary improvements (such as glazing upgrades or others). Total benefits are estimated at $208 million in present value terms, while incremental costs are estimated at $120 million (present value over 10 years). This means that the net present value (or net benefit) of the measure would be around $88 million, with a BCR of 1.7. In addition, we estimate that total savings of greenhouse gas emissions would amount to a cumulative total over the FY2024 – FY2050 of some 352,000 t CO_2-e. Further, avoided peak demand would reach almost 17 MW by FY2033, with the present value of this benefit over time being significant at just under $109 million.

Conclusions

We conclude that the adoption of NCC2019 in QLD would be highly cost-effective and also generate significant societal benefits, including avoided greenhouse gas emissions and peak electrical demand (and associated infrastructure costs). Further, we note that the net benefits could be even larger if the advantages of (voluntarily) adopting the NatHERS compliance verification pathway were widely communicated.

While we cannot quantify the value of benefits associated with improved Code compliance, due to accreditation of energy assessors and improved documentation of energy efficiency features on building plans, we expect these benefits to be significant. These steps would also be supportive of national policy directions agreed by Building Ministers. The incremental costs associated with these measures would be small – around $2.2 million for both measures, cf a net benefit for the overall package of $620 million – and readily offset by improvements in compliance. The measure would also improve accountability and enable home-owners to have greater confidence that they are getting what they pay for.

The resilience measures – roof strengthening and insulation, in the relevant building cohorts, are expected to be cost-effective if implemented together. However, while the insulation measure is highly cost-effective, the roof strengthening measure is not expected to be cost-effective in its own right. However, the value of the measure may depend upon perceptions of the risk associated with the possibility of future cyclones impacting in the SE QLD region, which is densely populated, and there would other societal benefits including reduced call on public resources during storms, and faster social recovery rates.

1. Introduction

The QLD Department of Energy and Public Works (DEPW) released a request for quote in November 2021 seeking suitably qualified consultants to undertake a range of analyses under the overall heading, "Cost Benefit Analysis of aligning Queensland's energy efficiency requirements for residential dwellings with national standards and other associated measures". The project involves three major parts:

- Part A – Alignment of Queensland's current energy efficiency provisions for new residential buildings (houses and units) with the minimum mandatory provisions required by the National Construction Code (NCC 2019).
- Part B – Improved building compliance by requiring the accreditation of house energy assessors and that energy efficiency features are documented on residential dwelling plans.
- Part C – Mandating a minimum standard that significant roof replacement or repair works must comply with additional work to improve resilience through structural and thermal performance measures.

The study makes no presumption that any of these measures will proceed; rather, it seeks to describe in a quantitative manner what differences would be expected if they were to proceed.

1.1 Context

1.1.1 Part A

Although the National Construction Code (NCC) is a national code, provisions are given effect through state and territory legislation, and jurisdictions may, and often do, make variations the Code. In Queensland, these changes or adjustments can be found in the Queensland Development Code (QDC), which consolidates specific building standards under one document. These matters can be outside the NCC or may be in addition to the NCC requirements. If there is an inconsistency between the NCC and the QDC, the QDC will prevail in Queensland.

The QDC is a dynamic document which undergoes updates and amendments from time to time. The appropriate section to this research and report is MP4.1 Sustainable Buildings. The most recent iteration of MP 4.1 was effective as of 1 March 2021. The two areas of particular relevance to this report are QDC 4.1 (V1.13), P1 & P2. These areas address the thermal performance of Class 1, enclosed 10a, Class 2 SOU's. (Attachment 1). The existing clauses provide alternate pathways to compliance through software (NatHERS) and the elemental (DTS) pathway, with either BCA 2009 or 2010 as the reference.

Ahead of the potential adoption of NCC 2022, which would raise the minimum compliance for energy efficiency in Class 1, enclosed 10A and Class 2 buildings to 7-star NatHERS performance, the Queensland Department of Energy and Public Works (DEPW) engaged Strategy Policy Research (SPR) to undertake a cost benefit analysis of updating the PM4.1 where NCC 2019 (under which 6-

star is the minimum requirement). This analysis is therefore separate from any consideration of NCC 2022 and 7 star. To undertake the necessary investigations that underpin the cost benefit analysis, SPR engaged RED Sustainability Pty, Ecolateral Pty, Ltd and Steele Wrobel (quantity surveyors), all of whom have a long history of carrying out compliance using both software modelling and elemental (DTS) reporting, as well as having a strong understanding of the Queensland climate and modelling with the QDC.

1.1.2 Part B

In 2006, soon after the introduction of energy efficiency measures for new Class 1, 10A & 2 into the NCC/BCA in 2003, the industry saw the formation of a regulatory body aptly named the Australian Building Sustainability Association (ABSA). The primary delivery of this NFP organisation is to maintain a high standard of modelling quality and accuracy, ensuring that the rating awarded was a true reflection of the performance of the building at design stage. Since then, two more accreditation Assessor Accredited Organisation (AAO's) have entered the market, Design Matters National and most recently HERA.

The Commonwealth Science and Industrial Research Organisation (CSIRO), who developed the overriding NatHERS software, has seen the software been upgraded and amended over the intervening years to the key tools available today, AccuRate, Bers Pro, FirstRate5 and Hero.

In concert with the development of these AAO's, CSIRO has recognised the benefits that come with an organised and audited approach and distinguishes those reports prepared by members of the AAO's from those prepared by non-members. Although both certificates are recognised, CSIRO does distinguish between the two by awarding a differently formatted Universal Certificate subject to the assessor's certification status. Some lending institutions are now requesting AAO accredited assessors reports in preference to non-accredited assessors.

CSIRO reports in their website that, of the twenty-two thousand and seventy-seven certificates issued in Queensland between June 2021 and July 2022, 36% were issued to non-certified assessors.[8]

SPR was requested, as part of this engagement, to undertake a CBA to ascertain the impact of recognising the need for all future NatHERS certifications in Queensland to be completed by suitability qualified assessors under the auspices of an AAO. Over time the portion of certified certifications issued will near 100%. It is important to note that this certification only applies to modelling software resulting in the issue of a CSIRO generated certificate. Those projects that choose to use the elemental (DTS) pathway are not captured under this protocol and will remain outside of the AAO sphere of influence and reporting.

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[8] https://ahd.csiro.au/dashboards/energy-rating/assessors/

1.1.3 Part C

Although Queensland has distinct climate zones, which bring with them a wide variety of microclimate events, storms can occur in any part of the State and rapidly move across wide areas of land, with the potential for serious impacts. Part C of this report undertakes a cost benefit analysis of "Mandating a minimum standard that significant roof replacement or repair works must comply with additional work to improve resilience through structural and thermal performance measures."

Finding reliable data on storm damage to housing has proved difficult. The insurance industry, which plays a major role on the funding of repairs, do not provide any data that would help to quantify the occurrence and extent of the damage on an annualized basis.

In 2020 the Queensland Department of Energy and Public Works commissioned the College of Science and Engineering at James Cook University Cyclone Testing Station to undertake a study that would help understand the benefits of retrofitting common Queensland house types for wind hazards in wind zones A, B1, B2,& C, This research culminated in Report TS1219 on the 15th October 2021 titled *Quantifying Benefits of Roof Upgrades for Selected Australian House Types*.[9] This and other work by the Cyclonic Testing Station has been used in this report, as they represent the most detailed analyses of this question that are available for QLD. There are certain limitations, however, associated with this work, as discussed further in Chapter 5.

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[9] BNHCRC project included a *Vulnerability and Adaption to Wind Simulation* (VAWS) (https://github.com/GeoscienceAustralia/vaws) and an internet – based interactive site with the intention of enabling end user and stakeholders or how to assess and repair. (www.weatherthestorm.com.au).

2. Methodology and Key Assumptions

2.1 Introduction

The aim of the project was to ascertain the costs and benefits of a potential change from the current QDC 4.1 requirements to the NCC 2019 requirements for residential energy performance. In order for the research to reflect the process industry would need to undertake in moving to NCC 2019, an extensive modelling process underpinned the analysis. The methodology developed to address the question was to take a representative sample of housing typologies currently being built in Queensland and assess them under both the NatHERS pathway and elemental pathway, as defined in QDC 4.1 and the NCC 2019.

A wide range of designs, orientations and site layouts, climate zones and typical construction practices across the state were applied to both the NatHERS and Elemental Pathways. The thermal parameters were varied to achieve the relevant QDC minimum compliance, and each model was subsequently upgraded to an NCC 2019 minimum standard. The cost difference between the two informed the Cost Benefit Analysis. Our detailed methodologies for each step of the analysis are set out below.

To make the analysis as realistic as possible, practical strategies based on current market practices were used to when upgrading to the NCC standard. A key assumption is that least-cost solutions are applied to meet regulatory requirements. In practice, it may be that home-owners or builders choose other solutions, for aesthetic or other reasons, that are not least-cost. However, these would represent voluntary choices, and the associated costs are therefore not attributable to regulations, but rather to the choices made.

The following underlying principles were agreed when conducting the research:

1. The same plans used by CSIRO to develop and upgrade their NatHERS models would be used for modelling in this project. Where suitable plans were not available such as, townhouses or the ‘Queenslander’ archetype, representative plan types were sourced, that were from current practice at the time of the research.
2. The dwelling design would not be altered when upgrades occurred. Window sizes and locations, walls, glazing and all other design elements were retained as per the sourced plans, without changing the appearance of the dwelling. We note that this removes what is generally the lowest-cost option, which are minor design changes such as to window locations or sizes. In practice, therefore, lower cost options may be available than modelled here.
3. The combined experience of the team would be used when choosing the most likely and cost-effective materials to upgrade plans to higher star ratings.
4. Relevant existing research and findings were used where available in the public domain.

2.1.1 QDC 4.1

Class 1 Dwellings

There are 6 options for demonstrating compliance with the QDC 4.1 energy efficiency provisions for a Class 1 dwelling. In QDC 4.1 they are Acceptable Solutions (2) through (7) addressing Performance Requirement P1.

Acceptable solutions (3) and (4) both represent solutions that are directly equivalent to NCC 2019. These potential compliance routes are therefore not considered in this analysis. If a proponent were to choose either of these options, there would be no variation to the cost or benefit of the design solution, compared to an assessment under NCC 2019.

The other Acceptable Solutions to P1 are:

> *(2) the building complies with the elemental method using NCC 2010, (with the exception that buildings in climate zones 1 and 2 may disregard the floor insulation requirements of 3.12.1.5*
>
> *(5) for buildings in CZ 1, 2 or 5, achieving a NatHERS Rating of at least 4.5 stars plus obtaining up to 1.5 stars worth nominal credits for inclusion of some or all of:*
>
> - *An outdoor living area with an insulated roof (R1.5)*
> - *A ceiling fan to the outdoor living area (min 900mm dia)*
> - *An on site PV system (min 1 kW)*
>
> *(6) for buildings in CZ3, achieving a NatHERS Rating of at least 5.0 stars plus obtaining nominal credits as above for (5)*
>
> *(7) The building complies with this subsection if:*
>
> > *(a) the building complies with parts 3.12.1, 3.12.2, 3.12.3 and 3.12.4 of the BCA 2009 (Volume 2); and*
> > *(b) a nominal credit of up to 1 star is obtained under subsection (8)*

It is these four options (2), (5), (6) and (7) that are used to generate the base conditions under the current QDC 4.1 requirements, for analysis of the transition from QDC4.1 to NCC 2019, for Class 1 dwellings.

When using options (5) or (6) for compliance, in some NatHERS climate zones, the QDC also requires the dwelling to meet certain heating and cooling load limits, in addition to the minimum Star Rating. These heating and cooling load limits also apply in the NCC 2019 provisions. In order to reduce the complexity of the assessment process for the Benefit Cost Analysis, these heating and cooling load limits were not investigated.

Class 2 Buildings

For Class 2 buildings, the performance requirement under QDC 4.1 is to comply with JP1 of the BCA 2009 (Vol.1). Essentially this means achieving a minimum 4 star NatHERS rating for each individual unit, and the average rating of all units in a building must achieve at least 5 stars.

When calculating the average rating of all units in climate zones 1 and 2, the QDC provides allowance for the proponent to apply credits to the rating of each sole-occupancy unit.

- 0.5 stars - An outdoor living area with an insulated roof (R1.5)
- 1.0 stars – the above + a ceiling fan to the outdoor living area (min 900mm dia)
- To achieve the full 1.0 star credit, an air-conditioner that services any room directly adjacent to the outdoor living area must automatically shut down when an external door that provides access to the outdoor living area is open for more than 1 minute.

It must be noted that these credits can only be used in order to get the average rating of the units in a Class 2 building to the minimum 5 stars. Individual units are still required to achieve 4 stars without the application of these credits.

For the purposes of this research, it was assumed that proponents would make use of the QDC optional credits as a least cost option for gaining a star to put towards the average star rating of units in a building.

In some NatHERS climate zones QDC also requires Class 2 units to meet certain heating and cooling load limits for individual units, in addition to the minimum 4-star NatHERS rating. These heating and cooling load limits also apply in the NCC 2019 provisions. In order to reduce the complexity of the assessment process for the Benefit Cost Analysis, these heating and cooling load limits were not investigated.

2.1.2 NCC 2019

To assess the Benefits and Cost of Queensland moving to align with the energy efficiency provisions of NCC 2019, analysis first needed to be undertaken to establish what changes to design strategies and design specifications may be employed to achieve the improvement from QDC 4.1 requirements to the NCC 2019 requirements. Incremental costs can then be attributed to those selected strategies, and the value of benefits of improved energy efficiency can be assessed and compared against the costs.

Class 1 Dwellings

When demonstrating compliance with the NCC Vol. 2, 2019 for a Class 1 dwelling there are two principal routes for demonstrating compliance:

1. The NatHERS pathway – as per Section 3.12.0.1 Heating and cooling loads, which spells out the NCC requirements for compliance with the energy efficiency provisions using NatHERS software. Namely:
    - 6 Star requirement generally; or
    - In climate zone 1 and 2, 5.5 stars where there is a compliant outdoor living area; or
    - In climate zone 1 and 2, 5 stars where there is a compliant outdoor living area and a permanently installed ceiling fan.

For the purpose this analysis, the concessions in climate zone 1 and 2 were disregarded as the difference between the current QDC requirement in these climate zones of 4.5 stars and the NCC 2019 5 star requirement was considered too minimal to warrant investigation.

2. The Elemental Method pathway - complying with all elemental (DTS) provisions of:
    - Part 3.12.1 – building fabric
    - Part 3.12.2 – external glazing and shading
    - Part 3.12.3 – building sealing
    - Part 3.12.4 - air movement

Each of these two compliance pathways needed to be analysed separately as there are potentially different strategies that may be employed in undertaking the different compliance routes.

There are also Performance Solutions and the use of Reference Building that are options for compliance with the NCC. Due to the potentially endless variability of potential solutions via these methods, the implications of demonstrating compliance via these methods, have not been considered as part of this research. Past experience also indicates that these compliance routes represent a very small proportion of projects.

Class 2 Dwellings

When demonstrating compliance with the NCC Vol.1, 2019 for Class 2 dwellings, only the NatHERS assessment pathway applies, and the following must be achieved:

- 5 stars minimum for each individual Class 2 dwelling in a building
- 6 stars average across all dwellings in building

Consequently, for Class 2 dwellings, only the NatHERS assessment pathway is analysed. Dwelling designs complying with these NCC 2019 energy efficiency requirements represent the ‘end point’ of the Benefit Cost Analysis. The starting point is represented by house designs that comply with the QDC 4.1 Sustainable Buildings.

2.1.3 Climate Zones

Four out of the eight NCC Climate Zones are represented in Queensland. These Climate Zones are 1, 2, 3 and 5. Figure 2 shows the geographical distribution of NCC climate zones in Queensland.

The QDC 4.1 and the NCC 2019 energy efficiency provisions set out different requirements for building fabric for each of the four Queensland climate zones, so it is important that all dwelling types are assessed in all climate zones, to ensure that the variations building fabric requirements that may be occurring due to climate, are picked up in the analysis.

Through analysis of data from the CSIRO AHD portal[10] on the number of new-build houses, the following four locations were selected as having the largest number of new houses approved over the previous 12 months and are used as the representative locations for the analysis:

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[10] CSIRO AHD Portal

- Climate zone 1 – Tropical e.g. Cairns
- Climate zone 2 – Subtropical e.g. Brisbane
- Climate zone 3 – Hot arid e.g. Charleville
- Climate zone 5 – Warm temperate e.g. Toowoomba

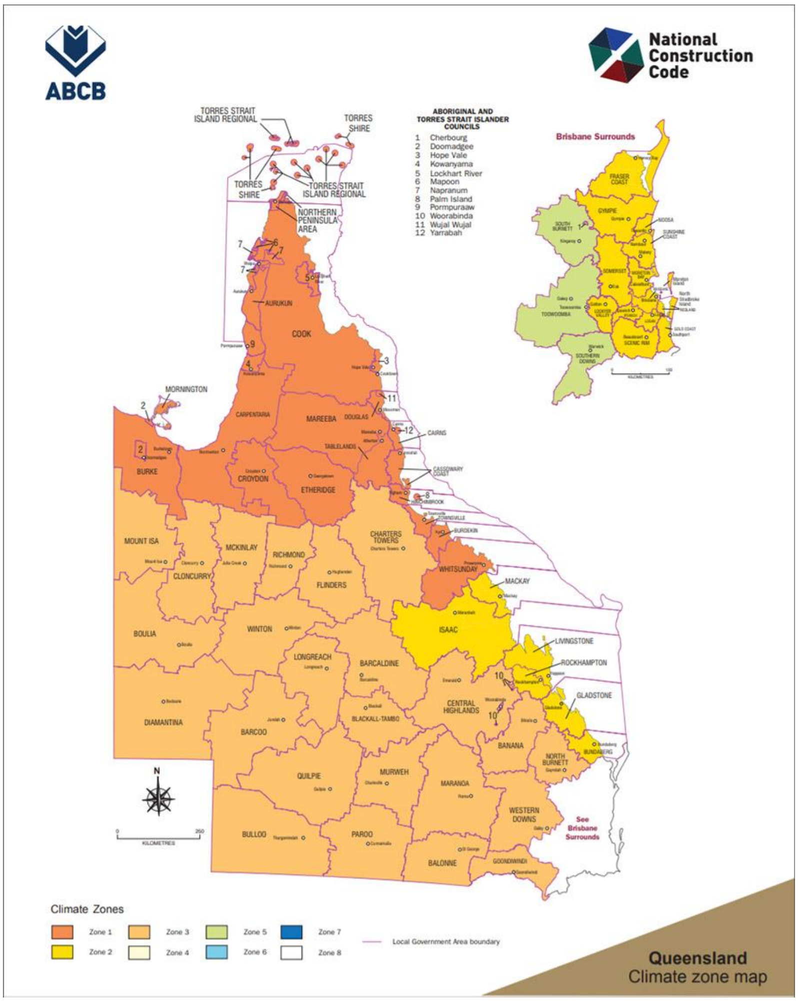

Figure 2: Queensland Climate Zone Map (source: Australian Building Codes Board)

2.1.4 Representative Dwelling Types

In order to provide a comprehensive analysis of Queensland dwellings, 6 x dwelling types were selected to provide a representative sample of new dwellings built across Queensland.

Table 6: Dwelling Archetypes

Dwelling ID	Description
SBA610	2 Bedroom internal apartment
SBA630	2 Bedroom corner apartment
SBH02	4 Bedroom single storey detached house
SBH03	3 Bedroom double storey detached house
THmid	3 Bedroom double storey attached middle townhouse
THend	3 Bedroom double storey attached end townhouse

The dwelling designs were selected on the following basis:

- **Comparability** - SBA610/SBA 630/SBH02/SBH03 all come from the standard NatHERS designs, used for similar analysis across the country, so they are generally accepted designs and the Queensland specific analysis done on them for this project can be compared to other NatHERS Analysis work across the country.
- **Layouts** – the designs were selected as examples of fairly typical designs that have been constructed in Queensland over the past few years.
- **Sizes** – the designs cover a range of sizes form small 2-bedroom apartments through to relatively large 3 and 4 bedroom detached homes.
- **Typologies** – the designs cover detached and attached class 1 dwellings as well as class 2 apartments. As there were no attached Class 1 types previously used for NatHERS testing, a typical attached townhouse design was selected from current practice.
- **Outdoor Living Area** – to qualify for credits under the QDC 4.1, a dwelling must have a covered outdoor living area meeting the criteria specified. Hence this is an important feature of each dwelling design selected.

SBA610 + SBA 630

To cover the Class 2 typology, an apartment building from the standard NatHERS designs was used. The apartment has two basic unit designs – SBA610 and SBA630. SBA610 is an ‘internal unit’ with neighbours on two sides, a common area on one side, and one exposed façade. SBA 630 is a corner unit with two neighbours and two exposed facades.

The building floor plate arrangement has 8 x apartments, 4 of each apartment type. The building notionally has three levels of apartments above a carpark level as seen in Figure 3. This arrangement allows both unit types to be assessed in all four orientations, and in three key locations within the building:

- Lower level – with carpark below and a neighbouring unit above
- Mid level – with neighbouring unit above and below
- Upper level – with a neighbour below and roof above.

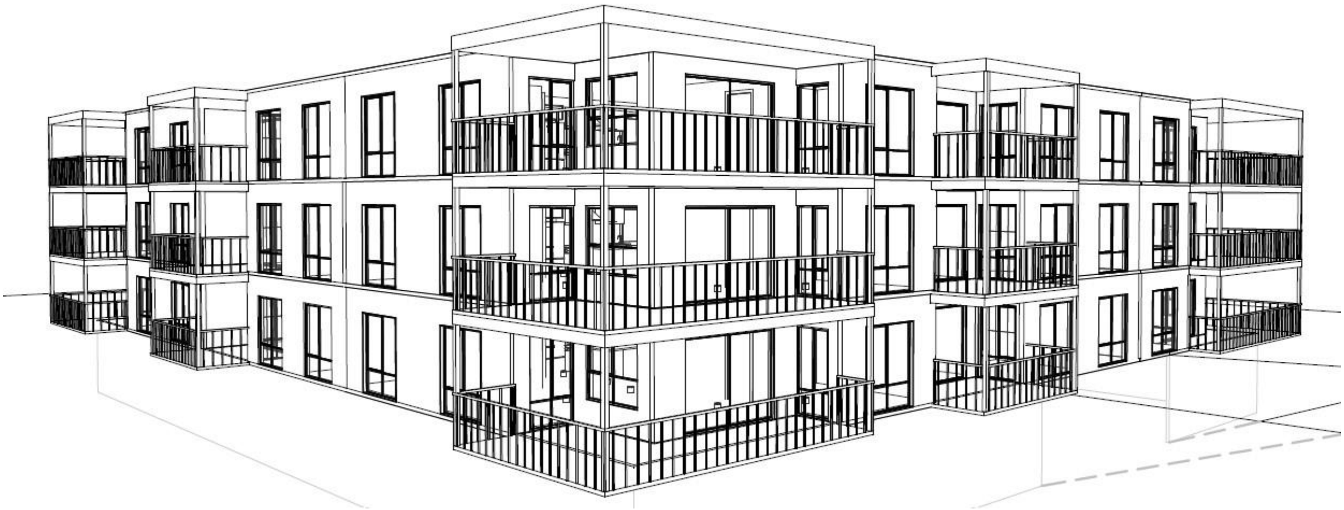

Figure 3: NatHERS standard apartment building - general view

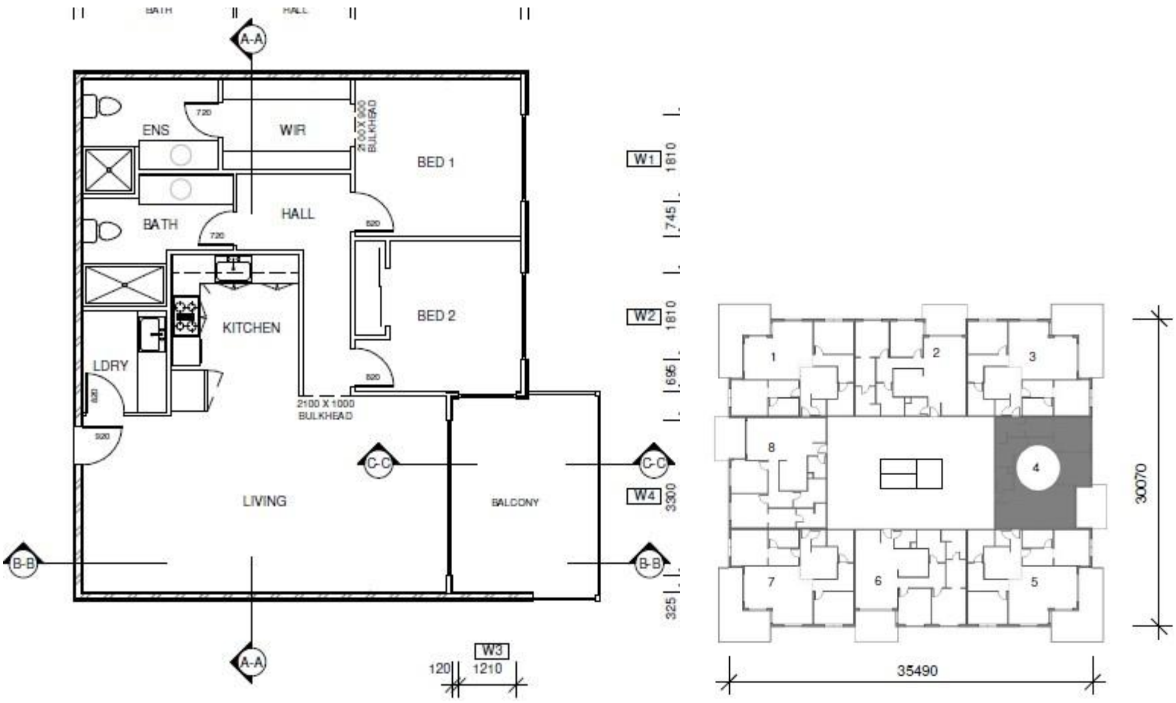

Figure 4: Apartment SBA610 - Floor Plan (Left) and location plan within the overall apartment building (right)

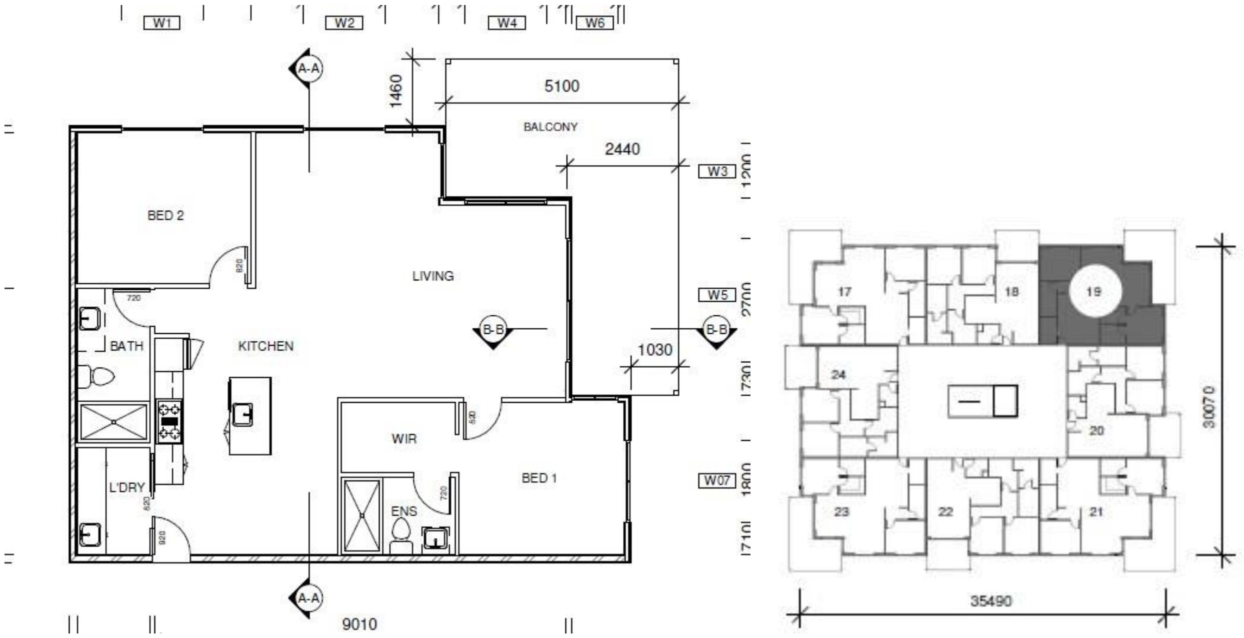

Figure 5: Apartment SBA630 - Floor Plan (Left) and location plan within the overall apartment building (right)

SBH02 (and 'Queenslander')

SBH02 is a large single level, 4-bedroom dwelling, from the NatHERS Standard range of dwellings. It is a design taken from project home builders, with a typical street frontage as seen below. The glazing is reasonably evenly distributed around the four facades.

This plan is also used for the 'Queenslander' dwelling version, with adjustments made to the construction as described in section 2.1.5.

Figure 6: SBH02 - Street front view

Figure 7: SBH02 - Floor Plan

SBH03

This is a 2-storey, 3-bedroom house, from the NatHERS standard range of dwellings, that has been used for similar thermal performance analysis across the country. The design is typical of a medium to large 2-storey dwelling seen throughout the various climate zones of Queensland. The distribution of glazing is reasonably even around the four facades, with outdoor living areas on two sides.

Figure 8: SBH03 - General View

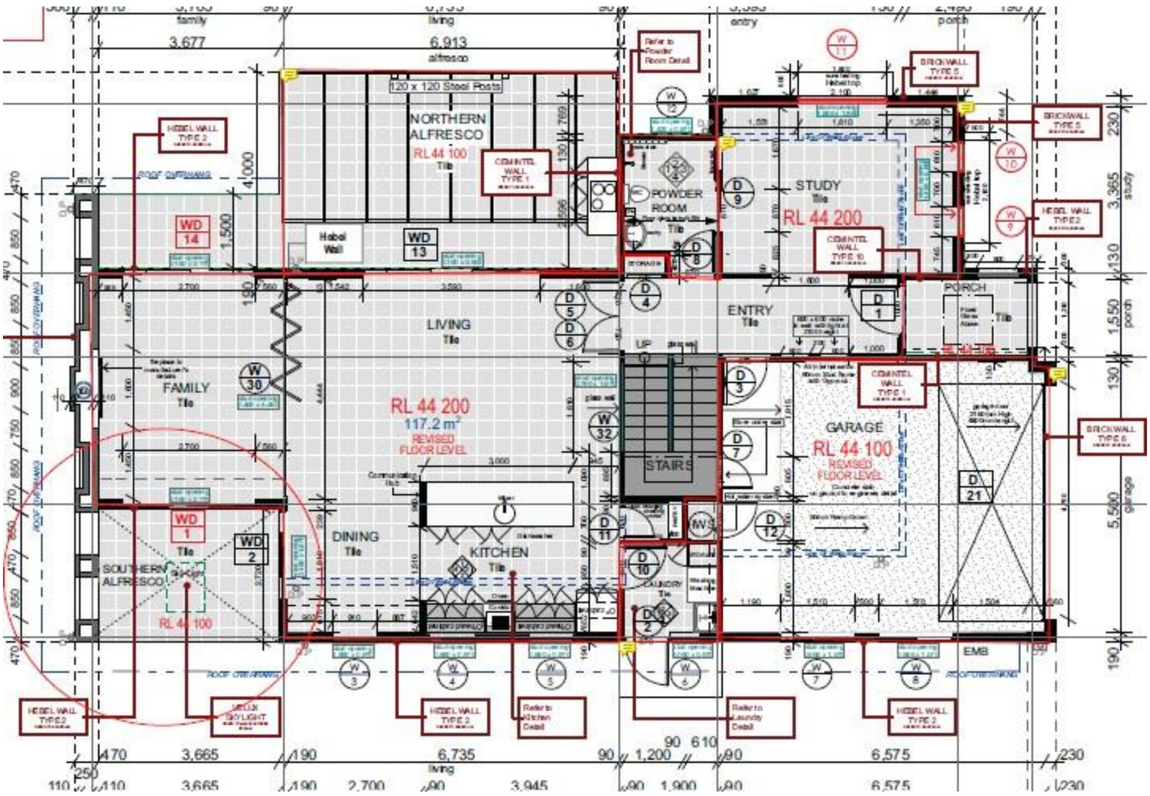

Figure 9: SBH03 - Ground Floor Plan

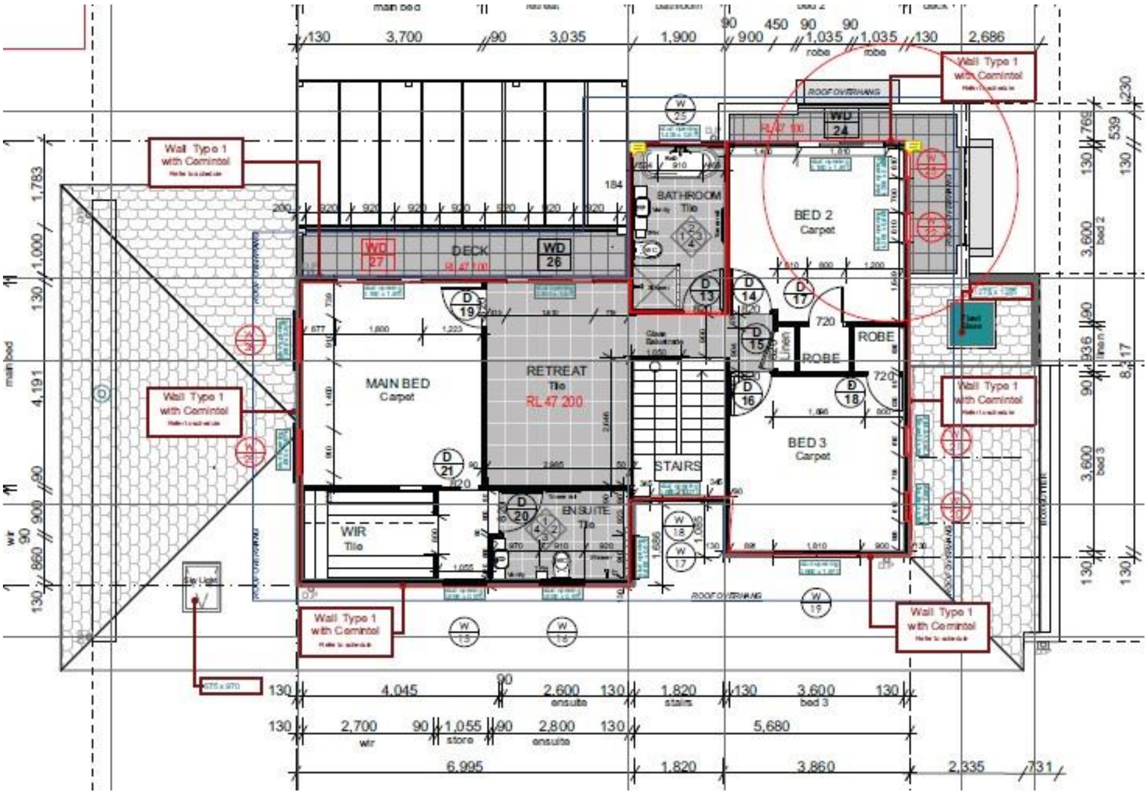

Figure 10: SBH03 - First Floor Plan

THMid and THEnd

As there were no attached townhouse designs in the standard NatHERS set of dwellings, the townhouse designs were selected from existing practice and based on the experience of the assessment team, as designs that are typical of current practices in Queensland. The dwellings are part of a terrace style development with ‘middle’ units that have neighbouring dwellings to 2 sides, and 2 exposed facades, and end units that have one neighbour and 3 exposed facades.

The end unit plan was chosen as the base design. It is a compact 4-bedroom design. To simulate the middle unit, the windows on the end wall were removed and the wall changed to a parti wall with a neighbour on the other side.

The figure below shows the front and back views of the units. For the townhouse designs the glazing is inherently not evenly distributed, with neighbouring walls that have no glazing and with a larger proportion of glazing on one façade, as seen in the lower image in Figure 11.

Figure 11: Townhouses Mid and End - General views of front and rear.

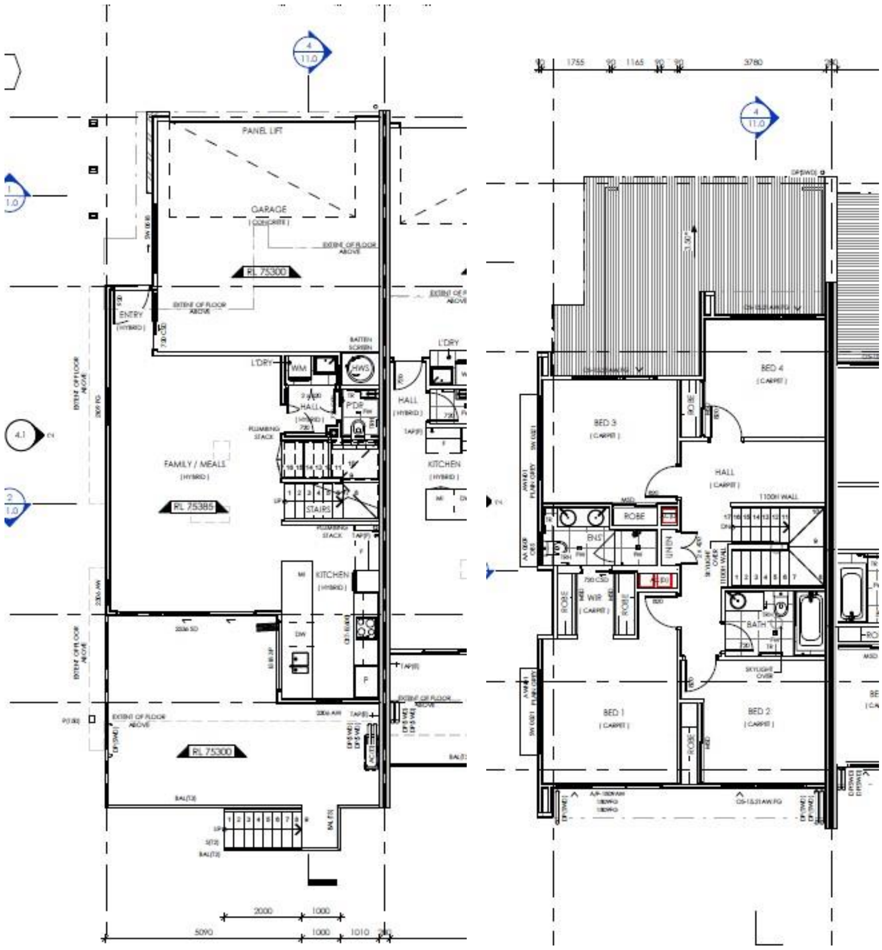

Figure 12: Townhouse (Mid and End) Ground Floor (left) and First Floor (right)

2.1.5 Detailed Analysis by Construction Method

To establish a comprehensive range of dwellings archetypes, the CSIRO's Australian Housing Data (AHD) portal, was used as a reference to determine the most common construction types across the various climate zones of Queensland. This analysis led to the modelling of multiple variations of each of the above dwelling types, based on common construction types. This helped to provide as comprehensive as possible a set of examples upon which to base the Benefit Cost Analysis, and most accurately represent Queensland residential construction.

- **Heavyweight Concrete Block Walls**. In Climate Zones 1 and 3 Heavy weight concrete block walls are a common construction type, so for these climate zones, this was added as a variation to the standard light weight BV walls which were tested in all climate zones.
- **Floor Construction**. Suspended timber floors (with enclosed sub-floor) and a standard concrete slab on ground were both tested for all climate zones.
- **'Queenslander' Style house**. Given the Queenslander is an iconic style associated with the state it was seen as important to including the Queenslander style of detached house as part of the analysis. However, given land size restrictions and modern building

preferences, few new Queenslanders are built to traditional layouts characterised by wide verandas and clearly segregated rooms. While many traditional Queenslanders are being retained and renovated, the focus of this research is on new builds. As a result, a ‘modern’ Queenslander layout as a subset of the SBH02 single storey house was selected for the modelling. This is believed to be reflective of modern living preferences while still retaining a lightweight look and feel with the option of traditional styling. The SBH02 Archetype was modified to light weight timber construction with an unenclosed, suspended timber floor, and lightweight timber cladding to model the ‘Queenslander’ style.

- **Class 2 apartments**. The apartment designs were modelled in 3 locations within a building. The lowest level, with a carpark below and an apartment above; a mid-level, with apartments above and below; and upper level, with an apartment below and a roof above. Variations to the wall or floor construction types were not tested for the Class 2 apartments.

Table 7 presents all the construction type iterations tested for the Class 1 Dwelling types.

Table 7: Construction Type Elements Tested – Class 1 Dwellings

		CZ 1	CZ 2	CZ 3	CZ 5
Dwelling Floor variations Modelled		**Wall Construction Variations Modelled**			
THmid	Unenclosed Suspended Timber Floor	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
	Concrete slab on Ground	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
THend	Unenclosed Suspended Timber Floor	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
	Concrete slab on Ground	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
SBH02	Enclosed Suspended Timber Floor	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
	Unenclosed Suspended Timber Floor	Light Weight Timber Clad (Queenslander)	Light Weight Timber Clad (Queenslander)	Light Weight Timber Clad (Queenslander)	Light Weight Timber Clad (Queenslander)
	Concrete slab on Ground	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer

		CZ 1	CZ 2	CZ 3	CZ 5
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
SBH03	Enclosed Suspended Timber Floor	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----
	Concrete slab on Ground	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer	Light Weight Brick Veneer
		Heavy Weight Concrete Block	-----	Heavy Weight Concrete Block	-----

2.2 NatHERS Assessment Pathway

2.2.1 Introduction

This component of the research was developed in order to assess the compliance options (5) and (6) from the QDC 4.1, as outlined above in Section 2.1.1., and compare them against the NCC 2019 NatHERS compliance pathway as per section 3.12.0.1, as outlined above in Section 2.1.2.

The method herein sets out the processes used to establish baseline NatHERS Thermal Performance models that represent the minimum compliance standard for QDC 4.1 options (5) and (6), and then the steps undertaken to make building fabric upgrades to those models in order that they achieve the NCC 2019 level of performance.

NatHERS modelling was conducted using the current version of the BERS Pro software. From the CSIRO AHD[11] portal it was established that 88% of NatHERS assessments submitted for dwellings in Queensland, were undertaken using BERS Pro. The use of BERS Pro for this research therefore represents typical industry practice in NatHERS assessments.

2.2.2 NatHERS Climate Zones

NatHERS uses 64 different climate files across Australia. For the purposes of this analysis, 4 representative climate files were selected based on the 4 locations as noted in Section 2.1.3. Table 8 presents the relationship between NCC Climate Zone, the representative locations used for the Benefit Cost Analysis, the NatHERS Climate Zones and the respective maximum energy loads to achieve a QDC minimum 4.5/5 star and 6 star NatHERS rating in each NatHERS Climate Zone. For CZ 1,2 and 5, the QDC minimum requirement is 4.5 stars. In CZ 3, the minimum requirement is 5 stars. For the NCC 2019 the minimum requirement in all CZ is 6 stars. The NatHERS Star bands are based on MJ of heating and cooling energy per m^2 per year, and the difference between the required QDC rating and the required NCC rating represents the relative improvement in energy efficiency achieved by moving to a 6-star energy rating. As can be seen, the energy savings varies across the

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[11] CSIRO AHD Portal -

climate zones, and because it is a m^2 based measure the amount of energy saved is also related to dwelling size.

Table 8: NatHERS Climate Zones and associated heating and cooling energy

NCC Climate Zone	Representative Location	NatHERS Climate Zone	4.5 star Energy (MJ/m^2/yr)	5.0 star Energy (MJ/m^2/yr)	6.0 star Energy (MJ/m^2/yr)	Difference (MJ/m^2/yr)
1	Cairns	32	167.0	n/a	128.0	39.0
2	Brisbane	10	62.0	n/a	43.0	19.0
3	Charleville	19	n/a	114.0	87.0	27.0
5	Toowoomba	50	110.0	n/a	78	32.0

2.2.3 Building Fabric Elements

NatHERS software models the entire building fabric of the house, so potentially, changes to any individual building element could improve or reduce the thermal performance and therefore impact the NatHERS star rating.

For the purposes of the research, it was defined that, in attempting to establish the QDC base models or the NCC 6-star models, there should be no changes to the design of the dwellings. Changes would only be made to the specification of materials and other minor elements not affecting the design. Therefore, the following aspects of the dwelling design were never changed from the base designs:

- Plan form/layout/size of the dwelling
- Section/elevations
- Window size or location
- External cladding materials (except as per testing out different wall construction types as per section 2.1.5)
- Floor structure (except as per testing out of different floor construction types as noted in section 2.1.5)
- Roof structure or material
- Eave size or location.

This leaves the following building elements that could be adjusted in the NatHERS modelling in order to establish the base QDC model or the NCC 6 star model:

- Insulation specification (external walls, internal walls, floors, ceilings/roof)
- Glazing specification
- Window operability
- Ceiling fans (of varied diameters)
- Sealing or unsealing of exhaust fans
- Internal floor finishes

- External wall colours
- Roof colour
- Roof space ventilation
- External window shading / sunhoods
- Underfloor enclosure (Queenslander or Townhouse scenario only – all other scenarios have enclosed floors or are slab on ground).

2.2.4 Building Elements for QDC credits

In order to achieve compliance under the QDC 4.1, for Class 1 dwellings, as well as achieving the minimum performance of 4.5 or 5 stars (depending on climate zone) there is the requirement to gain 'credit' of 1.0 or 1.5 stars as outlined above in section 2.1.1. For Class 2 dwellings, up to 1.0 star of credits can be claimed as part of achieving the minimum required 5 star average rating for all units in the building.

There is a cost associated with achieving these QDC credits that would potentially not otherwise be incurred to the project. As part of the Benefit Cost Analysis the costs of these elements are discounted from the NCC 2019 compliant scenarios.

Supply and install of the following building elements were accounted for:

- An outdoor ceiling fan
- R1.5 ceiling insulation to the extent of the outdoor living area
- 1kW PV system (Class 1 dwelling only)
- Reed switch for shutting off air-conditioning (applies to a Class 2 dwelling only)

For Class 1 dwellings in Climate zones 1,2 and 5 in which 1.5 stars worth of credit is required, the combination of the 1kW PV system and the insulation to the ceiling of the outdoor living area were the least cost combination to achieve 1.5 star credits.

For Class 1 dwellings in Climate zone 3, in which only 1.0 star worth of credit is required, the credit is assumed to be gained by the least cost elements which are the outdoor ceiling fan and the R1.5 added ceiling insulation.

For Class 2 dwellings, the 1.0 star credit may be obtained by installing the outdoor ceiling fan and insulating the ceiling of the outdoor living area, and there is the additional requirement of installing a reed switch which automatically shuts off air-conditioning to the unit, if the door to outdoor living area is left open for longer than 1 minute.

On-site PV System

It is recognised by the research team that the QDC requirement of a minimum 1kW PV system is unrealistic in the current market, in which the average installation size of a new PV system in Queensland according to a survey conducted by Canstar Blue is 5kW[12]. A 1kW system is not a cost-effective option in terms of kW output, however it still represents the cheapest option. For the

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[12] https://www.canstarblue.com.au/solar/average-solar-system-size-and-cost/

purposes of the analysis the requirement for a 1kW system as stated in the QDC has been taken literally as the 'minimum' requirement for costing purposes in those scenarios where a PV system is required to meet the QDC requirements.

Outdoor Living Area

Only the outdoor ceiling fan and insulation to the ceiling of the outdoor living area were counted as costs of claiming those QDC credits. The cost of the outdoor living area itself, its structure, roofing, and other aspects of the individual design, have not been considered as part of the cost of achieving a QDC 4.1 credit. All dwelling designs selected had a QDC 4.1 compliant outdoor living area. While theoretically the outdoor living areas could be removed, as they would not be required when a dwelling achieves a 6 star NatHERS rating, the outdoor living areas were seen as an integral part of the designs of the dwellings, that would have been included even if they were not being used to claim credit under QDC 4.1. The outdoor living areas were retained, unchanged when upgrading the dwelling scenarios for NCC 2019 compliance.

In Climate zones 1 and 2, the NCC 2019 has a special provision that permits a dwelling to achieve a 5 star NatHERS rating and claim a concessional star for a covered outdoor living area with a ceiling fan as equivalent to 6 stars. For the purposes of this study, this outdoor living area concession in NCC 2019 was disregarded and all dwelling were required to achieve a 6 star software rating. The difference cost and thermal performance, between the current QDC requirement of a 4.5 star NatHERS rating + 1.5 star worth of credits, and the NCC 2019 minimum 5 star rating with a compliant outdoor area was considered too minimal to warrant investigation.

2.2.5 Establishing QDC 4.1 equivalent base models – Class 1 dwellings

The 6 dwelling types were initially modelled as per the architectural documentation provided, in each of the 4 climate zones, in each of the 4 cardinal orientations. The initial NatHERS rating achieved for each of these scenarios was recorded. The variations of: dwelling design, climate zone, orientation, meant the initial result for each of these scenarios was unique.

The first task was to adjust all of these initial thermal performance models, in order that they achieved as close as possible to the minimum QDC 4.1 requirement. For the Class 1 dwellings this is 4.5 star in CZs 1, 2 and 5, and 5 stars in CZ 3.

For many scenarios the initial star rating of the models was above the minimum required QDC 4.1 rating. In these cases, the models were downgraded, by making adjustments to the building fabric.

In those scenarios where the initial star rating was below the minimum required QDC 4.1 rating, upgrades were undertaken to the initial models.

To ensure the baseline QDC ratings were representative of the current market response to achieving compliance, a combination of industry expertise from the project team, as well as consulting the AHD portal data, helped to direct the chosen building fabric. An iterative approach was taken attempting to utilise the least cost strategies in order to achieve the required ratings, as would be assumed to be the case in typical building practice.

The following inclusions formed the typical specifications:

- Medium roof / wall colours
- R1.5 bulk insulation + foil faced sarking to external stud frame walls
- No insulation to external block walls
- R2.5 bulk insulation to ceiling + foil faced sarking to underside of roof
- No underfloor insulation to suspended timber floors
- Floor covering as per design
- Ceiling fans as per design.

An Example of Establishing a QDC Base Model

An example is provided here, of an initial rating, and the process of reducing that rating down to the minimum required 4.5 stars QDC rating.

The scenario: SBH03, with lightweight, brick veneer walls, and a concrete slab on ground, was modelled and simulated in CZ 2 (Brisbane) with a south facing orientation. The initial rating of this scenario, as designed, was 4.8 stars.

As seen in Table 9 the following adjustments were made to reduce the performance of this scenario to 4.5 stars.

Table 9: Establishing a QDC baseline model from the initial NatHERS dwelling model

Element	As Designed Specification	Adjusted Specification for 4.5 star QDC rating
Insulation	R1.5 + foil faced sarking to External walls	Foil faced sarking removed
	R1.5 to internal walls around garage	-------
	R2.5 to ceilings + foil faced sarking to underside of roof	-------
Glazing specification	Clear, single glazing with aluminium frames	-------
Window operability	As per architectural documentation	-------
Ceiling fans (of varied diameters)	None	-------
Sealing or unsealing of exhaust fans	3 x Unsealed exhaust fans + 1 Kitchen Rangehood with a filter	-------
Internal floor finishes	Ceramic tiles to entire ground floor	-------
	Carpet with underlay to entire upper floor	-------
External wall colours	Mid coloured (SA 0.50)	-------
Roof colour	Dark (SA 0.85)	-------
Roof space ventilation	Unvented	-------

Element	As Designed Specification	Adjusted Specification for 4.5 star QDC rating
External window shading / sun hoods	Eaves and some sun hoods to windows as per architectural documentation	-------

This process was followed for all 232 initial scenarios, representing each dwelling and construction variation, all orientations, and in each of the four climate zones, to establish ratings that were as close as possible to the minimum required by the QDC – 4.5 stars in CZ 1,2, and 5 and 5 stars in CZ 3. An example of these variables is shown in Figure 13. This hierarchical structure was used for each dwelling type, resulting in 232 different scenarios.

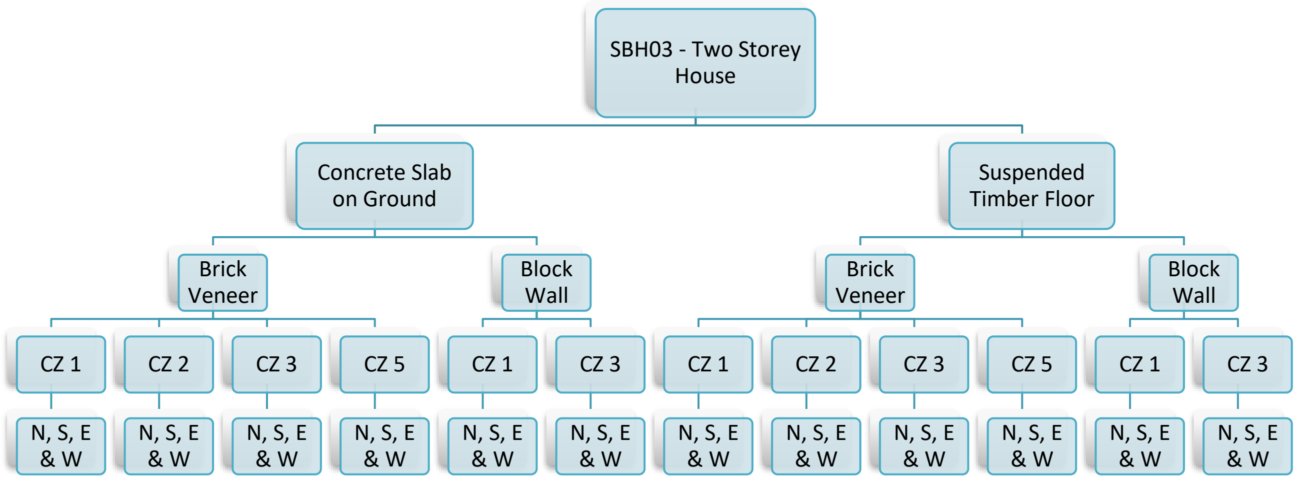

Figure 13: Variables modelled for SBH03 - Two Storey House

2.2.6 Establishing the NCC 2019 6 Star model - Class 1 dwellings

Once baseline QDC versions for the NatHERS models had been made, a similar iterative approach was taken to making upgrades to the dwellings in order to achieve NCC 2019 compliant 6-star versions.

In all scenarios there would be multiple options for improving the performance of the dwellings, so there needed to be a selection process to refine the strategies used. The attempt was made in all cases to employ the least-cost strategies, however it cannot be guaranteed that this is the case, due to practical limitations in the time and budget for analysis. However, all strategies employed were realistic, achievable and did not alter the overall design of the dwellings within the parameters outlined above.

Upgrade strategy selection was based on:

- the experience of the NatHERS assessors undertaking the research who have worked in Queensland assessing dwellings over the past 20 years;
- an understanding of the climatic conditions tailored the strategies selected. e.g. the tendency for overheating in CZ 1, a balance of overheating and underheating in CZ 2 and 3, and a tendency for more underheating in CZ 5;
- specific strategies due to conditions emerging from the dwelling orientation of the individual modelling scenario;
- a view to the AHD portal data that showed which of the strategies are typical of current practices;
- employing the simplest and least cost strategies were first.

An Example of Establishing a NCC 2019, 6 star model

Continuing on with the scenario of SBH03 shown in the previous section, Table 10 presents the upgrade options that were taken to achieve a 6 star NatHERS rating, for the scenario with lightweight, brick veneer walls, a concrete slab on ground, in CZ 2 with a south facing orientation.

The initial rating for this scenario showed that there was more overheating requiring cooling, than there was underheating, requiring heating. This started to direct the upgrade strategies to those that would assist in preventing overheating.

QDC 4.1 – 4.5 Star rating

- Heating Energy – 14.4 MJ/m^2/yr
- Cooling Energy – 47.4 MJ/m^2/yr
- Total Energy – 61.8 MJ/m^2/yr

Table 10: Upgrading a QDC 4.5 star model to an NCC 2019 6 star model

Element	Specification for 4.5 star QDC rating	Specification for 6 stars NCC 2019 Rating
Insulation	R1.5 to External walls	Foil faced sarking to all external walls
	R1.5 to internal walls around garage	-------
	R2.5 to ceilings + foil faced sarking to underside of roof	-------
Glazing specification	Clear, single glazing with aluminium frames	-------
Window operability	As per architectural documentation	-------
Ceiling fans (of varied diameters)	None	1 x 1200dia to Family room 2 x 1200dia to K/L/D 1 x 1200dia to retreat
Sealing or unsealing of exhaust fans	3 x Unsealed exhaust fans to bathrooms	3 x sealed exhaust fans to bathrooms

Element	Specification for 4.5 star QDC rating	Specification for 6 stars NCC 2019 Rating
	1 Kitchen Rangehood with a filter	
Internal floor finishes	Ceramic tiles to entire ground floor	-------
	Carpet with underlay to entire upper floor	-------
External wall colours	Mid coloured (SA 0.50)	-------
Roof colour	Dark (SA 0.85)	Medium (SA 0.50)
Roof space ventilation	Unvented	-------
External window shading / sun hoods	Eaves and some sun hoods to windows as per architectural documentation	-------

The inclusion of the foil-faced sarking reduces both overheating and underheating by reducing heat flow through the external walls. Likewise, the inclusion of self-closing mechanisms on exhaust fans reduces both overheating and underheating by reducing unwanted air infiltration into the dwelling. The inclusion of ceiling fans to the living areas, and the reduction in solar absorptance of the roof colour would aid in reducing overheating and the energy required for cooling.

NCC 2019 – 6.0 Star rating

- Heating Energy – 11.0 MJ/m^2/yr
- Cooling Energy – 31.8 MJ/m^2/yr
- Total Energy – 42.8 MJ/m^2/yr

The example scenario presented here is one in which it was relatively easy to upgrade from 4.5 to 6.0 stars. Many of the other scenarios, particularly those with suspended floors, were much more difficult and required more significant upgrades.

This process was repeated for all 232 base cases, resulting in over 1,000 modelled iterations as each orientation was treated and modelled separately.

2.2.7 Establishing QDC 4.1 equivalent base models – Class 2 dwellings

For the Class 2 dwellings the minimum required rating is 4.0 stars and the required average of all dwellings in the building is a minimum of 5.0 stars.

The process for establishing QDC 4.1 baseline models for Class 2 dwellings was different from the Class 1 dwellings. In addition to orientation, for class 2 dwellings there must also be consideration of the location of the dwelling in the building, on the lower, middle or upper level.

While a Class 1 dwelling is built individually, the Class 2 dwellings are built together as a whole. As seen in Section 0, the class 2 units are in a building of 24 units over 3 levels. The underlying assumption is made that the specification of all units in a building would be the same. It would not be a realistic proposition that a building developer would bother to adjust insulation levels, or glazing specifications etc, for different units in order to ensure that each individual unit is achieving the bare minimum required to comply with the QDC 4.1.

Each level of the Class 2 building was assessed independently, so that differences in thermal characteristics of units on the upper, middle and lower levels could be distinguished.

For each level, all 8 units on that level were assessed simultaneously. That is, they were assessed using the same specification. The units are identified by their position within the building. For each level there are 4 internal and 4 corner units, one of each of the four cardinal orientations.

1. The 8 units on each level were modelled using the specifications as per the provided Architectural documentation.
2. For each level, the poorest performing internal unit and the poorest performing corner unit was identified. This would be one particular orientation, for example the West facing corner unit and the south facing internal unit
3. These two units, on each level, became the representative units for the analysis, so 6 representative units in total for the building in each climate zone.
4. The QDC 4.1 baseline models were developed for these 6 units, as per the same iterative approach as for the Class 1 dwellings, by making adjustments to the material specifications so that the NatHERS rating was as close as possible to the minimum required 4 star rating.
5. This iterative process of identifying the poorest performing unit, and iteratively developing the QDC 4.1 baseline model, was repeated for each climate zone and each level of the building. It was not done for every orientation however, because the assumption is that if the poorest performing orientation is at minimum standard, then other orientations would be performing better and would comply based on the same specifications.

2.2.8 Establishing NCC 2019 5 star models – Class 2 dwellings

Once QDC baseline models had been established for each unit type, level of the building, and climate zone, the models could be iteratively upgraded to achieve the 5 star NCC 2019 compliant models. The task is to increase the performance of the poorest performing units on each level from the QDC minimum requirement of 4 stars to the NCC 2019 minimum requirement of 5 stars

As part of the analysis the team did not assess the required increase of the average rating of all units from 5 stars to 6 stars. Cursory assessment of the overall performance of apartments in the NatHERS standard apartment building indicated that if the poorest performing unit was achieving the minimum requirement, then typically the average of all units easily achieves the required average rating.

The upgrade process was essentially the same as described above for Class 1 dwellings, with minor differences to the strategies applied, based on the location of the unit within the building. For example, units on the lower level, above the carpark, may have strategies applied to the floor of the unit, to address heat flow in and out through the floor, but not to the ceiling/roof because there is a neighbouring unit above, which NatHERS assumes is conditioned as per the unit being modelled and hence there is essentially no heat flow.

As mentioned in the previous section, the assumption was made that whatever strategies are applied to the poorest performing, representative units, would be applied to all units on that level of the building.

2.2.9 Some Qualifying Assumptions for the NatHERS Pathway Analysis

The results of this research need to be considered in the light of the following qualifying assumptions.

- **The NatHERS modelling process differed from standard practice**. The process of modelling the 4.5/5.0 star QDC minimum standard, and the 6.0 star NCC 2019 minimum standard, was not typical of a NatHERS assessment conducted in everyday practice. The object of the modelling in the research, was to establish designs that rated as close as possible to each of the minimum standards, and then to test the impact of various changes to the designs ability to be improved to 6 stars. The object was not simply to rate the design per se.
- **Strategies were occasionally put in place, or removed, that would be unlikely in practice**. When many of the archetypes were first modelled, the initial results were 6 stars or above. This reflects the current average Queensland star rating of 6.6 stars according to the CSIRO AHD Portal[13]. To reduce the rating to the QDC 4.5 star, in some scenarios the changes made, may not have reflected standard practice in a given climate zone. For example, in Climate zone 1, it is standard practice to include ceiling fans in most rooms. However, in certain scenarios, where the building fabric had already been degraded to the lowest possible level and the typology was still rating above 4.5 stars, the ceiling fans were removed. This process of stripping out standard inclusions does not reflect common practice and in this way the research methodology deviated from what would be typical practice.
- **Design changes were not made, when sometimes such changes would have likely been more cost effective.** This study represents an investigation into the fabric improvement requirements needed to bridge the gap between current minimum QDC compliance and NCC 2019. Design changes were not made although it was recognised that this could have been the most cost-effective strategy in some instances. This is representative of a typical workflow in the housing industry where the NatHERS assessments are typically completed at Building Approval stage once documentation has been finalised. At this late point in the design process changes are no longer considered desirable or feasible. It must also be noted

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[13] AHD Portal

that such a process is not conducive to achieving the least cost solutions to energy efficiency housing.

- **Heating and cooling load caps were not considered.** The current QDC 4.1 and the NCC 2019 both have heating and cooling caps that need to be met alongside the relevant NatHERS star rating, to ensure that the worst 5 per cent of heating and cooling loads are eliminated. As part of this study, the heating and cooling load caps were not considered, meaning that some of the 4.5/5.0 Star QDC base models, or the 6.0 star NCC 2019 models, may not be fully compliant. The decision not to consider heating and cooling caps was based on the additional quantum of work required that would have been required to adjust QDC base models and NCC 2019. The process of adjusting the models as close as possible to 4.5 stars, and then as close as possible to 6.0 stars, along with the large number of iterations modelled was perceived to be a better use of time and to provide enough detail upon which to base the Benefit Cost Analysis.
- **When adjusting dwelling designs to test different wall types, some structural inconsistencies were ignored.** As noted in Section 2.1.5 different wall and floor construction types were tested. The standard designs already included brick veneer and lightweight clad stud frame external walls, however heavyweight construction was not represented. Heavyweight walls were tested for each of the class 1 dwelling archetypes in Climates zone 1 and 3 where heavyweight walls are often built to withstand cyclonic conditions. Rather than select different, new dwelling designs that were specifically designed with heavyweight walls, the four class 1 dwellings models simply had their external wall types changed. In reality this would present a structural problem for the two storey archetypes, namely the two-storey house SBH03 and the two Townhouse designs. Thermally however, there would be little impact and as a result the structural details were not considered in this instance. Being able to compare the impact of block wall construction versus brick veneer or lightweight cladding on the same design was considered more important than selecting a different design to accommodate the requirements of a heavyweight second storey.
- **There are multiple different ways to improve thermal performance.** For all of the scenarios assessed there will be more than one combination of upgrade strategies that could be used to achieve a 6 star rating. In reality, there may be many factors at play that lead to one set of strategies being chosen over another. For example, there may be material handling preferences and material availability issues that influence the actual choice of building fabric inclusions. While there was some optimisation and testing of different upgrade strategies, it was not feasible to test all possible combinations. Once material and install costs were obtained from the QS, these were used to guide the least cost upgrade approach.

2.3 Elemental Method (DTS) Pathway

2.3.1 Introduction

This component of the research was developed in order to assess the compliance options (2) and (7) from the QDC 4.1, as outlined above in Section 2.1.1., and compare them against the NCC 2019 NatHERS compliance route as per section 3.12.0 (a)(ii), the 'Elemental Method' as outlined above in Section 2.1.1.

When assessing a dwelling using the elemental pathway, each provision of NCC Section 3.12 is assessed independently to determine compliance. All provisions need to be complied with for the dwelling to be deemed-to-satisfy with the provisions.

In the research process, the analysis of the elemental pathway was carried out after analysis of the NatHERS method described above. This meant that the outcomes from the NatHERS analysis were used to inform the analysis process for the elemental pathway.

The same four, Class 1 dwelling designs were used to undertake the elemental pathway analysis. Each of the four Queensland climate zones are assessed separately as they typically have differing requirements under the BCA 2009 provisions and under the NCC 2019 provisions. Orientation was not specifically assessed except as it is relevant in assessing glazing using the ABCB Glazing Calculator as described in Section 2.3.3

Class 2 dwellings do not have the option of being assessed under the Elemental Method in NCC 2019 so do not form part of this section of the research.

Calculations of areas of building elements, such as floor areas, wall areas, and window areas, were extracted from the NatHERS modelling data, for use in the elemental pathway analysis. In this way, the two methods were directly comparable in terms of the potential upgrade costs incurred.

When undertaking the elemental (DTS) method compliance route, there is no direct way to establish the energy savings predicted to be achieved by upgrading from the QDC 4.1 to NCC 2019. Predicted energy savings were established with reference to the NatHERS Star bands. For example, the BCA 2009 elemental pathway is deemed to be equivalent to a 5 star NatHERS rating, and the NCC 2019 is equivalent to a 6 star NatHERS rating. The difference in MJ/m^2/yr of predicted heating and cooling energy between these two star ratings, in each climate zone, becomes the de facto energy saving used for the Benefit Cost Analysis.

2.3.2 QDC 4.1 Compliance Option (2)

With the 2010 requirements being in line with the 6-star NatHERS requirement, the 2010 NCC Elemental Provisions are essentially the same as the NCC 2019.

QDC compliance option (2) is found to be essentially the same as complying with NCC 2019, except that the QDC introduces the exception that, for dwellings in CZ 1 and 2, they may disregard the requirements for floor insulation under NCC section 3.12.1.5(a)(i) and (iii).

3.12.1.5(a)(i) relates to the minimum required Total Construction R-value that must be achieved by the floor structure of a house with a suspended floor. Therefore, this provision only relates to those scenarios with a suspended floor.

3.12.1.5(a)(iii) relates to dwellings with in-slab heating or cooling systems. None of the dwellings in this study are specified to have in floor heating or cooling systems and this would be a very rare occurrence in the Queensland climate zones.

Once analysis of the QDC option (7) was undertaken (as described below) it was found that option (7) would be a much more cost-effective way to comply with QDC 4.1, compared to Option (2). Even for those houses with a suspended floor in CZ 1 or 2.

From the available data of building approvals there is no way of distinguishing which of the options (2) or (7) have been used in past building approvals. However, in the professional judgement of the research team, it is thought that it would be very rare that option (2) would be used. If an elemental pathway option were to be used it would almost certainly be option (7) utilising the less stringent 2009 BCA requirements.

Consequently, analysis was undertaken of the cost differential of increased floor insulation for dwellings in CZ 1 and 2 however this compliance option was not included in the Benefit Cost Analysis, as the frequency of use of this option was assumed to be extremely low.

Table 11: Comparison of suspended floor insulation requirements - QDC 4.1 Option (2) vs NCC 2019

NCC Provision	QDC 4.1 Compliance Option (2)	NCC 2019	
		Climate Zone 1	Climate Zone 2
3.12.1.5(a)(i) – Minimum Total R-Vale for Suspended Floors	Nil	R1.5 Total Construction R value	R1.0 Total Construction R value

2.3.3 QDC Compliance Option (7)

QDC compliance option (7) references the BCA 2009. Therefore, comparison is made between the BCA 2009 Section 3.12 provisions, and those same provisions in the NCC 2019, to determine the required upgrades to achieve compliance with NCC 2019.

QDC 4.1 requires an extra star worth of credit be gained alongside compliance with BCA 2009. It was established that the most cost-effective means of achieving this star of credit is to specify:

- an outdoor ceiling fan, and
- R1.5 ceiling insulation to the extent of the outdoor living area.

The supply and install cost of these two elements was factored into the Benefit Cost Analysis for all of the scenarios under the elemental pathway analysis.

Table 12 provides a summary of the elemental (DTS) requirements of Section 3.12 highlighting the differences between BCA 2009 and NCC 2019. Note that only those provisions where there is a difference between the two versions have been presented in the table.

Table 12: Summary Comparison of BCA 2009 and NCC 2019 Energy Efficiency Provisions

NCC Provision	Climate Zone	BCA 2009	NCC 2019
3.12.1.2 Roofs	1	Min. R2.7 down	Min. R4.1 down (Med. colour)
	2	Min. R2.7 down	Min. R4.1 down (Med. colour)
	3	Min. R2.7 down and up	Min. R4.6 down and up (Med. colour)
	5	Min. R3.2 up	Min. R4.6 up (Med. colour)
3.12.1.3 Roof Lights	All	Where total area is > 1.5% but < 10% must comply with min. SHGC and U-Value.	Increase in Total U-Value and SHGC requirements from BCA 2009 and cannot exceed 5% as a percentage of the floor area of the room.
3.12.1.4 External Walls	1	Min. R1.9; or Min. R1.4 for slab on ground; or For walls with Surface Density more than 220kg/m2: Compliant shading.	Min. R2.8; or For walls with Surface Density more than 220kg/m2: Compliant shading; or Min. R0.5 insulation; with either - Slab on ground floor; or internal masonry walls to lowest habitable level.
	2	Min. R1.9; or Min. R1.4 for slab on ground; or For walls with Surface Density more than 220kg/m2: Below 300m altitude include compliant shading; or Above 300m altitude either – Min. R0.5 insulation; or Slab on ground floor; or Internal masonry walls.	Min. R2.8; or For walls with Surface Density more than 220kg/m2: Compliant shading; or Min. R0.5 insulation; with either - Slab on ground floor; or internal masonry walls to lowest habitable level.
	3	Min. R1.9; or Min. R1.4 for slab on ground.	Min. R2.8; or For walls with Surface Density more than 220kg/m2: Compliant shading; or Min. R0.5 insulation; with either - Slab on ground floor; or internal masonry walls to lowest habitable level.
	5	Min. R1.9; or Min. R1.4 for slab on ground; or For walls with Surface Density more than 220kg/m2: Min. R0.5 insulation; or Slab on ground floor; or Internal masonry walls.	Min. R2.8; or For walls with Surface Density more than 220kg/m2: Compliant shading; or Min. R0.5 insulation; with either - Slab on ground floor; or internal masonry walls to lowest habitable level.
3.12.1.5 Floors	1	Nil	Min. R1.5 up for suspended floors

NCC Provision	Climate Zone	BCA 2009	NCC 2019
	2	Nil	Min. R1.5 up for suspended floors
	3	Nil	Min. R1.5 up for suspended floors
	5	Nil	Min. R1.5 up for suspended floors
3.12.2.1 External Glazing	All	As per Glazing Calculator BCA 2009	As per Glazing Calculator NCC 2019
3.12.3.3 External Windows and Doors	All	Seals required to external doors, openable windows and the like serving conditioned spaces.	Seals required to external doors, openable windows and the like serving conditioned spaces AND between Class 1 and unconditioned Class 10a. Bottom edge of external swing doors must have a draft protection device.
3.12.4.1 Air Movement	1	Min. air movement to habitable rooms: - 15% without a ceiling fan or evaporative cooler - 12.5% with a ceiling fan - 15% with an evaporative cooler	Min. air movement to habitable rooms: - 10% without a ceiling fan or evaporative cooler - 7.5% with a ceiling fan - 10% with an evaporative cooler
	2	Min. air movement to habitable rooms: - 10% without a ceiling fan or evaporative cooler - 5% with a ceiling fan - 10% with an evaporative cooler	Min. air movement to habitable rooms: - 10% without a ceiling fan or evaporative cooler - 7.5% with a ceiling fan - 10% with an evaporative cooler
	3	Min. air movement to habitable rooms: - 12.5% without a ceiling fan or evaporative cooler - 7.5% with a ceiling fan - 7.5% with an evaporative cooler	Min. air movement to habitable rooms: - 10% without a ceiling fan or evaporative cooler - 7.5% with a ceiling fan - 7.5% with an evaporative cooler
	5	Min. air movement to habitable rooms – No difference between BCA 2009 and NCC 2019	Min. air movement to habitable rooms – No difference between BCA 2009 and NCC 2019
3.12.4.3 Ceiling Fans and Evaporative Coolers	All	900mm min fan diameter	1200mm min fan diameter for room area of 25m^2

As mentioned in the introduction to this section, each element is assessed individually, without reference to the other provisions. This makes it relatively straight forward to determine the upgrade requirements for most of the Elemental provisions. For example, in climate zone 1, a medium-coloured roof must achieve a minimum total R-Value of 2.7 downwards under the BCA 2009 requirements. In NCC 2019, this is increased to R4.1. Assuming the worst-case scenario of an unventilated roof and a standard metal clad pitched roof with a flat ceiling such as in the SBH02 Single Storey House the added insulation required increased from R2.5 to R3.5 as shown in Table 13. This result is the same irrespective of the orientation or floor type, i.e. whether it was a slab on ground typology of suspended floor.

Table 13: Elemental Assessment of roofing insulation requirements for a pitched roof with a flat ceiling in Climate Zone 1

Pitched roof with flat ceiling – Unventilated roof space		BCA 2009	NCC 2019
Metal Roof	Total R-Value of roof, sarking and ceiling materials	R1.08	R1.08
	Minimum added R-Value of insulation	R2.5	R3.5

Glazing Calculations

The Glazing provisions, Section 3.12.2.1, are a more complex exercise in terms of analysis of the different requirements between BCA 2009 and NCC 2019. Compliance with the glazing provisions is demonstrated using the ABCB Glazing Calculator. The ABCB glazing calculator assesses the contribution of glazing to the thermal performance of the dwelling based on:

- Size of glazing
- Orientation of glazing
- Shading to the glazing
- Whole of window U and SHGC values
- Floor area of the storey of the dwelling
- Floor type of the storey of the dwelling (suspended or in contact with the ground)
- Climate zone

The glazing of each storey of a dwelling is assessed separately, and both storeys of a double storey building must comply in order that the dwelling complies with the glazing provisions. This can potentially lead to different minimum requirements for the glazing specification for the two storeys of the house. Where this happened in the analysis, the glazing specification of the storey with the more stringent requirement was used for the costing purposes. Where there was a requirement for an increase in the glazing specification to meet the NCC 2019 provisions, this more stringent specification was applied to both storeys for the purpose application of increased glazing costs.

Outcomes of NatHERS Assessments were used to establish the scenarios for each dwelling that were used to form the basis of the Glazing Calculations. For each dwelling type, in each climate zone, the worst performing and best performing orientations, based on the NatHERS results, were selected as the scenarios upon which to undertake the glazing calculations.

Once the results from the glazing calculations were established, based on the best and worst orientations, the cost of upgrading glazing (if applicable) for both of these scenarios, were then averaged in order to provide a single input for glazing upgrade costs into the Benefit Cost Analysis.

2.3.4 Some Qualifying Assumptions for the Elemental Method Pathway

- **Some simplifications were made in the analysis process.** Certain provisions of the elemental pathway provide several options for demonstrating compliance depending on variables such as floor construction, shading, orientation or colour. For example, the minimum total required R Value of a wall might range from R1.9 where no concessions apply, to R1.4 if the floor system is slab on ground, to an appropriately shaded wall only if the surface density if greater than 220kg/m2. While generally an improvement is required from BCA 2009 to NCC 2019, each of the standards has this level of variability. This means that in certain designs, different walls within a dwelling could have different treatments based on the level of shading and construction. Based on the experience of the team, it was determined that although this is permissible according to the regulations, in practice it is unlikely to occur. Therefore, the worst-case scenario option was determined for the whole design and applied in working out the upgrade costs.
- **Design changes were not made, when sometimes such changes would have likely been more cost effective.** As noted in the NatHERS pathway section, design changes were not made although it was recognised that it could have been a more cost-effective strategy in some instances.

2.4 Costing

2.4.1 Introduction

Costing of building elements that were used as upgrade options, was undertaken by an independent Building Cost Consultant – Steele Wrobel.

Full costing of the dwellings was not undertaken. Simply, costing of elements that changed between QDC 4.1 compliance and the NCC 2019 compliance scenarios. Refer Appendix C **Error! Reference source not found.** for full detail of the building element, material and install costs.

The cost of building fittings and fixtures can vary widely depending on factors such as quality, design etc. A high-end ceiling fan can cost many times the price of a budget model, yet the selection makes no difference to thermal comfort. Similarly, floor coverings can range widely in price depending on materials, even if thermally they perform the same. For the purposes of this research, a middle-of-the-road approach was taken. For fittings and fixtures that have a significant range in price, a medium-priced option that would be available from a large supplier, was selected. This means that both boutique and warehouse type prices were excluded.

Table 14 presents a full list of the building elements that were potentially involved in upgrade scenarios, the variations included and the units of measure. In some instances, the install cost also needed to be included as part of the upgrade. For example, if a wall that previously did not require insulation had R1.5 batts installed then the installation cost needed to be added to the material cost. But in the case of glazing for example, only the upgrade cost of materials was allowed for, as the window installation cost would have already been factored into the initial price of the dwelling.

Table 14: Costed building elements that were upgraded

Element	Unit	Install Cost	Material Variations
External Walls	M^2 Wall Area	Yes	Wall Bulk – R1.5, R2.0, R2.5, R2.7
	M^2 Wall Area	Yes	Single sided foil sarking
	M^2 Wall Area	Included	Block work wall, plasterboard lined
	M^2 Wall Area	Included	Block work wall + 20 air gap + 90mm Timber stud wall with PB internally
Intertenancy Walls	M^2 Wall Area	Included	Hebel – stud wall either side with plasterboard
	M^2 Wall Area	Included	Solid core filled block – stud wall either side with plasterboard
Internal Walls	M^2 Wall Area	Yes	Wall Bulk – R1.5, R2.0, R2.5, R2.7
Ceilings / Roofs	M^2 Ceiling Area	Yes	Ceiling Bulk – R2.5, R3.5, R4.1
	M^2 Roof Area	Yes	PIR Insulation – R2.0, R2.5
	M^2 Roof Area	Yes	Single sided anti-glare foil; R1.3 Anticon Roof Blanket
	Per Roof Space	Included	Eave vents and ridge vents at 1500mm internals; Roof exhaust fan
	M^2 Roof Area	Included	Concrete tiles; metal Colorbond roof sheets
Floors	M^2 Floor Area	Yes	Floor Bulk – R1.5, R2.0, R2.5
	M^2 Floor Area	Yes	Double sided reflective foil
	M^2 Soffit Area	Yes	PIR Insulation – R0.5, R1.0, R1.5
	M^2 Soffit Area	Yes	Phenolic board – R0.5, R1.0, R1.5
	M^2 Soffit Area	Yes	XPS board – R0.5, R1.0, R1.5
	M^2 Floor Area	Yes	Timber laminate flooring, Vinyl sheet flooring, carpet with underlay, standard format tiles
	M^2 Wall Area	Included	Underfloor enclosure – R1.5 wall
Windows	M^2 Window Area	Included	Clear single glazing in aluminium frames; Low-e single glazing in aluminium frames; Tinted single glazing in aluminium frames; Clear double glazing in aluminium frames; Low-e double glazing in aluminium frames; Tint low-e double glazing in aluminium frames
	M^2 Window Area	Included	Window operability - Fixed, awning, sliding, casement, sliding door, stacker sliding door
	M^2 Window Area	Yes	Fall protection – diamond grille or similar; Crimsafe or similar
Shading	Per length	Yes	400mm deep sunhood
	Per M^2	Yes	External horizontal louvre; external vertical louvre
Other	Per Item	Yes	Ceiling Fans – 900mm dia, 1200mm dia, 1400mm dia, outdoor rated
	Per Item	Yes	Standard exhaust with no backdraft damper; Exhaust with backdraft damper
	Per Item	Included	1kW PV panels and inverter
	Per Item	Yes	Reed switch

2.4.2 Method

The items were priced by obtaining, where possible, materials supply costs and estimating installation rates. The final costs have then been benchmarked against pricing received by Steele Wrobel on recent relevant projects and published data to ensure that they fell within a typical range.

While published reference costs have not been used as the primary method of pricing they have been considered in checking the final rates presented.

The base rates are for a single, new house construction. They do not consider any significant discount that may be offered for large bulk orders or multiple residence. This makes our costings conservative, as larger volume builders would be likely to be able to secure lower costs.

It must be noted that the research has been conducted at a time in which there has been significant upheaval in the construction industry in the wake of the COVID 19 pandemic and flood recovery, in which there have been significant and abnormal costs increases. Current tenders at the time that price estimating was conducted, suggested that an uplift of 40% is required to cover potential current pricing within some sectors of the residential sector. It is difficult to state if this increase will remain or is just resulting from these recent upheavals and supply shortages.

The published data[14] for regional indexing of costs, was used to account for geographical differences as per the following table:

Table 15: Regional cost indexing used for the different climate zones

Locations

Brisbane	Cairns	Charleville	Toowoomba
100%	108%	125%	103%

2.5 Benefit Cost Analysis Methodology – QDC4.1 to NCC2019

2.5.1 Approach

The general approach to the benefit cost analysis in this study is consistent with national guidelines,[15] as previously applied by SPR for Code-related analyses and regulation impact statements.[16] Policy and regulatory proposals are assessed on a 'with/without' basis; that is, comparing expected outcomes *with* the proposed change(s) in place against the outcomes that are expected *without* the change(s). All other factors, that are causally unrelated to the proposed change, are held consistent in the two cases. This does not mean that we assume a static future. Rather, it means that all future developments that are considered relevant and material to the policy case – but that are *not caused* by it – should be included in the reference case, while the policy case reflects only those incremental impacts that are expected to be *caused by* the proposed or possible change. This approach highlights just the expected incremental impact of the change, to the exclusion of other factors.

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[14] Rawlinsons? - TBC

[15] Commonwealth of Australia, Office of Best Practice Regulation, *Guidance note: cost benefit analysis*, March 2020.

[16] See, for example, SPR, *Inclusion of Heating and Cooling Energy Load Limits in NatHERS Software: Final Regulation Impact Statement for Decision*, prepared for the Australian Building Codes Board, October 2018.

The analysis assumes that potential policy/regulatory changes could take effect from FY2024 and remain in place for 10 years; that is, until the end of FY2033. That said, the analysis is not sensitive to such assumptions. For each year that the new policy is assumed to apply, incremental costs are incurred, and incremental benefits arise. The longer the measure is assumed to apply, the larger the costs but also the larger the benefits, while the benefit cost ratio (BCR) is likely to remain unchanged. If the start is delayed, and the measure is cost effective, then there is an opportunity cost, or foregone benefit, associated with the delay.

2.5.2 Stock Modelling

The measures covered in this report relate to specific cohorts of dwellings:

1. For the NCC2019/QDC4.1 comparison, and for assessor accreditation, the relevant cohort is new dwellings from FY2024, as these would be impacted by the measure
2. For the resilience measures, the first would apply only to pre-1982 dwellings, while the second would apply to pre-September 2003 dwellings.

For the first set, we capture data from the Australian Bureau of Statistics on dwelling completions. This data is segmented into 'houses' (class 1ai dwellings) and 'other residential' (which combines class 1aii (semi-detached or townhouses) and class 2 (apartments). We therefore have to estimate the split of townhouses and apartments. This is done using an SPR stock model constructed to agree with Census data. The resulting historical completions trends are shown in Figure 14, noting that FY2022 includes estimates based on part-year data available at the time of analysis.

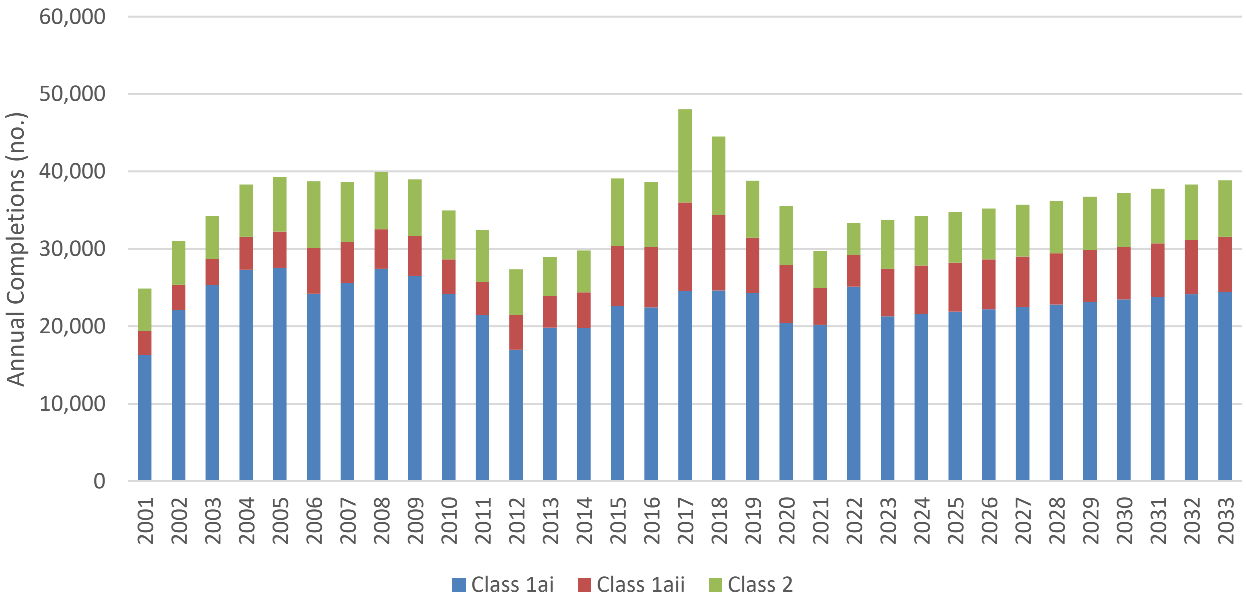

Figure 14: Historical and Expected Dwelling Completions: QLD (derived from ABS data)

The average annual rate of growth in completions over the period to FY2022 was 1.4%, although it is evident that this varies considerably from year to year in line with building and economic cycles. For the FY2024 – FY2033 period, we assume that the same average rate of growth applies – noting that, as for the duration of the measures discussed above, the analysis is not sensitive to this assumption. If growth is faster than assumed, then more cost and more benefit will arise, and if it is slower, less cost and less benefit will arise – in both cases, no significant change to the benefit cost ratio would be expected, although the net present value will rise and fall with such trends (these terms are defined in Section 2.5.4. For the projections period, the expected split between dwelling classes is based on the average shares of each constructed in the five years to FY2022 (63% detached, 18.3% semi-detached and 18.7% apartments).

The next step is to layer the stock by NCC climate zone. For this we make use of NatHERS ratings data from CSIRO's *Australian Housing Data* portal, with results averaged over the 2017 – 2022 period.[17] It may be noted in Table 16 below that new dwellings, and particularly new apartments, are significantly concentrated in climate zone 2 (SE QLD).

Table 16: Split of Class 1 and Class 2 Dwellings by Climate Zone (2017 – 2022)

Class	Climate Zone	No. of Ratings	% of Total
1	1	12,383	11.6%
	2	89,678	83.8%
	3	537	0.5%
	5	4,355	4.1%
Total Class 1		106,953	100.0%
2	1	373	2.1%
	2	17,251	97.0%
	3	22	0.1%
	5	131	0.7%
Total Class 2		17,777	100.0%

The next step is to estimate the portions of the stock growth by archetype (in addition to class and climate zone). As discussed above, archetypes were selected to be representative of the typical new dwelling stock as it occurs in different regions of QLD. Generally, we draw for this analysis on data provided by CSIRO (supplied by DEHW, based on the ratings data in the *Australian Housing*

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[17] https://ahd.csiro.au/

Data portal). However, in some cases no data was available, and reasonable estimates had to be made.

For example, the split between 1-storey and 2-storey housing in the new stock, and how this might vary by climate zone, is not known (see estimates below). Likewise, the share of 'Queenslander' designs in the new construction task is not known. We estimate this as a share of broader group which feature both light weight walls and suspended timber floors. Since we model both 'end of row' and 'middle of row' townhouses, we had to estimate the shares of each. Based on a typical row of townhouses containing 5 townhouses, this means 40% would be 'end' and 60% 'mid'.

Table 17: Key Housing Archetype Assumptions/Data by Climate Zone

	Climate Zone 1	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 5**
1 storey	65%	55%	70%	55%
2 storey	35%	45%	30%	45%
Sub-total	*100.0%*	*100.0%*	*100.0%*	*100.0%*
Lightweight wall type	21.6%	91.0%	80.5%	94.2%
Concrete block wall type	77.3%	4.2%	15.3%	0.8%
Queenslander wall type	1.1%	4.8%	4.2%	5.0%
Sub-total	*100.0%*	*100.0%*	*100.0%*	*100.0%*
CoG floor type	86.6%	89.7%	67.8%	92.9%
Suspended timber floor type	13.4%	10.3%	32.2%	7.1%
Sub-total	*100.0%*	*100.0%*	*100.0%*	*100.0%*
End townhouses	*40.0%*	*40.0%*	*40.0%*	*40.0%*
Mid townhouses	*60.0%*	*60.0%*	*60.0%*	*60.0%*
Sub-total	*100.0%*	*100.0%*	*100.0%*	*100.0%*

Since we model three floorplates of Class 2 dwellings – corresponding to ground-level, mid-level and upper floors, we need also to estimate how the new apartment dwelling stock is attributed to these categories. For this analysis we rely on data published by Geoscience Australia known as NEXIS, or the National Exposure Information System.[18] This data is available at various levels of spatial

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[18] See https://www.ga.gov.au/scientific-topics/national-location-information/nexis

disaggregation down to SA1 and Local Government Area. For this purpose, however, we summed totals up to the SA 4 level, which divides QLD into 19 zones. Each of these zones was then associated with an NCC climate zone.

NEXIS includes data on the total number of *dwelling units* (houses, townhouses and also apartments divided into 2-storeys, 3-storeys and 4-storeys or more), and also (by deduction) the total number of apartment *buildings*. This enables the number of apartments at ground and top levels to be estimated (based on the average number of dwellings per floor), with the balance of apartment dwellings assumed to be 'mid-level' (that is, neither ground-level nor penthouse). This analysis was undertaken for each SA4, and then aggregated up to the level of NCC climate zones.

As a second pass, and reflecting analysis by the technical team which noted that a critical factor was the number ground-level apartments situated immediately above carparks (or other voids), the ground-floor apartment search criteria were changed to focus on just this situation, rather than all ground-level apartments. This data was not available from NEXIS but had to be estimated based on the technical team's experience. The team noted that most new Class 2 dwellings at the lowest level of the residential tower are built over podiums, rather than car-parks or voids. In less urbanised areas (where Class 2s are less common in any case), the additional cost of providing underground carparking is substantial and not often incurred (ground level parking is offered instead, as land costs are often lower). Of course, these are rules of thumb, as actual data does not exist. Also, the NEXIS data represents the composition of the whole dwelling stock and not only of the new construction. The technical team notes that new Class 2 buildings are less likely than older and smaller ones to have carparks below the ground floor, although this will still occur in some cases. The resulting estimates are shown in Table 18.

Table 18: Estimated Split of Apartments by Level (derived from Geoscience Australia NEXIS data)

NCC CZ	Ground level apartments (above carpark)	Mid level apartments	Top level apartments
1	413	30,872	3,484
2	4,605	255,118	24,968
3	94	5,143	755
5	429	17,670	2,373
Totals	**5,541**	**308,803**	**31,580**
1	1.2%	88.8%	10.0%
2	1.6%	89.6%	8.8%
3	1.6%	85.8%	12.6%

NCC CZ	Ground level apartments (above carpark)	Mid level apartments	Top level apartments
5	2.1%	86.3%	11.6%

Other key inputs drawn from CSIRO data include an estimate that 67% of new dwellings utilise NatHERS to demonstrate compliance (this observation – provided via DEPW – was not broken down by climate zone and is therefore assumed to apply equally in all climate zones). We therefore assume that 33% use the elemental (DTS) pathway but, in reality, this group would include those using other permitted pathways including reference building modelling and expert opinion.

Also, the CSIRO data source includes the split of new dwellings (rated under NatHERS) by star rating, and this enables us to estimate that 74% (on average) of new Class 1 dwellings constructed over 2017 – 2022 already achieved 6 stars or better, as did almost 69% of Class 2 dwellings. However, these values vary significantly by climate zone, with climate zone 1 showing the highest share of 6-star or better dwellings (see Table 19). Also, it is possible that the spread of star ratings in the stock using the elemental (DTS) pathway would differ from that of the share actually rated under NatHERS. In principle, NatHERS and element solutions are supposed to have equivalent energy performance, but this is not guaranteed.

Table 19: Shares of New Construction Meeting or Exceeding 6 Stars by Class and Climate Zone, 2017 - 2022

Search	Climate zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 5
Class 1:	*83.5%*	*76.1%*	*56.0%*	*76.7%*
Class 2:	*85.5%*	*52.9%*	*59.1%*	*77.9%*

Combining the above parameters, we obtain a ‘map’ of the new construction task by archetype, class and climate zone, as summarised in Table 20.

Table 20: Archetype ‘Map’ by Building Class and Climate Zone

NCC Sub-Class	NCC Name	Archetype	Construction Type	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 5
1ai	House	1-Storey	LW CoG	12.1%	44.9%	38.2%	48.1%
1ai	House	1-Storey	LW Susp	1.9%	5.2%	18.2%	3.7%
1ai	House	1-Storey	CB CoG	43.5%	2.1%	7.2%	0.4%
1ai	House	1-Storey	CB Susp	6.7%	0.2%	3.4%	0.0%
1ai	House	1-Storey	Queens	1.1%	4.8%	4.2%	5.0%
1ai	House	2-Storey	LW CoG	6.5%	36.7%	16.4%	39.4%
1ai	House	2-Storey	LW Susp	1.0%	4.2%	7.8%	3.0%
1ai	House	2-Storey	CB CoG	23.4%	1.7%	3.1%	0.3%
1ai	House	2-Storey	CB Susp	3.6%	0.2%	1.5%	0.0%
	Sub-total			*100%*	*100%*	*100%*	*100%*
1aii	Townhouse	TH - end	LW CoG	7.9%	34.4%	23.0%	36.9%
1aii	Townhouse	TH - end	LW Susp	1.2%	4.0%	10.9%	2.8%
1aii	Townhouse	TH - end	CB CoG	26.8%	1.5%	4.1%	0.3%
1aii	Townhouse	TH - end	CB Susp	4.1%	0.2%	2.0%	0.0%
1aii	Townhouse	TH - mid	LW CoG	11.8%	51.5%	34.5%	55.3%
1aii	Townhouse	TH - mid	LW Susp	1.8%	5.9%	16.4%	4.2%
1aii	Townhouse	TH - mid	CB CoG	40.1%	2.3%	6.2%	0.4%
1aii	Townhouse	TH - mid	CB Susp	6.2%	0.3%	3.0%	0.0%
	Sub-total			*100%*	*100%*	*100%*	*100%*
2	Apartment	Apart – gnd (above car park)		1.2%	1.6%	1.6%	2.1%
2	Apartment	Apart - mid		88.8%	89.6%	85.8%	86.3%
2	Apartment	Apart - top		10.0%	8.8%	12.6%	11.6%
	Sub-total			*100%*	*100%*	*100%*	*100%*

2.5.3 Energy and Emissions Savings

The stock shares shown in Table 20 were used to calculate the estimated change in (space conditioning) energy consumption and associated greenhouse gas emissions, by archetype and climate zone, across the whole of QLD.

The change in expected annual energy consumption associated with space conditioning is drawn from the technical analysis described above. In particular, RED Sustainability Consultants and Ecolateral Pty Ltd simulated the annual thermal loads expected to be experienced in each combination of archetype, orientation, climate zone. For the benefit side of the benefit cost equation, the change in expected annual energy consumption (in kWh per year) associated with moving from the 'mandatory minimum' performance allowed under QDC4.1 to the mandatory minimum allowed under NCC2019 was calculated.

Note that we make the conservative assumption that heat pump co-efficients of performance (COPS) in new housing average only 3 in FY2020 and increase slowly to average 4.3 in FY2033. For the fuel mix for new housing, we assume that gas is only used (for space heating) in climate zone 5. We also assume that the share of new dwellings in climate zone 5 that using gas heating falls over time, from 15% of class 1s and 5% of class 2s in FY2020, down to zero by 2035 for class 1s and by 2025 for class 2s, in line with a general trend towards electrification and the dominance of heat pumps installed for space cooling purposes, which can double as space heaters when required.

We then allocate the archetype-level energy savings in accordance with the Table 20 archetype map, multiplying these shares by the total new construction task (as summarised in Figure 14 above) to estimate total energy savings (by fuel) at the whole of state level, reflecting the diversity of construction types and designs by climate zone. Note that we average the modelled conditioning energy consumption by orientation, as the actual distribution of orientations in the new dwelling stock is not known, but generally assumed to be quite diverse (that is, no particular orientation is assumed to dominate).

Note that we assume that the share of the new dwelling stock that *already* achieves 6 stars or better would incur no incremental costs, but also achieve no incremental benefits, under NCC2019 cf the status quo. That is, the energy and emissions savings values reported in Chapter 3 are already discounted by the (significant) shares of both houses and apartments that are over-achieving the current mandatory minimum performance requirements under QDC4.1.

The economy-wide fuel savings are converted into greenhouse gas emissions equivalents using values from the Australian Government's *National Greenhouse Accounts Factors Workbook* (Table 46), extrapolated into the future as shown in Figure 15. The emissions pathway follows that contained in the Australian Government's *Australia's Emissions Projections 2021*, Appendix D, which run to 2030, and then we extrapolate these trends thereafter in a linear manner. Of course, the actual future path of greenhouse gas emissions intensity is uncertain. If grid emissions intensity were to fall more rapidly, this would tend to reduce somewhat the scope for *additional* emissions savings associated with the energy savings induced by NCC2019, and vice versa if emissions fall less quickly.

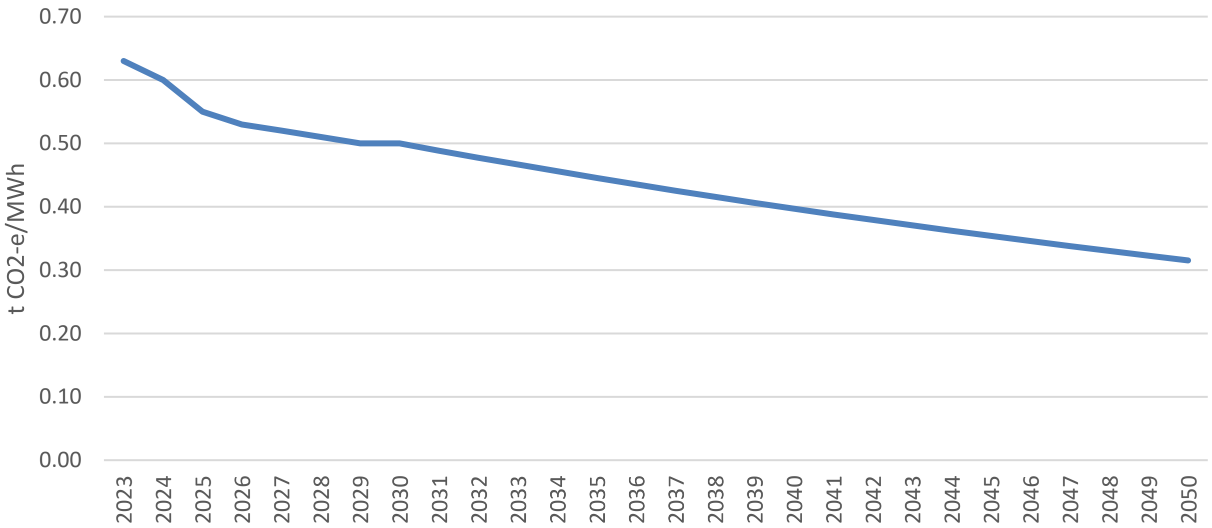

Figure 15: Greenhouse Gas Intensity of Electricity Consumption Assumptions

2.5.4 Valuing Incremental Benefits and Costs

The next step in the benefit cost analysis is to value the incremental benefits and costs. The benefits (quantified here) include:

- fuel savings over time
- greenhouse gas emissions savings
- avoided electrical infrastructure costs associated with reduced peak demands
- downsizing of space conditioning equipment.

Other benefit classes could be considered but are more challenging to 'monetise' (associate with monetary values).

Electricity savings are valued in two segments:

1. Energy consumption savings (avoided energy consumption) is valued using a retail price estimate discounted by 40% to remove the estimated share of network costs from the retail price

2. Avoided network costs are then valued separately, as these are proportional to the change in peak network *demand*, rather than the change in consumption, attributable to the policy case.[19]

For the (discounted) retail electricity price, and also for gas pricing, we draw on values used in the Australian Energy Markets Operator's (AEMO's) latest *2022 Integrated System Plan* (ISP). The ISP expresses price changes over time by scenario as indexes by scenario, which we then associated with current prices. We select the more conservative *Progressive Change* scenario for fuel pricing, although the ISP reports that the more ambitious *Step Change* scenario is considered by stakeholders to be more likely. Electricity price trends do not vary greatly by scenario in any case.

Similarly, gas price trends are taken from *Progressive Change*. We apply a loading of 15% to both electricity and gas prices to reflect the significant increases that have occurred since ISP assumptions were formed in early 2021. The resulting electricity and gas price assumptions are shown in Figure 16. Recall that the electricity price is not full retail but has estimated network costs removed.

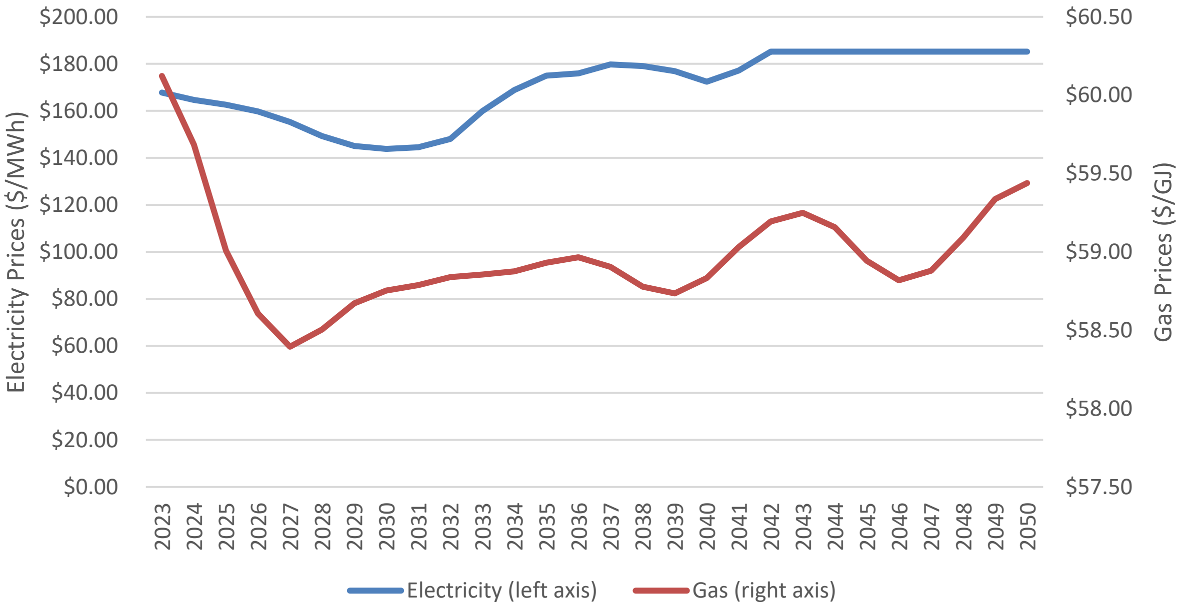

Figure 16: Electricity and Gas Price Assumptions (derived from AEMO ISP 2022)

To estimate avoided electricity network infrastructure costs, due to the lower peak demand of housing built to NCC2019 than to QDC4.1, we utilise the Conservation Load Factor (CLF) method, originally documented by Energetics and the Institute for Sustainable Futures.[20] This methodology

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[19] *Demand* refers to *instantaneous* power demand – broadly reflecting the amount of equipment that is connected and operating at a given moment in time; whereas energy *consumption* refers to the quantities of energy consumed over time (usually a year).

[20] UTS Institute for Sustainable Future and Energetics, *Building our Savings: reduced infrastructure costs from improving building energy efficiency: final report*, July 2010.

is widely used by electricity networks, *inter alia*, and it estimates the reduction in (winter and summer) peak demand associated with a change in energy consumption, as a function of a) the specific end-use technology and b) the degree to which the peak demand for that technology co-incides with the seasonal peak demand on the network. A brief technical description, drawn from p. 27 of the ISF report, is as follows: ”…the Conservation Load Factor (CLF)…is a way of relating energy savings to peak load savings. It equals the average reduction in load (per unit of time) divided by the peak reduction in load (per same unit of time). The CLF is typically calculated as follows:”

$$\mathrm{CLF} = \frac{\dfrac{\text{Annual energy savings (MWh)}}{8{,}760\text{ h}}}{\text{Peak demand reduction (MW)}} \quad \text{for electricity}$$

$$\mathrm{CLF} = \frac{\dfrac{\text{Annual energy savings (GJ)}}{365\text{ days}}}{\text{Peak demand reduction (GJ/day)}} \quad \text{for natural gas}$$

By definition, an end-use that is ‘flat’ (constant through the 24-hour and seasonal cycles) has a CLF of 1. If peak demand is shifted towards the system peak, then the CLF value falls; while if peak demand is shifted towards the off-peak period, the CLF will be greater than 1.

For example, if an energy savings measure improved the efficiency of electric storage hot water systems, and the peak demand of those systems was shifted into off-times, then the CLF method would estimate no (or very little) reduction in peak system demand as a result. However, the more ‘peaky’ the end-use demand avoided, the greater the reduction in the overall system peak, and therefore in system cost. The ISF reference notes that residential space conditioning is (on average) the most ‘peaky’ load of all. This reflects typical dwelling occupancy and energy use patterns, with air-conditioning most likely to be used in morning and (especially) late-afternoon or evening peaks. Thus, measures that reduce the demand for residential space conditioning (such as Code-driven improvements to the performance of housing thermal envelopes) are likely to be relatively effective at reducing peak electrical loads (below what they would otherwise be – not necessarily in absolute terms).[21] For this analysis, we assume a CLF of 0.25, with the ISF report citing values as low as 0.03 and as high as 0.15 (see pp 29 – 31), making 0.25 a conservative choice.[22]

To value the avoided peak demand using the CLF methodology, it also necessary to estimate the (avoidable) cost of network infrastructure provision. Values are included in the ISF work, but these are now dated. Our value of $621,000 per MW is based on the ISF value, converted to FY2022 dollars. In practice, network costs vary very widely from one distributor to the next, and the share of total cost that is avoidable will also vary. Some cost elements are reported by individual distribution network service providers (DNSPs) to the Australian Energy Regulator (AER), including

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[21] There is a common misconception that efficiency measures cannot be considered effective in reducing peak demand unless total system peak falls in absolute terms. However, the relevant ‘counterfactual’ is “What would the system peak be in the absence of this measure?” This is consistent with the overall ‘with/without’ methodology noted in Section 2.5.1.

[22] The lower the value, the higher the avoided peak demand.

augmentation network capital expenditure (‘augex’), but it would be difficult (and out of scope) to determine a suitable QLD -wide average from these sources.

The final benefit class was avoided greenhouse gas emissions. Here we apply a ‘shadow’ carbon price that seeks to represent the social cost associated with these emissions. We apply the ‘central policy scenario’ from the Climate Change Authority’s (undated) *Review of Targets and Progress #5*,[23] understood to relate to 2014, rebased to FY2022 dollars. We note that quantitative estimates of the Social Cost of Carbon (SCC) are currently being revised as part of the Inter-government Panel on Climate Change’s (IPCC’s) 6th Assessment Report process,[24] and it is widely expected that much higher ‘damage cost’ estimates will apply in future.

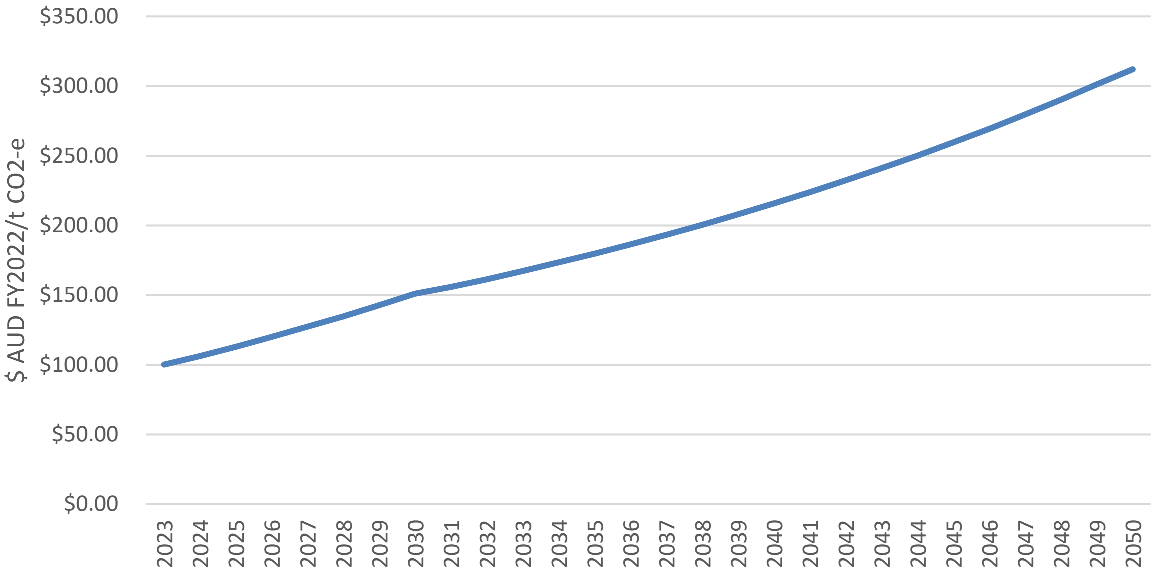

Figure 17: Shadow Cost of Carbon Assumptions (derived from the Australian Government Climate Change Authority)

An additional benefit of an improved envelope is that less air-conditioning installed capacity is now required to achieve the same comfort conditions, compared to the amount needed under QDC4.1. In practice, of course, air conditioner installers may tend to over-size systems but, even if that were the case, the ‘baseline’ around which sizing decisions are made is unequivocally lower under the NCC performance specifications. We estimate the avoided capacity for each archetype using the CLF methodology described above, as a function of the difference between the annual (space conditioning) energy consumption under QDC 4.1 and under NCC2019. As a gross average across all the archetypes and climate zones, the saving was around 0.7 kW per house. Based on current a/c pricing, we applied an average (avoided) cost/kW installed of $264. Thus, while this saving is not large on average, it does contribute to the overall benefits, as noted in Chapter 3.

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[23] http://climatechangeauthority.gov.au/targets-and-progress-review-5

[24] https://www.ipcc.ch/assessment-report/ar6/

Incremental construction costs were estimated for each archetype (in terms of quantities of materials) by the technical team, and then valued by quantity surveyors, Steele Wrobel, as detailed above. SPR then applied a similar process as above to aggregate cost up from the archetype level to the whole-of-economy level. That is, archetype-level incremental costs were multiplied by the archetype shares shown in Table 20 above. Noting that current costs in the construction sector are affected by global supply chain and inflationary pressures, we assume that incremental costs fall modestly from their current high levels, by 3% per year, over the next 5 years (that is, representing a total cost reduction from current levels of 15% by the end of 5 years).

To combine the above elements, the benefit cost analysis sums the annual benefits at the level of each individual archetype/climate zone, with each brought back to a 'present value' by discounting values that occur in the future (costs and benefits) at 7% real discount rate, in line with OBPR guidelines cited above. Similarly, the incremental costs expected to be experienced by each new dwelling archetype is summed and discounted back to a present value.

The two BCA indicators most commonly-reported are the net present value (NPV) of the measure and the benefit cost ratio (BCR). The NPV is simply the present value of the benefits *minus* the present value of the costs, and it is measured in dollars (or millions of dollars, in this case). NPV is a reliable indicator of the change in 'net social welfare' associated with a policy/regulatory measure. A positive NPV means that society as a whole would be better off if the measure were implemented, while a negative NPV means that the society as a whole would be better off if it were not implemented.[25] The larger the NPV, the greater the net social benefit. The BCR is the *ratio* of the present value of benefits to the present value of costs. As such as BCR is dimensionless. A BCR of 1 means that the present value of benefits is equal to the present value of costs. A BCR less than 1 indicates that the present value of costs is larger than the present value of benefits (so the NPV would be negative), while a BCR greater than 1 means that the present value of benefits is larger than the present value of costs (so the NPV would be positive).

BCR is less valid as an indicator of net social welfare, as its dimensionless nature can obscure the underlying values. For example, if there are two policy choices, and the first has a BCR of 5, and the second only 2, then there could a temptation to conclude that the first choice is the 'better'. However, the NPV of the first measure might be $1 million while the NPV of the second may be $100 million. This indicates that society would be (much) better off if the second policy choice were preferred, despite the lower BCR. However, this reality is obscured by the BCR metrics. We include BCR values in this report only because they are a required output, but we advise that decisions should be influenced by NPV values and not by BCR values. With NPV, the simple rule of thumb can be applied, 'the bigger the better'. This is not true of BCRs – even though this is a common misconception. As per our hypothetical example above, an option with a higher BCR can also have a lower NPV and should not be the preferred measure. Also, if an option has a very high BCR, it is generally the case that the impacts of that option will be small, with little difference from a 'without

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[25] As noted in the OBPR Guidelines, a positive NPV does not mean that *everyone* is better off; rather that

measure’ business-as-usual case. That is, the option in question would have little effect, even if the small effect it does have is cost-effective.

2.5.5 Elemental Benefit Cost Methodology

The elemental (DTS) benefit cost methodology is in almost every regard the same as that described above. The only differences are that:

1. We capture specific elemental (DTS) pathway incremental costs and savings at the archetype level from the technical team, as described above
2. We apply these costs and savings rates to the portion of the new construction task annual that a) is assumed to use the elemental (DTS) pathway (estimated at not more than 33%) and b) both costs and benefits are discounted for the share of the stock already shown the achieve or exceed 6 stars over the last 5 years (and therefore are assumed to incur no incremental costs or benefits as a result of the proposed regulatory change).

3. QDC4.1/NCC2019 Transition – NatHERS Pathway

3.1 Technical Analysis

3.1.1 Introduction

Each scenario in the NatHERS pathway analysis - in which a dwelling is upgraded from QDC 4.1 minimum standard to NCC 2019 minimum standard – is assessed individually and is assigned an individual code based on the following assignment of characteristics:

House Design Identifier + External Wall construction (where applicable) + Floor construction Identifier (where applicable) + Climate zone + Orientation + Location in Building (Class 2 only)

For example, the scenario with SBH03 with brick veneer walls, slab on ground, in Brisbane, with a south facing orientation has the code: SBH03LWCoGCZ2S.

Table 21: Scenario Codes and Identifiers for the NatHERS Pathway Analysis

Code Item	Identifiers
House Identifiers	SBH02 – single storey house SBH03 – double storey house SBA610 – internal apartment SBA630 – corner apartment THMid – middle townhouse THEnd – end townhouse
External Wall construction	LW – Lightweight Brick Veneer CB – Concrete Block Queens – Queenslander Style construction
Floor Construction	CoG – Concrete Slab on Ground Susp – Suspended timber floor Queens – Queenslander Style Construction
Climate Zone	CZ1 CZ2 CZ3 CZ5
Orientation	N – North E – East W – West S - South
Location in Building (Class 2 Only)	L – Lower Level M – Middle Level U – Upper Level

3.1.2 Calculating the QDC 4.1 Credit Cost

In moving from the QDC 4.1, 4.5 star rating + optional credits, to compliance with the NCC 2019 6-star standard, a proponent would no longer need to obtain the QDC 4.1 credits. In order to factor the cost savings of not having to achieve the QDC 4.1 credits, the costs of achieving those credits have been identified and isolated from the rest of the house construction costs as per Table 22.

Table 22: Calculation of QDC Credit Costs for the NatHERS Pathway

QDC Credit Item	Supply and Install Costs
Class 1 – Climate Zones 1,2 and 5	
Insulation to ceiling of outdoor living	$177.00
1kW PV system	$2350.00
Total QDC Credit Costs	**$2527.00**
Class 1 – Climate Zone 3	
Outdoor ceiling fan	$489.00
Insulation to ceiling of outdoor living	$177.00
Total QDC Credit Costs	**$666.00**
Class 2 – All climate zones	
Outdoor ceiling fan	$489.00
Insulation to ceiling of outdoor living	$177.00
Reed Switch	$633.00
Total QDC Credit Costs	**$1299.00**

3.1.3 Calculating the cost of upgrades

The example in Table 23 shows the specific upgrades costed for the scenario of SBH03 with the combination of lightweight brick veneer wall construction, and a concrete slab on ground, in CZ 1 with a South orientation.

Table 23: Example Calculation of the cost of upgrades

SBH03LW/CoGCZ1S Building Element	QDC 4.1 Scenario	QDC 4.1 Cost	NCC 2019 Scenario	NCC 2019 Cost	Cost Difference
External wall insulation	External Walls: None: None	$0.00	External Walls: Foil + bulk: Foil + R1.5	$3,700.13	$3,700.13
External wall colour		$0.00	Dark to medium	$0.00	$0.00
Internal wall insulation	Internal walls: None: None	$0.00	Internal walls: Int walls bulk: R1.5	$306.42	$306.42
Floor coverings					

SBH03LW/CoGCZ1S Building Element	QDC 4.1 Scenario	QDC 4.1 Cost	NCC 2019 Scenario	NCC 2019 Cost	Cost Difference
Ceiling insulation	Ceilings/Roofs: Ceiling bulk: R2.5	$2,303.72	Ceilings/Roofs: Ceiling bulk: R3.5	$2,719.98	$416.26
Roof insulation					
Roof colour					
Glazing	4Clr	$25,636.90	4Clr	$25,784.70	$147.80
External window shading 1					
External window shading 2					
Exhausts unsealed	3	$1,041.00	0	$0.00	-$1,041.00
Exhausts sealed	1	$364.60	4	$1,458.40	$1,093.80
Ceiling fan 900mm #					
Ceiling fan 1200mm #					
Ceiling fan 1400mm #					
Underfloor insulation					
Underfloor enclosure					
Intermediate floor insulation					
Roof space ventilation					
				Total	$4623.41

To explain the example in Table 23 above:

1. Only those building elements that were changed in the process of upgrading to NCC 2019, are included in the costing process.
2. The cost of the element in the QDC 4.1 scenario is the base cost.
3. Where the element is not present in the QDC Scenario, the base cost is therefore zero. In the example above there was no external wall insulation in the QDC 4.1 scenario but some was added for the NCC 2019 scenario, hence in this case, the cost of upgrade is the total supply and install cost of the R1.5 insulation + the foil faced sarking.
4. Where an item was already in place in the QDC 4.1 scenario, but is upgraded, only the cost of the upgraded material is included. In the example above the QDC 4.1 scenario includes R2.5 ceiling insulation, which is upgraded to R3.5 for the NCC 2019 scenario. In this case the cost difference is simply the material cost difference between R2.5 and R3.5 batts. This installation cost is not included because it was already included in the QDC scenario.
5. Glazing cost. Glazing cost may change because of the glazing specification, e.g. increase from clear single glazing to low-e single glazing, or may change due to the change in operability of some windows in the design. Increasing window operability was one strategy used to reduce overheating. In the example above, the glazing specification has stayed the same, as clear single glazing, but there is a small increase in the cost of the windows due to some windows being changed from fixed to operable.

6. Where a building element is not attributed a cost, such as many of the elements in the table above, it simply means that there was no change to that element in the process of upgrading from QDC 4.1 standard, to NCC 2019 standard, therefore there is no cost to account for. For example, there were floor coverings in both scenarios, but they did not change as part of the upgrade process in this particular example.
7. In some instances, there may be a cost reduction to be factored into the upgrade to the NCC 2019 scenario. In the example above it can be seen that unsealed exhaust fans are replaced with sealed exhaust fans. In this case the cost of the unsealed fans is removed, and the cost of the new sealed fans is added.
8. For some building elements, the upgraded strategy is a zero-cost strategy, for example roof colour. In the example above, the roof colour was changed from dark to mid coloured. This is noted in the table, but the cost of both scenarios is the same, so no cost difference is recorded.

Calculation of the final upgrade costs for each scenario is as per the following formula:

(Cost of upgraded elements in the NCC Scenario – Cost of elements in the QDC base scenario) – QDC Credit costs = Final Upgrade Costs

Table 24 presents an example of the calculation of upgrade costs for the 16 different scenarios of SBH03 with lightweight BV walls and a concrete slab on ground, in the 4 different climate zones and the 4 different orientations. The example scenario presented in Table 23 is highlighted in Table 24 below. Summary tables for all scenarios are presented in Appendix 0.

Table 24: Calculating the cost of upgrades - example of SBH03 with lightweight BV walls and a concrete slab on ground

House ID	QDC base costs	NCC upgrade costs	NCC – QDC Upgrade costs	QDC credit cost	Final Upgrade Costs
SBH03LW/CoGCZ1N	$27,042.50	$31,503.10	$4,460.60	$2,526.57	$1,934.03
SBH03LW/CoGCZ1E	$30,532.82	$35,757.08	$5,224.26	$2,526.57	$2,697.70
SBH03LW/CoGCZ1S	$29,346.22	$33,969.63	$4,623.41	$2,526.57	$2,096.84
SBH03LW/CoGCZ1W	$32,988.61	$37,601.67	$4,613.06	$2,526.57	$2,086.50
SBH03LW/CoGCZ2N	$34,122.56	$37,616.16	$3,493.59	$2,526.57	$967.03
SBH03LW/CoGCZ2E	$33,739.16	$39,584.55	$5,845.39	$2,526.57	$3,318.82
SBH03LW/CoGCZ2S	$28,981.49	$34,116.38	$5,134.89	$2,526.57	$2,608.32
SBH03LW/CoGCZ2W	$35,356.71	$40,259.65	$4,902.94	$2,526.57	$2,376.37
SBH03LW/CoGCZ3N	$35,999.57	$38,791.14	$2,791.57	$665.57	$2,126.00
SBH03LW/CoGCZ3E	$38,243.82	$46,408.61	$8,164.79	$665.57	$7,499.22
SBH03LW/CoGCZ3S	$36,168.26	$40,566.73	$4,398.47	$665.57	$3,732.90
SBH03LW/CoGCZ3W	$48,456.25	$61,246.84	$12,790.60	$665.57	$12,125.03
SBH03LW/CoGCZ5N	$29,022.42	$34,103.98	$5,081.56	$2,526.57	$2,555.00
SBH03LW/CoGCZ5E	$30,851.22	$36,437.45	$5,586.24	$2,526.57	$3,059.67
SBH03LW/CoGCZ5S	$32,983.53	$40,362.16	$7,378.63	$2,526.57	$4,852.07
SBH03LW/CoGCZ5W	$31,031.22	$36,497.45	$5,466.24	$2,526.57	$2,939.67

3.1.4 Calculating the Energy Benefits

The increased thermal performance of the dwellings under the 2019 NCC as compared to the QDC 4.1 produces some predicted savings to the household of heating and cooling energy. These saving vary according to the Climate Zone as summarised in Table 8. Calculation of the energy benefits to the household, flowing from the change from QDC 4.1 to NCC 2019 are calculated by the equation:

Heating and cooling energy demand reduction – lost benefit of PV production (if applicable).

Table 25 below presents an example of how the Energy benefits were calculated.

The Thermal Performance Assessment (TPA) is calculated for the QDC 4.1 scenario and the NCC 2019 scenario. The difference in MJ/m^2/yr is obtained and converted into MJ by multiplying by the conditioned floor area of the house. This is then converted into an amount of kWh/yr of predicted reduction in heating and cooling energy demand.

For scenarios in climate zones 1,2 and 5 a 1kW PV system is assumed to be installed as part of achieving the QDC 4.1 credits. For the 2019 NCC scenarios, this PV system is removed, therefore the benefit to the household of the energy produced by the PV system must also be removed.

PV Generation was calculated for the three separate locations of Cairns, Brisbane and Toowoomba in order to predict the kWh/yr of benefit being provided to households in those locations.

Table 25: Example of how energy benefits are calculated for SBH03

House ID	Conditioned area m2	QDC TPA MJ/m2 /yr	NCC TPA MJ/m2 /yr	Diff TPA MJ/m2 /yr	QDC TPA MJ/yr	NCC TPA MJ/yr	Diff TPA MJ/yr	Diff TPA kWh/yr	QDC Star Rating	NCC Star Rating	PV generation kWh/yr per 1kW of PV
SBH03LW/CoGCZ1N	179.5	166.3	127.3	39	29818	22855	6963	1934	4.5	6	1519
SBH03LW/CoGCZ1E	179.5	166.3	127.8	38.5	29843	22931	6912	1920	4.5	6	1519
SBH03LW/CoGCZ1S	179.5	166.6	127.9	38.7	29897	22958	6939	1928	4.5	6	1519
SBH03LW/CoGCZ1W	179.5	166.4	127.1	39.3	29872	22810	7062	1962	4.5	6	1519
SBH03LW/CoGCZ2N	179.5	61.8	42.8	19	11094	7680	3414	948	4.5	6	1560
SBH03LW/CoGCZ2E	179.5	61.6	42.7	18.9	11055	7659	3396	943	4.5	6	1560
SBH03LW/CoGCZ2S	179.5	61.6	42.5	19.1	11049	7635	3414	948	4.5	6	1560
SBH03LW/CoGCZ2W	179.5	61.4	42.8	18.6	11013	7688	3325	924	4.5	6	1560
SBH03LW/CoGCZ3N	179.5	113.6	86.9	26.7	20389	15600	4789	1330	5	6	0
SBH03LW/CoGCZ3E	179.5	112.8	86.4	26.4	20250	15499	4751	1320	5	6	0
SBH03LW/CoGCZ3S	179.5	113.5	86.7	26.8	20362	15566	4796	1332	5	6	0
SBH03LW/CoGCZ3W	179.5	113.9	86.9	27	20448	15592	4856	1349	5	6	0
SBH03LW/CoGCZ5N	179.5	109.6	77.5	32.1	19675	13906	5769	1603	4.5	6	1672
SBH03LW/CoGCZ5E	179.5	109.9	77.3	32.6	19716	13876	5840	1622	4.5	6	1672
SBH03LW/CoGCZ5S	179.5	108.9	77.1	31.8	19540	13840	5700	1583	4.5	6	1672
SBH03LW/CoGCZ5W	179.5	109.4	77.7	31.7	19676	13951	5725	1590	4.5	6	1672

3.2 Incremental Costs – by Archetype

3.2.1 Introduction

The thermal modelling undertaken as part of assessing the NatHERS pathway involved testing over 1000 iterations for the Class 1 designs, in four orientations, across 4 different climate zones, with differing floor and wall construction types. The process of, firstly refining the base models to achieve the QDC minimum 4.5/5.0 star ratings, and then secondly improving the models up to the NCC minimum 6.0 star rating, in the most cost-effective manner, lead to a number of trends being identified.

The different variables (Dwelling design, orientation, climate zone, floor type, wall type) all have an impact on how difficult it is to improve the thermal performance of a particular scenario. The difficulty in moving from QDC 4.5 star performance to NCC 6 stars for each individual scenario can be measured by the incremental cost of the upgrades required. The more expensive the upgrade costs the more difficult it is for a particular scenario to be improved to 6 stars.

The analysis below presents a breakdown of the incremental costs by the different variables. This analysis presents the simple average incremental cost increase (or decrease) per dwelling, in moving form QDC 4.1 (including credits) to NCC 2019 of each particular scenario.

3.2.2 Dwelling Design

Table 26 through Table 35 present some summary results for the 6 dwelling architypes assessed using the NatHERS verification pathway. The main variables presented are climate zone, orientation and floor/wall construction combinations. It should be noted that as per convention, negative values are presented in red, however, these indicate a reduction in the incremental construction cost which in this instance represents a benefit as a negative incremental cost is being incurred for that scenario.

It is important to remember that changes to the designs of the dwellings were not used as an improvement strategy in this study. The only changes made were ‘invisible’ changes to the building fabric. However, in many instances, tweaking the base building design to better suit climate and site orientation, may be the more cost-effective strategy for achieving a 6-star rating. As such, consideration should be given by the industry to test the thermal performance of a design early in the design process before all the elements are locked in, in order to achieve potentially more cost-effective solutions.

SBH03 – 2 storey archetype

Table 26 and Table 27 present some summary results for SBH03, the two-storey archetype. The two clear trends that can be seen here are that:

1) Orientation can make a big difference to the thermal performance of this design. The design has a higher proportion of glazing on one façade. When this façade is facing north, the design performs best. In other orientations, overheating and underheating increase, and typically the glazing specification needs to be increased to compensate.

2) Connection to the ground via a slab-on-ground, makes it considerably easier to achieve compliance. Where the dwelling design has a suspended ground floor, performance drops significantly, and upgrades to insulation are typically not enough to improve the

performance to NCC 6-star standard, so multiple upgrades are required, most notably to glazing.

This archetype has a smaller proportion of floor area to ground compared to SBH02, the single storey archetype. In Queensland climates generally, connection to the ground, and the thermal mass in a concrete slab, assists in maintaining comfortable temperature so single storey dwellings that are connected to the ground, tend to perform better than double storey dwellings.

The size of the dwelling also increases the cost of upgrades – for example in scenarios where glazing is upgraded, all glazing in the house is assumed to be upgraded. Hence for this house design there is a large amount of glazing. Similarly, there is a relatively large roof or external wall area which increases the cost of upgrading those elements.

Table 26: Average Incremental cost of SBH03 scenarios by climate zone and orientation

SBH03	North	East	South	West
CZ 1	$3,296	$11,157	$2,969	$4,666
CZ 2	$2,947	$4,208	$4,625	$4,214
CZ 3	$2,188	$6,466	$7,537	$10,135
CZ 5	$5,427	$9,885	$7,077	$8,590

Table 27: Average incremental cost of SBH03 Scenarios by climate zone and floor/wall construction type

SBH03	LW/CoG	LW/Susp	CB/CoG	CB/Susp
CZ 1	$2,204	$14,495	$2,254	$3,549
CZ 2	$2,318	$5,679	n/a	n/a
CZ 3	$6,371	$10,315	$3,968	$8,467
CZ 5	$3,352	$12,138	n/a	n/a

SBH02 – single storey archetype

Table 28 and Table 29 present summary results for SBH02, the single storey archetype. The two clear trends that can be seen here are that:

1) The upgrade costs are significantly less than the 2 storey archetype. Even though the two dwellings have a similar conditioned floor area, the single storey dwelling tends to perform better and be easier to upgrade. Many of the scenarios for SBH02 involve a

decrease in cost when complying with NCC 2019 compared to QDC 4.1, due to the subtraction of assumed QDC 4.1 credit costs.

2) The lightweight 'Queenslander' archetype is significantly more difficult to upgrade to 6 stars than the other construction types largely due to the lack of thermal mass and connection to the ground.

The standard SBH02 single storey design significantly benefits from having all living spaces connected to the ground in the concrete slab typology. This means the base specification of building elements in the QDC 4.5 / 5 stars versions is typically lower. For example, many QDC iterations had little insulation in the walls and therefore the upgrades in insulation were very cost effective. This is in contrast to the elevated floor types where the base 4.5 / 5 star version was significantly better insulated to begin with, requiring more costly upgrades such as glazing to achieve a 6 star rating.

Table 28: Average Incremental cost of SBH02 scenarios by climate zone and orientation

SBH02	North	East	South	West
CZ 1	-$3,201	-$2,873	-$2,917	-$1,751
CZ 2	$6,061	$5,153	$4,097	$82
CZ 3	$1,593	$2,308	-$893	-$233
CZ 5	$4,811	$4,310	$1,286	-$31

Table 29: Average incremental cost of SBH02 Scenarios by climate zone and floor/wall construction type

SBH02	LW/CoG	LW/Susp	CB/CoG	CB/Susp	Queenslander
CZ 1	-$2,971	-$856	-$1,883	-$5,643	-$2,076
CZ 2	-$1,593	$1,097	n/a	n/a	$ 12,040
CZ 3	-$752	-$2,058	-$3,045.63	-$1,005.90	$ 10,389
CZ 5	-$2,086	$582	n/a	n/a	$ 9,286

THMid – middle terrace townhouse

Table 30 and Table 31 present some summary results for THMid, the middle townhouse archetype. The two clear trends that can be seen here are that:

1) Given the terrace/townhouse typology, the design has all glazing concentrated on just two facades, meaning orientation makes a big difference to the thermal performance.

When this is facing in the optimum orientation, the design performs best. In other orientations, shading of windows and / or an increase in glazing specification is required to compensate.

2) Despite the sensitivity in orientation, the middle townhouse typology benefits from having neighbours on either side of it, meaning reduced areas of external envelope compared to the end townhouse typology and the detached dwellings. This meant external heat losses and gains were lower due to the buffering of the external environment provided by the neighbours. Additionally, upgrades to the external envelope were more cost effective when they were required given the smaller area.

Table 30: Average Incremental cost of TH-Mid scenarios by climate zone and orientation

THMid	North	East	South	West
CZ 1	-$2,025	-$1,295	-$1,740	-$1,745
CZ 2	-$1,070	-$513	$1,758	-$789
CZ 3	-$1,042	$2,754	-$270	$1,658
CZ 5	-$2,067	-$306	-$1,223	-$1,628

Table 31: Average incremental cost of TH-Mid Scenarios by climate zone and floor/wall construction type

THMid	LW/CoG	LW/Susp	CB/CoG	CB/Susp
CZ 1	-$1,595	-$1,998	-$1,966	-$1,245
CZ 2	-$252	-$55	n/a	n/a
CZ 3	$142	$390	-$503	$3,071
CZ 5	-$1,276	-$685	n/a	n/a

THEnd – end terrace townhouse

Table 32 and Table 33 present some summary results for THEnd, the end townhouse archetype. The two clear trends that can be seen here are that:

1) Similarly to the middle townhouse typology, orientation is a key factor in the performance of this design in spite of additional windows on the third façade. This is because the glazing is still largely concentrated on the two main facades. In poorer orientations,

glazing was a key factor that required improvement via additional shading and / or a better window specification.

2) The slab-on-ground versions of this typology consistently performed better than suspended timber floors. However, to fully benefit from this thermal coupling effect, the floor covering was often changed from the specified laminate floating floor of the original design to vinyl sheet flooring or tiles.

Two storey designs typically present more of a challenge in thermal performance than single storey designs of the same floor area as noted above. The townhouse typology is double-storey, however it has two main thermal benefits over the SBH03 detached two storey dwelling. The first is the adjacent neighbour which moderates the external climate on at least one side of the dwelling and means a smaller external envelope. The benefit of the intertenancy wall was evident in that any thermal improvements that were made to it through increased insulation, had a negative effect on the thermal loads. The second benefit is the smaller overall area of the dwelling meaning any upgrades amounted to fewer materials.

Table 32: Average Incremental cost of TH-End scenarios by climate zone and orientation

THEnd	North	East	South	West
CZ 1	-$921	$273	-$1,140	$534
CZ 2	-$396	-$959	$1,454	-$235
CZ 3	$1,318	$3,793	$1,113	$3,745
CZ 5	-$655	$2,091	$5,280	$1,727

Table 33: Average incremental cost of TH-End Scenarios by climate zone and floor/wall construction type

THEnd	LW/CoG	LW/Susp	CB/CoG	CB/Susp
CZ 1	$633	$432	-$80	-$2,239
CZ 2	-$690	$623	n/a	n/a
CZ 3	$1,236	$4,593	$662	$3,477
CZ 5	$1,835	$2,386	n/a	n/a

SBA610 and SBA630 - internal apartment and corner apartment

Table 34 and Table 35 present the average incremental cost for the apartment archetypes for the lower, middle and upper-level locations in the building. It can be seen that in the majority of cases a negative incremental cost has been achieved in the move to NCC 6-star compliance. These costs factor in the removal of building elements required for the QDC 4.1 credits.

A couple of factors to note in these results are:

1) The overall incremental costs, whether they by positive or negative, are small relative to the other dwelling types. This is because the dwellings themselves are smaller and have smaller areas of building fabric involved in upgrade strategies.
2) Typically, lower and upper unit locations perform poorer, all other things being equal in apartment designs. However, what this means is that certain strategies, for example roof insulation in the upper-level units or floor insulation to the lower-level unit, were often in place as part of the QDC base model. Therefore, when it came to upgrading the upper and lower-level dwellings these costs were already in place. Middle-level dwellings however, have less to work with in terms of upgrades, so are more reliant on glazing up grades, which tend to be more expensive, particularly for the SBA630 corner unit which has a higher proportion of glazing.

Table 34: Average Incremental cost of SBA610 scenarios by location with the building

SBA610	Lower	Middle	Upper
CZ 1	-$302	$300	-$852
CZ 2	-$584	-$297	-$72
CZ 3	-$563	-$1,173	-$308
CZ 5	-$745	-$1,225	-$1,246

Table 35: Average Incremental cost of SBA630 scenarios by location with the building

SBA630	Lower	Middle	Upper
CZ 1	-$465	$445	-$817
CZ 2	-$346	$1,177	-$72
CZ 3	-$115	-$735	-$8
CZ 5	-$549	-$1,121	-$533

3.2.3 Orientation

As previously identified, optimal orientation is by far the most cost-effective strategy to achieving the highest rating. Well-orientated designs in many instances required minimal improvement to the building fabric to bring the result up to 6 stars. This was particularly evident in designs where the window configuration favoured particular orientations, such as in the townhouse typology. In this instance, the difference in the base case between the best and worst orientated layouts was 1 star. Where windows were more evenly distributed around the facades, the difference was 0.5 stars.

The impact of orientation varied by climate zone, depending on the mix of heating and cooling required. In Climate Zone 2, 3 and 5 there was a greater range in incremental cost generally. In scenarios with more glazing to the north, and least to the east and west it was easier to comply such as when the townhouse typology was ideally orientated. As these climates are all both heating and cooling climates, balancing glazing across orientations assists with managing over and under heating in various orientations.

Climate Zone 1 was sensitive to orientation in situations where a higher proportion of glazing was facing east and west. This is because it is almost entirely a cooling climate and overheating was prevalent in less favourable orientations.

The impact of orientation was particularly evident in the different design, due to the varying placement of glazing across the facades. In summary:

1. SBH02 – the impact of orientation was not as pronounced in the single storey house because the windows relatively evenly spread out around the four facades as shown in Table 28.
2. SBH03 –the double storey house has a higher proportion of glazing on one façade which accounted for some difference in the impact of orientation as shown in Table 26.
3. THMid and THEnd – both townhouse typologies are sensitive to orientation as the glazing is predominantly located on two facades. Orientation alone made a 1-star difference to the base townhouse case as shown in Table 30 and Table 32.
4. SB610 – The middle apartment experienced the greatest impact of orientation in all four climate zones because the glazing is concentrated on one façade as shown in Table 29.

3.2.4 Glazing

Glazing represents one of the greatest challenges for thermal performance. Compared to an equivalent insulated section of wall, windows allow heat transfer at a much higher rate. Aluminium framed windows with clear single glazing are the preferred window type in new Queensland construction based on the CSIRO NatHERS AHD data set and were the starting point for all the typologies tested in this study. These tend to be the lowest performing in terms of U-value and Solar Heat Gain Coefficient (SHGC).

For a dwelling design with thermal mass (concrete slab on ground), well oriented glazing and a glass to floor area ratio below 25% single glazing can be sufficient to meet code requirements. However, in the absence of thermal mass such as in the suspended timber floor typologies or where the glass to floor area ratio is high, the performance of glass can have a significant negative impact on the thermal performance.

For the concrete slab on ground typologies tested in this study, glass improvements were rarely required, except in the two-storey house because of the higher incidence of overheating on the upper storey in the absence of thermal mass. The suspended timber floor typologies on the other hand typically required double glazing as the glass performance was a more significant factor in the absence of thermal mass.

The need for improved glazing varied by climate zone. In Climate Zone 1, 4mm clear glass in a standard aluminium frame was the standard used and even the worst performing typology, the Queenslander did not require an improvement to this specification. By contrast in Climate Zone 2, 3 and 5 the glazing specification progressively became the weakest thermal link as the climate became more extreme. This was particularly accentuated by the floor type, but generally Climate Zone 3 required a higher glazing specification more often than the milder Climate Zone 2.

Making upgrades to glazing specification is typically a more expensive option than others, therefore, upgrading a dwelling's glazing from clear to tinted, or low-e, or even to double glazing, was generally used as a last resort when other strategies had been already implemented. In these situations, the upgrade was necessary to achieve the minimum 6 star rating.

Identifying scenarios where glazing upgrades may be required early in the design process has the potential to reduce costs by allowing changes to be made to the design or having the cost factored in to avoid unexpected increases.

3.2.5 Climate Zones

The four different NCC climate zones present in Queensland all demand different strategies for dealing with thermal comfort. Strategies that work effectively in Climate Zone 1 in the tropics such as improving air movement, make little difference in dry hot Climate Zone 3 in Central Queensland.

One consistent feature noted across all climate zones is the impact of thermal mass. A concrete slab on ground with a floor covering such as tiles or thin vinyl that exposes the indoor air to the thermal mass is of benefit across Queensland. In every base scenario, the concrete slab on ground version outperformed the equivalent suspended timber floor, enclosed or otherwise. This effect was not as pronounced in Climate Zone 1, which is also the only region where the 'Queenslander' typology performed relatively well. See Table 27 and Table 29 for examples.

In spite of Climate Zone 1 having the largest required change in energy use of 39 MJ/m^2 per annum between a 4.5 star rating and a 6 star rating, this climate zone was the easiest to improve in a cost effective way as shown in Table 36. Light colours, ceiling insulation and air movement through ventilation openings and ceiling fans were very effective, low-cost options for improving the thermal performance. As the lightweight floors fared relatively well in this climate zone, it was less affected by the improvement costs experience in other regions. Notably, Climate Zone 1 is almost entirely a cooling climate, meaning that improvements in the building fabric only need to bring down the heat load and improve air movement to combat humidity.

Climate Zones 2, 3 and 5 are mixed climates to a varying degree. In these regions, both heating and cooling needs to be managed, meaning that improvements to balance the impact between heating and cooling. For example, in Climate Zone 2, additional shading over a window may reduce summer heat gain, thereby reducing cooling loads. But if at the same time, the shading prevents winter sun penetration, the heating load may be increased, and the overall benefit is negated. This was particularly the case in Climate Zone 2 and 5.

Colour is one of the elements that varies by climate in that there is no one ideal colour in Queensland and the selection should carefully consider the specific need for heating and cooling in particular in mixed heating / cooling regions. While in Climate Zone 1, a light roof proved the best option in almost every circumstance, other climates had differing results. In certain instances, a light roof worked against the model by decreasing cooling needs but increasing heating requirements. Wall colours tended to be less sensitive in their impact with the exception of uninsulated block walls. Generally, as insulation levels in the walls and underside of the roof are increased, the impact of colour selection decreases.

Climate Zone 3 often proved to be the most challenging to improve across all the typologies and construction types. The presence of thermal mass in the form of a concrete floor or concrete block external walls was one of the most significant positive thermal factors. The lightweight suspended floors in all typologies and the 'Queenslander' in particular, proved very costly to upgrade as shown in Table 36. This is due principally to the need for multiple upgrade strategies as previously identified and the improvement in glazing. Air movement made very little difference in this region meaning the relatively cost-effective improvement of addition of ceiling fans couldn't be used and other strategies were required. Most notably, the need to keep out the external temperature extremes meant the thermal properties of the glazing needed to be increased in this climate zone more often than in any of the other 3 regions.

Table 36: Comparison of average incremental costs for each typology in the four climate zones

	SBH02	Queens (SBH02)	SBH03	THEnd	THMid	SBA610	SBA630
CZ 1	-$2,838	-$2,076	$5,626	-$313	-$1,701	-$285	-$279
CZ 2	-$248	$12,040	$3,998	-$34	-$154	-$318	$253
CZ 3	-$1,715	$10,389	$7,280	$2,492	$775	-$681	-$286
CZ 5	-$752	$9,286	$7,745	$2,111	-$980	-$1,072	-$735

3.2.6 Construction Variations – Floors and Walls

A concrete slab on ground presents one of the best thermal outcomes in all climate zones in Queensland. The thermal mass of the slab in connection with the earth helps to moderate both heating and cooling loads across the year. Rooms that are used during the day such as living areas derive the greatest benefit from a concrete slab on ground. Careful consideration should be given to floor coverings to maximise the benefit of this construction. Namely, the thermal mass needs to be exposed to the indoor air with tiles or thin vinyl. The benefit is reduced when covered with timber, planking or carpet. This is one of the most effective thermal upgrades which can also reduce construction costs as was evident in numerous typologies.

The lack of thermal mass in suspended timber floors means the same design performs quite differently when the construction is a slab on ground. Insulation in the underfloor was almost always required to suspended floors, however, enclosing the sub floor and not insulating the sub-floor is one way to improve the thermal performance of a suspended timber floor.

The three key findings for the materials tested were:

1. A suspended floor makes the single biggest difference and causes the largest incremental costs in the move to 6 stars. This is not because of upgrades to the floor insulation, but because the poorer performance of houses with a suspended floor required more upgrades of other building elements, in order to improve to 6 stars.
2. The most extreme case of this is the 'Queenslander' archetype based on SBH02, in which the suspended floor is open underneath, and walls are lightweight with lightweight timber cladding as shown in Table 36.
3. Concrete block walls provide thermal mass benefits that are not offered by brick veneer construction. In many cases, concrete block walls performed sufficiently well without the need for any thermal insulation. In this instance the concrete block walls tended to be more sensitive to colour, meaning more overheating when they are dark versus light. None of the designs modelled had sufficient shading to fully offset this effect. However, when they need to be insulated, the incremental cost is higher than brick veneer due to the type of wall insulation for example EPS or the additional framing required for a block veneer type construction.

3.3 Economy-Wide Benefit Cost Analysis

3.3.1 Incremental Costs

Incremental costs (which include negative costs, or cost savings, in some cases) are incurred for all dwellings built over the expected life of the measure (FY2024 – FY2033). The stock of each archetype by climate zone is shown in Section 2.7 above, while the archetype level costs are discussed in Section 3.2 above.

SPR‘s stock turnover model calculates the incremental cost that would be incurred each year for each archetype by climate zone. Overall, the annual incremental cost is around $2.4 million, with a discounted[26] present value of $17.4 million. However, this result is an average two very different trends by building class. As noted in Section 0, incremental costs for the Class 2 archetype are mostly negative, although there are some exceptions. The simple average of the Class 1 incremental costs, across all climate zones, archetypes and orientations, is $1,575/dwelling, as compared to -$499 for the Class 2s.

That said, there are positive incremental costs in some cases, such as the mid-level corner apartment archetype in Climate Zone 2. Because this is a common archetype, this means that there are economy-wide costs modelled for Class 2s as a whole, despite cost savings for many. Overall, the present value of economy-wide costs for Class 2s is $4.3 million, while Class 1s total just over $13 million.

Table 38 shows the present value of costs for each combination of dwelling class, archetype/construction method and climate zone.

3.3.2 Fuel Savings

Electricity savings average over 1,500 MWh for each year that the measure applies (FY2024 – FY2033). However, since a new cohort of buildings is built each year, and the energy savings persist for the economic life of each dwelling (generally estimated at 50 years or more), the total savings accumulate over the FY2024 – FY2033 period, reaching 15,365 MWh/year by FY2033 and remaining at that level thereafter. The value of the annual savings varies over time as a function of expected electricity prices (Figure 16 in Section 2.7), reaching around $2.5 million in FY2033 and with a present value of $26.8 million.

Gas savings are much smaller, in volume and value terms, due to the limited use/distribution of this fuel in QLD. The present value of gas savings totals only some $677,000.

Table 38 also shows the present value of electricity and gas savings for each combination of dwelling class, archetype/construction method and climate zone.

3.3.3 Avoided Peak Demand

The peak demand that would be avoided, due to the improved thermal performance of house envelopes, and the ability to downsize heat pumps and other space conditioning equipment, provides a societal benefit that is additional to the energy consumption savings experienced by households. We estimate that by FY2033, avoided demand reaches 7 MW, and this benefit will persist for the economic lives of the dwellings built to a higher thermal performance standard. From the network’s point of view, there is an avoided cost known as ‘deferral’ of the need to invest in this capacity.

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[26] Recalling the default assumption is a 7% real discount rate.

It is important to note that this benefit is not invalidated by other, causally-unrelated factors that might cause growth in demand, such as overall economic and population growth, electrification, electric vehicles or other factors. Such factors will occur anyway, regardless of whether this mooted policy change happens or not, so the relevant question is what difference would this policy change make on its own, assuming all other 'business as usual' factors occur as expected?

The value of avoided or deferred demand is determined by the network cost per MW – confined to the 'avoidable' cost, sometimes referred to as the growth cost.[27] As noted in Chapter 2, this value is not a simple look-up, but is estimated based on targeted research by Energetics and UNSW. The present value of this benefit over time is estimated at $44.5 million.

Also, we note that this analysis is confined to electricity, given the limited distribution of natural gas to QLD households, and also due to the higher 'fixed' (or not avoidable) share of capital expenditure in the gas, cf the electricity, sector. In principle, the CLF methodology can, however, be applied to gas network investment.

3.3.4 Reduced Space Conditioning Capacity

While a relatively small benefit, the higher thermal performance of dwellings in principle enables the capacity of space conditioning to be reduced while achieving the same internal comfort conditions. As discussed in Chapter 2, households (or buildings) may choose to over-size space conditioning equipment, but this does not invalidate this benefit, as such over-sizing represents an avoidable cost that is created by the policy measure, regardless of whether builders/households choose to capture this benefit or not. On average, the higher-performance houses required 0.7 kW less space conditioning capacity than before, but up to 1.3 kW in Climate Zone 1. With an average value of around $264/kW, this represents a one-off savings of around $172/dwelling on average, but higher or lower depending upon the archetype and climate zone. In our analysis, the relevant values are deducted from the incremental costs, as reported in Section 3.3.1.

3.3.5 Avoided Greenhouse Gas Emissions

Greenhouse gas emissions are avoided annually with each cohort of dwellings built to the higher standard, taking into account the changing (falling) expected emissions intensity of electricity consumption over time. We note that it is also possible that the emissions intensity of gas consumption could change if green/biogases replace fossil methane, but we do not model this as uncertainties are high.

The cumulative emissions benefit peaks in FY2033 – the final year in which it is assumed that the measure will apply – at some 7,200 t CO_2-e. However, this value is expected to fall over time, as noted above, falling to just energy 5,000 t CO_2-e by 2050 – assuming that the emissions intensity of

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[27] Individual networks generally report their 'augex', or augmentation capital expenditure, but this is not likely to capture all of the avoidable costs, particularly post Australian Energy Regulator scrutiny of the efficiency of their overall cost structures. Augex is also highly variable from year to year, by investment/augmentation type, and from network to network.

electricity consumption falls as currently expected. If the reduction in intensity is slower than expected (see Figure 15, Chapter 2) the avoided emissions will be higher, and *vice versa*. The present value of these savings is estimated at $12.8 million, using the methodology described in Chapter 2. We note that, on the balance of probabilities, there is some risk that the transition to clean energy will be faster than currently assumed, leading to lower avoided emissions, but also that the value ascribed to avoided emissions will be higher in future – as climate change intensifies and the value of avoiding emissions becomes more apparent – and these two effects will tend to cancel each other out, meaning that the estimate is likely to remain reasonable over time, despite the uncertainties.

3.3.6 Overall Net Present Value and Benefit Cost Ratio

The net present value (NPV) of a measure can be thought as an overall indicator of its 'net social worth', or of the change in net social welfare that it is expected to induce. It sums the present values of all of the benefits, as noted above, and deducts the present value of the incremental costs. Benefit cost ratios (BCRs) express the sum of the present values of all benefits, *divided by* the incremental costs. BCRs are therefore 'dimensionless' and, our view, less reliable as a KPI than NPV. However, a BCR of 1 or more is considered cost-effective.

Table 37: Key BCA Indicators: QDC4.1 – NCC2019: NatHERS Pathway

NPV Summary	Modelled only
Present value of costs	$17,368,291
Present value of benefits	$84,672,304
Net Present Value	**$67,304,013**
Benefit Cost Ratio	**4.9**

Table 37 indicates that there is a very significant NPV associated with this measure, of over $67 million. That is, if NCC2019 were adopted in place of QDC4.1, and for those new dwellings that use the NatHERS pathway to verify compliance, there would be a net societal benefit of over $67 million. The present value of benefits exceeds the present value of incremental costs by almost 5 times.

3.3.7 Diversity of Results by Archetype and Climate Zone

The sections above summarise the average and overall results for the NatHERS verification pathway. However, as noted in the previous technical sections (3.1 and 3.2), results vary by climate zone, building class and construction type. Table 38 provides a detailed summary of KPIs at this disaggregated level, also disaggregating the benefit/cost type, and showing individual net present values (NPVs) and benefit cost ratios (BCRs) for each combination of class, type, construction method and climate zone.

Table 38: Detailed Results by Archetype and Climate Zone: QDC4.1 to NCC2019: NatHERS Pathway ($ FY2023 real)

Class	Dwelling Type	Construction Type	Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
House	1-storey	LW CoG	1	$441,334	$0	$733,984	$208,974	$1,384,292	-$730,692	$2,114,984	**negative cost**
House	1-storey	LW Susp	1	$68,200	$0	$113,423	$32,293	$213,915	-$40,673	$254,588	**negative cost**
House	1-storey	CB CoG	1	$1,548,631	$0	$2,575,531	$733,283	$4,857,444	-$1,748,425	$6,605,869	**negative cost**
House	1-storey	CB Susp	1	$241,007	$0	$400,819	$114,118	$755,943	-$733,044	$1,488,987	**negative cost**
House	2-storey	LW CoG	1	$169,501	$0	$281,897	$80,259	$531,657	$234,558	$297,099	**2.3**
House	2-storey	LW Susp	1	$26,995	$0	$44,895	$12,782	$84,672	$263,347	-$178,675	**0.3**
House	2-storey	CB CoG	1	$608,377	$0	$1,011,793	$288,069	$1,908,239	$860,614	$1,047,626	**2.2**
House	2-storey	CB Susp	1	$93,263	$0	$155,106	$44,160	$292,529	$219,288	$73,241	**1.3**
House	1-storey	Queens	1	$39,912	$0	$66,377	$18,898	$125,188	-$49,585	$174,773	**negative cost**
House	1-storey	LW CoG	2	$8,123,043	$0	$13,509,448	$3,846,288	$25,478,778	-$14,963,229	$40,442,008	**negative cost**
House	1-storey	LW Susp	2	$950,938	$0	$1,581,506	$450,272	$2,982,716	$921,952	$2,060,764	**3.2**
House	2-storey	LW CoG	2	$4,835,460	$0	$8,041,863	$2,289,607	$15,166,930	$15,411,294	-$244,364	**1.0**
House	2-storey	LW Susp	2	$564,804	$0	$939,327	$267,437	$1,771,568	$4,477,755	-$2,706,187	**0.4**
House	1-storey	Queens	2	$864,462	$0	$1,437,688	$409,325	$2,711,475	$10,841,255	-$8,129,780	**0.3**
House	1-storey	LW CoG	3	$101,420	$0	$168,670	$48,023	$318,113	-$71,699	$389,812	**negative cost**
House	1-storey	LW Susp	3	$46,576	$0	$77,461	$22,054	$146,092	-$79,091	$225,183	**negative cost**
House	1-storey	CB CoG	3	$18,801	$0	$31,268	$8,903	$58,972	-$45,285	$104,257	**negative cost**
House	1-storey	CB Susp	3	$8,669	$0	$14,417	$4,105	$27,191	-$8,056	$35,248	**negative cost**
House	2-storey	LW CoG	3	$30,625	$0	$50,933	$14,501	$96,060	$194,191	-$98,131	**0.5**
House	2-storey	LW Susp	3	$14,411	$0	$23,967	$6,824	$45,203	$150,952	-$105,749	**0.3**
House	2-storey	CB CoG	3	$5,932	$0	$9,866	$2,809	$18,607	$22,563	-$3,957	**0.8**
House	2-storey	CB Susp	3	$2,799	$0	$4,655	$1,325	$8,779	$23,415	-$14,637	**0.4**
House	1-storey	Queens	3	$11,393	$0	$18,948	$5,395	$35,736	$82,211	-$46,475	**0.4**
House	1-storey	LW CoG	5	$661,373	$316,260	$1,099,212	$362,589	$2,439,433	-$1,024,773	$3,464,206	**negative cost**
House	1-storey	LW Susp	5	$48,720	$23,297	$80,973	$26,710	$179,700	$10,658	$169,042	**16.9**
House	2-storey	LW CoG	5	$388,231	$185,647	$645,246	$212,842	$1,431,967	$1,122,924	$309,043	**1.3**
House	2-storey	LW Susp	5	$29,436	$14,076	$48,923	$16,138	$108,573	$325,072	-$216,499	**0.3**
House	1-storey	Queens	5	$67,604	$32,327	$112,359	$37,063	$249,354	$403,824	-$154,470	**0.6**
Townhouse	TH - end	LW CoG	1	$42,077	$0	$69,979	$19,924	$131,980	$19,311	$112,669	**6.8**
Townhouse	TH - end	LW Susp	1	$6,665	$0	$11,084	$3,156	$20,905	$1,679	$19,226	**12.4**
Townhouse	TH - end	CB CoG	1	$148,094	$0	$246,296	$70,123	$464,514	-$35,864	$500,378	**negative cost**
Townhouse	TH - end	CB Susp	1	$22,315	$0	$37,112	$10,566	$69,992	-$52,717	$122,709	**negative cost**
Townhouse	TH - mid	LW CoG	1	$63,579	$0	$105,738	$30,105	$199,421	-$109,921	$309,343	**negative cost**

Class	Dwelling Type	Construction Type	Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
Townhouse	TH - mid	LW Susp	1	$10,592	$0	$17,616	$5,016	$33,224	-$21,052	$54,276	**negative cost**
Townhouse	TH - mid	CB CoG	1	$224,492	$0	$373,354	$106,298	$704,144	-$453,815	$1,157,959	**negative cost**
Townhouse	TH - mid	CB Susp	1	$35,140	$0	$58,441	$16,639	$110,220	-$46,729	$156,948	**negative cost**
Townhouse	TH - end	LW CoG	2	$928,109	$0	$1,543,540	$439,463	$2,911,112	-$1,462,802	$4,373,914	**negative cost**
Townhouse	TH - end	LW Susp	2	$109,422	$0	$181,980	$51,812	$343,214	$117,691	$225,523	**2.9**
Townhouse	TH - mid	LW CoG	2	$1,390,609	$0	$2,312,723	$658,458	$4,361,790	-$947,347	$5,309,137	**negative cost**
Townhouse	TH - mid	LW Susp	2	$164,066	$0	$272,858	$77,686	$514,609	-$45,209	$559,819	**negative cost**
Townhouse	TH - end	LW CoG	3	$9,267	$0	$15,410	$4,388	$29,065	$14,207	$14,858	**2.0**
Townhouse	TH - end	LW Susp	3	$4,340	$0	$7,217	$2,055	$13,611	$27,076	-$13,465	**0.5**
Townhouse	TH - end	CB CoG	3	$1,659	$0	$2,760	$786	$5,205	$1,244	$3,961	**4.2**
Townhouse	TH - end	CB Susp	3	$752	$0	$1,250	$356	$2,357	$3,667	-$1,310	**0.6**
Townhouse	TH - mid	LW CoG	3	$14,202	$0	$23,618	$6,725	$44,545	$360	$44,185	**123.7**
Townhouse	TH - mid	LW Susp	3	$7,255	$0	$12,064	$3,435	$22,754	$2,334	$20,421	**9.7**
Townhouse	TH - mid	CB CoG	3	$2,536	$0	$4,217	$1,201	$7,954	-$2,152	$10,106	**negative cost**
Townhouse	TH - mid	CB Susp	3	$1,236	$0	$2,055	$585	$3,875	$4,819	-$944	**0.8**
Townhouse	TH - end	LW CoG	5	$76,582	$36,621	$127,281	$41,985	$282,469	$163,326	$119,144	**1.7**
Townhouse	TH - end	LW Susp	5	$5,763	$2,756	$9,578	$3,159	$21,256	$16,585	$4,671	**1.3**
Townhouse	TH - mid	LW CoG	5	$117,391	$56,135	$195,106	$64,358	$432,990	-$205,535	$638,526	**negative cost**
Townhouse	TH - mid	LW Susp	5	$8,953	$4,281	$14,880	$4,908	$33,022	-$9,176	$42,198	**negative cost**
Apartment	Apart - gnd		1	$529	$0	$879	$250	$1,658	-$479	$2,137	**negative cost**
Apartment	Apart - mid		1	$35,075	$0	$58,332	$16,607	$110,014	$22,608	$87,406	**4.9**
Apartment	Apart - top		1	$4,422	$0	$7,354	$2,094	$13,870	-$7,913	$21,783	**negative cost**
Apartment	Apart - gnd		2	$67,660	$0	$112,525	$32,037	$212,223	-$108,443	$320,665	**negative cost**
Apartment	Apart - mid		2	$2,824,462	$0	$4,697,366	$1,337,392	$8,859,220	$4,624,305	$4,234,915	**1.9**
Apartment	Apart - top		2	$382,832	$0	$636,689	$181,272	$1,200,793	-$144,593	$1,345,387	**negative cost**
Apartment	Apart - gnd		3	$136	$0	$226	$64	$427	-$99	$526	**negative cost**
Apartment	Apart - mid		3	$7,763	$0	$12,907	$3,676	$24,345	-$13,036	$37,381	**negative cost**
Apartment	Apart - top		3	$900	$0	$1,497	$426	$2,824	-$435	$3,259	**negative cost**
Apartment	Apart - gnd		5	$375	$3	$624	$178	$1,180	-$688	$1,869	**negative cost**
Apartment	Apart - mid		5	$14,229	$115	$23,663	$6,754	$44,762	-$49,076	$93,838	**negative cost**
Apartment	Apart - top		5	$2,426	$20	$4,035	$1,152	$7,633	-$5,160	$12,793	**negative cost**
Totals				**$26,747,820**	**$671,537**	**$44,482,812**	**$12,770,135**	**$84,672,304**	**$17,368,291**	**$67,304,013**	**4.9**

Note that BCRs are not meaningful when the change in cost is negative; that is, where there is a reduction in the construction cost. These examples are indicated by red negative values in the Present Value of Incremental Costs column, and 'negative cost' in the BCR column. Similarly, where the NPV is negative, this indicates that the particular combination of class, type, construction method and climate zone is not modelled to be cost effective. NPV values are again shown in red, in these cases and, by definition, the BCRs will be less than 1.

Overall, these results indicate:

- 33 out of 65 of the combinations shown in Table 38 have a negative cost – that is, construction costs are modelled to be lower under NCC2019 than under QDC4.1
- When these 33 are weighted by their archetype shares in the annual construction task, more than 58% of all new dwellings impacted by this measure (ie, those using the NatHERS verification pathway and not already achieving or exceeding 6 stars) show an absolute reduction in construction costs under NCC2019, cf QDC4.1[28]
- These 58% of new dwellings that experience a reduction in construction costs also generate gross benefits (fuel cost savings, avoided infrastructure costs, avoided emissions costs) with a present value of more than $70 million – essentially as a free good (strictly, not just free, but negative cost) associated with this change
- The construction-weighted share of new dwellings constructed that experience a BCR less than 1 (that is, that are assessed as not cost-effective) is 8.7%, and these experience a combined net social loss of $11.9 million
- The final cohort is those dwellings that achieve cost effective, but not negative cost, savings (that is, they have a BCR > 1). These represent a construction-weighted share of just under 33% of all new dwellings constructed, and together they achieve a net benefit of $8.8 million.

Summarising this distributional analysis, Table 39 indicates that 91.3% of the new dwellings impacted by this measure (ie, those choosing the NatHERS verification pathway and not already achieving 6 stars or more) would experience a net social gain, with that gain valued at $79.2 million, while 8.7% would experience a net social loss, with the value of that loss being $11.9 million.

Table 39: Distributional Analysis: QDC4.1 to NCC2019: NatHERS Pathway ($ FY2023 real)

	Share	Net Present Value ($ FY 2023 real)
Net social gain	91.3%	$79,218,655
Net social loss	8.7%	-$11,914,642
Net present value	**100.0%**	**$67,304,013**

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[28] Note that this does not imply that *any* or *every* Class 2 dwelling will experience a reduction in capital costs, but it does imply this will occur *on average*.

For a more summary overview of the diversity of results, we also provide summary tables for each key variable. Table 40, for example, shows that a change from QDC4.1 to NCC2019 would be cost-effective (or negative cost) for all housing classes. Table 41 shows that the same change would be cost-effective or negative cost in all climate zones. Table 42 shows that the change would be highly cost effective for Class 1s with concrete slab on ground construction, cost-effective (but less so) for those with suspended timber floors, but not cost effective for the ‘Queenslander’ archetype modelled. This is due to the significant combination of upgrades required to the ‘Queenslander’ archetype and in particular due to the glazing improvements necessary to counter the lack of thermal mass in the lightweight structure. Finally, Table 43 indicates that the change is modelled to be cost-effective or negative for all archetypes, with the exception that the BCR for the Class 1, 2-storey archetype, is just under 1, at 0.9.

Table 40: Summary Results by Building Class: QDC4.1 to NCC2019: NatHERS Verification Pathway ($ FY2023 Real)

Class	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
House	$20,011,917	$571,607	$33,280,558	$9,565,046	$63,429,127	$16,071,322	$47,357,805	3.9
Townhouse	$3,395,094	$99,792	$5,646,156	$1,623,185	$10,764,227	-$3,020,021	$13,784,248	negative cost
Apartment	$3,340,809	$138	$5,556,099	$1,581,904	$10,478,950	$4,316,990	$6,161,960	2.4
Totals	**$26,747,820**	**$671,537**	**$44,482,812**	**$12,770,135**	**$84,672,304**	**$17,368,291**	**$67,304,013**	**4.9**

Table 41: Summary Results by Climate Zone: QDC4.1 to NCC2019: NatHERS Verification Pathway ($ FY2023 Real)

Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
1	$3,830,198	$0	$6,370,012	$1,813,612	$12,013,822	-$2,409,503	$14,423,325	negative cost
2	$21,205,866	$0	$35,267,513	$10,041,048	$66,514,427	$18,722,626	$47,791,801	3.6
3	$290,672	$0	$483,405	$137,637	$911,714	$307,187	$604,527	3.0
5	$1,421,084	$671,537	$2,361,882	$777,837	$5,232,341	$747,980	$4,484,361	7.0
Total	**$26,747,820**	**$671,537**	**$44,482,812**	**$12,770,135**	**$84,672,304**	**$17,368,291**	**$67,304,013**	**4.9**

Table 42: Summary Results by Construction Type (Class 1 only): QDC4.1 to NCC2019: NatHERS Verification Pathway ($ FY2023 Real)

Construction Type (Class 1)	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
LW CoG	$17,392,803	$594,662	$28,924,649	$8,328,488	$55,240,602	-$2,355,828	$57,596,430	negative cost
LW Susp	$2,067,135	$44,410	$3,437,753	$985,737	$6,535,034	$6,119,900	$415,134	1.1
Queens	$983,371	$32,327	$1,635,373	$470,682	$3,121,753	$11,277,705	-$8,155,952	0.3
Total	**$19,459,938**	**$639,072**	**$32,362,401**	**$9,314,225**	**$61,775,636**	**$3,764,072**	**$58,011,564**	**16.4**

Table 43: Summary Results by Archetype: QDC4.1 to NCC2019: NatHERS Verification Pathway ($ FY2023 Real)

Archetype	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
1-storey	$13,242,082	$371,884	$22,022,086	$6,328,292	$41,964,344	-$7,234,652	$49,198,995	negative cost
2-storey	$6,769,835	$199,723	$11,258,472	$3,236,754	$21,464,783	$23,305,973	-$1,841,190	0.9
TH - end	$1,355,044	$39,376	$2,253,486	$647,772	$4,295,679	-$1,186,598	$5,482,277	negative cost
TH - mid	$2,040,049	$60,416	$3,392,670	$975,413	$6,468,548	-$1,833,423	$8,301,971	negative cost
Apart - gnd	$68,700	$3	$114,255	$32,530	$215,488	-$109,709	$325,197	negative cost
Apart - mid	$2,881,528	$115	$4,792,269	$1,364,430	$9,038,342	$4,584,801	$4,453,541	2.0
Apart - top	$390,581	$20	$649,575	$184,944	$1,225,120	-$158,102	$1,383,222	negative cost
	$26,747,820	**$671,537**	**$44,482,812**	**$12,770,135**	**$84,672,304**	**$17,368,291**	**$67,304,013**	**4.9**

3.4 Summary and Conclusions

Overall, a move from QDC4.1 to NCC2019, for the share of new construction that uses the NatHERS verification pathway, would be highly cost-effective – even before considering the hot water provisions (see Chapter 5). The BCR is 4.9, meaning that total benefits are valued almost 5 times more the total incremental costs – and with a *net* economic benefit for the state of $67.3 million, measured at a 7% real discount rate. The measure would also realise peak avoided greenhouse gas emissions of a little over 7,200 t CO_2-e per year in FY2033, and a cumulative lifetime total for the FY2024 – FY2033 cohort of some 221,000 t CO_2-e. As noted, peak electrical demand in QLD would be around 7 MW lower than otherwise each year due the change in the peak demand of the NatHERS cohort. A summary of the key contributors to these results is shown in Table 44, rounded to the nearest $'000.

Table 44: Summary of the Present Value of Costs and Benefits (and Benefit Cost Ratio): QDC4.1 vs NCC2019: NatHERS Verification Pathway (7% real discount rate)

Benefit/Cost Element	Net Present Value ($ FY2023 real)	**Benefit Shares (%)**
Avoided Electricity Costs	$26,748,000	32%
Avoided Gas Costs	$672,000	1%
Avoided Electricity Infrastructure Costs	$44,483,000	53%
Avoided GHG Emissions Costs	$12,770,000	15%
Total Benefits	**$84,673,000**	**100%**
Incremental Construction Costs	$17,368,000	
Net Benefit (Net Present Value)	**$67,305,000**	
Benefit Cost Ratio	**4.9**	

Table 38 to Table 43 above provide a highly detailed picture of how these overall results vary by climate zone, modelled archetype, building class and construction type. They indicate that the move to NCC2019 would be:

- cost-effective for every building class
- cost effective for every climate zone in QLD
- cost effective for all archetypes except the Queenslander modelled
- cost effective for all house, townhouse and apartment archetypes, except for the 2-storey detached dwelling (which was almost cost-effective at BCR = 0.9).

While there is a clear net benefit associated with this change, the scale of the impacts (costs and benefits) is reasonably modest, as the mooted changes in moving from QDC4.1 to NCC2019 are themselves not large on average. For example, the average change in the thermal load across the dwelling archetypes, from QDC4.1 to NCC2019, is just under 30 MJ/sqm.a. However, given the prevalence of electric heat pumps (air conditioners) in the new dwelling stock, the change in energy consumption is reduced by the high energy efficiency of these devices.

Also, as noted in Chapter 2, some 74% of new Class 1 dwellings and 68% of Class 2 dwellings already meet 6 star or better, well above QDC4.1 or NCC2019 minimum requirements. Interestingly, these values rise to 83% and 86% respectively in Climate Zone 1, where climate conditions are most severe, revealing a market preference for better, and above regulatory minimum, thermal performance levels, particularly in the more severe climates. We recall from Chapter 2 that we ascribe no *incremental* or additional costs or benefits to these dwellings that are already performing above minimum requirements. Of course, these dwellings are experiencing significant net benefits, compared to dwellings that are minimally-compliant with QDC4.1, but we do not attribute these net benefits to the proposed new measure (NCC2019), as they are already being achieved without it in place.

The average incremental cost per dwelling upgraded, across all the archetypes, climate zones and dwelling orientations is $1,360, or $7.29/sqm, equivalent to less than 0.2% of the cost of a $700,000 house, for example. However, this cost is not incurred by all new dwellings. Only some 67% of new dwellings in QLD use the NatHERS verification pathway and, on average, over 71% of these already achieve 6 stars or better. We estimate that just under 70,000 dwellings would be improved by this measure (excluding those using the elemental (DTS) pathway, which is covered in Chapter 4) over the 10-year implementation period, out of the almost 245,000 dwellings expected to be constructed over this period.

Across all the archetypes, the annual energy savings average over $77 per dwelling, based on current electricity prices, while the annual increment to a mortgage would be less than $65 per dwelling on average, at a 5% real interest rate. Thus, on average, householders would be ahead, in cashflow terms, from Year 1, as well deliver the societal (emissions and network) benefits noted.

3.4.1 Overall Conclusions

We conclude that there is a clear and very significant net benefit for QLD for the proposal to move from QDC4.1 to NCC2019 using the NatHERS verification pathway. Net benefits occur for all dwelling classes and climate zones and for most archetypes/construction type combinations. That said, not all design/construction combinations perform equally well, and there would be both private and societal benefit if actual construction practice were to evolve in the direction of the more cost-effective options.

4. QDC4.1/NCC2019 Transition – Elemental (DTS) Pathway

4.1 Technical Analysis

4.1.1 Introduction

Analysis of the upgrade cost based on the elemental pathway – also known as deemed-to-satisfy or DTS – is essentially a comparison of BCA 2009 energy efficiency provisions, with those same provisions in the NCC 2019 (refer back to the discussion in Section 2.3). Class 2 is not assessed under the elemental pathway in NCC2019.

The scenarios in the elemental pathway analysis are assigned an individual code based on the following characteristics:

> *House Design Identifier + External Wall construction (where applicable) + Floor construction Identifier (where applicable) + Climate zone.*

Table 45: Scenario Codes and Identifiers for the Elemental Pathway Analysis

Code Item	Identifiers
House Identifiers	SBH02 SBH03 THMid THEnd
External Wall construction	LW – Lightweight Brick Veneer CB – Concrete Block Queens – Queenslander Style construction
Floor Construction	CoG – Concrete Slab on Ground Susp – Suspended timber floor Queens – Queenslander Style Construction
Climate Zone	CZ1 CZ2 CZ3 CZ5

Orientation is not analysed for each individual scenario except in relation to glazing requirements. Refer Section 4.2.3 for more detailed discussion on orientation and how it effects glazing requirements when assessing via the elemental pathway.

4.1.2 Calculating the QDC 4.1 Credit Cost

QDC Credit costs were calculated in the same way as for the NatHERS pathway analysis, but for the elemental pathway it is simpler because all climate zones have the same options, requiring 1.0 star worth of credit. The combined cost of the insulation to the ceiling of the outdoor living area and outdoor ceiling fan were lower than the cost of a 1kW PV system therefore these were the upgrades that were used.

Table 46: QDC Credit costs - Elemental Pathway

QDC Credit Item	Supply and Install Costs
Class 1 – All Climate Zones	
Insulation to ceiling of outdoor living	$177.00
Outdoor ceiling fan	$489.00
Total QDC Credit Costs	**$666.00**

4.1.3 Calculating the Cost of Upgrades

The elemental pathway to compliance with the NCC Energy Efficiency measures requires each individual elemental (DTS) provision to be complied with. In essence, each provision is treated individually of any other provision. Therefore, establishing the cost of each individual upgrade comes down to the comparison of each NCC 2019 provision with the corresponding BCA 2009 provision. The total cost of upgrades, is then calculated by the simple summing of each of the individual elemental (DTS) upgrades.

The cost of each upgrade is calculated in the same way as for the NatHERS pathway as per the following formula:

(Cost of upgraded elements in the NCC 2019 Scenario – Cost of elements in the BCA 2009 base scenario) – QDC Credit costs = Final Upgrade Costs

Table 47 presents an example of the costing of upgrades for SBH03 with lightweight BV walls, and a concrete slab on ground in Climate Zone 1.

Table 47: Example calculation of the cost of upgrades - Elemental Pathway

NCC Clause	SBH03LWCoGCZ1			
	Item	Area (m2)	Item No	Incremental Upgrade Cost
3.12.1.2 Roofs	Increased roof insulation R2.5 to R3.5	151.8		$416.54
3.12.1.4 External Walls	additional R1.0 wall insulation	223.3		$1,604.04

NCC Clause	SBH03LWCoGCZ1			
3.12.2.1 External Glazing	single tinted to double glazed, low-e tinted	59.3		$8,895.00
3.12.3.4 Exhaust Fans	self-closing damper to exhaust fans in bathrooms		4	$70.40
	Upgrades - Total Cost			$10,985.98
	Remove insulation to outdoor living area ceiling			$177.00
	Remove cost of outdoor fan			$489.00
	Upgrade Cost - QDC Credits			$8,229.00

Explanation of the example table above:

1. As per the NatHERS verification pathway methodology, only those building elements that were changed in the process of upgrading from BCA 2009 to NCC 2019, are included in the costing process. The cost of the element in the QDC 4.1 scenario (BCA 2009) is the base cost.
2. Where an item was already in place in the QDC 4.1 scenario, but is upgraded, only the cost of the upgraded material is included. In the example above the QDC 4.1 scenario includes R2.5 ceiling insulation, which is upgraded to R3.5 for the NCC 2019 scenario. In this case the cost difference is simply the material cost difference between R2.5 and R3.5 batts. The installation cost is not included because it was already included in the QDC scenario.
3. Where an item is not already in place in the QDC 4.1 scenario, the material cost + install costs are both included. For example, in some climate zones in some scenarios, wall insulation was not required in BCA 2009, but is not required in NCC 2019.

Roof/Ceiling Insulation

Roof/ceiling upgrades from BCA 2009 to NCC 2019 essentially involve an increase in the Total R value required to be achieved for the roof/ceiling construction. In all cases tested added insulation was already a requirement under BCA 2009, so the incremental cost increase is that of increased material cost only.

External Wall insulation

External wall upgrades from BCA 2009 to NCC 2019 essentially involve an increase in the Total R value required to be achieved for the wall construction. In all cases tested added insulation was already a requirement under BCA 2009, so the incremental cost increase is that of increased material cost only. This applied in both, the case of concrete block walls and brick veneer walls.

Some simplification was undertaken where there are options for different R values for walls of differing orientations and shading in some climate zones. It was assumed that the same level of insulation would be applied to all walls of the house. This was assumed for both the BCA 2009 and NCC 2019 scenarios.

Floor Insulation

Added floor insulation is not required for concrete slab on ground construction in any climate zones of Queensland, in either the BCA 2009 or the NCC 2019, unless an in-slab heating system is present. As these are very rare in Queensland, it was assumed that no insulation would be required in any of the typologies.

For suspended floors there was no requirement for underfloor insulation in any Climate Zone in Queensland under BCA 2009. Therefore, there has been an increase in the Total R value required to be achieved by the floor construction requiring an upgrade from BCA 2009 to NCC 2019 including both materials and labour.

Glazing

The stringency of glazing provisions was increased significantly between the BCA 2009 and NCC 2019. However, the required glazing specification is based on the size, orientation, and shading provided to the windows of the house, so the required specification may vary markedly for the same dwelling design in different orientations and / or climate zones. Only the cost difference in window specification was factored into the upgrade costing windows were assumed to be the same size frequency for the BCA 2009 and NCC 2019 scenarios.

Sealing of exhaust fans

The NCC 2019 introduces the need for self-closing mechanisms to exhaust fans. The incremental upgrade cost of these, was taken as the cost difference between an exhaust fan without a self-closing mechanism, and one with a self-closing mechanism. The same number of exhaust fans was assumed in the BCA 2019 and NCC 2019 scenarios.

4.1.4 Calculating the Energy Benefits

The increased thermal performance of dwellings under the NCC 2019, compared to the BCA 2009, produces some predicted savings to the household, of heating and cooling energy. Exact savings are not predicted when the elemental pathway is used. In lieu of this, the predicted energy savings based on equivalent NatHERS ratings have been used as the energy savings for the elemental pathway analysis. The performance of dwellings in all climate zones moves from 5 stars to 6 stars. The predicted amount of heating and cooling energy saved due to the upgrade to 6 stars varies depending on the Climate Zone and the size of the house, as seen in Table 48.

Table 48: Predicted energy savings for all dwelling archetypes under the Elemental Pathway

House ID	Conditioned area m2	QDC TPA MJ/m2	NCC TPA MJ/m2	QDC TPA MJ	NCC TPA MJ	Diff TPA MJ	Diff TPA kWh/yr	QDC Star Rating	NCC Star Rating
SBH03LWCoGCZ1DTS	179.5	153	128	27463.5	22976.0	4487.5	1246.5	5	6
SBH03LWCoGCZ2DTS	179.5	55	43	9872.5	7718.5	2154.0	598.3	5	6
SBH03LWCoGCZ3DTS	179.5	114	87	20463.0	15616.5	4846.5	1346.3	5	6

House ID	Conditioned area m2	QDC TPA MJ/m2	NCC TPA MJ/m2	QDC TPA MJ	NCC TPA MJ	Diff TPA MJ	Diff TPA kWh/yr	QDC Star Rating	NCC Star Rating
SBH03LWCoGCZ5DTS	179.5	98	78	17591.0	14001.0	3590.0	997.2	5	6
SBH02LWCoGCZ1DTS	248.3	153	128	37989.9	31782.4	6207.5	1724.3	5	6
SBH02LWCoGCZ2DTS	248.3	55	43	13656.5	10676.9	2979.6	827.7	5	6
SBH02LWCoGCZ3DTS	248.3	114	87	28306.2	21602.1	6704.1	1862.3	5	6
SBH02LWCoGCZ5DTS	248.3	98	78	24333.4	19367.4	4966.0	1379.4	5	6
THendLWCoGCZ1DTS	130.89	153	128	20026.2	16753.9	3272.3	909.0	5	6
THendLWCoGCZ2DTS	130.89	55	43	7199.0	5628.3	1570.7	436.3	5	6
THendLWCoGCZ3DTS	130.89	114	87	14921.5	11387.4	3534.0	981.7	5	6
THendLWCoGCZ5DTS	130.89	98	78	12827.2	10209.4	2617.8	727.2	5	6
THmidLWCoGCZ1DTS	130.89	153	128	20026.2	16753.9	3272.3	909.0	5	6
THmidLWCoGCZ2DTS	130.89	55	43	7199.0	5628.3	1570.7	436.3	5	6
THmidLWCoGCZ3DTS	130.89	114	87	14921.5	11387.4	3534.0	981.7	5	6
THmidLWCoGCZ5DTS	130.89	98	78	12827.2	10209.4	2617.8	727.2	5	6

No photovoltaic system (PV) benefits are discounted under the elemental pathway because a PV system was assumed not be used as part of the QDC credits, hence there was no benefit provided by a PV system under the QDC 4.1 scenario.

4.2 Incremental Costs

The different variables (Dwelling design, CZ, floor type, wall type) all have an impact on how difficult it is to improve the thermal performance of a particular scenario. The difficulty in moving from BCA 2009 performance to NCC 2019 for each individual scenario can be measured by the incremental cost of the upgrades required. The more expensive the upgrade costs the more difficult it is for a particular scenario to be improved to NCC 2019.

The analysis below presents a breakdown of the incremental costs by the different variables. This analysis presents the simple average incremental cost increase (or decrease) in moving form QDC 4.1 (BCA 2009, including required credits) to NCC 2019 for each particular scenario.

4.2.1 Dwelling Design

In contrast to the NatHERS verification pathway which had a dynamic interplay of factors, the results from the Elemental Method are more straightforward to interpret.

SBH03 – double storey house

Table 49 presents some summary results for SBH03, the two-storey house archetype. The two clear trends that can be seen here are that:

1) The two-storey typology needs a significant improvement to glazing due to the suspended floor on the second level. This has a significant impact on the incremental cost. In Climate

Zone 3 and 5 where the cost is counterintuitively lower than in Climate Zone 1 and 2, this has occurred because the glazing specification required under BCA 2009 was at a higher level to begin with. The incremental cost therefore of moving to NCC 2019 was the difference between a medium performance glass to a high-performance glass.

2) The scenarios that involve construction with a slab on ground do not appear to gain benefit from this construction method under the elemental pathway, as compared to the NatHERS pathway. The impact of the two-storey design and suspended upper floor means there is little difference in the incremental cost of the slab on ground scenario and the suspended ground floor scenario.

Table 49 Average incremental cost of SBH03 Double Storey House Scenarios by climate zone and floor/wall construction type

SBH03	LW/CoG	LW/Susp	CB/CoG	CB/Susp
CZ 1	$10,320	$11,566	$10,320	$11,566
CZ 2	$10,320	$11,566	n/a	n/a
CZ 3	$4,983	$6,229	$3,379	$6,229
CZ 5	$4,983	$6,229	n/a	n/a

SBH02 – single storey house

Table 50 presents some summary results for SBH02, the single storey house archetype. The two clear trends that can be seen here are that:

1) SBH02 benefits from being a single storey archetype and displays the same pattern of incremental cost upgrades as in the NatHERS verification pathway in that the concrete slab on ground construction method is more cost effective than the suspended floor construction.

2) In contrast to the NatHERS verification pathway, the Elemental Method does not distinguish between the brick veneer clad suspended floor version and the 'Queenslander' typology. The costs of upgrades are the same because the same elements are present in both construction scenarios.

Table 50 Average incremental cost of SBH02 Single Storey House Scenarios by climate zone and floor/wall construction type

SBH02	LW/CoG	LW/Susp	CB/CoG	CB/Susp	Queenslander
CZ 1	$1,129	$3,877	$1,129	$3,877	$3,877
CZ 2	$1,129	$3,877	n/a	n/a	$3,877
CZ 3	$1,129	$5,375	$1,129	$5,375	$5,375
CZ 5	$2,627	$6,873	n/a	n/a	$6,873

THMid – middle terrace townhouse

Table 51 presents some summary results for THMid, the middle townhouse archetype. The two clear trends that can be seen here are that:

1) The suspended floor typologies in all climate zones are significantly more expensive to upgrade, because of two factors. The first is the additional cost of insulation. While the second is the added improvement in the window specification required by the glazing calculator because of the suspended floor.
2) The middle townhouse typology benefits from having neighbours on either side of it, meaning reduced areas of external envelope compared to the end townhouse typology. In this instance heat losses / gains are not directly factored as they are in the NatHERS verification pathway, but the upgrades to the external envelope are more cost effective given the smaller area.

Table 51 Average incremental cost of THMid Middle Townhouse Scenarios by climate zone and floor/wall construction type

THMid	LW/CoG	LW/Susp	CB/CoG	CB/Susp
CZ 1	$126	$769	$126	$769
CZ 2	$1,644	$2,287	n/a	n/a
CZ 3	$2,679	$3,322	$2,679	$3,322
CZ 5	$1,644	$2,287	n/a	n/a

THEnd – end terrace townhouse

Table 52 presents some summary results for THEnd, the middle townhouse archetype. The two clear trends that can be seen here are that:

1) In spite of being a two-storey typology, the townhouse does not require the same level of improvements to glazing as the two-storey house, and therefore has a significantly lower incremental upgrade cost. This is due to the lower glass to floor area ratio on the second level of the townhouse meaning higher performance windows were not required.
2) The small difference in cost between the middle and end townhouse typologies in all instances is attributable to the increased external wall area of the end townhouse. As the upgrades are calculated by increasing the R value of the insulation and calculating the per m^2 cost, the impact of the additional external wall is only accounted for in additional insulation not the dynamic heat flows through it.

Table 52 Average incremental cost of THEnd End Townhouse Scenarios by climate zone and floor/wall construction type

THEnd	LW/CoG	LW/Susp	CB/CoG	CB/Susp
CZ 1	$439	$1,030	$439	$1,030
CZ 2	$2,276	$3,869	n/a	n/a
CZ 3	$2,944	$3,535	$2,944	$3,535
CZ 5	$2,312	$2,903	n/a	n/a

4.2.2 Building Elements

Each of the building elements has been assessed separately and contributes to the overall incremental cost. Table 53 presents a breakdown the average incremental cost by element for each of the housing typologies. In three of the four house designs, the cost of the glazing is the most significant factor. In SBH02, it is the flooring cost upgrades that are the most significant, which is mostly attributable to the suspended floor versions of SBH02

Table 53: The average incremental cost of upgrades by element

House Design	Roof/Ceiling	External Walls	Floors	Glazing	Other Elements
SBH02	$544	$836	$1,374	$599	$56
SBH03	$312	$602	$467	$5,226	$53
THMid	$220	$335	$241	$1,794	$40
THEnd	$270	$571	$221	$2,296	$40

Roof/Ceiling

The incremental cost of the required upgrades for the roof / ceiling is a straightforward comparison of the improvement in R value of the ceiling insulation. In both instances, insulation is required, hence the upgrade cost is the difference in cost between R2.5 and R3.5 insulation. As shown in Table 53, the larger the roof area as in the SBH02 single storey house, the larger the cost. It should be noted that NCC 2019 distinguishes between roof colours and a higher total R-Value is required for a dark roof when compared to a light roof. In this instance, a medium roof was adopted, but it could be said that the incremental cost is a function of roof area and colour.

External Walls

Similarly to the upgrade of the roof, the incremental cost of improving the external walls is the difference in cost between insulation with a lower R value and one with a higher R value and is determined by the overall square meterage of external walls. The lower incremental cost of the external wall upgrades is evident in Table 53 for the THMid townhouse middle typology where the upgrade cost is two thirds of the other townhouse typology and almost half of SBH03 double storey house.

Floors

Floor construction type was the primary determining factor in the upgrade of flooring. Concrete slab on ground generally requires no insulation in either of the regulatory scenarios assuming no in slab heating is present. However, two storey designs may have some external suspended floors on the second level. This is the case for the two townhouse typologies, where the upper level extends beyond the ground floor. In this scenario, there are some upgrade costs for the floor under the Elemental Method.

Table 53 notes a large incremental cost for upgrading the floor of SBH02 single storey house. This is due to the suspended floor archetypes and the Queenslander archetype. The table presents averages across the scenarios and the additional lightweight suspended floor significantly increases the average cost for this dwelling design.

Glazing

The need to upgrade glazing was determined by the ABCB Glazing Calculator and varied significantly by typology and floor type. The SBH03 double storey house required significant upgrades to the glass even with a slab on ground construction. This typology had the largest area of windows at almost 60m^2 when compared to the middle townhouse that had the smallest area of windows at almost 28m^2 or less than half. However, the SBH02 had 43m^2 area of glass and yet as shown in Table 53 this design experienced the lowest incremental cost upgrades compared to the other typologies. This is due to the lower glass to floor area ratio typical of single storey design.

In the ABCB Glazing Calculator, each level is assessed separately which means that in two storey designs the area of windows is divided into a smaller floor plate on each level when compared to a single storey house with a similar overall area but on a single floor plate. Therefore, in spite of the townhouse typologies having a lower overall area of windows, the incremental costs were higher as they are two storey dwellings, compared to SBH02 single storey house.

Other Elements

The other elements include self-closing dampers and additional draft seals to the bottom of external swing doors. The incremental cost in all cases is minor and is determined by the number of exhaust fans and external doors. This is a function of both the design and the ventilation required to enclosed spaces.

4.2.3 Orientation

Orientation was only distinguished in relation to the Glazing provisions – Part 3.12.2.1. Orientation of glazing is important to thermal performance and is taken into consideration by the ABCB Glazing Calculator. To ensure that the impact of orientation of glazing was factored into upgrade costing, the best and worst performing orientations from the NatHERS pathway analysis were identified for each house design/climate zone/wall and floor type combination. Glazing Calculations were run, using the ABCB Glazing Calculator, for each of these two orientation scenarios and the outcomes averaged to produce the incremental cost relating to glazing for each particular house design/climate zone/wall and floor type combination.

The required upgrades for glazing for differently oriented dwellings, varied significantly depending on CZ and house design. The example in Table 54 shows the scenario of the Middle Townhouse with lightweight BV walls and concrete slab on ground in CZ 5. In the worst case, the glazing is required to be upgraded from clear single glazing to low-e double glazing. In the best case, there is no upgrade required at all from the BCA 2009 to NCC 2019 requirements. In this case, the average glazing upgrade cost ($1518.00) is factored into the overall upgrade cost to be used in the Benefit Cost Analysis.

Table 54: Example of comparison of glazing upgrade costs based on dwelling orientation

THmidLWCOGCZ5 **NCC Clause**	**NatHERS Pathway Scenario**	**Upgrade Item**	**Area (m2)**	**Incremental Upgrade Cost**
3.12.2.1 External Glazing	Worst - 'West oriented'	Clear single glazing to low-e double glazing clear	27.6	$3,036.00
3.12.2.1 External Glazing	Best - 'North oriented'	Clear single no change	27.6	$ -

4.2.4 Climate Zone

The Elemental Method sets out different requirements for each of the 4 climate zones. While the requirements vary for total required R values for walls and roofs these differences are largely negated by the available material R-Values which typically increase in increments of R0.5. This means that differences by climate zone are effectively erased due to the available products. The impact of climate in the elemental pathway is seen in the results of the glazing calculator.

Table 55 presents the average costs for upgrading each of the Class 1 typologies in the 4 climate zones. In each instance, there is an incremental cost incurred between QDC 4.1 and NCC 2019.

Unlike in the NatHERS pathway where the 'Queenslander' typology only performed relatively well in Climate Zone 1, under the elemental pathway, the incremental cost is only slightly higher than for SBH02 single storey house. This is because the glazing upgrades required are not as significant in the NCC 2019 Glazing Calculator as they needed to be in the NatHERS modelling.

Where significantly higher incremental costs are shown in Table 55, these are the result of glazing improvements required in that climate zone. The relatively low upgrade costs for SBH03 two storey house in Climate Zone 3 when compared to Climate Zones 1 and 2 is because of the higher stringency currently required under QDC 4.1 and the glazing calculator. For example, the glazing required in Climate Zone 2 for SBH03 under QDC 4.1 was tinted, single glazing in an aluminium frame. Under NCC 2019, the minimum requirement is for low-e, tinted double glazed windows. By comparison, in Climate Zone 3, SBH03 required double glazed, tinted glass under QDC 4.1 and low-e, tinted double glazed windows in the NCC 2019 calculator. In this example, the incremental cost in Climate Zone 2 is significantly higher than Climate Zone 3 and is reflected in the results.

Table 55: The average costs of upgrading each house design by climate zone including QDC credit costs

House Design	CZ 1	CZ2	CZ3	CZ5
SBH02	$2,503	$2,503	$3,252	$4,750
Queens	$3,877	$3,877	$5,375	$6,873
SBH03	$10,943	$10,943	$5,205	$5,606
THMid	$448	$1,966	$3,001	$1,966
THEnd	$735	$3,073	$3,240	$2,608

Following a similar pattern to the NatHERS pathway, apart from SBH03 two storey house, Climate Zone 1 has the lowest incremental cost for upgrades. As the climate becomes harsher, the incremental costs increase, with the highest costs for SBH02 and the 'Queenslander' in Climate Zone

5, while Climate Zone 3 incurred the highest costs for the two townhouse typologies. In Climate Zone 2, three of the typologies shared the same upgrade costs as those incurred in Climate Zone 1. However, the two townhouse typologies in Climate Zone 2 incurred significantly higher costs than Climate Zone 1, matching and even exceeding those in Climate Zone 5. This is driven by the increase in glazing requirements from single glazing in QDC 4.1 and double low-e glazing in the NCC 2019 calculators.

4.2.5 NatHERS vs Elemental (DTS) Pathway Comparison

Given the two (main) verification pathways studied – recalling others are possible – it is useful to compare the difference in incremental costs between the methods. Table 56 shows a comparison of the incremental cost between the NatHERS and the elemental pathway for each climate zone and dwelling archetype. The results include the subtraction of cost of QDC credits in both verification pathways.

Table 56: A comparison of average incremental costs between the NatHERS Pathway and Elemental Method for each climate zone and typology including the subtraction of QDC credit costs

	CZ 1		CZ2		CZ3		CZ5	
	NatHERS	Elemental	NatHERS	Elemental	NatHERS	Elemental	NatHERS	Elemental
SBH02	-$2,838	$2,503	-$248	$2,503	-$1,715	$3,252	-$752	$4,750
Queens	-$2,076	$3,877	$12,040	$3,877	$10,389	$5,375	$9,286	$6,873
SBH03	$5,626	$10,943	$3,998	$10,943	$7,280	$5,205	$9,286	$5,606
THMid	-$1,701	$448	-$154	$1,966	$775	$3,001	-$980	$1,966
THEnd	-$313	$735	-$34	$3,073	$2,492	$3,240	$2,111	$2,608

It is notable that the NatHERS pathway results in negative incremental costs, represented in red, in some of the scenarios whereas the elemental pathway always has a positive incremental cost. This indicates that by using the NatHERS pathway, it is possible to decrease the cost of construction while achieving a higher level of thermal performance. The same cannot be said for the elemental pathway and an increase in cost will always be incurred alongside the improvement in thermal performance. This might be an argument for dispensing with DTS provisions but cannot be considered definitive, as the elemental pathway may, under certain circumstances, produce a lower cost result. As previously noted, the negative incremental cost in some of the scenarios is explained by the removal of the cost of QDC credits.

Apart from a small number of scenarios, the NatHERS pathway is the more cost effective of the two compliance methods in terms of incremental cost. This is largely due to the prescriptive nature of the Elemental Method. Each building element needed to be upgraded between the QDC 4.1 and NCC 2019. This means in every part of the dwelling and in particular the glazing, an incremental cost was incurred. The NatHERS pathway by contrast allows for greater trade-off of elements and is more dynamic, responding with greater sensitivity to the relationship between glazing, shading, and thermal mass, and responding to changes in elements such as floor coverings, colours, the addition of ceiling fans and the like. Where incremental costs were incurred, the NatHERS pathway allowed the lowest cost option to be tested first. With the elemental pathway such optimisation is not possible.

The notable exception is the 'Queenslander' typology in Climate Zones 2, 3 and 5. As previously highlighted, this typology had high incremental costs using the NatHERS modelling predominantly due to the lack of thermal mass and subsequent upgrade costs of the windows. This is significantly less pronounced in the Elemental method, in that the upgrade costs for the 'Queenslander' are higher, but not excessively so when compared to the SBH02 single storey house. For this type of construction, the Elemental Method would be the more favourable option.

4.3 Economy-Wide Benefit Cost Analysis

4.3.1 Incremental Costs

As with the NatHERS verification pathway, for the elemental (DTS) pathway, incremental costs are incurred annually over the expected life of the measure (FY2024 – FY2033). Data sourced from CSIRO's Housing Data Portal indicates that 67% of all dwelling approvals in QLD, over the 2017 – 2022 period, used the NatHERS pathway, so we assume that 33% use the elemental (DTS) pathway. As noted in Chapter 7, a small number may instead use other permitted verification pathways, such as reference building or expert opinion.

Compared to incremental costs under NatHERS, elemental (DTS) pathway incremental costs are *significantly* higher, as discussed above. Across all archetypes and orientations, the simple average incremental cost under the elemental (DTS) pathway is $3,790/dwelling, cf only $1,360 under the NatHERS pathway. These findings are consistent with the purpose and function of NatHERS being to provide for more cost-effective, performance-based solutions than are possible under the prescriptive approach.

As a result, when aggregated to the whole of economy level, and weighted by the shares of the relevant archetypes, the present value of incremental cost is $59.2 million, which is more than 3 times higher than for NatHERS, even though only half the number of dwellings use the elemental (DTS) pathway in QLD, compared to those that use NatHERS. Also, as there is no elemental (DTS) solution for Class 2s at present, so these costs would be proportionately higher if compared to NatHERS for Class 1s only.

Note that we apply the same assumption as for the NatHERS pathway over time, which is that the current relatively high level of costs in the industry – exacerbated by inflation linked to shorter term factors – gradually abates over the five years from FY2024 – FY2029, reducing by 15% over that period.

4.3.2 Fuel Savings

The reduction in average thermal loads (across all archetypes, climate zones and orientations) in the elemental (DTS) case is 21% less than in the NatHERS case. This, together with the 33% share of new building work, leads to electricity savings averaging around 426 MWh for each year that the measure applies (FY2024 – FY2033), or less than one third of the NatHERS case. Cumulative savings reach around 4,200 MWh by FY2033, the final year of the measure, and persist at that level for the economic lives of the dwellings (modelled to FY2070). The value of annual electricity cost savings reaches a peak of some $790,000/year by 2043 (although this depends on the actual path of future electricity prices), and this stream of savings has a present value of $7.4 million.

Gas savings are again assumed to be small, reaching less than 77 MWh by FY2033, with a present value of only some $205,000.

4.3.3 Avoided Peak Demand

Using the CLF method, avoided peak demands are proportional to energy consumption savings. As a result of the lower consumption savings for the elemental (DTS) pathway, then, the avoided peak demand for this cohort is also smaller, reaching 1.9 MW by 2033. The present value of the avoided peak demand is $12.3 million, using the same methodology and assumptions as for the NatHERS pathway (see section 2.5.4).

4.3.4 Reduced Space Conditioning Capacity

Noting the smaller average annual thermal load savings under the elemental (DTS) pathway, compared to NatHERS, the opportunity to downsize space-conditioning equipment is somewhat less, averaging 0.5 kW/dwelling across all archetypes, climate zones and orientations, but up to 0.9 kW in some cases. The average capital cost reduction is only some $135/dwelling, but this still contributes to the overall benefits attributable to the measure.

4.3.5 Avoided Greenhouse Gas Emissions

Avoided emissions are proportional to avoided fuel use (mainly electricity). These peak at just over 2,000 t CO_2-e/year in FY2033, but then fall due to falling emissions intensity of electricity consumption in QLD. The present value of these avoided emissions is some $3.5 million.

Table 57: Detailed Results by Archetype and Climate Zone: QDC4.1 to NCC2019: Elemental Pathway ($ FY2023 real)

Type	Archetype	Construction Detail	Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
House	1-storey	LW CoG	1	$138,103	$0	$229,679	$65,392	**$433,174**	$100,230	**$332,944**	**4.3**
House	1-storey	LW Susp	1	$21,409	$0	$35,605	$10,137	**$67,152**	$61,970	**$5,182**	**1.1**
House	1-storey	CB CoG	1	$494,335	$0	$822,129	$234,069	**$1,550,533**	$358,771	**$1,191,762**	**4.3**
House	1-storey	CB Susp	1	$76,633	$0	$127,449	$36,286	**$240,368**	$221,821	**$18,547**	**1.1**
House	2-storey	LW CoG	1	$53,758	$0	$89,405	$25,455	**$168,618**	$596,910	**-$428,292**	**0.3**
House	2-storey	LW Susp	1	$8,334	$0	$13,860	$3,946	**$26,140**	$103,876	**-$77,737**	**0.3**
House	2-storey	CB CoG	1	$192,426	$0	$320,024	$91,114	**$603,564**	$2,136,622	**-$1,533,057**	**0.3**
House	2-storey	CB Susp	1	$29,830	$0	$49,611	$14,125	**$93,566**	$371,822	**-$278,256**	**0.3**
House	1-storey	Queens	1	$12,916	$0	$21,481	$6,116	**$40,512**	$37,386	**$3,126**	**1.1**
House	1-storey	LW CoG	2	$2,560,577	$0	$4,258,501	$1,212,442	**$8,031,519**	$4,331,508	**$3,700,011**	**1.9**
House	1-storey	LW Susp	2	$294,651	$0	$490,035	$139,518	**$924,204**	$1,829,777	**-$905,573**	**0.5**
House	2-storey	LW CoG	2	$1,514,521	$0	$2,518,803	$717,131	**$4,750,456**	$35,306,730	**-$30,556,274**	**0.1**
House	2-storey	LW Susp	2	$174,279	$0	$289,844	$82,522	**$546,645**	$4,556,948	**-$4,010,303**	**0.1**
House	1-storey	Queens	2	$273,228	$0	$454,405	$129,374	**$857,007**	$1,696,738	**-$839,731**	**0.5**
House	1-storey	LW CoG	3	$49,179	$0	$81,789	$23,287	**$154,254**	$32,444	**$121,810**	**4.8**
House	1-storey	LW Susp	3	$23,373	$0	$38,872	$11,068	**$73,313**	$87,950	**-$14,637**	**0.8**
House	1-storey	CB CoG	3	$9,329	$0	$15,516	$4,418	**$29,263**	$6,155	**$23,108**	**4.8**
House	1-storey	CB Susp	3	$4,434	$0	$7,374	$2,100	**$13,908**	$16,685	**-$2,777**	**0.8**
House	2-storey	LW CoG	3	$15,237	$0	$25,340	$7,215	**$47,791**	$74,241	**-$26,450**	**0.6**
House	2-storey	LW Susp	3	$7,242	$0	$12,043	$3,429	**$22,714**	$44,410	**-$21,696**	**0.5**

Type	Archetype	Construction Detail	Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
House	2-storey	CB CoG	3	$2,890	$0	$4,807	$1,369	**$9,066**	$9,396	**-$330**	**1.0**
House	2-storey	CB Susp	3	$1,374	$0	$2,285	$650	**$4,309**	$8,425	**-$4,116**	**0.5**
House	1-storey	Queens	3	$5,455	$0	$9,072	$2,583	**$17,110**	$20,526	**-$3,416**	**0.8**
House	1-storey	LW CoG	5	$201,547	$96,377	$334,975	$110,496	**$743,395**	$526,645	**$216,750**	**1.4**
House	1-storey	LW Susp	5	$15,419	$7,373	$25,627	$8,453	**$56,873**	$109,841	**-$52,967**	**0.5**
House	2-storey	LW CoG	5	$119,210	$57,005	$198,130	$65,356	**$439,701**	$851,761	**-$412,060**	**0.5**
House	2-storey	LW Susp	5	$9,120	$4,361	$15,158	$5,000	**$33,639**	$81,869	**-$48,230**	**0.4**
House	1-storey	Queens	5	$20,762	$9,928	$34,507	$11,383	**$76,581**	$147,902	**-$71,321**	**0.5**
Townhouse	TH - end	LW CoG	1	$13,662	$0	$22,721	$6,469	**$42,851**	$6,724	**$36,127**	**6.4**
Townhouse	TH - end	LW Susp	1	$2,118	$0	$3,522	$1,003	**$6,643**	$2,915	**$3,728**	**2.3**
Townhouse	TH - end	CB CoG	1	$46,456	$0	$77,262	$21,997	**$145,715**	$22,866	**$122,850**	**6.4**
Townhouse	TH - end	CB Susp	1	$7,202	$0	$11,977	$3,410	**$22,589**	$9,913	**$12,676**	**2.3**
Townhouse	TH - mid	LW CoG	1	$20,492	$0	$34,081	$9,703	**$64,277**	$481	**$63,795**	**133.5**
Townhouse	TH - mid	LW Susp	1	$3,177	$0	$5,283	$1,504	**$9,964**	$3,131	**$6,833**	**3.2**
Townhouse	TH - mid	CB CoG	1	$69,684	$0	$115,893	$32,996	**$218,573**	$1,637	**$216,936**	**133.5**
Townhouse	TH - mid	CB Susp	1	$10,803	$0	$17,966	$5,115	**$33,884**	$10,648	**$23,236**	**3.2**
Townhouse	TH - end	LW CoG	2	$299,347	$0	$497,845	$141,742	**$938,934**	$2,076,347	**-$1,137,412**	**0.5**
Townhouse	TH - end	LW Susp	2	$34,447	$0	$57,288	$16,311	**$108,045**	$410,070	**-$302,025**	**0.3**
Townhouse	TH - mid	LW CoG	2	$449,021	$0	$746,768	$212,613	**$1,408,402**	$2,229,176	**-$820,774**	**0.6**
Townhouse	TH - mid	LW Susp	2	$51,670	$0	$85,932	$24,466	**$162,068**	$360,093	**-$198,026**	**0.5**
Townhouse	TH - end	LW CoG	3	$4,522	$0	$7,520	$2,141	**$14,184**	$17,715	**-$3,531**	**0.8**

Type	Archetype	Construction Detail	Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
Townhouse	TH - end	LW Susp	3	$2,149	$0	$3,574	$1,018	**$6,741**	$10,179	**-$3,438**	**0.7**
Townhouse	TH - end	CB CoG	3	$815	$0	$1,355	$386	**$2,556**	$3,193	**-$636**	**0.8**
Townhouse	TH - end	CB Susp	3	$387	$0	$644	$183	**$1,215**	$1,835	**-$620**	**0.7**
Townhouse	TH - mid	LW CoG	3	$6,783	$0	$11,281	$3,212	**$21,276**	$24,080	**-$2,803**	**0.9**
Townhouse	TH - mid	LW Susp	3	$3,224	$0	$5,361	$1,527	**$10,112**	$14,317	**-$4,205**	**0.7**
Townhouse	TH - mid	CB CoG	3	$1,223	$0	$2,033	$579	**$3,834**	$4,340	**-$505**	**0.9**
Townhouse	TH - mid	CB Susp	3	$581	$0	$966	$275	**$1,822**	$2,580	**-$758**	**0.7**
Townhouse	TH - end	LW CoG	5	$23,575	$11,273	$39,182	$12,925	**$86,954**	$105,666	**-$18,712**	**0.8**
Townhouse	TH - end	LW Susp	5	$1,804	$862	$2,998	$989	**$6,652**	$10,230	**-$3,578**	**0.7**
Townhouse	TH - mid	LW CoG	5	$35,362	$16,910	$58,773	$19,387	**$130,431**	$110,890	**$19,542**	**1.2**
Townhouse	TH - mid	LW Susp	5	$2,705	$1,294	$4,496	$1,483	**$9,979**	$11,987	**-$2,009**	**0.8**
				$7,420,782	**$205,384**	**$12,341,047**	**$3,545,865**	**$23,513,079**	**$59,180,368**	**-$35,667,290**	**0.4**

4.3.6 Net Present Value

Overall, the NPV of this element on its own is negative, as shown in Table 58. This result is discussed in Section 4.3.6 below. Generally, this result is consistent with the elemental (DTS) pathway being a higher cost pathway than NatHERS and, importantly, selecting the elemental (DTS) pathway is a voluntary choice, not a regulatory requirement: this analysis suggests that only rarely would this choice be more cost-effective that NatHERS.

Table 58: Summary of BCA Indicators: Elemental Pathway

Benefit/Cost Type	Present Values ($FY2023 real)	Share of Benefits (%)
Avoided Electricity Costs	$7,420,782	32%
Avoided Gas Costs	$205,384	1%
Avoided Electricity Infrastructure Costs	$12,341,047	52%
Avoided GHG Emissions Costs	$3,545,865	15%
Total Benefits	**$23,513,079**	**100%**
Incremental Construction Costs	$59,180,368	
Net Benefit (Net Present Value)	**-$35,667,290**	
Benefit Cost Ratio	**0.4**	

4.3.7 Diversity of Results by Archetype and Climate Zone

The diversity of results by archetype and climate zone is shown in Table 57. We note that less than 35% of the 52 combinations have a positive NPV. Summing these, this group would experience net benefits of $6.1 million. However, these benefits are more than offset by the more than 65% of combinations that have negative NPVs. These total -$41.8 million, with the total of these two equalling the overall net benefit of -$35.7 million.

4.4 Conclusions

Overall, we conclude that it would not be cost-effective, on average, to choose the elemental (DTS) pathway to verify compliance with NCC2019. Of course, we do not know whether the elemental (DTS) pathway under QDC4.1 is itself cost-effective, as this was outside our terms of reference.

Second, it follows that it would be far more cost-effective, on average, to verify compliance via the modelled or NatHERS pathway. Use of the elemental (DTS) pathway is a voluntary choice – no-one is required to use this pathway to verify compliance. If, in a particular case, it is not cost-effective to use the elemental (DTS) pathway, we could expect builders to use NatHERS. That said, the results show that the elemental (DTS) pathway is cost-effective in some cases. Where this occurs, we could expect builders to use the elemental (DTS) pathway (unless NatHERS were *more* cost-effective). Overall, these results are consistent with the elemental (DTS) pathway being a higher cost and less cost-effective pathway than NatHERS. Putting the elemental (DTS) pathway and NatHERS results together, the overall results are cost-effective, with an NPV of $31.7 million and a BCR of 1.4 – see Table 59.

Table 59: QDC4.1 to NCC2019: Cost-Effectiveness by Compliance Pathway

NPV Summary	Modelled share of new builds	Elemental (DTS) share of new builds	Overall Measure
PV Costs	$9,094,000	$59,180,000	$68,275,000
PV Benefits	$84,672,000	$23,513,000	$108,185,000
NPV	**$75,578,000**	**-$35,667,000**	**$39,911,000**
BCR	**9.3**	**0.4**	**1.6**

The underlying assumption behind the 'combined' result is that the current 67%/33% split between modelling and the elemental (DTS) pathway is maintained over time. However, the economics suggest that it would be much more cost effective if NatHERS were more widely used in QLD, and the elemental (DTS) pathway less widely used. As noted, this is a voluntary choice, and therefore it might be expected that NatHERS would have a higher share in future, particularly if parties are aware of the cost savings that are available. Also, it follows that there would be a net societal benefit in QLD if the elemental (DTS) pathway were discouraged, and/or the NatHERS pathway promoted and encouraged.

We note that it is surprising that up to 1/3 of new housing in QLD is using an elemental approach to verify compliance, when this is shown to be far from a least-cost solution, at least in most cases. It is difficult to argue that this reflects any conscious choice by home-owners as, at least in the vast majority of cases, home-owners would have no awareness of the verification pathway chosen (by the builder), nor of its significance for construction costs. Given the results of this work, promotion of these differences and their cost implications is recommended, in order to inform both practitioners and new homeowners.

5. Hot Water and Lighting

5.1 Introduction – Hot Water

The provisions of QDC 4.1 for hot water apply to Class 1 (or 10) buildings only. Part 4 – Variation of BCA (Building Code of Australia) - Performance Requirement P5 - provides that:

> *For a class 1 building or a class 10 building or structure, the following provisions of the BCA do not apply to a hot water system in Queensland:*
>
> *a) Performance requirement P2.6.2, and*
>
> *b) Deemed-to-satisfy clause 3.12.5.6.*

Section P2.6.2 of NCC2019 (Volume 2) notes, in particular, that domestic services (hot water systems) must obtain their heating energy from a source that has a greenhouse gas intensity that does not exceed 100 g CO2-e/MJ of thermal energy load (*inter alia*). This would have the practical effect of disallowing electric storage hot water systems (with certain exceptions, discussed below), but would allow all other common forms of hot water heating in QLD.

Section 3.12.5.6 directs the reader to Part 2.6, Volume 3 (Plumbing Code of Australia). Section BV2.1 (Volume 3) sets out the requirements for establishing the greenhouse gas intensity of a water heater. It notes that:

> *The annual greenhouse gas emissions from each energy source in BV2.1(2) is the product of the—*
>
> *(a) annual amount of energy consumed from that energy source; and*
>
> *(b) emission factor of—*
>
> > *(i) if the energy source is electricity, 253 g CO2-e/MJ; or*
> >
> > *(ii) if the energy source is liquefied petroleum gas, 65 g CO2-e/MJ; or*
> >
> > *(iii) if the energy source is natural gas, 61 g CO2-e/MJ; or*
> >
> > *(iv) if the energy source is wood or biomass, 4 g CO2-e/MJ.*

The explanatory information in Volume 3 notes (pp 49 – 50):

> *BP2.6(2) permits the energy source of the heated water service to be considered. This means that the net energy obtained from renewable energy sources such as solar, geothermal, wind, and biofuels may be considered as 'free' energy in calculating the energy consumption.*

Also, we note that Section B2.2 (1) (d) of Volume 3 (deemed-to-satisfy provisions), allows:

> *an electric resistance water heater with no storage or a heated water delivery of not more than 50 litres in accordance with AS 1056.1 may be installed when—*
>
> *(i) the building has—*

(A) not more than 1 bedroom; and

(B) not more than 1 electric resistance water heater installed; or

(ii) the building has—

(A) a water heater that complies with B2.2(1)(b) or B2.2(1)(c); and

(B) not more than 1 electric resistance water heater installed; or

(iii) the greenhouse gas emission intensity of the public electricity supply is low.

In practice, this means that where a new dwelling has a (suitably sized) PV system installed, it would be compliant to install electric resistance hot water systems, whether storage-based or instantaneous – with the latter becoming a more popular choice in QLD. Since more and more new houses in QLD do feature large PV systems, it is likely that this provision would apply in many cases. That said, for smaller houses or townhouses, with limited roof area, it may not always be feasible to install sufficient PV capacity to ensure that 100% of hot water energy consumption is covered by that system. In such a case, it would be necessary to rely on another DTS solution that is allowed, as above, or else choose a heat pump or other compliant hot water system. We note that some consumers prefer systems other than heat pumps on the grounds that heat pump systems can be noisy in space-constrained settings.

Our analysis below is based on heat pumps being selected, as we cannot assume that all new houses will have suitable PV systems and, in this sense, it may represent a 'worst case' from an economic perspective. Which hot water technology would deliver the largest energy and/or emissions savings is a separate question, that is likely to vary greatly from house to house based on PV system size, inter alia, and a full exploration of these issues is outside the scope of this study.

5.2 Analysis – Hot Water

Noting the performance requirement is specified in terms of *thermal* energy load (essential the energy used to heat the water), the actual associated energy consumption, and therefore greenhouse gas emissions, depends on the efficiency of hot water service in converting input fuels into thermal energy. Reference sources, including the last hot water Regulation Impact Statement,[29] note that the efficiency of hot water systems vary considerably – particularly for solar hot water heaters and heat pumps – but we make the following assumptions for average efficiency values – see Table 60. Taking a 'medium' hot water demand of 40 MJ per peak day,[30] this translates the annual energy consumption (MJ) values noted also noted in Table 60.

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[29] George Wilkenfeld & Associates, *Regulation Impact Statement: for Decision: Phasing Out Greenhouse-Intensive Water Heaters in Australian Homes*, November 2010.

[30] Ibid, p. 15.

Table 60: Reference Values by Hot Water Technology Type

	Electric storage med /large	Electric storage – small	Gas – instant (LPG)	Gas – instant (mains)	Gas storage (LPG)	Gas storage (mains)	Heat pump	Solar electric	Solar gas
Average Efficiency	90%	70%	50.4%	50.4%	50.4%	50.4%	350%	350%	200%
Annual Energy Consumption (MJ) at 40 MJ thermal load/day	16,222	20,857	28,968	28,968	28,968	28,968	4,171	4,171	7,300
Average annual running costs (Tariff 31 for electricity)	$778	$1,000	$1,742	$1,742	$1,742	$1,742	$200	$200	$439

On this basis, and assuming the current off-peak Tariff 31 (17.266 c/kWh) applies in real (inflation adjusted) terms over the forecast period, while gas pricing is as noted in Figure 16 above, the average annual running costs for the hot water types are as shown in Table 60 (gas pricing from FY2024).

For the purposes of this analysis, it is not necessary to calculate the economics of every possible hot water conversion option. The impact of NCC2019 would be, in effect, to restore the previous ban on electric storage hot water systems (with certain exceptions) that applied in QLD until 2014. With the availability of gas for residential hot water being limited in QLD, but also still available as a choice under NCC2019, we assume no change would occur for those already choosing gas hot water systems. Data from the 2022 Residential Baseline Study suggests that in QLD in 2022, some 59% of dwellings use large electric hot water storage systems – although it does not indicate the share of new dwellings making the same choice. Practically, this is not a critical variable for the analysis, as a higher or lower share would increase/decrease both benefits and cost proportionally, without changing the overall benefit cost ratio, therefore we use this value to also represent the share of new dwellings choosing large electric storage under QDC 4.1. This means that 59% of the annual Class 1 cohort each year (from FY2024 – FY2033) is modelling as incurring the incremental cost of upgrading hot water systems under NCC2019.

Of the electrical options that would be eligible under NCC2019, heat pumps are expected to be the least cost choice in most cases so, as noted above, we make this the basis of analysis. That said, electrically-boosted solar appears to be not much more expensive than, and would be likely to have similar energy efficiency performance characteristics to, heat pumps.[31] Based on a web-search, we assume capital costs for ~300 litre hot water systems as shown in Table 61.

We note that these costs may be higher than those available to the construction industry after volume discounts. That said, volume discounts may not affect the relativities between prices. On this basis, we estimate a typical *incremental* cost for upgrading from electric storage to heat pump would be ~$1,628. Average annual running costs (assuming Tariff 31 applies) are shown in Table 60 above, implying that typical annual savings would be ~$578.

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[31] Wilkenfeld notes that the efficiency of solar hot water heaters is highly variable from one model to the next, and efficiency will also vary by location/climate zone within QLD.

Table 61: Reference Capital Costs for Hot Water Systems (FY2023 real)

Type	Capital Cost (FY2023 real)
Electric storage (315 l)	$1,089.00
Solar electric-boosted (300 l)	$3,184.00
Heat pump (290 l)	$2,800.00
Heat pump (280l)	$2,634.00
Heat pump (average)	$2,717.00

5.3 Economy Wide Impacts – Hot Water

5.3.1 Incremental Capital Costs

With, on average, some 29,500 Class 1 dwelling expected to be completed annually in QLD over the FY2024 – FY2033 period (refer back to Section 2.5.2 for details), this implies that, under NCC2019, around 17,500 dwellings per year would incur one-off capital costs associated with upgrading to heat pumps (or another compliant system of the consumers' choice). This sums to around $28.5 million per year, with a present value (discounted at 7% real) of $198.5 million. These costs would be incurred by new home-owners.

5.3.2 Value of Energy Savings

Per-dwelling energy savings can be noted by Table 60, averaging some 3.3 MWh/year. These savings accumulate to almost 55,000 MWh in FY2024, rising to some 586,000 MWh by FY2033. Savings are then assumed to decline, as the units installed in FY2024 are assumed to reach the end of their economic lives after 10 years (noting this may be conservative as an average figure, but reflects typical warranty periods), while the units installed in FY2033 would be retired by end FY2042.

Assuming Tariff 31 maintains its current value (17.266 c/kWh) in real terms over time, the financial value of these savings to new home-owners would exceed $101 million by FY2033. The present value of these savings is just under $530 million.

5.3.3 Avoided Greenhouse Gas Emissions

Noting the energy (electricity) savings above, the cohort of new homes converting to heat pumps would avoid over 273,000 t CO_2-e annually by FY2033, with this value then falling in line with falling energy savings (retirements of heat pump systems). In cumulative terms, these emissions savings exceed 2.7 million t CO_2-e over the FY2024 – FY2042 period, despite the assumption of falling emissions intensity of electricity consumption. Applying the social cost of carbon assumptions noted in Chapter 2, these emissions savings would have a present value of just over $232 million.

5.3.4 Avoided Electrical System Costs

Given that both electric storage and heat pump hot water systems operating on Tariff 31 would be shifted into off-peak periods, we assume that no infrastructure cost savings would arise.

5.3.5 Net Benefits

Table 62 indicates that even considering only costs and benefits that fall on home-owners, the adoption of NCC2019 hot water provisions would generate private net benefits of around $331 million, with a private BCR of 2.7. When the additional (societal) benefits of 27 million t CO_2-e of avoided greenhouse gas emissions are added in, these values increase to a net societal benefit of over $563 million at a BCR of 3.8. On this basis we find that adoption of NCC2019 hot water provisions in QLD would be highly cost effective.

Table 62: Net Benefits (Societal and Private) – Hot Water Provisions

Parameter	Present Value (FY2023 real, 7% real discount rate)
Present Value of Electricity Savings	$529.7
Present Value of GHG Savings	$232.2
Present Value of Benefits (Societal)	$761.9
Present Value of Incremental Costs	$198.5
Benefit Cost Ratio (Societal)	3.8
Net Present Value (Societal)	$563.3
Benefit Cost Ratio (Home-owners)	2.7
Net Present Value (Home-owners)	$331.2

5.4 Lighting

Under the current QDC 4.1 specification, Class 1 (and 10a) buildings must comply with P2.6.2(a) of BCA2010 (Volume 2), while Acceptable Solution A3 notes:

> *A class 1 building, including a verandah, balcony or an enclosed class 10a building attached to a class 1 building, has:*

(a) artificial lighting that complies with Part 3.12.5.5 of BCA 2010 (Volume 2); or

(b) energy efficient lighting for a minimum of 80 per cent of total fixed artificial lighting.

Part 3.12.5.5 of BCA 2010 specifies (*inter alia*) that lamp power density or illumination power density of artificial lighting, excluding heaters that emit light, must not exceed—

(i) in a Class 1 building, 5 W/m2; and

(ii) on a verandah or balcony attached to a Class 1 building, 4 W/m2;

For Class 2 under QDC 4.1, performance requirement P4 notes that fixed artificial lighting in a sole-occupancy unit of a class 2 building must be energy efficient, while acceptable solution A4 notes that:

> *Each sole-occupancy unit of a class 2 building, including a verandah, balcony or an enclosed class 10a building attached to a class 2 building, has energy efficient lighting for a minimum of 80 per cent of total fixed artificial lighting.*

Under NCC2019, the equivalent requirements for Class 1 dwellings is effectively the same:

3.12.5.5 Artificial lighting

(a) The lamp power density or illumination power density of artificial lighting, excluding heaters that emit light, must not

exceed the allowance of—

(i) 5 W/m2 in a Class 1 building; and

(ii) 4 W/m2 on a verandah, balcony or the like attached to a Class 1 building…

For Class 2s, NCC2019 (Volume 1) part J6.2 requires:

J6.2 Artificial lighting

(a) In a sole-occupancy unit of a Class 2 building or a Class 4 part of a building—

(i) the lamp power density or illumination power density of artificial lighting must not exceed the allowance of—

(A) 5 W/m2 within a sole-occupancy unit; and

(B) 4 W/m2 on a verandah, balcony or the like attached to a sole-occupancy unit…

Thus, the only practical difference between QDC 4.1 and NCC2019 with respect to lighting is that the general requirement that 80% of class 2 lighting be energy efficient would be replaced by the more specific requirement that installed lamp power density must not exceed either 4 or 5 W/m2, depending upon the context.

In the early years of application of BCA2010, and hence QDC 4.1, it is likely that ‘energy efficient lighting’ would practically have been defined with reference to compact or tubular fluorescent lamps, although this is not specified. With modern LED lighting generally offering higher efficiency (lumens/Watt) than fluorescent technology – and, even more to the point, with fluorescent lighting generally no longer supplied in the Australian new homes market – it is clear that LED systems would be likely to exceed both BCA2010 and NCC2019 provisions as a matter of course, with no incremental costs or benefits arising by definition. The one ‘intangible’ benefit from adopting NCC2019 rather than QDC4.1 would be the former’s greater clarity with respect to Class 2 performance requirements.

6. Part B – Accreditation and Documentation

6.1 Introduction

At present in QLD, there is no requirement for energy efficiency features to be documented on building plans (or in contracts), and there is no requirement for NatHERS ratings to be undertaken by accredited persons. The concern is that this may lead to builders being unaware of the specific requirements for a particular dwelling, or for those requirements to be incorrectly established by potentially untrained and unqualified personnel, who are nevertheless legally able to undertake energy assessments at present. This, in turn, may lead to a percentage of house-owners receiving a new home that consumes more energy than it should, at the home-owner's expense. To the extent that this occurs, expected greenhouse gas emissions abatement would also not be achieved. Practically, there is unlikely to be any remedy available to home-owners, even if they were able to detect the poorer-than-expected energy performance, which is unlikely.

Nationally and for many years now there has been a debate about the degree of compliance with Code energy performance requirements, and indeed about other building compliance issues. A 2014 report, the *National Energy Efficient Buildings Project Stage 1 Report*,[32] drew on over 1,000 stakeholder engagements in all states and territories, including regional centres, and documented 'systemic failures' in Code implementation, making 43 recommendations. More recently, the Shergold and Weir report, *Building Confidence* (2018), made a further 24 recommendations aimed at 'improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia' (the Report's sub-title). The Building Ministers Forum established an implementation plan in March 2019, and a progress report was released in May 2021.[33] This report refers to a draft National Registration Framework for Building Practitioners. Accreditation of energy assessors, and better documentation of energy efficiency features in QLD would be consistent with these nationally-agreed policy directions.

6.1.1 Accreditation of NatHERS Assessors

Accreditation of NatHERS Assessors occurs via Assessor Accrediting Organisations (AAOs). Nationally there are three AAOs through which assessors can be accredited:

- ABSA (Australian Building Sustainability Association)
- HERA (House Energy Raters Association)
- Design Matters

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[32] https://www.energymining.sa.gov.au/industry/energy-efficiency-and-productivity/national-energy-efficiency-building-project, viewed online 26/09/2022.

[33] ABCB, Delivery of the Building Confidence Report National Framework, Public Report, 2021.

In turn, these AAOs are accredited by the NatHERS Administrator. The NatHERS Assessor Accrediting Organisations Protocol[34] provides the operational framework for AAOs, including processes and expectations in relation to:

- Assessor accreditation
- Quality assurance systems for Assessor services

To become accredited an assessor must hold a Certificate IV in one of the following:

- Certificate IV in Home Energy Efficiency and Sustainability (Thermal Performance Assessment) – CPP41119
- Certificate IV in Home Energy Efficiency and Sustainability (Home Sustainability Assessment and Thermal Performance Assessment) – CPP41119
- Certificate IV in NatHERS Assessment – CPP41212 (no longer available)

Once a prospective assessor has completed their Certificate IV, they can apply to be accredited by an AAO. This involves: signing a code of practice; obtaining relevant Professional Indemnity Insurance; and, paying a membership fee and or yearly accreditation fee.

Part of on-going accreditation requirements are for Accredited Assessors to undertake Continuing Professional Development (CPD). Upon yearly renewal of accreditation Assessors must have undertaken and formally logged 12 points (typically 12 hours) worth of approved CPD.

As noted above, AAOs have a role in providing Quality Assurance for NatHERS. Current requirements under the AAO Protocol are for AAOs to audit 20% of Assessors accredited with the AAO, per 12-month period. Auditing typically involves requiring the Assessor to submit documentation from a project that has been issued with a NatHERS certificate within the previous 12 months. Highly experienced Assessors are engaged by the AAOs to undertake detailed audits of the Thermal Performance modelling, and documentation processes of the Assessor.

Failing of a QA Audit may result in a requirement for re-training, mentoring, or in the case of repeated underperformance, the removal of accreditation status of the Assessor.

6.1.2 NatHERS Documentation Requirements

In order to certify a project and provide a NatHERS Certificate, an Accredited Assessor must be able to confirm project details, via appropriately detailed Architectural drawings, schedules and or specifications.

The minimum documentation required, in the form of drawings, notes, schedules or specifications is:

- Site plan – including a north point
- Floor plans

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[34] NatHERS Assessor Accrediting Organisations Protocol

- Elevations
- Sections
- Construction materials and details
- Lighting plan / electrical schedule
- Window/skylight/door schedule and or details including:
    - Size and location
    - Glazing type
    - Frame type
    - Opening style

If required information is missing from the Architectural documentation, the Accredited Assessor must request it be added, and may not certify the project until the required information is provided.

Once the project design is finalised and the required information is provided, the Accredited Assessor stamps the relevant documentation, and provides the NatHERS Certificate for Building Approval purposes.

The NatHERS Certificate represents confirmation that the information presented on the Architectural documentation has been included in the Thermal Performance model, and that the predicted NatHERS Rating is based on the stamped Architectural documentation. The NatHERS Certificate does not form part of the Architectural documentation that can be a substitute for missing information on the Architectural documentation.

If there are changes to the Architectural documentation changes after a NatHERS Certificate has been issued, before construction commences, or if the design or material selections change during construction, these changes must be assessed by the Accredited Assessor. The Assessor must confirm that either the changes do not affect the results on the originally supplied NatHERS Certificate or, if the changes do effect the results, whether it is necessary to issue a replacement NatHERS Certificate.

6.2 Methodology

6.2.1 Accreditation and Documentation Benefit Cost Analysis Methodology

Accreditation of energy assessors under NatHERS, and also improved documentation of energy efficiency features on building plans, would be expected to lead to:

- more accurate ratings, with fewer and smaller errors
- improved and more effective guidance from energy assessors to builders, architects and home-owners regarding cost-effective energy efficiency options
- greater compliance by builders with required and approved energy efficiency features

- greater accountability for builders, including greater ease of formal or informal audits to determine whether energy efficiency features have been installed as specified
- improved access to green mortgages or interest-rate discounts linked to energy performance
- better outcomes for home-owners and society, associated with lifetime energy and emissions savings and improved comfort outcomes.

However, while the costs associated with accreditation and (to a lesser extent) documentation can be estimated with reasonable confidence, the extent of benefits can only be known with confidence after the event; for example, if a careful before/after 'longitudinal' study were undertaken. In principle, a suitable study from another Australian jurisdiction could be used to estimate expected impacts in QLD, but we were unable to identify any such studies, despite direct engagement with several jurisdictions and the NatHERS Administrator.

In such circumstances, it is not feasible to quantify or value the expected benefit with confidence in advance, and therefore an alternative methodology is required, which is known as 'cost-effectiveness analysis'. Under this approach, the costs are estimated and quantified, and then the *degree* of benefit or impact that would be required to offset this cost is quantified (that is, to make the measure cost-effective). Decision-makers can then assess whether they consider it likely that this much benefit will result from the measure.

For the costs associated with accreditation, we examine price offers for Cert 4 courses for NatHERS accreditation in QLD – this is a one-off cost that newly accredited persons would need to incur. Pricing appears to range from under $4,000 to $4,700. However, it was also noted that most service providers offer recognition for prior experience in the field, with discounts of up to 50% being cited. In a situation such as that in QLD at present, with many more unaccredited than accredited assessors (see below), we can expect that many of the unaccredited assessors will indeed have significant experience and therefore benefit from such discounts. If half of the unaccredited assessors were eligible for this discount, the average cost of training would be $3,150 – based on a median full cost of $4,200 discounted by 25% for prior learning. The 25% estimate is based on up to 50% of those trained receiving a 50% discount (50% * 50% = 25%). This is in line with practitioner experience from our own team.

We then consider ongoing annual costs such as membership of a relevant association, annual accreditation fees and associated continuous professional development (CPD). Based on pricing available online, we estimate these costs at $870 per year.

DEPW made inquiries with the NatHERS Administrator and ascertained that there are currently 50 accredited NatHERS assessors based in QLD (noting that assessors based in other states may also operate in QLD). While the number of unaccredited assessors is not known exactly, the software firm Energy Inspection Pty Ltd shared that some 370 licences for its BERS Pro and AccuRate packages are registered in QLD. BERS Pro is understood to be the main ratings software used in QLD. Some may use FirstRate5, but we have not to this point been able to quantify this number. On the other hand, some of the BERS Pro and AccuRate licences were noted to be for older and out of date versions, while some are inactive and others may be used for research or education purposes, rather than in the field. On this basis we put the estimate of total assessors in QLD at 250, 50 of which are already accredited.

The next question is how many of the unaccredited but active assessors would choose to remain in the industry if accreditation were required? Informally it is understood that at least some of the unaccredited assessors may be builders themselves – particular smaller-volume builders – or their staff, while larger-volume builders more often use accredited assessors. For example, data from CSIRO's *Australian Housing Data* portal notes that the parties who undertook 80% of all ratings in QLD since 2016 (over 135,000 ratings in total) stated that they faced no conflicts of interest, which may be taken as a proxy for being independent of the builder and at least more likely to be accredited. That is, it is likely that the majority of ratings are already undertaken by accredited assessors, even if there is a larger number of unaccredited assessors in QLD.

Given the costs involved in accreditation, it would be likely that those unaccredited parties that are currently undertaking very few ratings per year would not be able to justify the expense, and therefore may not seek accreditation. Instead, these ratings would be likely to be procured – at lower cost, since the accreditation costs would be avoided by these parties – from accredited assessors. While it is uncertain how often this would occur, we make an allowance of 25% of the currently unaccredited assessors making this choice. If so, this would leave some 150 assessors that that currently unaccredited who may seek accreditation if it becomes a mandatory requirement.

For the documentation measure, it is difficult to estimate either costs or benefits with confidence, firstly because it is unclear how many plans are already appropriately documented. Informal advice is that this is 'not often', outside the major volume builders, but more likely amongst those high-volume builders.

Second, the incremental cost of adding notes on the key efficiency requirements (insulation R values, glazing specifications, etc) may be very small – a time commitment of a minute or two per plan. Indeed, once plan templates are set up to specify these features as a matter of course, the incremental cost is likely to be zero. However, there may be a small one-off cost incurred to alter plan templates or associated software settings. If we assume that 25% of plans are already appropriately documented (including a higher percentage of those of high-volume builders) and that, on average, 15 minutes are required to amend plan templates or software for each of the balance of the 34,000 or so houses expected to be built in QLD in FY2024 (based on our stock model, as described above), then the total one-off cost would not exceed $835,000, assuming an hourly rate of $130. In practice, since many project home designs are re-used for multiple clients per year, potentially with minor modifications, it is likely that the actual one-off cost would be much lower than this.

Quantifying the expected benefits associated with assessor accreditation and improved documentation, in advance of implementation, has not been possible within the scope of this project. As noted, doing so would require baseline audits and other processes that would be invasive and time-consuming for industry as well as government. By expressing the costs that need to be overcome with benefits to make these measures cost-effective in practical terms – such as how many houses would need to be built to the required energy performance standard, rather than being half- or one-star out, for example, gives decision-makers a way of interpreting the reasonableness of the measure.

6.3 Key Findings

6.3.1 Accreditation

As noted above, it is relatively straightforward to estimate the costs associated with each person accredited. However, what is not known is:

a) How many unaccredited assessors are there in QLD?

b) Of these, how many would choose to seek (and secure) accreditation in the event it became mandatory?

As discussed above, we estimate that around 150 assessors may fall into the latter category. These parties would, if they chose to do so, incur training and initial registration/accreditation fees that would total just over $600,000 in the first year, and then incur annual registration/accreditation fees that would total to around $130,000 per year. The present value of these cost over 10 years is just under $1.4 million.

In terms of benefits, each dwelling that complies with 6 star under NCC2019, rather than the QDC4.1 minimum requirement, realises a net benefit of ~$1,083 on average in net present value terms. Therefore, if just 1,250 dwellings out the almost 70,000 not already expected to be built to 6 star or more in QLD over FY2024 – FY2033 period were built to NCC2019 rather than the minimum requirements under QDC4.1 (or 1.8% of new houses in this currently-less-than-6-star cohort), this would fully offset the accreditation costs.

Another way of estimating the reasonableness of the cost is by noting that if 3,100 houses per year, that might otherwise have been built to only 5.5 star (due, at least in part, to unaccredited practitioners and ratings error) were instead built to 6 star, then this would fully offset the accreditation costs. If the base case were only 5 star, then it would take just 1,480 houses per year being built instead to 6 star to fully offset the accreditation costs.

6.3.2 Documentation

As noted above, the cost of documenting energy efficiency features on building plans is likely to be very low, and largely a one-off cost associated with changing drawing templates. If we allow 15 minutes per plan for this task, at $130/hr, for ~75% of plans that may not already have appropriate documentation, this would imply a one-off cost of $835,000. As per the accreditation example, if just over 1,900 houses per year we built to 6 star rather than 5.5 star, this benefit would fully offset the documentation cost. If the base case were only 5 star, then it would take only just over 900 houses a year to be built instead at 6 star to offset the documentation cost.

6.4 Conclusions

For this measure, it is not possible to be unequivocal in advance about the expected net benefits. Not only are the costs uncertain – due to a lack of clarity about the number of unaccredited assessors, and how many are likely to seek and retain accreditation if this became a mandatory requirement – but the benefits are also uncertain, as they depend on behavioural factors, such as current practices and the extent to which they might change with mandatory accreditation and documentation requirements. However, this analysis demonstrates that costs are modest and would be offset by a relatively small share of new dwellings having improved energy performance.

In any case, these measures would be consistent with the national policy directions recommended in the Shergold/Weir and earlier reports, and agreed by the Building Ministers Forum, and would help to build confidence and accountability for the benefit of home-owners.

Ideally, if one or both of these measures were introduced, a baseline audit of current practices and outcomes would be undertaken, in order to support later evaluation and assessment of the degree of change that the measures induced.

7. Part C – Roof Replacements – Strengthening

7.1 Introduction

As noted, there are two components to the resilience analysis:

1. Improved strength – where an existing house (class 1 building) is located in wind regions B1, B2 and C under AS/NZS 1170.2 Structural design actions – Wind actions (AS/NZS 1170.2), and has a building approval before 1982, the replacement roof is to be strengthened to improve its structural integrity.
2. Improved energy efficiency – when replacing a roof on any existing house (class 1 building) and unit building (class 2) that has a building approval before 1 September 2003, the replacement roof must include a total level of insulation installed consistent with the relevant acceptable solutions under NCC 2019.

This chapter covers the first component, while the second is covered in Chapter 6.

7.2 Methodology

7.2.1 Roof Strengthening

The incremental costs and benefits associated with strengthening roofs – effectively, tying them down to the slab or footings – has been investigated by the James Cook University Cyclone Testing Station.[35] James Cook use two methodologies: one examining the expected reduction in damage by wind region over a 30-year period, and one examining the extent of reduction in annual insurance costs that would be required to produce a BCR of 1. It finds (p. 2) that BCRs greater than 1 are only realised for houses in Wind Region C in the case where roof strengthening occurs at a time when the roof is being replaced in any case. It also finds that significant insurance premium reductions would be required to justify the costs of a full roof upgrade if this is conducted at an arbitrary time, but lower, although still substantial, reductions are required in the case where roof strengthening occurs at a time when the roof is being replaced in any case.

The James Cook University report also notes (p. 3) that 'Damage investigations carried out by the Cyclone Testing Station (CTS) following severe windstorms have typically shown that houses built after the mid-1980s in Queensland to contemporary building standards perform better than houses constructed before the 1980s.'

The first question addressed in this report is to establish how much housing – and specifically pre-1982 housing – exists in each wind zone in QLD. The wind regions in QLD (and elsewhere) are shown in Figure 18, which is sourced from *AS/NZS 1170.2 – Wind actions*. This indicates that the majority of inland QLD is in Wind Zone A (the lowest wind strength zone), while Wind Zone C (the highest

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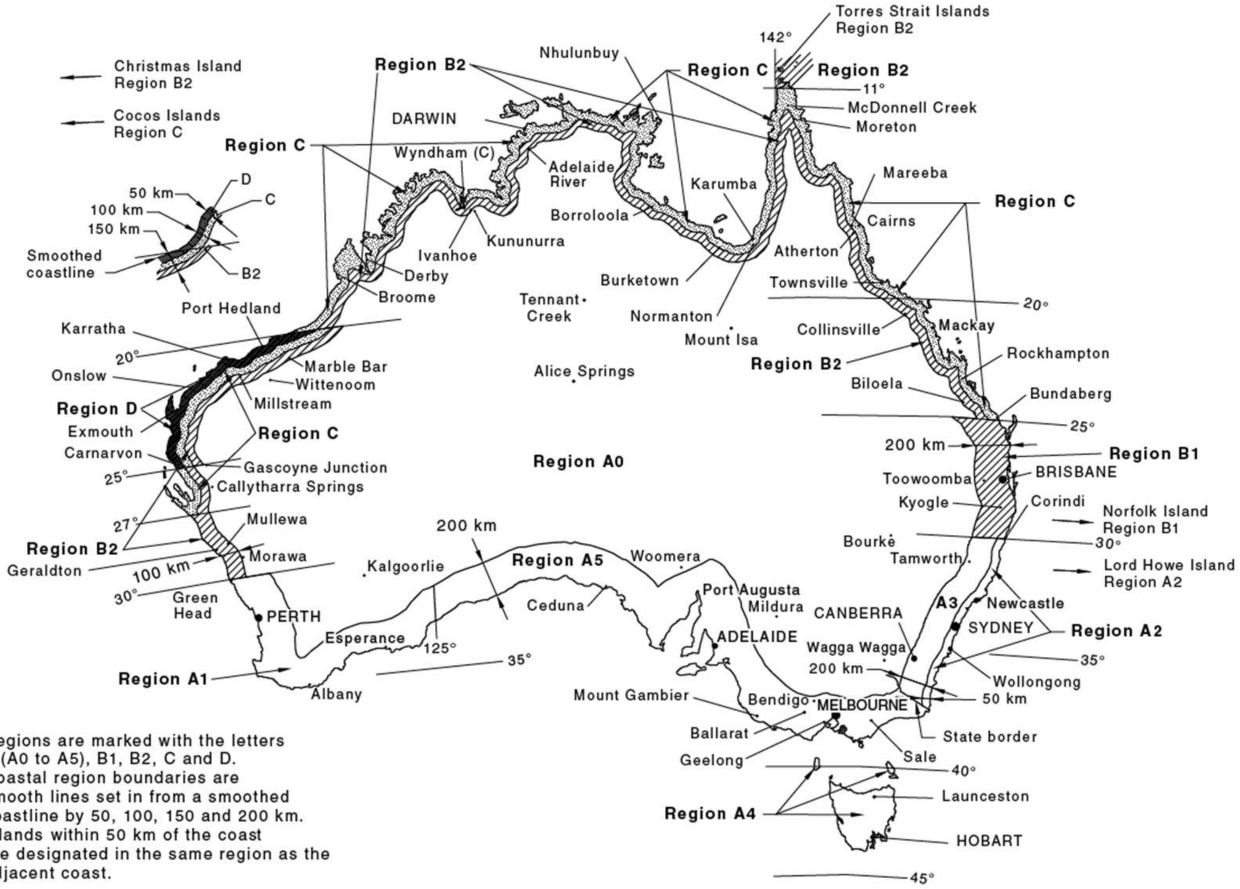
[35] James Cook University, Cyclone Testing Station, College of Science and Engineering, Report No, TS1219, *Quantifying Benefits of Roof Upgrades for Selected Australian House Types*, 15 October 2021.

wind strength zone in QLD)[36] is represented by a band including offshore islands and also a coastal strip 50 kms wide, from approximately Bundaberg and northwards to the NT border. Behind this (that is, further inland) is another 50km-wide zone, B2, which is the second-highest wind strength zone. Wind zone B1 (the third highest wind strength zone) is defined by a strip that extends 200kms inland from the coast from roughly Bundaberg south to the NSW border, and including offshore islands, approximating 'SE QLD'.



Regions are marked with the letters A (A0 to A5), B1, B2, C and D. Coastal region boundaries are smooth lines set in from a smoothed coastline by 50, 100, 150 and 200 km. Islands within 50 km of the coast are designated in the same region as the adjacent coast.

Figure 18: Wind Regions Map (Wind Regions B1 and B2 are depicted from AS 1684:2021 and SA 4055:2021

To determine the spread of housing by wind region, we made use of an excellent resource maintained by the QLD Government Statistician's Office known as *Queensland Regional Profiles*.[37] This is an online resource, built essentially on Census data, that enables users to tailor reports on numerous subjects, including dwelling structures (eg, numbers of dwellings by dwelling type), at regional scales down to the SA2 level. There are 546 SA2 regions in QLD alone, and this makes it feasible to at least broadly align housing numbers by SA2 (or SA3) with wind zones – with one or

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[36] Wind region D only occurs in WA.

[37] https://statistics.qgso.qld.gov.au/qld-regional-profiles

two exceptions, generally in Far North Queensland and near the NT border, where one or two SA2 regions straddle the B2/C wind zone divide.

One limitation with this source of housing data is that it is (currently) restricted to private occupied dwellings only, rather than all dwellings. For this reason, we convert the absolute numbers of dwellings estimated per wind region into percentages – with the implicit assumption being that unoccupied and public dwellings have a similar distribution by wind region. These percentages can then be applied to either to whole stock or, as discussed below, just the pre-1982 part of the stock. Summary data, compiled by SPR from *Queensland Regional Profile* reports, show the following results (noting that these may not be precise, given differences between wind zone and SA2 boundaries):

Table 63: Estimated Dwelling Numbers and Share (2021) by Wind Zone

Wind Zone	Dwelling Numbers (2021)	Share of Totals
A	82,374	5.9%
B1	1,067,716	76.4%
B2	12,848	0.9%
C	234,982	16.8%
Total QLD	**1,397,920**	**100.0%**

Wind zone B1, in SE QLD, dominates the dwelling shares, with over 76% of all dwellings in QLD. Wind zone A is geographically very large but contains fewer than 6% of all dwellings.

There is no data source known that defines the construction dates for (or ages of) Queensland housing and that would therefore provide a ready way to gauge the number of pre-1982 houses in QLD, let alone their regional distribution. Analogies could be drawn from other states where these values are tracked (VIC, WA, SA), but age profiles drawn from these states may or may not be applicable in QLD. Therefore, we have taken a different approach, essentially rolling our stock model back to 1981. The 1981 Queensland Census provides a value of 787,813 dwellings in 1981, but this is not broken down by Class in the Census results.[38] Based on the more recent CSIRO data reviewed above (from the *Australian Housing Data* portal), we find that 81.3% of dwellings completed in the last 5 years are Class 1, and on this basis we factor down the 1981 count by (1-81.3%), giving an estimate of 639,813 Class 1 dwellings in that year.

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[38] R.J. Cameron, Australian Statistician, *Census of Population and Housing, 30 June 1981 – Summary Characteristics of Persons and Dwellings, Queensland*, ABS Catalogue No. 2437.0, 1983, p. 4.

We then assume that the retirement rate (demolitions and conversions to other building classes) is 2% per year. Unfortunately, there are no national or QLD statistics on actual retirement rates, although the ABS is understood to be working on a least a trial data collection in this area. 2%/year is a value that has been found to have general support from councils and data-based firms working in the property industry. This assumption generates a pre-1982 dwelling stock projection as shown in Figure 19. It may be noted that this shows that while the stock declines over time, the rate of decline falls, reflecting an assumption that some of this stock will be renovated, potentially many times, and experience economic lives much longer than the roughly 50-year average generally assumed for Australian housing.

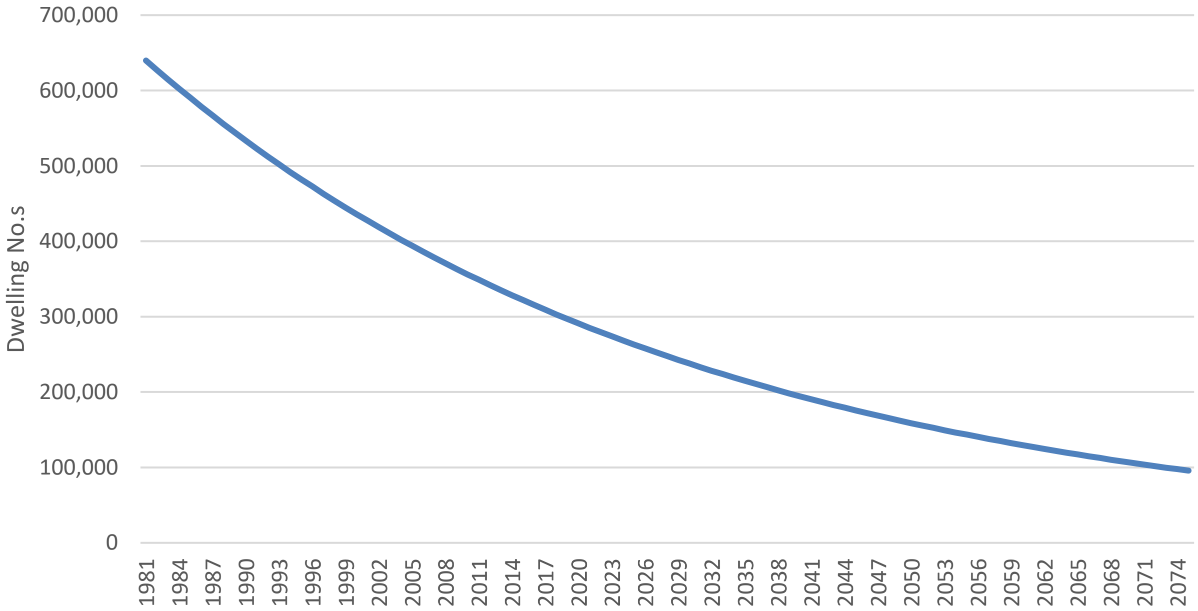

Figure 19: Stock Projection of Pre-1982 Dwellings, QLD

Combining the above, Figure 20 shows the expected distribution of pre-1982 dwellings by wind zone over time.

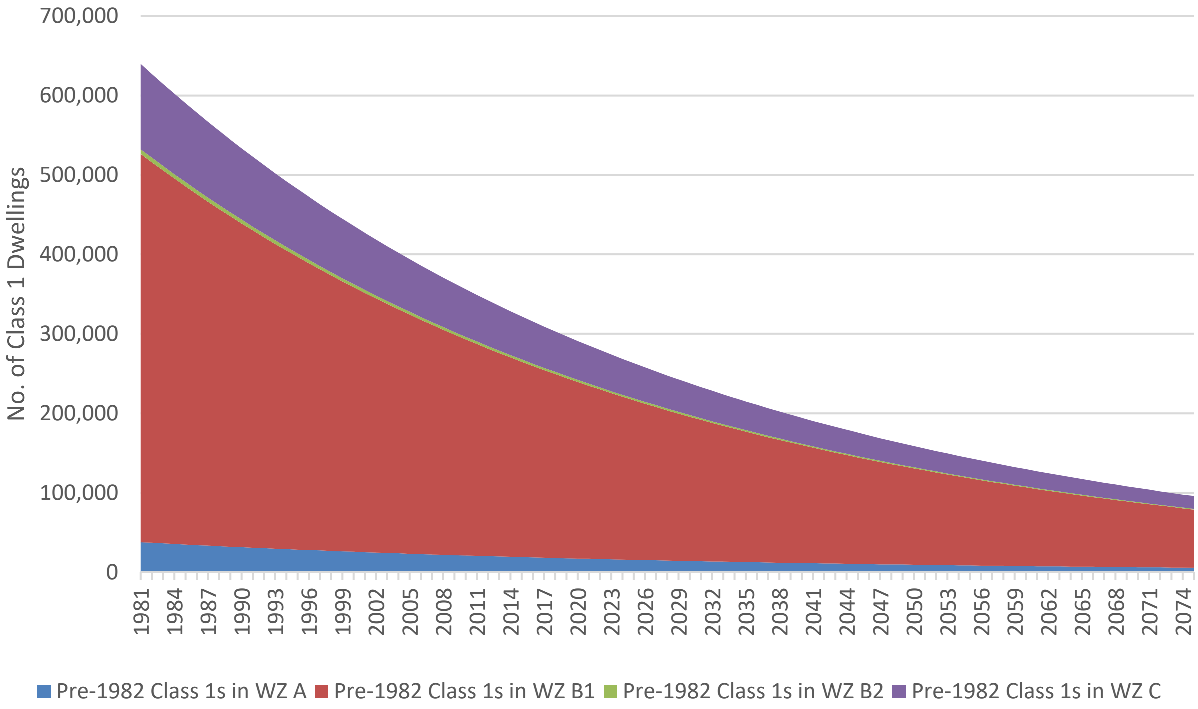

Figure 20: Stock of Pre-1982 Class 1 Dwellings by Wind Zone

The next question is how many of these houses are reroofed annually? First, we agreed with DEPW that the definition of 'reroofing' includes replacement of the roof *surface* (eg, tiles or sheeting), in addition to replacement (or refurbishment) of the roof *structure*, such as battens and rafters, but would not include lesser treatments such as repainting or patching of existing roofs. Broadly, then, there are two sets of circumstances in which houses are reroofed:

1. when the roof fails or tires due to old age that is, at end-of-economic-life (EOEL) of the roof, but not the house
2. when the roof is significantly damaged, or else destroyed, by storm damage (but without the whole house being damaged to the extent that a completely new house (and roof) is built.

In practice, this distinction may not be clear-cut, as it is more likely that an older roof will be damaged in a storm event. However, it provides a way to estimating roof replacement rates. We note that we tried different routes to determine the *actual* number of roof replacements per year in QLD, including talking to contacts in both the building and insurance sectors, but no firm estimates were able to be provided (the insurance industry appears to treat this information as confidential).

In general for this measure, it should be recalled that the *youngest* pre-1982 house in QLD is already 41 years old in 2022. According to our estimates, as shown in Figure 19, only some 43% of the 1981 housing stock is still standing, and this number will decline every year. As time passes, there is an increasing risk the owner may not consider that a reroofing investment is justified, as that investment may have a 40 – 50-year economic life, meaning the house may be 90 years old or more when the investment is fully amortised). This means that demolition could become a more frequent choice. That said, the phenomenon of ‘gentrification' militates against this, as these older houses are likely to be increasingly valuable in financial terms over time, and this may justify a reroofing expenditure even on an older house.

Considering EOEL roof replacement, 41 years is likely to be close the end of the economic life of most roof cladding materials (but probably not of roof structures, such as trusses, provided roofs have been well-maintained). Therefore, we should expect that EOEL roof replacements for pre-1982 houses are a reasonably common occurrence, and this impression was confirmed by informal conversations with builders in QLD. For this component of the total, we make what may be a conservative estimate that, on average, 0.5% of the residual pre-1982 stock undergoes an EOEL roof replacement annually. There is no reason to suspect that this value would vary greatly by wind zone, and so we assume that this rate applies in all of the pre-1982 stock, regardless of wind zone. This would imply that some 1,400 pre-1982 houses will be reroofed in QLD in FY2022 due to EOEL wear and tear alone. This number will fall annually as the pre-1982 stock falls but is estimated to still be around 1,120 roofs in FY2033, assuming this measure were to apply from FY2024 - FY2033 (see Table 64).

Table 64: Estimated No. of Roof Replacements due to End-of-Economic-Life Replacement, by Wind Zone, Pre-1982 Houses Only

EOEL replacement rate for pre-1982 stock	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Pre-1982 Class 1s in WZ A	79	77	76	74	73	71	70	69	67	66
Pre-1982 Class 1s in WZ B1	1,025	1,004	984	965	945	927	908	890	872	855
Pre-1982 Class 1s in WZ B2	12	12	12	12	11	11	11	11	10	10
Pre-1982 Class 1s in WZ C	226	221	217	212	208	204	200	196	192	188
Total No. of pre-1982 roof replaced at EOEL:	**1,342**	**1,315**	**1,289**	**1,263**	**1,238**	**1,213**	**1,189**	**1,165**	**1,142**	**1,119**

The second reason why roofs might be replaced is following severe storm damage, and this is more likely to occur in a high wind zone, and for pre-1982 houses. Indeed, for this analysis, the key question is how much less likely is it that a pre-1982 house would be deroofed (but not destroyed) through storm damage if that roof has been strengthened, as compared to the situation where it has not been strengthened, and how does this vary by wind zone? This is clearly a complex question, where the answer can only ever be probabilistic and will depend on many factors including the dwelling's design, the nature of roof and wall materials used, roof shape and other factors, in addition to the dwelling's age. The Cyclone Testing Station and Geosciences Australia have developed specific software known as VAWS (Vulnerability and Adaptation to Wind Simulation) for this and related purposes.

In addition, a report from the Bushfire and Natural Hazards Co-operative Research Centre (BNHCRC), *Improving the Resilience of Existing Housing to Severe Wind Events* (2020), presents the results of modelling wind loading and structural response data for 10 common house types, including examining costs associated with water ingress and other cost drivers. The report also notes that the QLD Government offers a *Household Resilience Program* which provides funding to low income eligible home-owners to improve the resilience of their homes against cyclones. This program managed by the Queensland Department of Housing & Public Works (QDHPW) commenced in late 2018 and has been extended through 2020. Eligible home-owners can apply to receive a Queensland Government grant of 75% of the cost of improvements (up to a maximum of $11,250 including GST). About 1700 houses had been retrofitted by the 2020 publication date.

Now, it is well beyond the scope of the current project to add any value to this significant body of expert research. Our task is to try to extract a reasonable answer to the question posed above; that is, to quantify the benefit that could be expected if pre-1982 houses were to be required to have their roofs strengthened in the circumstance where the roof was being replaced in any case (whether due to storm damage or EOEL), and how this varies by wind zone.

The James Cook research finds that roof strengthening can be cost effective, but only in Wind Zone C and only when strengthening works are undertaken at a time when the roof is being replaced in any case (referred to as 'Case 2' in its report).[39] At low discount rates (eg, 2%), BCRs of up to 0.5 were nevertheless found for wind region B1, and up to 0.66 in wind region B2. That is, the expected benefits were material (eg, NPV of up to $7,200 per house), but the costs were higher than this (see below) and thus the investment was judged not cost-effective in these wind zones (noting the JCU study did not take into account losses from societal impacts). Note that the results cited here refer to the damage mitigation method, rather than reduced insurance costs, as commercial considerations (eg, changing risk perceptions) bring an additional layer of uncertainty into the latter.

In terms of the incremental costs of roof tie-downs, these were quantified by James Cook (p. 6), through a contract with a professional quantity surveyor, as ranging between $7,807 - $12,031 in wind regions A, B1 and B2, and between $7,534 - $13,417 in wind region C.

For our economy-wide analysis (which did not take include any costs due to impacts on the community/society), we assume average incremental costs for each house strengthened, and also average benefits, as above, and model these based on our analysis of the distribution of pre-1982 housing by wind zone. Key assumptions for our analysis are:

1. Where a roof is replaced in wind zone C, for any reason, that roof is likely to be strengthened in any case – in part, thanks to the Household Resilience Program and also the excellent

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[39] Cyclone Testing Station (2021), pp 16 – 18.

industry guidance materials produced by the Cyclone Testing Station. On this basis, we attribute no incremental costs in Wind Zone C.

2. Where a roof is replaced in other wind zones, it would not be likely to be strengthened, unless this were mandated. Therefore, incremental costs could arise in Wind Zones B1 and B2.

The number of houses deroofed due to storm/cyclone events in QLD per year is not known (at least, in the public domain). However, Cyclone Yasi destroyed 150 homes and extensively damaged another 650 homes in February 2011, while a further 2,275 homes sustained 'moderate damage'.[40] In 2015, Cyclone Marcia damaged 1500 homes.[41] In 2017, tropical cyclone Debbie damaged over 700 houses in the Airlie Beach, Bowen and Proserpine regions, with 45% of those in Airlie Beach classified as 'moderate' or 'severe/total' damage (and around 33% in Bowen and 24% in Proserpine).[42] The shares of homes damaged or destroyed that were pre/post 1982 is not clear, while it appears that the majority of the homes damaged or destroyed are in wind zone C.

Given the above values associated with single events, it appears reasonable to assume that at least as many roofs are replaced due to storm/cyclone damage, on average, as are replaced due to EOEL – estimated at 1,342 pre-1982 homes in FY2024. However, we assume that the majority of these events occur in wind zone C. On this basis, as noted above, it is likely that the roofs of those houses damaged (but not destroyed) in wind zone C would be strengthened at time of repairs, with or without the proposed mandate. Therefore, no incremental costs or benefits would arise. To the extent that there were storm/cyclone damaged roofs in other wind zones, there could be incremental costs/benefits, but the incidence of such damage is not known.[43]

On this basis, the number of reroofing events that would incur incremental costs, due to this potential measure, falls from around 1,037 in FY2024 down to 865 in FY2033 (due to the expected decline in the pre-1982 dwelling stock) – see Table 64.

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[40] https://www.abc.net.au/news/2011-02-07/cyclone-yasi-destroyed-150-homes/1933632#:~:text=Cyclone%20Yasi%20destroyed%20almost%20150,homes%20are%20still%20without%20power.

[41] https://www.hurriyetdailynews.com/1500-homes-damaged-by-cyclone-marcia-in-australia--78665

[42] Cyclone Testing Station/James Cook University, *Tropical Cyclone Debbie – Damage to buildings in the Whitsunday Region*, CTS Technical Report no. 63, June 2017.

[43] Potentially this could be estimated by other parties. However, knowing the exact number is unlikely to change the overall conclusions of this analysis, as the Cyclone Testing Station research suggests that strengthening roofs outside Wind Zone C is not cost-effective, regardless of the number of roofs impacted.

Table 65: Estimated Total Number of Pre-1982 Roofs with Incremental Impacts due to Strengthening, by Wind Zone

Wind Zone	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
A	-	-	-	-	-	-	-	-	-	-
B1	1,025	1,004	984	965	945	927	908	890	872	855
B2	12	12	12	12	11	11	11	11	10	10
C	-	-	-	-	-	-	-	-	-	-
Total	**1,037**	**1,017**	**996**	**976**	**957**	**938**	**919**	**901**	**883**	**865**

7.3 Key Findings

7.3.1 Incremental Costs

Incremental costs per house strengthened are taken from Cyclone Testing Station Report No. TS1219, October 2021. These costs are assumed to be incurred by each house strengthened, where this is not already assumed to occur (ie, Wind Zone C, while Wind Zone A is outside the scope of the measure. The expected present value of costs is just under $88 million (Table 66).

Table 66: Incremental Costs Per House, and Present Value of Costs, Roof Strengthening, by Wind Zone

Houses by Wind Zone	Costs per house	Present value of incremental costs (2% real discount rate)
Pre-1982 Class 1s in WZ A	$10,264	$0
Pre-1982 Class 1s in WZ B1	$10,264	$86,721,808
Pre-1982 Class 1s in WZ B2	$10,264	$1,043,538
Pre-1982 Class 1s in WZ C	$10,112	$0
Total		**$87,765,346**

7.3.2 Benefits

As noted, benefits are represented in the Cyclone Research Station’s analysis (p. 13) as avoided:

- damage costs to houses (as noted, we use these rather than avoided insurance costs)

- water ingress costs (eg, damage to home contents)
- temporary accommodation costs.

Not included as potential benefits are avoided:

- health system and loss of life costs
- damage to ancillary items, such as roof ventilators, gutters and TV aerials, impacts from fallen trees
- damage to the dwelling structures due to severely degraded elements due to lack of maintenance.

We estimate the present value of benefits by reverse-engineering the stated BCRs in the Cyclone Testing Station report, as we do not have access to the underlying model. This also means that we cannot break down the benefit over time or by sub-type. We select the most favourable BCRs, which are associated with a low 2% real discount rate. A low discount rate is often used where the primary benefit, or avoided cost, is either long-term (such as climate change) or associated with risk of loss of human life. While there are other analytical techniques that can be used, a low discount rate is one approach to expressing a low tolerance for risk when it comes to factors that involve the (avoidable) risk of loss of human life.

The estimated present value of benefits on this basis is $24.7 million (Table 67).

Table 67: Present Value of Benefits, and BCRs (@ 2% Real Discount Rate), by Wind Zone

Wind Zones	Average BCR (@ 2% real discount rate)	Implied Present Value of Benefits
A	-	-
B1	0.28	$24,282,106
B2	0.44	$459,157
C	-	-
Total		**$24,741,263**

7.3.3 Net Present Values and Benefit Cost Ratios

Based on the above inputs and assumptions, the overall NPV associated with this measure would be negative, at -$63 million, with an overall BCR of 0.3, even at a low 2% real discount rate (Table 68).

Table 68: Net Present Values and Benefit Cost Ratios by Wind Zone, Roof Strengthening

Wind Zone	NPV	BCR
A		
B1	-$62,439,702	0.3
B2	-$584,381	0.4
C		
Total	**-$63,024,083**	**0.3**

7.4 Conclusions

Overall, these findings derive directly from similar findings by the Cyclone Research Station, with the only significant difference being that we have attempted to estimate the incremental number of reroofing occurrences that this specific measure would impact, excluding those that are likely to be strengthened in any case when reroofed. That said, there are several factors that could lead to a higher net social value being associated with the measure, which we have not been able to quantify.

1. As noted, not all benefits potentially attributable to the measure have been accounted for, including avoided loss of life and health system costs, which could be very large
2. We do not have access to reliable data on roof losses due to storm and cyclone events by climate zone. If such events in fact occur outside Wind Zone C, this would increase the net benefit associated with the measures. This factor may be able to be explored by other parties.
3. Climate change may lead to a changed frequency, severity and spatial distribution of storm and cyclone events. Particularly if these events were to impact in SE QLD (Wind Zone B1) in future, the potential for economic and social losses could be very high, due to the much greater housing density in this region. As a result, the benefits associated with roof strengthening in this region could also be much higher than assessed. As above, this factor may be able to be explored by other parties.

8. Part C – Roof Replacements – Insulation

8.1 Introduction

This Chapter presents our methodology for, and results of, analysing a potential measure that would require that when replacing a roof on any existing house (class 1 building) and unit building (class 2), that has a building approval before 1 September 2003, the replacement roof must include a total level of insulation installed consistent with the relevant acceptable solutions under NCC 2019.

8.2 Methodology

8.2.1 Introduction

By contrast with previous task, the methodology for quantifying the benefits and costs associated with adding NCC2019 elemental (DTS) levels of insulation to the roofs of pre-September-2003 residential buildings (Class 1 and 2), at a time when they are being reroofed in any case, is relatively straight-forward. RED Sustainability Consultants and Ecolateral have estimated the per-building level benefits, and also costs, drawing on Steele Wrobel inputs for the latter. SPR then applied these benefits and costs to a stock model of pre-September-2003 housing in QLD to estimate the economy-wide benefits and costs. The methodology for each element is described briefly below.

8.2.2 Building Level Analysis Methodology

To analyse the benefits of adding ceiling insulation to re-roofed dwellings, the dwelling archetypes modelled in NatHERS software as outlined in Section 2.1.4, were used to provide a comprehensive coverage of the types of dwellings in Queensland that may need re-roofing.

Stripped back NatHERS models of each of the 6 dwelling archetypes were developed with no insulation to external walls, floor or roof, to represent pre 2003 housing stock (before energy efficiency measures were introduced in the BCA). Each of the six dwelling designs were simulated in each of the 4 QLD climate zones, and in each of the 4 cardinal orientations.

The variations of floor and wall types were not tested separately. The four Class 1 dwellings were assumed to have lightweight brick veneer walls and a concrete slab on ground. However, the ‘Queenslander’ type house with lightweight walls and a lightweight, unenclosed floor, based on the SBH02 model, was separately simulated.

The resulting heating and cooling energy consumption from these simulations form the base level of energy efficiency performance against which to compare an upgraded scenario in which ceiling insulation has been installed.

Ceiling insulation as per the NCC 2019 minimum requirement for the relevant climate zone was then added to each of the above scenarios and the models re-simulated to produce a predicted heating and cooling energy requirements for the post-insulation installation.

NCC provisions prescribe a 'Total Construction R-Value' which takes into consideration the whole of roof/ceiling construction. Added R values of approx. R0.5 less than the total construction R-value required, have been assumed for costing and simulation purposes. (refer Table 69 for R-values used in the calculations)

The Total Construction R value required under 3.12.1.2 varies depending on the colour of roof specified. To simplify the calculations, a 'Mid' coloured roof was assumed, as the middle of the insulation range, with dark roofs requiring a higher R value and light roofs requiring a lower R value in certain climate zones. A higher insulation value would have a slightly higher upfront cost more but would also provide a slightly more savings from reduced heating and cooling demand. Vice versa a lower insulation value would have a lower up-front cost but would not provide as much ongoing energy savings.

Table 69: R-value of added insulation assumed for thermal modelling purposes

	CZ 1	CZ 2	CZ 3	CZ 5
Total Construction R Value as per NCC 2019 3.12.1.2	Min. R4.1 down (Med. colour)	Min. R4.1 down (Med. colour)	Min. R4.6 down and up (Med. colour)	Min. R4.6 up (Med. colour)
Added Insulation Assumed	R3.5	R4.1	R4.1	R4.1

Class 2 Dwellings

In NCC 2019, Class 2 dwellings do not have Elemental provisions that prescribe R values to be achieved for ceiling/roof construction. In lieu of this, the total construction R value of the Class 1 provisions was used.

For the purpose of the analysis, it is assumed that roof replacement would only occur in the top floor of apartment buildings, and the improved thermal performance due to the addition of insulation is assumed to only benefit those same top floor dwellings.

It is also assumed that the whole roof of the apartment building would be replaced. Therefore, all apartments on the top level of the building would benefit from improved thermal performance once insulation is installed.

As seen in Section 2.1.4, there are 8 apartments in the floor plate of the apartments building. All 8 apartments are modelled representing each orientation of the 2 x unit types (corner unit and internal unit). The energy savings from all 8 units are then summed to compare against the cost of the whole of building insulation installation.

For the purpose of the roof replacement analysis, the roofs of the Class 2 units was changed, in the NatHERS models, from a concrete roof (which was used for the Benefit Cost Analysis of moving from QDC 4.1 to NCC 2019), to a framed roof with sheet metal roofing. This was for two reasons, 1) because the roofs of older apartment buildings were assumed to be smaller buildings that were more likely to have a framed roof, and 2) because it was assumed that a framed roof would be more likely to be requiring of replacement than a concrete roof.

Costing of Insulation

Table 70: Roof Insulation Installation costing factors. Table 70 shows the basic cost factors involved in costing the installation of roof insulation. Costing of installation of insulation is made up of the material cost of the insulation product, plus the install cost, to the entire roof area of each dwelling. These material and installation costs are considered in isolation of any other roof replacement costs mentioned so that the costs can be compared directly against predicted energy savings. Geographical cost adjustment factors were included in the costing Table 15.

Table 70: Roof Insulation Installation costing factors

	Cairns (CZ1)	Brisbane (CZ2)	Charleville (CZ3)	Toowoomba (CZ5)
Locational Cost Factor	108%	100%	125%	103%
Added R Value	3.5	4.1	4.1	4.1
Material Cost	$\$10.43/\text{m}^2$	$\$15.12/\text{m}^2$	$\$15.12/\text{m}^2$	$\$15.12/\text{m}^2$
Install cost	$\$7.50/\text{m}^2$	$\$7.50/\text{m}^2$	$\$7.50/\text{m}^2$	$\$7.50/\text{m}^2$

8.2.3 Building Level Results

The overall cost of installation varies depending on the size of roof, the R-value of insulation required to be installed, and the geographic location. Table 71 shows the overall costing for each of the archetypes and compares those costs to the average benefit in predicted heating and cooling energy savings.

For the Class 2 apartment building the entire roof is assumed to be replaced hence the total roof area of the building is used to calculate the cost of insulation installation

Table 71: Roof insulation installation costs vs average heating and cooling energy benefit

	Cost – Install + Materials ($)						Benefit (kWh/yr)			
	Ceiling Area (m^2)	CZ1	CZ2	CZ3	CZ5		CZ1	CZ2	CZ3	CZ5
SBH02	300.4	$5,817.07	$6,795.05	$8,493.81	$6,998.90		2821.0	4195.2	9861.3	9456.1
Qlder	265.3	$5,137.38	$6,001.09	$7,501.36	$6,181.12		5262.6	9697.5	21964.2	21553.8
SBH03	151.7	$2,937.58	$3,431.45	$4,289.32	$3,534.40		1546.9	2458.2	5447.3	5188.0
THMid	106.7	$2,066.18	$2,413.55	$3,016.94	$2,485.96		656.2	1200.2	2733.1	2620.0
THEnd	106.1	$2,054.56	$2,399.98	$2,999.98	$2,471.98		690.9	1298.1	2787.1	2688.0
Class 2 Building (Framed Roof)	1067.0	$20,661.81	$24,135.54	$30,169.43	$24,859.61		50366.3	33855.0	64181.0	59286.6

Table 71 also shows that the heating and cooling energy savings in the single storey house are predicted to be the largest compared to the other archetypes. This is because the single storey archetype has the largest proportion of roof/ceiling area to house area. Hence the act of improving the roof/ceiling performance has the biggest impact on this design.

The heating and cooling energy savings predicted for the Queenslander design is significantly more than the standard SBH02 design. This is largely because the starting performance of the uninsulated Queenslander is significantly poorer than that of the SBH02 design with its concrete slab on ground and brick veneer walls.

It must be remembered that these energy savings predictions are based on starting conditions in which there is no ceiling insulation. Some dwellings will have partially insulated ceilings, or ceiling insulated with a lower level of insulation. The expected savings in those cases would be smaller.

Table 72 and Table 73 present an example of the predicted thermal performance based on NatHERS ratings of the 6 dwelling architypes (+Queenslander) in Climate Zone 1, with a north orientation, before (Table 72) and after (Table 73) the installation of roof insulation.

Table 72: Example Thermal Performance Results - Uninsulated Roofs - Climate Zone 1 - North Orientation

	Heating (MJ/m^2/yr)	Cooling (MJ/m^2/yr)	Total (MJ/m^2/yr)	Star Rating
SBH02	0.5	163.4	163.9	4.6
SBH03	1.0	223.7	224.6	2.7
Queenslander	2.2	215.0	217.1	2.9
THMid	1.4	118.0	119.4	6.4
THEnd	1.7	145.2	147.0	5.2
SB610 + framed roof	1.5	399.5	401.0	0.0
SB630 + framed roof	0.4	366.9	367.3	0.0

Table 73: Example Thermal Performance Results - Insulated Roofs - Climate Zone 1 - North Orientation

	Heating (MJ/m^2/yr)	Cooling (MJ/m^2/yr)	Total (MJ/m^2/yr)	Star Rating
SBH02	0.0	121.0	121.0	6.3
SBH03	0.4	190.1	190.4	3.7
Queenslander	0.2	135.8	135.9	5.7
THMid	0.2	104.1	104.3	7.0
THEnd	0.4	129.9	130.2	5.9
SB610 + framed roof	0.0	147.0	147.0	5.2
SB630 + framed roof	0.0	156.8	156.8	4.9

The example from climate zone 1 (Cairns) demonstrates that significant thermal improvement is achieved through the installation of ceiling insulation. In this case, due to the climate, the expected energy saving is essentially through reduced need for cooling. In the other 3 climate zones there is a mix of savings from reduce need for heating. and for cooling. Table 74 and Table 75 show the same scenario but in climate zone 2 (Brisbane).

Table 74: Example Thermal Performance Results - Uninsulated Roofs - Climate Zone 2 - North Orientation

	Heating (MJ/m²/yr)	Cooling (MJ/m²/yr)	Total (MJ/m²/yr)	Star Rating
SBH02	63.6	43.2	106.9	2.7
SBH03	87.7	68.8	156.5	1.7
Queenslander	132.4	68.4	200.8	1
THMid	46.5	27.6	74.1	3.9
THEnd	67.3	36.5	104.8	2.8
SB610 + framed roof	133.4	172.1	305.5	0
SB630 + framed roof	70.6	170.6	241.2	0.5

Table 75: Example Thermal Performance Results - Insulated Roofs - Climate Zone 2 - North Orientation

	Heating (MJ/m²/yr)	Cooling (MJ/m²/yr)	Total (MJ/m²/yr)	Star Rating
SBH02	17.5	26.8	44.3	5.9
SBH03	52	53.6	105.6	2.8
Queenslander	20.5	40.7	61.3	4.6
THMid	20.1	22.1	42.2	6.1
THEnd	39.6	29	68.5	4.1
SB610 + framed roof	12.3	43.8	56.1	4.9
SB630 + framed roof	15.9	46	61.9	4.5

8.2.4 Economy-wide Analysis

SPR created a model of pre-2003 housing (that is, commencing in FY2002), drawing on Census data for QLD. As per the previous section's pre-1982 stock model, we assume a 2%/year retirement rate of the pre-2003 stock.

A difference from the pre-82 model is that the pre-2003 model requires us to consider apartment *buildings* (and not dwellings), as the measure would apply to a pre-2003 Class 2 buildings that were being reroofed. Clearly the measure would only affect those apartments on the top level of the apartment building, so the model needs to count whole apartment buildings. As described above, RED Sustainability Consultants have quantified the incremental benefits and costs at the level of a whole Class 2 building archetype.

Census data counts Class 2 dwellings but not Class 2 buildings. Similarly, ABS Building Activity data counts Class 2 dwellings (and, indeed, mixes these with Class 1 townhouses). Fortunately, the Geoscience Australia NEXIS database (introduced above) enables a count of Class 2 buildings, in addition to houses. Since the NEXIS database is not linked to a specific point in time, we do not use the absolute count from NEXIS, but rather apply the observed ratio of Class 2 buildings to Class 2 dwellings from NEXIS, to our Census-derived stock model. On this basis, we observed that the count of Class 2 buildings in QLD is a little over 9% of the apartment dwelling count (implying an average count of apartments/dwelling of just under 11). We acknowledge there is a risk that the ratio of buildings/apartments may have been different in the pre-2003 stock, but this is not illuminated by available data. Figure 21 shows the estimated stock of pre-2003 residential buildings over time by building type. Note that the share held by apartment buildings is very small and therefore difficult to see at the bottom of this figure.

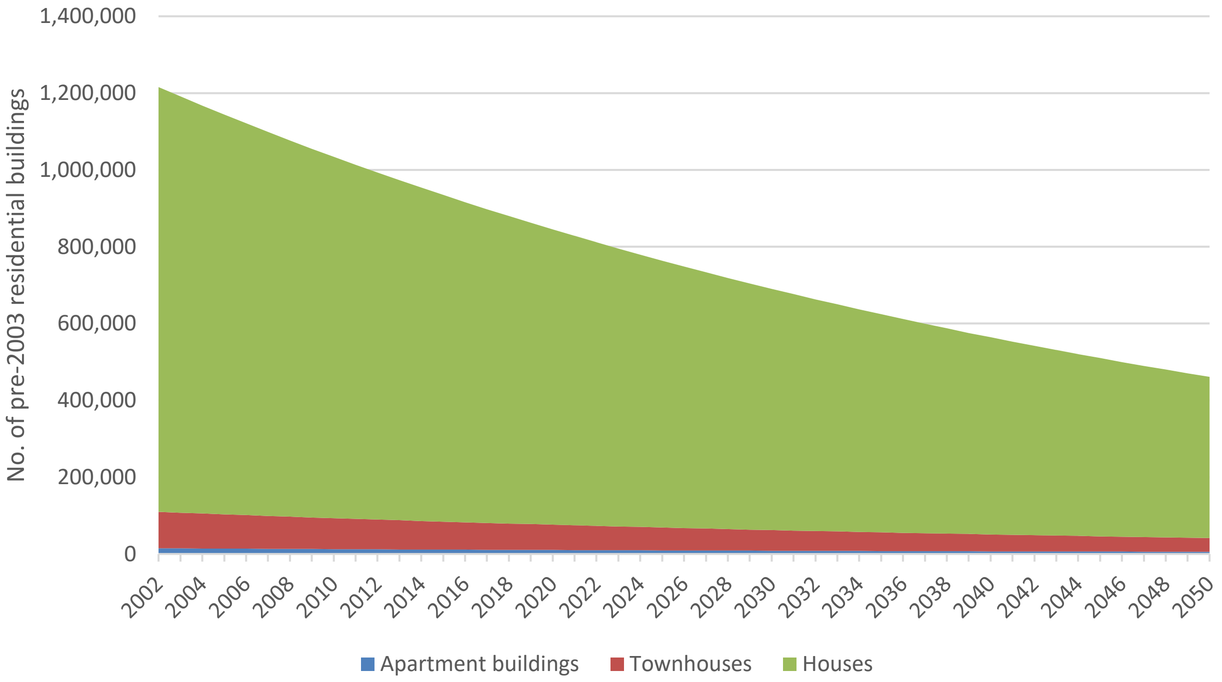

Figure 21: Estimated Stock of Pre-2003 Residential Buildings, QLD

Again, there are two circumstances in which this potential measure could be triggered: end-of-economic-life (EOEL) replacement of worn-out roofs, and replacement of roofs damaged or removed by storms/cyclones. Compared to the pre-1982 roofs, for the pre-2003 roofs we assume:

- A lower EOEL replacement rate of 0.25% of the stock per year, due to this being a newer housing cohort

- A lower storm/cyclone damage rate (also estimated at 0.25%), due to these also being post-1982, and therefore already strengthened in Wind Zones C and B2.

This generates an estimate of around 3,900 pre-2003 residential buildings in total being roofed in FY2024, falling to around 3,250 by FY2033, due to the stock of pre-2003 falling over time – see Figure 22.

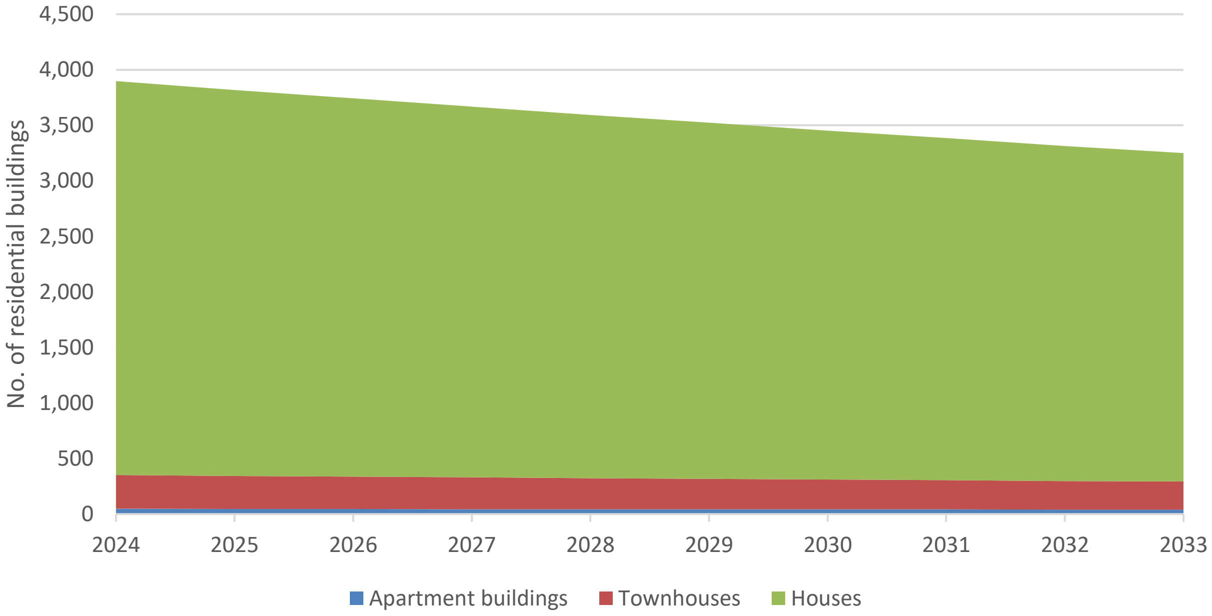

Figure 22: Estimated Stock of Pre-2003 Residential Buildings Reroofed Annually, QLD, FY2024 – FY2033

NEXIS data was again used to map the pre-2003 stock by climate zone, and *QLD Regional Profiles* were used to map the same by wind zone, as described in the previous section for the pre-1982 stock. We express both in terms of stock percentages, as noted in Table 76 (by climate zone) and Table 77 (by wind zone).

Table 76: Map of Pre-2003 Residential Buildings by Climate Zone, QLD

CZ	Apartment Buildings	Townhouse	House	Total
1	0.20%	0.82%	10.35%	**11.37%**
2	1.45%	8.38%	67.82%	**77.65%**
3	0.04%	0.16%	4.30%	**4.50%**
5	0.14%	0.51%	5.82%	**6.48%**
Total	**1.84%**	**9.87%**	**88.29%**	**100.00%**

Table 77: Map of Residential Buildings by Wind Zone, QLD

Wind Zone	A	B1	B2	C	Total
Apartment Buildings	0.03%	1.15%	0.00%	0.12%	**1.30%**
Townhouse	0.70%	11.30%	0.05%	1.29%	**13.34%**
House	6.37%	65.19%	0.73%	13.06%	**85.35%**
Total	**7.10%**	**77.65%**	**0.79%**	**14.46%**	**100.00%**

While there is no known source of data on the current insulation status of pre-2003 houses in QLD, we expect the share would be low due to a) not being a requirement in pre-2003 building regulations, and b) limited uptake of NCC2019-compliant (bulk) insulation in QLD under retrofit initiatives, such as the 'pink batts' scheme in the 2000s. At the same time, it is unlikely that the share is zero, so we make a small allowance of 5% of the pre-2003 stock already being insulated to NCC2019 standards. This assumption does not have a material impact on the analysis, as it cuts both cost and benefits in equal proportion.

Then, in a manner described in detail above in Sections 2.5.2 to 2.5.4, we estimate the incremental costs, electricity savings, gas savings, avoided electrical infrastructure and avoided carbon costs, by archetype and climate zone, for the pre-2003 stock that is retrofitted with ceiling insulation under this measure. All key inputs as the same those shown above, including for fuel prices, emissions intensity of fuels, incremental costs (sourced from Steele Wrobel). KPIs expressed again comprise:

- The net present value (NPV) of the measure (present value of benefits minus the present value of costs)
- The benefit cost ratio (BCR – present value of benefits divided by the present value of costs).

Other indicators quantified include the volume and value of each benefit component: electricity savings, gas savings, peak demand avoided and avoided greenhouse gas emissions.

For Class 2 buildings, we undertook analysis of both concrete and metal-framed roof structures. While the distribution of these two types in the pre-2003 stock is not known, we understand that framed roofs were much more common than they are today, and ubiquitous on low-rise, large footprint Class 2s. We therefore apply an 85% weighting for framed roofs, and a 15% weighting for concrete roofs. While there is a larger benefit for framed roofs, this assumption is not significant enough to have an impact on the overall results for Class 2s.

8.3 Key Findings

8.3.1 Incremental Costs

Incremental costs average just under $17million a year over the assumed 10-year life of the measure (FY2024 – FY2033). The present value of these costs is $120.6 million. Table 80 below provides a detailed breakdown of these costs by climate zone and archetype.

8.3.2 Fuel Cost Savings

This measure would avoid around 4,500 MWh of electricity consumption for each annual cohort of buildings insulated. Assuming the measure applies for 10 years, from FY2024 to FY2033, total electricity savings would reach almost 37,000 MWh by FY2033 and remain at this level for the balance of the economic lives of the buildings. Gas savings are much smaller at around 228 MWh per cohort-year, reaching 1,250 MWh by FY2033. The present value of electricity savings is $65.3 million and the present value of gas savings is $3.4 million. The spread of results by archetype and climate zone is shown in Table 80.

8.3.3 Avoided Electrical Infrastructure

Avoided peak demand would reach almost 17 MW by FY2033, with the present value of this benefit being significant at just under $109 million. This reflects the fact that additional insulation helps to reduce air-conditioner use, with the latter strongly correlated with electrical system peaks. System peak demand is, in turn, the key driver of costs for electricity networks.

8.3.4 Avoided Greenhouse Gas Emissions

Each annual cohort of buildings improved under this measure would save around 2,750 t CO_2-e per year, accumulating to a total of almost 17,500 t CO_2-e by FY2033. As noted earlier in the report, the emissions savings start to reduce thereafter, as the emissions intensity of the electricity grid is falling. Despite this, cumulative emissions savings over the FY2024 – FY2050 period would be very significant, at some 352,000 t CO_2-e. Using the shadow carbon prices described in Chapter 2, the present value these avoided emissions is just over $31 million.

8.3.5 Net Present Value and Benefit Cost Ratio

Overall, this measure would be cost-effective, with an NPV of over $88 million and a BCR of 1.7, as shown in Table 78.

Table 78: Benefit Cost Analysis Summary Indicators – Roof Insulation

Cost/Benefit Type	Present Value ($million FY2023 real, 7% real discount rate)
Avoided Electricity Costs	$65.3
Avoided Gas Costs	$3.4
Avoided Electricity Infrastructure Costs	$108.7
Avoided GHG Emissions Costs	$31.4
Total Benefits	**$208.8**
Incremental Construction Costs	$120.6
Net Benefit (Net Present Value)	**$88.2**
Benefit Cost Ratio	**1.7**

8.3.6 Diversity of Results

Table 80 overleaf provides a detailed map of results by building type, archetype and climate zone. This analysis did not separately consider construction details. For summary analyses of these details, Table 79 shows that this measure would be cost effective in all climate zones.

Table 79: BCA Results by Climate Zone: Roof Insulation Measure

Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
1	$4.9	$0.0	$8.2	$2.3	$15.4	$11.3	$4.2	1.4
2	$46.8	$0.0	$77.9	$22.1	$146.8	$94.7	$52.1	1.5
3	$5.6	$0.0	$9.3	$2.6	$17.4	$6.3	$11.2	2.8
5	$8.0	$3.4	$13.4	$4.3	$29.1	$8.3	$20.8	3.5
	$65.3	**$3.4**	**$108.7**	**$31.4**	**$208.8**	**$120.6**	**$88.2**	**1.7**

Table 80: Detailed BCA Results by Archetype and Climate Zone: Roof Insulation Measure

Type	Archetype	Climate Zone	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
House	1-Storey	1	$1.7	$0.0	$2.9	$0.8	$5.4	$4.8	$0.5	1.1
House	2-Storey	1	$1.6	$0.0	$2.7	$0.8	$5.0	$5.0	-$0.0	1.0
Townhouse	TH - end	1	$0.0	$0.0	$0.1	$0.0	$0.1	$0.2	-$0.0	0.7
Townhouse	TH - mid	1	$0.1	$0.0	$0.1	$0.0	$0.2	$0.2	-$0.1	0.7
Apartment Buildings	Apartment Buildings	1	$1.5	$0.0	$2.5	$0.7	$4.8	$1.0	$3.8	4.7
House	1-Storey	2	$18.7	$0.0	$31.2	$8.9	$58.7	$34.0	$24.7	1.7
House	2-Storey	2	$19.2	$0.0	$32.0	$9.1	$60.3	$47.5	$12.8	1.3
Townhouse	TH - end	2	$0.7	$0.0	$1.1	$0.3	$2.1	$1.9	$0.2	1.1
Townhouse	TH - mid	2	$0.9	$0.0	$1.6	$0.4	$3.0	$2.9	$0.1	1.0
Apartment Buildings	Apartment Buildings	2	$7.2	$0.0	$12.0	$3.4	$22.7	$8.4	$14.2	2.7
House	1-Storey	3	$3.1	$0.0	$5.2	$1.5	$9.7	$3.3	$6.4	3.0
House	2-Storey	3	$1.9	$0.0	$3.2	$0.9	$6.0	$2.5	$3.5	2.4
Townhouse	TH - end	3	$0.0	$0.0	$0.0	$0.0	$0.1	$0.0	$0.0	1.9
Townhouse	TH - mid	3	$0.0	$0.0	$0.1	$0.0	$0.1	$0.1	$0.1	1.9
Apartment Buildings	Apartment Buildings	3	$0.5	$0.0	$0.8	$0.2	$1.5	$0.4	$1.1	4.1
House	1-Storey	5	$3.2	$1.6	$5.3	$1.8	$11.9	$3.0	$8.9	4.0
House	2-Storey	5	$3.4	$1.7	$5.7	$1.9	$12.7	$4.2	$8.6	3.0
Townhouse	TH - end	5	$0.1	$0.0	$0.1	$0.0	$0.3	$0.1	$0.2	2.4
Townhouse	TH - mid	5	$0.1	$0.1	$0.2	$0.1	$0.4	$0.2	$0.3	2.4
Apartment Buildings	Apartment Buildings	5	$1.2	$0.0	$2.0	$0.6	$3.7	$0.8	$2.9	4.6
Totals			**$65.3**	**$3.4**	**$108.7**	**$31.4**	**$208.8**	**$120.6**	**$88.2**	**1.7**

Table 81 shows that the measure would also be cost-effective for all dwelling classes.

Table 81: BCA Results by Building Class: Roof Insulation Measure

Class	Present Value of Electricity Savings	Present Value of Gas Savings	Present Value of Electricity Infrastructure Cost Savings	Prevent Value of GHG Emissions Savings	Present Value of Total Benefits	Present Value of Incremental Costs	Net Present Value	Benefit Cost Ratio
House	$52.9	$3.3	$88.1	$25.5	$169.8	$104.4	$65.4	1.6
Townhouse	$2.0	$0.1	$3.3	$1.0	$6.4	$5.7	$0.7	1.1
Apartment Buildings	$10.4	$0.0	$17.3	$4.9	$32.6	$10.6	$22.1	3.1
Totals	**$65.3**	**$3.4**	**$108.7**	**$31.4**	**$208.8**	**$120.6**	**$88.2**	**1.7**

8.4 Conclusions

Insulating pre-2003 (strictly, pre-September-2003) roofs at a time when the roof was being replaced in any case would be cost-effective in all climate zones in QLD and for all residential building classes. The benefits are expected to be 70% higher than the incremental costs on average, as indicated by the BCR of 1.7. Energy savings are relatively large as these pre-2003 dwellings predate the introduction of energy efficiency standards, and insulation is generally the most effective ‘first treatment’ for a dwelling without any existing energy efficiency features. Some residential buildings in QLD may have had insulation retrofitted since 2003, but this may or may not be to the standard required in NCC2019. For this study, we assume that the same levels of insulation are fitted to both Class 2 and Class 1 residences.

9. Appendices

Appendix A: About the Team

9.1.1 Strategy Policy Research (SPR)

SPR brings to this project its Principal (Philip Harrington's) 37 years' experience in applied economic and policy analysis, including extensive experience in Code development, benefit cost analysis and regulatory impact assessment, including for the Australian Building Codes Board. SPR undertook a detailed Baseline Study of residential and commercial buildings in QLD in 2018, as well as the national *Commercial Building Baseline Study* in 2012, and also the 2022 update to the 2012 study. SPR is the author of *Best Practice Policy and Regulation for Low Carbon Outcomes in the Built Environment*, published by the Co-operative Research Centre for Low Carbon Living, 2017. Philip was previously Division Head, Energy Efficiency Policy Analysis at the International Energy Agency in Paris. Within the project, Philip acted as Project Manager, lead author and economic analyst.

9.1.2 RED Sustainability Consultants

Dr Steve Watson is the founder and Managing Director of RED Sustainability Consultants. Steve has a PhD in Architecture (University of Queensland), and has been active in sustainable design, research, education and consulting in the 23 years since graduating. RED Sustainability Consultants regularly partners with SPR on national housing sustainability projects, for example for the NatHERS Administrator. Steve previously worked as a ESD Consultant with Ecolateral Pty Ltd, based in Queensland, over the 2006 - 2014 period. He has extensive knowledge of QLD climate zones, architectural styles and sustainability issues.

Assisting Steve in this project was Dr Rebecca Boyle, Senior Consultant, RED Sustainability Consultants. Rebecca is an experienced Thermal Performance Assessor and home and small business sustainability assessor who has been undertaking NatHERS assessments for 6 years.

9.1.3 Ecolateral Pty Ltd

John Moynihan, Principle of Ecolateral, has been a Brisbane based sustainability consultant for 40 years. He is a BERS modeller, Passivehouse Consultant, Liveable Housing Assessor, Building designer, Registered Builder and Building Air Tester.

John was assisted in this project by Eliza Morawska, Senior Consultant, Ecolateral. Eliza is a Brisbane -based sustainable built environment consultant and architectural graduate with 6 years' experience in undertaking NatHERS assessments across various regions in Queensland.

9.1.4 Steele Wrobel Pty Ltd

Ben Foster is a Director of Steele Wrobel, Building Surveyors, based in Brisbane. Steele Wrobel is a third party QA certified to ISO 9001:2015. Ben is an experienced professional Cost Manager with 30 years' experience. Ben was assisted in this project by Brendan Lee (Senior Cost manager) Brendan is an experienced cost planner with over 20 years' experience in which he has provided cost management services on a range of similar developments and is well aware of the specific issues of this sector. Steele Wrobel played the key role of assessing cost inputs for this project that were used by the team to estimate incremental costs.

Appendix B: Building Element Costing

This Appendix identifies the base costs assumed for individual building elements, drawing on inputs from Steele Wrobel Pty Ltd. Regional cost loadings are noted in the report.

Ceiling/Roof Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Ceilings/Roofs	None	None	Ceilings/Roofs: None: None	$/m^2	$0.00	$0.00	$0.00
Ceilings/Roofs	Ceiling bulk	R2.5	Ceilings/Roofs: Ceiling bulk: R2.5	$/m^2	$7.50	$7.69	$15.19
Ceilings/Roofs	Ceiling bulk	R3.5	Ceilings/Roofs: Ceiling bulk: R3.5	$/m^2	$7.50	$10.43	$17.93
Ceilings/Roofs	Ceiling bulk	R4.1	Ceilings/Roofs: Ceiling bulk: R4.1	$/m^2	$7.50	$15.12	$22.62
Ceilings/Roofs	Ceiling bulk	R1.5	Outdoor living area: Ceiling bulk: R1.5	$/m^2	$7.50	$4.27	$11.77
Ceilings/Roofs	Sarking	Single sided anti-glare foil	Ceilings/Roofs: Sarking: Single sided anti-glare foil	$/m^2	$2.85	$6.29	$9.14
Ceilings/Roofs	Sarking	R1.3 Anticon roof blanket	Ceilings/Roofs: Sarking: R1.3 Anticon roof blanket	$/m^2	$2.85	$13.43	$16.28
Ceilings/Roofs	Roof space ventilation	Eave vents and ridge vents at 1500mm internals	Ceilings/Roofs: Roof space ventilation: Eave vents and ridge vents at 1500mm internals	per house	(inc)	$2,640.00	$2,640.00
Ceilings/Roofs	Roof space ventilation	Addition of roof exhaust fan	Ceilings/Roofs: Roof space ventilation: Addition of roof exhaust fan	per item	(inc)	$650.00	$650.00
Ceilings/Roofs	Apartment conc roof PIR ins	Addition of roof exhaust fan	Ceilings/Roofs: Apartment conc roof PIR ins: Addition of roof exhaust fan	per item	(inc)	$650.00	$650.00
Ceilings/Roofs	Apartment conc roof PIR ins	R2.0	Ceilings/Roofs: Apartment conc roof PIR ins: R2.0	$/m^2	$24.00	$35.35	$59.35
Ceilings/Roofs	Apartment conc roof PIR ins	R2.5	Ceilings/Roofs: Apartment conc roof PIR ins: R2.5	$/m^2	$24.00	$42.95	$66.95
Ceilings/Roofs	Roofing material	Concrete tiles e.g. Monier Horizon	Ceilings/Roofs: Roofing material: Concrete tiles e.g. Monier Horizon	$/m^2	(inc)	$64.00	$64.00
Ceilings/Roofs	Roofing material	Metal Colourbond roof	Ceilings/Roofs: Cost: Metal Colourbond roof	$/m^2	(inc)	$59.00	$59.00

External Wall Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
External Walls	None	None	External Walls: None: None	$/m^2	$0.00	$0.00	$0.00
External Walls	Wall bulk	R1.5	External Walls: Wall bulk: R1.5	$/m^2	$6.50	$4.27	$10.77
External Walls	Wall bulk	R2.0	External Walls: Wall bulk: R2.0	$/m^2	$6.50	$6.36	$12.86
External Walls	Wall bulk	R2.5	External Walls: Wall bulk: R2.5	$/m^2	$6.50	$11.45	$17.95
External Walls	Wall bulk	R2.7	External Walls: Wall bulk: R2.7	$/m^2	$6.50	$18.58	$25.08
External Walls	Single side foil sarking	Single side foil sarking	External Walls: Single side foil sarking: Single side foil sarking	$/m^2	$2.50	$3.26	$5.76
External Walls	Foil + bulk	Foil + R1.5	External Walls: Foil + bulk: Foil + R1.5	$/m^2	$9.00	$7.53	$16.53
External Walls	Foil + bulk	Foil + R2.0	External Walls: Foil + bulk: Foil + R2.0	$/m^2	$9.00	$9.63	$18.63

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
External Walls	Foil + bulk	Foil + R2.5	External Walls: Foil + bulk: Foil + R2.5	$\$/m^2$	$9.00	$14.72	$23.72
External Walls	Foil + bulk	Foil + R2.7	External Walls: Foil + bulk: Foil + R2.7	$\$/m^2$	$9.00	$21.84	$30.84
External Walls	Blockwork external wall	Block work wall - PB Lined internally on a furring channel	External Walls: Blockwork external wall: Block work wall - PB Lined internally on a furring channel	$\$/m^2$	(inc)	$230.00	$230.00
External Walls	Blockwork external wall	Block work wall + 20 air gap + 90mm Timber stud wall with PB internally	External Walls: Blockwork external wall: Block work wall + 20 air gap + 90mm Timber stud wall with PB internally	$\$/m^2$	(inc)	$270.00	$270.00
External Walls	Intertenancy walls	Hebel - stud wall either side with plasterboard	External Walls: Intertenancy walls: Hebel - stud wall either side with plasterboard	$\$/m^2$	(inc)	$324.00	$324.00
External Walls	Intertenancy walls	Solid core filled block - stud wall either side with PB	External Walls: Intertenancy walls: Solid core filled block - stud wall either side with PB	$\$/m^2$	(inc)	$345.00	$345.00

Internal Wall Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Internal walls	None	None	Internal walls: None: None	$\$/m^2$	$0.00	$0.00	$0.00
Internal walls	Int walls bulk	R1.5	Internal walls: Int walls bulk: R1.5	$\$/m^2$	$6.50	$4.58	$11.08
Internal walls	Int walls bulk	R2.0	Internal walls: Int walls bulk: R2.0	$\$/m^2$	$6.50	$6.37	$12.87
Internal walls	Int walls bulk	R2.5	Internal walls: Int walls bulk: R2.5	$\$/m^2$	$6.50	$11.45	$17.95
Internal walls	Int walls bulk	R2.7	Internal walls: Int walls bulk: R2.7	$\$/m^2$	$6.50	$18.58	$25.08

Floor Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Floor	None	None	Floor: None: None	$\$/m^2$	$0.00	$0.00	$0.00
Floor	Floor bulk	R1.5	Floor: Floor bulk: R1.5	$\$/m^2$	$6.50	$4.58	$11.08
Floor	Floor bulk	R2.0	Floor: Floor bulk: R2.0	$\$/m^2$	$6.50	$6.37	$12.87
Floor	Floor bulk	R2.5	Floor: Floor bulk: R2.5	$\$/m^2$	$6.50	$11.45	$17.95
Floor	Double sided foil sarking	Double sided foil sarking	Floor: Double sided foil sarking: Double sided foil sarking	$\$/m^2$	$2.85	$3.71	$6.56
Floor	Apartment Basement carpark soffit – PIR	R0.5	Floor: Apartment Basement carpark soffit – PIR : R0.5	$\$/m^2$	$30.00	$48.38	$78.38
Floor	Apartment Basement carpark soffit – PIR	R1.0	Floor: Apartment Basement carpark soffit – PIR : R1.0	$\$/m^2$	$30.00	$57.43	$87.43
Floor	Apartment Basement carpark soffit – PIR	R1.5	Floor: Apartment Basement carpark soffit – PIR : R1.5	$\$/m^2$	$30.00	$66.68	$96.68
Floor	Apartment Basement carpark soffit – XPS board	R0.5	Floor: Apartment Basement carpark soffit – XPS board: R0.5	$\$/m^2$	$30.00	$32.62	$62.62
Floor	Apartment Basement carpark soffit – XPS board	R1.0	Floor: Apartment Basement carpark soffit – XPS board: R1.0	$\$/m^2$	$30.00	$37.33	$67.33
Floor	Apartment Basement carpark soffit – XPS board	R1.5	Floor: Apartment Basement carpark soffit – XPS board: R1.5	$\$/m^2$	$30.00	$60.67	$90.67

Shading Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Shading	400mm deep Sunhood	600mm long	Shading: 400mm deep Sunhood: 600mm long	per item	$240.00	$300.00	$540.00
Shading	400mm deep Sunhood	900mm long	Shading: 400mm deep Sunhood: 900mm long	per item	$240.00	$440.00	$680.00
Shading	400mm deep Sunhood	1200mm long	Shading: 400mm deep Sunhood: 1200mm long	per item	$240.00	$562.00	$802.00
Shading	400mm deep Sunhood	1500mm long	Shading: 400mm deep Sunhood: 1500mm long	per item	$240.00	$700.00	$940.00
Shading	400mm deep Sunhood	1800mm long	Shading: 400mm deep Sunhood: 1800mm long	per item	$240.00	$840.00	$1,080.00
Shading	400mm deep Sunhood	2100mm long	Shading: 400mm deep Sunhood: 2100mm long	per item	$240.00	$980.00	$1,220.00
Shading	400mm deep Sunhood	2700mm long	Shading: 400mm deep Sunhood: 2700mm long	per item	$240.00	$1,260.00	$1,500.00
Shading	External horizontal louvre.	External horizontal louvre.	Shading: External horizontal louvre. : External horizontal louvre.	per item	$280.00	$500.00	$780.00
Shading	Ext verticle louvre (60%)	Ext vertical louvre (60%)	Shading: Ext vertical louvre (60%): Ext vertical louvre (60%)	\$/m^2	$280.00	$470.00	$750.00

Ground Floor Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Ground Floors	Floor finishes	Timber laminate flooring	Ground Floors: Floor finishes: Timber laminate flooring	\$/m^2	(inc)	$73.43	$73.43
Ground Floors	Floor finishes	Vinyl sheet flooring	Ground Floors: Floor finishes: Vinyl sheet flooring	\$/m^2	(inc)	$52.00	$52.00
Ground Floors	Floor finishes	Standard carpet	Ground Floors: Floor finishes: Standard carpet	\$/m^2	(inc)	$66.25	$66.25
Ground Floors	Floor finishes	Carpet with underlay	Ground Floors: Floor finishes: Carpet with underlay	\$/m^2	(inc)	$71.25	$71.25
Ground Floors	Floor finishes	Standard format floor tiles	Ground Floors: Floor finishes: Standard format floor tiles	\$/m^2	(inc)	$145.00	$145.00
Ground Floors	CSOG	300m2 single storey house	Ground Floors: CSOG: 300m2 single storey house	per item	(inc)	$41,400.00	$41,400.00
Ground Floors	CSOG	155m2 ground floor of a two storey house	Ground Floors: CSOG: 155m2 ground floor of a two storey house	per item	(inc)	$22,940.00	$22,940.00
Ground Floors	CSOG	90m2 ground floor of a two storey townhouse	Ground Floors: CSOG: 90m2 ground floor of a two storey townhouse	per item	(inc)	$13,770.00	$13,770.00
Ground Floors	Waffle pod	300m2 single storey house	Ground Floors: Waffle pod: 300m2 single storey house	per item	(inc)	$37,200.00	$37,200.00
Ground Floors	Waffle pod	155m2 ground floor of a two storey house	Ground Floors: Waffle pod: 155m2 ground floor of a two storey house	per item	(inc)	$20,770.00	$20,770.00
Ground Floors	Waffle pod	90m2 ground floor of a two storey townhouse	Ground Floors: Waffle pod: 90m2 ground floor of a two storey townhouse	per item	(inc)	$12,510.00	$12,510.00
Ground Floors	Suspended timber floor on + BV enclosure	300m2 single storey house	Ground Floors: Suspended timber floor on + BV enclosure: 300m2 single storey house	per item	(inc)	$98,400.00	$98,400.00
Ground Floors	Suspended timber floor on + BV enclosure	155m2 ground floor of a two storey house	Ground Floors: Suspended timber floor on + BV enclosure: 155m2 ground floor of a two storey house	per item	(inc)	$53,785.00	$53,785.00
Ground Floors	Suspended timber floor on + BV enclosure	90m2 ground floor of a two storey townhouse	Ground Floors: Suspended timber floor on + BV enclosure: 90m2 ground floor of a two storey townhouse	per item	(inc)	$32,130.00	$32,130.00
Ground Floors	Suspended timber floor + FC enclosure	300m2 single storey house	Ground Floors: Suspended timber floor + FC enclosure: 300m2 single storey house	per item	(inc)	$73,650.00	$73,650.00
Ground Floors	Suspended timber floor + FC enclosure	155m2 ground floor of a two storey house	Ground Floors: Suspended timber floor + FC enclosure: 155m2 ground floor of a two storey house	per item	(inc)	$40,997.50	$40,997.50

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Ground Floors	Suspended timber floor + FC enclosure	90m2 ground floor of a two storey townhouse	Ground Floors: Suspended timber floor + FC enclosure: 90m2 ground floor of a two storey townhouse	per item	(inc)	$25,515.00	$25,515.00
Ground Floors	Suspended timber floor + 190mm block enclosure	300m2 single storey house	Ground Floors: Suspended timber floor + 190mm block enclosure: 300m2 single storey house	per item	(inc)	$84,900.00	$84,900.00
Ground Floors	Suspended timber floor + 190mm block enclosure	155m2 ground floor of a two storey house	Ground Floors: Suspended timber floor + 190mm block enclosure: 155m2 ground floor of a two storey house	per item	(inc)	$49,910.00	$49,910.00
Ground Floors	Suspended timber floor + 190mm block enclosure	90m2 ground floor of a two storey townhouse	Ground Floors: Suspended timber floor + 190mm block enclosure: 90m2 ground floor of a two storey townhouse	per item	(inc)	$30,690.00	$30,690.00
Ground Floors	Suspended timber floor – open under	300m2 single storey house	Ground Floors: Suspended timber floor – open under: 300m2 single storey house	per item	(inc)	$65,400.00	$65,400.00
Ground Floors	Suspended timber floor – open under	155m2 ground floor of a two storey house	Ground Floors: Suspended timber floor – open under: 155m2 ground floor of a two storey house	per item	(inc)	$35,185.00	$35,185.00
Ground Floors	Suspended timber floor – open under	90m2 ground floor of a two storey townhouse	Ground Floors: Suspended timber floor – open under: 90m2 ground floor of a two storey townhouse	per item	(inc)	$21,240.00	$21,240.00
Ground Floors	Suspended concrete slab / concrete block enclosure	300m2 single storey house	Ground Floors: Suspended concrete slab / concrete block enclosure: 300m2 single storey house	per item	(inc)	$117,000.00	$117,000.00
Ground Floors	Suspended concrete slab / concrete block enclosure	155m2 ground floor of a two storey house	Ground Floors: Suspended concrete slab / concrete block enclosure: 155m2 ground floor of a two storey house	per item	(inc)	$65,100.00	$65,100.00
Ground Floors	Suspended concrete slab / concrete block enclosure	90m2 ground floor of a two storey townhouse	Ground Floors: Suspended concrete slab / concrete block enclosure: 90m2 ground floor of a two storey townhouse	per item	(inc)	$38,700.00	$38,700.00

Window Elements

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Windows	Fixed window	4Clr	Fixed window - 4Clr	$/m^2	$120.00	$230.00	$350.00
Windows	Fixed window	4EA	Fixed window - 4EA	$/m^2	$120.00	$265.00	$385.00
Windows	Fixed window	4Gy	Fixed window - 4Gy	$/m^2	$120.00	$250.00	$370.00
Windows	Fixed window	4/10/4	Fixed window - 4/10/4	$/m^2	$120.00	$300.00	$420.00
Windows	Fixed window	4/10/4EA	Fixed window - 4/10/4EA	$/m^2	$120.00	$340.00	$460.00
Windows	Fixed window	4Gy/10/4EA	Fixed window - 4Gy/10/4EA	$/m^2	$120.00	$400.00	$520.00
Windows	Fixed window	4Gy/10Ar/4EA	Fixed window - 4Gy/10Ar/4EA	$/m^2	$120.00	$400.00	$520.00
Windows	Awning window	4Clr	Awning window - 4Clr	$/m^2	$120.00	$340.00	$460.00
Windows	Awning window	4EA	Awning window - 4EA	$/m^2	$120.00	$375.00	$495.00
Windows	Awning window	4Gy	Awning window - 4Gy	$/m^2	$120.00	$360.00	$480.00
Windows	Awning window	4/10/4	Awning window - 4/10/4	$/m^2	$120.00	$410.00	$530.00
Windows	Awning window	4/10/4EA	Awning window - 4/10/4EA	$/m^2	$120.00	$450.00	$570.00
Windows	Awning window	4Gy/10/4EA	Awning window - 4Gy/10/4EA	$/m^2	$120.00	$510.00	$630.00
Windows	Awning window	4Gy/10Ar/4EA	Awning window - 4Gy/10Ar/4EA	$/m^2	$120.00	$510.00	$630.00
Windows	Sliding window	4Clr	Sliding window - 4Clr	$/m^2	$120.00	$310.00	$430.00
Windows	Sliding window	4EA	Sliding window - 4EA	$/m^2	$120.00	$345.00	$465.00
Windows	Sliding window	4Gy	Sliding window - 4Gy	$/m^2	$120.00	$330.00	$450.00
Windows	Sliding window	4/10/4	Sliding window - 4/10/4	$/m^2	$120.00	$380.00	$500.00

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Windows	Sliding window	4/10/4EA	Sliding window - 4/10/4EA	$/m²	$120.00	$420.00	$540.00
Windows	Sliding window	4Gy/10/4EA	Sliding window - 4Gy/10/4EA	$/m²	$120.00	$480.00	$600.00
Windows	Sliding window	4Gy/10Ar/4EA	Sliding window - 4Gy/10Ar/4EA	$/m²	$120.00	$480.00	$600.00
Windows	Casement window	4Clr	Casement window - 4Clr	$/m²	$120.00	$350.00	$470.00
Windows	Casement window	4EA	Casement window - 4EA	$/m²	$120.00	$385.00	$505.00
Windows	Casement window	4Gy	Casement window - 4Gy	$/m²	$120.00	$370.00	$490.00
Windows	Casement window	4/10/4	Casement window - 4/10/4	$/m²	$120.00	$420.00	$540.00
Windows	Casement window	4/10/4EA	Casement window - 4/10/4EA	$/m²	$120.00	$460.00	$580.00
Windows	Casement window	4Gy/10/4EA	Casement window - 4Gy/10/4EA	$/m²	$120.00	$520.00	$640.00
Windows	Casement window	4Gy/10Ar/4EA	Casement window - 4Gy/10Ar/4EA	$/m²	$120.00	$520.00	$640.00
Windows	Sliding door	4Clr	Sliding door - 4Clr	$/m²	$120.00	$310.00	$430.00
Windows	Sliding door	4EA	Sliding door - 4EA	$/m²	$120.00	$345.00	$465.00
Windows	Sliding door	4Gy	Sliding door - 4Gy	$/m²	$120.00	$330.00	$450.00
Windows	Sliding door	4/10/4	Sliding door - 4/10/4	$/m²	$120.00	$380.00	$500.00
Windows	Sliding door	4/10/4EA	Sliding door - 4/10/4EA	$/m²	$120.00	$420.00	$540.00
Windows	Sliding door	4Gy/10/4EA	Sliding door - 4Gy/10/4EA	$/m²	$120.00	$480.00	$600.00
Windows	Sliding door	4Gy/10Ar/4EA	Sliding door - 4Gy/10Ar/4EA	$/m²	$120.00	$480.00	$600.00
Windows	Stacker Sliding Door	4Clr	Stacker Sliding Door - 4Clr	$/m²	$120.00	$860.00	$980.00
Windows	Stacker Sliding Door	4EA	Stacker Sliding Door - 4EA	$/m²	$120.00	$895.00	$1,015.00
Windows	Stacker Sliding Door	4Gy	Stacker Sliding Door - 4Gy	$/m²	$120.00	$880.00	$1,000.00
Windows	Stacker Sliding Door	4/10/4	Stacker Sliding Door - 4/10/4	$/m²	$120.00	$930.00	$1,050.00
Windows	Stacker Sliding Door	4/10/4EA	Stacker Sliding Door - 4/10/4EA	$/m²	$120.00	$970.00	$1,090.00
Windows	Stacker Sliding Door	4Gy/10/4EA	Stacker Sliding Door - 4Gy/10/4EA	$/m²	$120.00	$1,030.00	$1,150.00
Windows	Stacker Sliding Door	4Gy/10Ar/4EA	Stacker Sliding Door - 4Gy/10Ar/4EA	$/m²	$120.00	$1,030.00	$1,150.00
Windows	Bi-fold	4Clr	Bi-fold - 4Clr	$/m²	$120.00	$1,080.00	$1,200.00
Windows	Bi-fold	4EA	Bi-fold - 4EA	$/m²	$120.00	$1,115.00	$1,235.00
Windows	Bi-fold	4Gy	Bi-fold - 4Gy	$/m²	$120.00	$1,100.00	$1,220.00
Windows	Bi-fold	4/10/4	Bi-fold - 4/10/4	$/m²	$120.00	$1,150.00	$1,270.00
Windows	Bi-fold	4/10/4EA	Bi-fold - 4/10/4EA	$/m²	$120.00	$1,190.00	$1,310.00
Windows	Bi-fold	4Gy/10/4EA	Bi-fold - 4Gy/10/4EA	$/m²	$120.00	$1,250.00	$1,370.00
Windows	Bi-fold	4Gy/10Ar/4EA	Bi-fold - 4Gy/10Ar/4EA	$/m²	$120.00	$1,250.00	$1,370.00

Other Items

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Other Items	Ceiling fans	None	Other Items: Ceiling fans: None	per item	$0.00	$0.00	$0.00
Other Items	Ceiling fans	900mm dia	Other Items: Ceiling fans: 900mm dia	per item	$160.00	$239.00	$399.00
Other Items	Ceiling fans	1200mm dia	Other Items: Ceiling fans: 1200mm dia	per item	$160.00	$269.00	$429.00
Other Items	Ceiling fans	1400mm dia	Other Items: Ceiling fans: 1400mm dia	per item	$160.00	$329.00	$489.00
Other Items	Ceiling fans	Outdoor rated ceiling fan	Other Items: Ceiling fans: Outdoor rated ceiling fan	per item	$160.00	$329.00	$489.00
Other Items	Ceiling fans	Standard exhaust with no backdraft damper	Other Items: Ceiling fans: Standard exhaust with no backdraft damper	per item	$160.00	$187.00	$347.00

Element	Material	Parameter	Reference	Pricing unit	Install cost	material cost	Total cost
Other Items	Ceiling fans	Exhaust with backdraft damper	Other Items: Ceiling fans: Exhaust with backdraft damper	per item	$160.00	$204.60	$364.60
Other Items	PV/inverter	1kW + inverter	Other Items: PV/inverter: 1kW + inverter	per item	(inc)	$2,350.00	$2,350.00
Other Items	PV/inverter	Most cost effective size PV? (3 or 3.5kW) + inverter	Other Items: PV/inverter: Most cost effective size PV? (3 or 3.5kW) + inverter	per item	(inc)	$3,690.00	$3,690.00
Other Items	PV/inverter	6kW + inverter	Other Items: PV/inverter: 6kW + inverter	per item	(inc)	$7,900.00	$7,900.00
Other Items	Reed switch	Reed switch	Other Items: Reed switch: Reed switch	per item	$335.00	$298.00	$633.00
Other Items	Fall protection for upper storey windows	Diamond grill or similar	Other Items: Fall protection for upper storey windows: Diamond grill or similar	$/m²	$60.00	$225.00	$285.00
Other Items	Fall protection for upper storey windows	Crimsafe mesh or similar	Other Items: Fall protection for upper storey windows: Crimsafe mesh or similar	$/m²	$60.00	$375.00	$435.00

Appendix C: Detailed Costing Results of Thermal Performance Analysis

Please refer to separate report.

Making the
business case
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