NCC Section J in the Northern Territory

NCC Section J Case Studies: Single-Storey Office Buildings Darwin and Alice Springs

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Prepared For:	Building Advisory Services Policy Northern Territory Government Department of Infrastructure, Planning and Logistics (DIPL)
Author(s):	DeltaQ – Joyce Yeoh Hoogland Consult – Matt Hoogland Enerefficiency – Hongsen Zhang Strategy Policy Research – Philip Harrington
Reviewer:	Grace Foo
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Disclaimer:	*Readers should keep in mind that the results in this report are based on simulated building models with predetermined forms and geometries. Specific building designs may perform differently depending on their designed form, servicing and geometry.*

Executive Summary

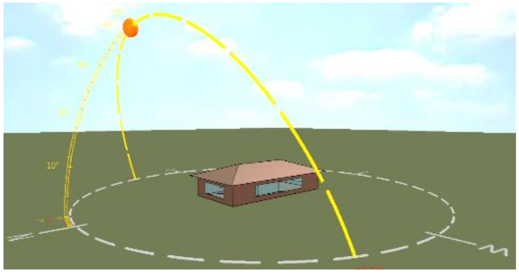
Section J of the National Construction Code (NCC) Volume One details the energy efficiency requirements for commercial buildings. The requirements are performance-based, and hence there are two ways to comply: 1) using Deemed-to-Satisfy (DTS) provisions, and/or 2) other Performance Solutions[1], which include Verification Methods provided in the NCC. Here, two case studies based on single-storey offices are presented. The case studies show how different designs can demonstrate NCC2019 compliance using the DTS method (Case Study 1) and Verification Method JV3 (Case Study 2). Both case studies considered the single-storey office building, located in Darwin and Alice Springs.

Context

These case studies are based on the single-storey office building archetype. They are an extension of the core study,[2] which reported on the cost-benefit analysis of implementing NCC2016 and NCC2019 Section J energy efficiency requirements in the Northern Territory, using the DTS method for compliance. In the Core Study, different commercial building archetypes (hotels, multi-storey offices, single-storey offices, hospital wards and schools) were investigated; amongst these, the single-storey office was the most sensitive from a cost benefit perspective, due to high building envelop to floor area ratio.

The Core Study found that NCC2019 was significantly more cost beneficial than NCC2016.

- NCC2019 produces a net social benefit for the NT Government of $276 million (present value) and a benefit cost ratio of 3.6.
- From an owner-occupier perspective, NCC2019 will deliver a net present value of $295million, with a benefit cost ratio of 3.8.



These case studies are directly applicable to single-storey offices compliant with NCC2019 Section J, though the principles of these case studies may also be beneficial for larger buildings design. Construction costs were determined by an NT construction firm (Sunbuild) and energy use was modelled with IES-VE software.

Case Study 1: NCC 2019 Section J Deemed-to-Satisfy (DTS) Pathway – Alternative Designs

Four different building designs that meet NCC2019 Section J DTS were considered. The designs are that of the Core Study, and three variations of it (Scenario A, B and C). Results show that the cost and benefit of complying with NCC2019 Section J, via the DTS Provision, varies depending on the building design. In particular,

- Adding insulation on top of the ceiling, instead of using thicker under-roof blankets, is cheaper and results in more energy savings.
- Designing a building with windows dimensioned/positioned to reduce solar exposure can reduce the cost of compliance.
- Adjusting both the roof construction and window dimensions results in the most cost-beneficial design, amongst the designs considered in this Case Study.

Table 1: Scenarios considered in each Case Study

	Scenario	Scenario Description
Case Study 1	DTS Scenario A	R2.0 ceiling insulation (keeping R1.5 under-roof blanket) instead of increasing roof insulation to comply with DTS. This avoids the need for an insulation spacer system.
	DTS Scenario B	Alternative window design (overall window-to-wall ratio kept at 30%, matching the core study) to comply with DTS
	DTS Scenario C	Scenario A and B
Case Study 2	JV3	Testing alternative designs ('proposed design') where some building elements are non-compliant with DTS requirements.

Case Study 2: JV3 – Verification using a reference building

The Verification Method JV3 is an alternative solution that can be considered when the building design does not meet the DTS requirements. The case study demonstrates how JV3 method can be applied for a single-storey office. It also shows that that the JV3 method can permit greater design flexibility to achieve the same performance, and at times, reduce compliance cost.

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[1] For more detail, refer to the National Construction Code Part A2 *Compliance with the NCC*.

[2] "NT Section J Cost Benefit Analysis Report", prepared for the Northern Territory Government, Department of Infrastructure, Planning and Logistics, by DeltaQ, Hoogland Consult, EnerEfficiency, and Strategy Policy Research, 2022

1 Case Study 1 – NCC2019 DTS Pathway - Alternative Building Designs

Case Study 1

- While an uncommon construction practice in the Northern Territory, adding ceiling insulation can lead to significant construction cost and energy savings, compared to further increasing roof insulation for compliance.
- Buildings designed to have window dimensions that reduce solar exposure may require lower-cost glazing, and can have an overall lower construction costs and some energy savings.

1.1 About DTS Provisions

Compliance with NCC is achieved by complying with the Performance Requirement JP1, which in turn can be satisfied using the Deemed-to-satisfy (DTS) prescriptive requirements laid out in Section J. Section J Parts J1, J3, J5, J6, J7, and J8, respectively state the DTS Provisions for building fabric, building sealing, air-conditioning and ventilation systems, artificial lighting and power, heated water supply and swimming pool and spa pool plant, and facilities for energy monitoring.

J0.0 Deemed-to-Satisfy Provisions

(a) Where a Deemed-to-Satisfy Solution is proposed, Performance Requirement JP1 is satisfied by complying with—

(i) J0.1 to J0.5; and
(ii) J1.1 to J1.6; and
(iii) J3.1 to J3.7; and
(iv) J5.1 to J5.12; and
(v) J6.1 to J6.8; and
(vi) J7.1 to J7.4; and
(vii) J8.1 to J8.3.

Section J - NCC 2019 Volume One Amendment 1

1.2 What alternative designs can be used for DTS compliance?

Two alternative designs were considered under the DTS compliance scenario, each with the objective of achieving NCC2019 compliance at a lower cost solution than the core study. The alternative designs included:

- **Alternative roof construction (Scenario A).** In this scenario, the design of the roof construction was altered to include insulation batts on top of the ceiling. In the core study, roof R-values required for Section J compliance were achieved with an R3.3 roof blanket insulation beneath the metal roof, within a roof raising framing system, as per common industry practice in the NT. In this alternative roof construction, the costs of the roof raising framing system are avoided and less square-metre coverage of thicker insulation is required because the insulation is laid on the horizontal plane as opposed to the plane of the pitched roof (note the R1.5 base case roof insulation blanket is retained). It is acknowledged that the practice of insulating on top of the ceiling is not commonplace in the NT commercial building industry.

- **Alternative window dimensions (Scenario B).** In this scenario, the placement and dimensions of windows were altered from the core study archetype with the intent of reducing window solar exposure. Consequently, this reduces glazing performance costs. Various dimensions were trialled against the DTS NCC2019 Wall-Glazing Calculator, with two criterion: (1) that the height of the top of the window relative to the eave remains unchanged, and (2) that windowsills sit no higher than 1.09m from the ground.

*The **incremental construction cost** is the difference in construction cost between the NCC2019 compliant case (Core Study, DTS Scenarios A, B, and C) and the base case construction cost. The base case was defined as part of the core study, being representative of typical construction practices in the NT. The incremental construction costs include the cost for the floor, roof, wall, glazing, building services, design and consultancy fees, and savings associated with reduced mechanical plant capacities.*

These alterations in design are illustrated in Figure 1. Note that as the single-storey office building model used is rectangular, two orientations of the building were investigated (N-S and E-W), see illustration in Figure 1.

The total incremental construction cost for each scenario and building orientation in Darwin and Alice Springs are shown in Figure 2. The total cost for Scenarios A, B and C are lower than the Core Study, due to reasons mentioned in the preceding paragraphs. The cost for Scenario A is in all cases lower than Scenario B; reflecting that larger cost savings can be realised if a roof construction with ceiling insulation is used, when compared to the alternative window dimensions investigated in this study. As expected, Scenario C (which combines both Scenario A and B) had the lowest incremental construction cost, as this scenario absorbed cost savings from downgraded glazing performance as well as savings from removal of the roof raising framing system.

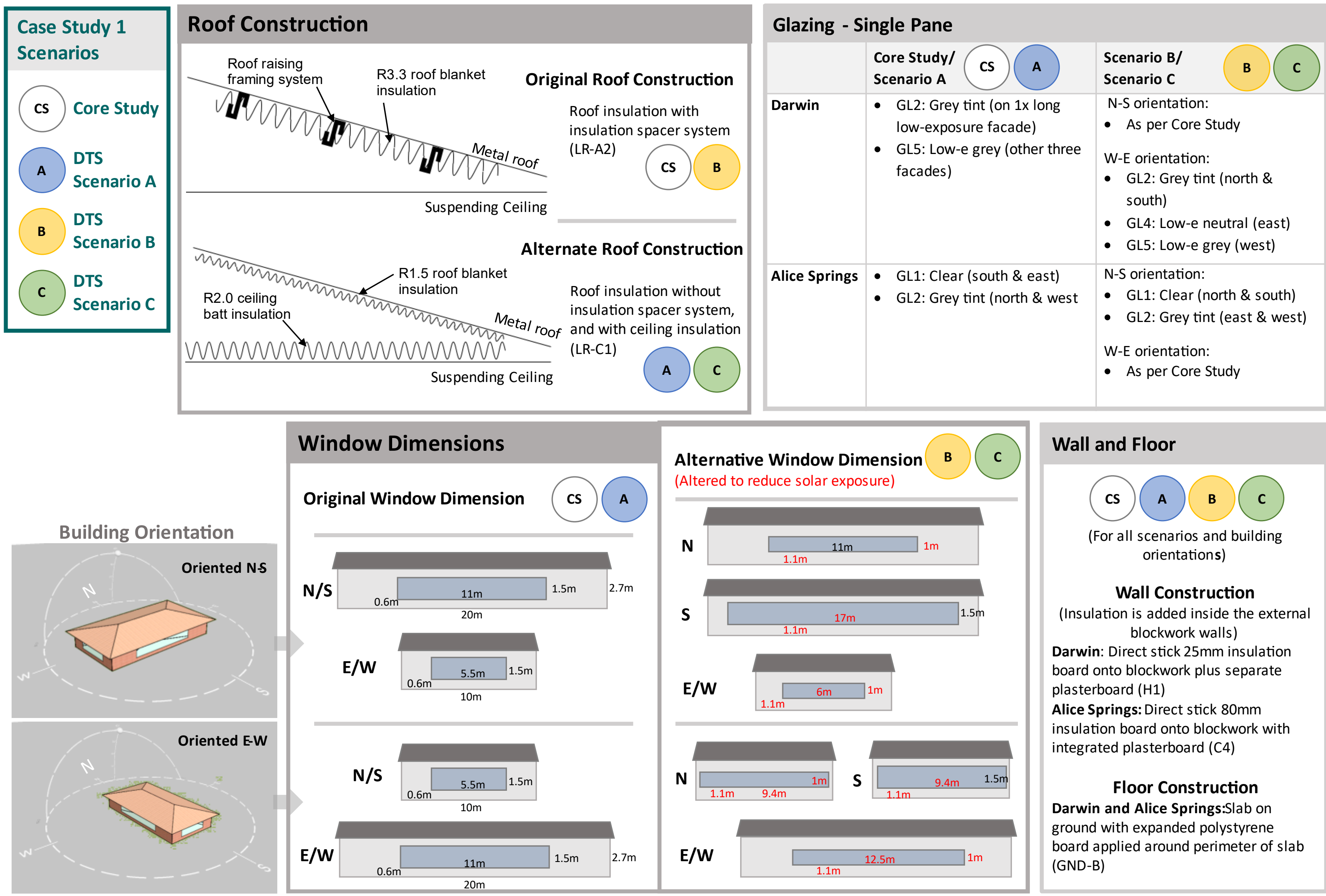

Figure 1: Section J DTS compliant building construction options assessed for the Core Study and Case Study 1 Scenarios.

Note: The draft NCC2022 code (public comment version, Section J4D7 (2)) specifies that a slab-on-ground without in-slab heating or cooling system is considered to achieve a total R-Value of 2.0. Under this provision, the floor for this model would not require additional insulation for NCC2022. (NCC 2022 Volume One - Version 20210906.pdf, accessed on 20 February 2021)

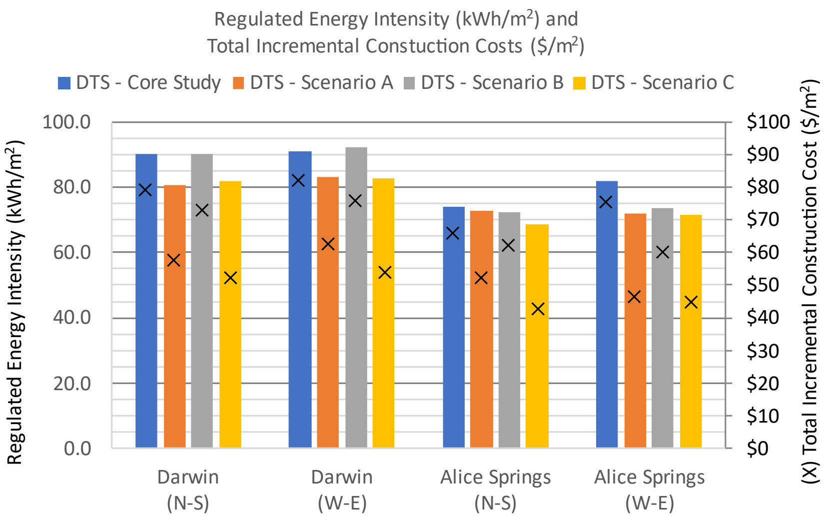

Figure 2: Regulated energy intensity (kWh/m²) and total incremental construction costs ($/m²) for different DTS-compliant building designs (Core Study, Scenario A, B and C).

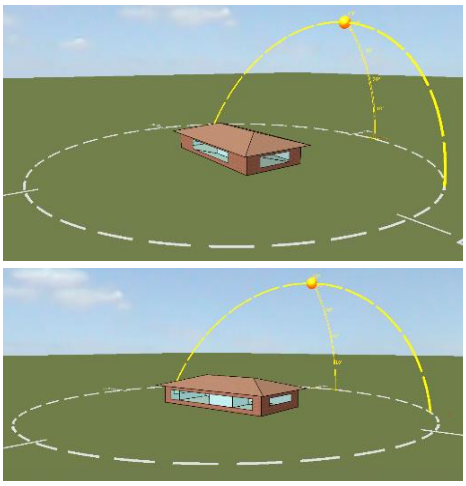

Figure 3: Single-storey office building geometry for (top) the Core Study and DTS Scenario A, (bottom) Scenarios B and C.

Table 2: Energy intensity, incremental construction cost, and benefit cost ratio for different DTS single-storey office designs. Averaged across buildings oriented N-S and E-W. Percentage values, in parenthesis, correspond to energy and cost savings of Scenarios A, B, or C relative to the Core Study.

	Energy Intensity[3] (kWh/m²)		Incremental construction cost[4] ($/m²)		Benefit Cost Ratio	
	Darwin	Alice Springs	Darwin	Alice Springs	Darwin	Alice Springs
Core Study	90.6	77.9	$81	$71	1.4	2.5
DTS Scenario A	81.9 (-10%)	72.4 (-7%)	$60 (-25%)	$49 (-30%)	2.9	4.3
DTS Scenario B	91.4 (1%)	73.0 (-6%)	$74 (-8%)	$61 (-13%)	1.5	3.4
DTS Scenario C	82.1 (-9%)	69.9 (-10%)	$53 (-34%)	$44 (-38%)	3.2	5.2

1.3 How does building energy use change with alternative designs?

The predicted energy intensity[5] for each scenario is shown in Figure 2 (and Table 2). The results show that alternative designs can influence the building's energy intensity, although the magnitude of change varies depending on the type of design change, building location and orientation.

Single-storey office buildings with the alternative roof construction consume less energy compared to buildings with the initial roof construction design. For Darwin, the energy intensity of Scenario A buildings was 9 and 11% lower than the Core Study, for N-S and W-E oriented buildings, respectively. Energy intensities for Alice Springs were 1 and 12 %, lower for N-S and W-E oriented buildings, respectively. This demonstrates that adding ceiling insulation to meet the DTS requirements can be more effective than only using the roof blanket insulation[6]; this is mainly because the ceiling insulation reduces the amount of cooling energy lost into the roof space.

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[3] The regulated energy intensity is report – this is the annual energy consumed, per sqm of total floor area, that is associated with maintaining the regulated services of a building (e.g. HVAC systems and lighting. It excludes plug-in loads)
[4] Difference in construction cost between the NCC 2019 complaint case (Core Study, DTS Scenarios A, B, and C) and the base case construction cost. The base case was defined as part of the core study, representative of typical construction practices in the NT.
[5] Predicted energy intensities were based on simulations performed using dynamic thermal and energy simulation software IES<VE>.
[6] The total R-value of the original roof construction (LR-A2) is marginally lower than the alternative roof construction (LR-C1) (3.76 versus 3.80).

Results from Scenario B reveal that strategic placement of window glazing can be beneficial from a cost and/or energy perspective. The impact of altering window dimensions and glazing performances (Scenario B) is more significant for buildings in Alice Springs than Darwin. In Darwin, Scenario B buildings had either the same, or marginally higher energy intensities (1%) than the Core Study.[7] In contrast, in Alice Springs, the energy use for Scenario B was 2% and 10% less than the Core Study, for N-S and W-E oriented buildings, respectively. These results demonstrate that, in Darwin, the use of lower performance glazing did not markedly increase the case study's energy use, as the glazing was carefully located to maximise passive shading by the building form. Whereas the energy modelling revealed that, in Alice Springs, the strategically placed glazing, despite having higher thermal conductivity, was beneficial compared to the lower conductivity glazing modelled for the Core Study. This could be because Alice Springs has a significant diurnal temperature range and higher thermal conductivity through the glazing system helps the building structure cool down overnight.

In all but one of the cases considered, combining the alternative roof construction and window dimensions (forming Scenario C), resulted in the lowest building energy intensity, amongst the different design options considered in this Case Study. The exception is for Darwin N-S oriented buildings, where the energy intensity of Scenario C was similar to Scenario A (1.1kWh/m^2 difference). Across Alice Springs and Darwin, for both building orientations, the regulated energy intensities for Scenario C were 7 – 15% lower than the Core Study (and 22-34% lower than the base case energy intensity).

1.4 Does using different building designs to comply with DTS change the economic analysis results?

From an owner-occupier perspective, all designs considered were cost-beneficial with benefit cost ratio (BCR) values larger than 1.0 (see Table 2). The alternative designs considered (scenarios A, B and C) were more cost beneficial than the core study, as indicated by the larger BCR value. On average across both building orientations, the best performing single-storey office had window dimensions altered to reduce solar exposure and a roof construction that included insulation laid above the ceiling. The building design with the alternative roof construction performed second best. These results clearly demonstrated that implementing NCC2019 Section J can be more cost-beneficial if building designs are optimised.

[7] Although at a lower total incremental construction cost.

2 Case Study 2 - JV3 Verification using a Reference Building

Case Study 2

- The process of using the JV3 method to comply was demonstrated using the single-storey office building model. It showed a reduction in compliance cost is possible, but not always achievable. Whilst this case study utilised a small building, this method could potentially be of greater benefit for larger buildings.
- It should be emphasised that the number of iterations and designs considered were limited by the scope of work. Consequently, the design scenarios used in the case study are not necessarily the only or the best design. Alternative designs could still lead to different cost and compliance outcomes.

2.1 About JV3

The Verification Method JV3 is an alternative solution that can be used when the proposed building design does not meet the Deemed-to-Satisfy requirements. It can allow greater flexibility for designers, as it considers the performance of the whole building rather than individual building aspects (as done in the DTS provisions). In some cases, compliance costs could be reduced using this method.

JV3 compares the proposed building against a reference building, both modelled using energy simulation software. An excerpt of the JV3 performance requirements is shown below.

To meet JV3 requirements, the proposed building must meet thermal comfort requirements, and its annual greenhouse gas (GHG) emissions must not exceed that of the reference design. JV3 also allows renewable energy generated on site, such as roof-top solar PV, to offset the proposed design's modelled annual greenhouse gas emissions. As this case study focuses on alternative building designs, on-site renewable energy generation is not considered here.

*The **Reference Building** is the reference point to which the proposed building is compared to in the JV3 method. The reference building must –*

- *comply with the DTS Provisions in Parts to J7; and*
- *have the same building form as the proposed building (i.e. identical roof geometry, floor plan, number of storeys, size and location of glazing)*

Refer to JVb Clauses 2 and 3 for further details on the requirements for the reference building

JV3 Verification using a reference building *(extract from Section J - NCC 2019 Volume One Amendment 1)*

(a) For a Class 3, 5, 6, 7, 8 or 9 building or common area of a Class 2 building, compliance with JP1 is verified when—

(i) it is determined that the *annual greenhouse gas emissions* of the proposed building are not more than the *annual greenhouse gas emissions* of a *reference building* when—

(A) the proposed building is modelled with the proposed *services*; and

(B) the proposed building is modelled with the same *services* as the *reference building*; and

(ii) in the proposed building, a thermal comfort level of between a Predicted Mean Vote of -1 to +1 is achieved across not less than 95% of the floor area of all occupied zones for not less than 98% of the annual hours of operation of the building; and

(iii) the building complies with the additional requirements in Specification JVa.

(b) The *annual greenhouse gas emissions* of the proposed building may be offset by—

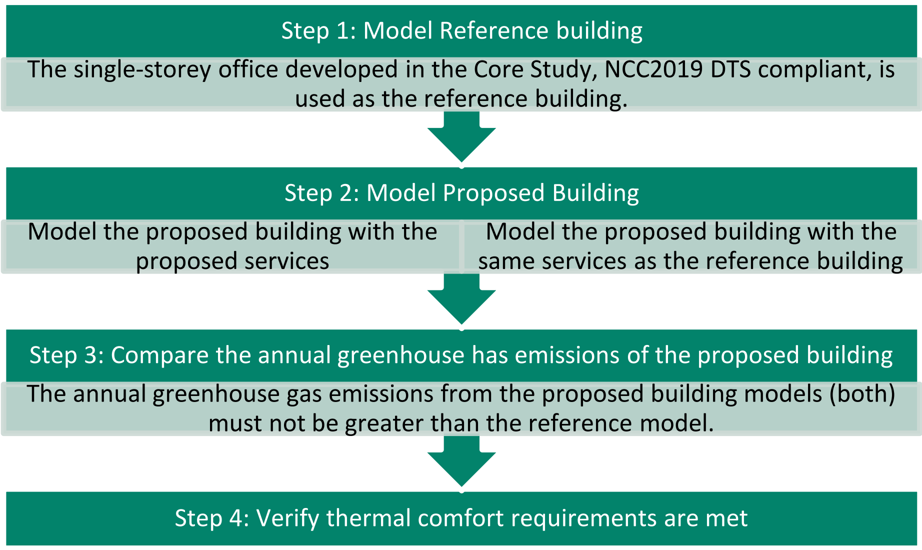
(i) *renewable energy* generated and used on *site*; and

(ii) another process such as reclaimed energy, used on *site*.

(c) The calculation method used for (a) and (b) must comply with—

(i) ANSI/ASHRAE Standard 140; and

(ii) Specification JVb.



The proposed building must be modelled using the same software.

Figure 4: Steps involved in JV3 Verification using a reference building

2.2 Reference building and JV3 scenario building construction details

In this case study, an alternative single-storey office design, with certain building fabric elements that do not satisfy DTS, was explored. The JV3 scenarios had the same building services specification as the reference building.

Details of the construction for the reference building and proposed buildings (JV3 scenario) for Darwin and Alice Springs are summarised in Table 3 and Table 4, respectively[8]. As the single-storey office building model used is rectangular, two orientations of the building were investigated (N-S and E-W, as used in Case Study 1, and illustrated in Figure 1).

An iterative approach can be taken to determine a suitable design. *In Case Study 2, an iterative approach was applied. Results from the final iteration are reported in this case study. For Alice Springs, the design proposed for both building orientations were compliant in the first iteration. For Darwin, the first iteration had an uninsulated slab floor, and the roof blanket insulation was increased from R3.3 to R3.6. However, this design did not meet the JV3 requirements. The modelling results indicated that while the proposed design met thermal comfort requirements, the annual energy intensity (and hence GHG emissions) was larger than the reference building. The proposed design for Darwin was revised – the wall insulation was increased, and remodelled. The revised proposed design was compliant for one orientation of the building, but not the other. Due to the limitation on the number of iterations allowed for this case study, a decision was made not to investigate additional design iterations.*

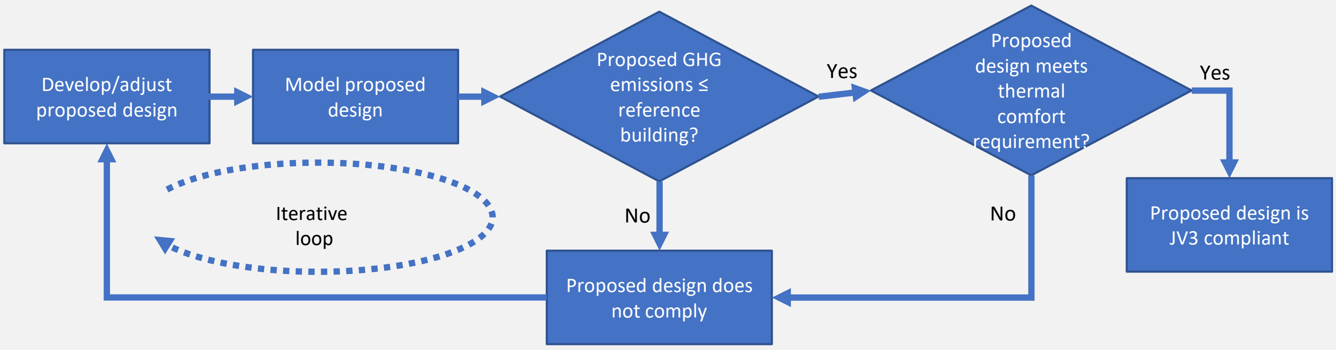


Figure 5: Flowchart of the iterative approach utilised to determine a suitable design

[8] This case study focuses on alternative building designs, hence roof top solar PV was not considered. Note that JV3 allows the use of on-site renewable energy generation to offset the annual GHG emissions.

Table 3: Construction details for Single-Storey Offices in Darwin, Reference Building and JV3 Scenario (JV3 deviations from the reference building are denoted in red font).

Darwin	Reference Building (Core Study)	JV3 Scenario – DRW
Roof	LR-A2: R3.3 (140mm) blanket (no foil underneath)[9] and insulation spacing system	LR-D1: R3.6 (145mm) blanket (no foil underneath) and insulation spacing system
Walls (insulation to be added inside external blockwork walls)	H1: Direct stick 25mm insulation board onto blockwork plus separate plasterboard	H2: Direct stick 40mm insulation board onto blockwork plus separate plasterboard
Windows (single pane unless otherwise stated)	Orientation N-S • GL2: Grey tint (South - long low-exposure facade) • GL5: Low-e grey (north, west & east) Orientation E-W • GL2: Grey tint (East - long low-exposure facade) • GL5: Low-e grey (north, south & west)	Same as the Reference Building
Floor	GND-B: Slab on ground with expanded polystyrene board applied around the perimeter of the slab	BC1: Uninsulated slab
Building Services	NCC2019 DTS compliant services	Same as the Reference Building

Table 4: Construction details for Single-Storey Offices in Alice Springs, Reference Building and JV3 Scenario (JV3 deviations from the reference building are denoted in red font)

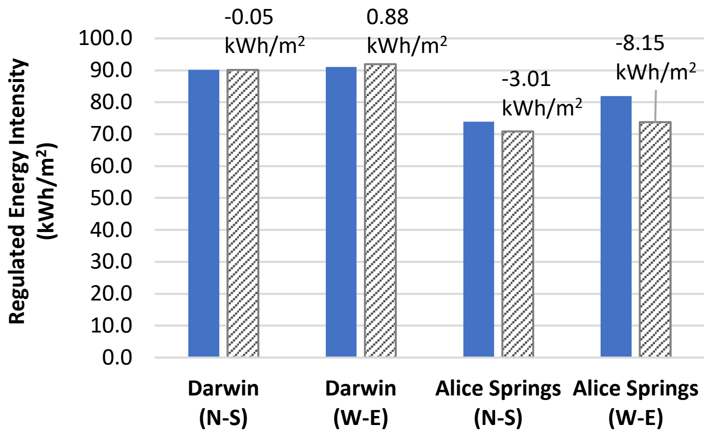
Alice Springs	Reference Building (Core Study)	JV3 scenario – Alice Springs
Roof	LR-A2: R3.3 (140mm) blanket (no foil underneath)[7] and spacing system	Same as the Reference Building
Walls (insulation to be added inside external blockwork walls)	C4: Direct stick 80mm insulation board onto blockwork with integrated plasterboard	H2: Direct stick 40mm insulation board onto blockwork plus separate plasterboard
Windows (single pane unless otherwise stated)	Orientation N-S and E-W • GL1: Clear (south & east) • GL2: Grey tint (north & west)	Orientation N-S • GL1: Clear (south) • GL2: Grey tint (north & west) • GL5: Low-e grey (east) Orientation E-W • GL1: Clear (south) • GL2: Grey tint (east & west) • GL5: Low-e grey (north)
Floor	GND-B: Slab on ground with expanded polystyrene board applied around the perimeter of the slab	Same as the Reference Building
Building Services	NCC2019 DTS compliant services	Same as the Reference Building

[9] Note 100mm R2.5 blanket with perforated foil underneath is required by the DIPL Sustainability Minimum Design Standards for buildings (under the Section J Compliance Threshold). DIPL officers have suggested it is beneficial to keep fibre contained between foil layers across the building life.

2.3 Does the Proposed Design Comply using JV3?

As the single-storey office buildings modelled in this case study were fully electric, comparing the energy intensities provided a good indication of how the GHG emission will compare between the reference building and the proposed design. The annual GHG emissions are determined from the predicted energy intensity of the building using greenhouse gas emissions factors (permitted values are specified in JVb Clause 3). It should be noted that the energy use is factored differently depending on the source (e.g. electricity or gas) and location of the building (i.e. state/ territory).

Three of the four proposed designs complied using JV3 (see Figure 6). The exception is the JV3 design proposed for the Darwin small-office (oriented W-E), which did not comply because the modelled energy intensity was higher than the reference building (0.88 kWh/m^2 more).



	Darwin (N-S)	Darwin (W-E)	Alice Springs (N-S)	Alice Springs (W-E)
Reference model (kWh/m²)	90.2	91.0	73.9	81.9
JV3 Scenario (kWh/m²)	90.1	91.9	70.9	73.8
Is the annual emissions for JV3 scenario less than the reference building?	✓	✗	✓	✓
Are modelled thermal comfort requirements met?	✓	✓	✓	✓
Was an approved simulation software used?	✓	✓	✓	✓

Figure 6: Comparison of JV3 models with the reference model.

The regulated energy intensity of the reference model and JV3 scenario are shown in the bar chart, the difference in energy intensity between the reference building and JV3 scenario is labelled (negative value indicates that the JV3 proposed design has a lower energy intensity than the reference building).

2.4 Is the JV3 proposed design cheaper than the reference building?

The construction costs[10] for the reference building and JV3 scenarios are shown in Figure 7.

The total incremental construction costs for three out of four cases were marginally higher than the reference building (0.1% higher than the base case construction cost). The W-E building in Alice Springs is an exception, with the lower total incremental cost arising from a significant increase in plant capacity cost savings (the proposed design for this case is more energy efficient, as reflected in the lower energy intensity, and hence the mechanical plant size can be reduced).

The higher cost stems from the difference in design and consultancy fees; the JV3 consultancy fee (approximately $3,000 per building) is higher than the DTS consultancy fee ($1800 per building). This is because the JV3 consultancy fee also includes fees for modelling services. However, as with all costs, the fee could be subject to competitive market forces. As part of this work, a range of fees for a JV3 consultancy were obtained and the higher fee was used to be more realistic of the present time. Using the lower JV3 consultancy fee of $2,000 would result in Alice Spring's JV3 proposed designs, across both building orientations, being cheaper than the reference case.

[10] Reported as incremental costs, relative to the base case construction

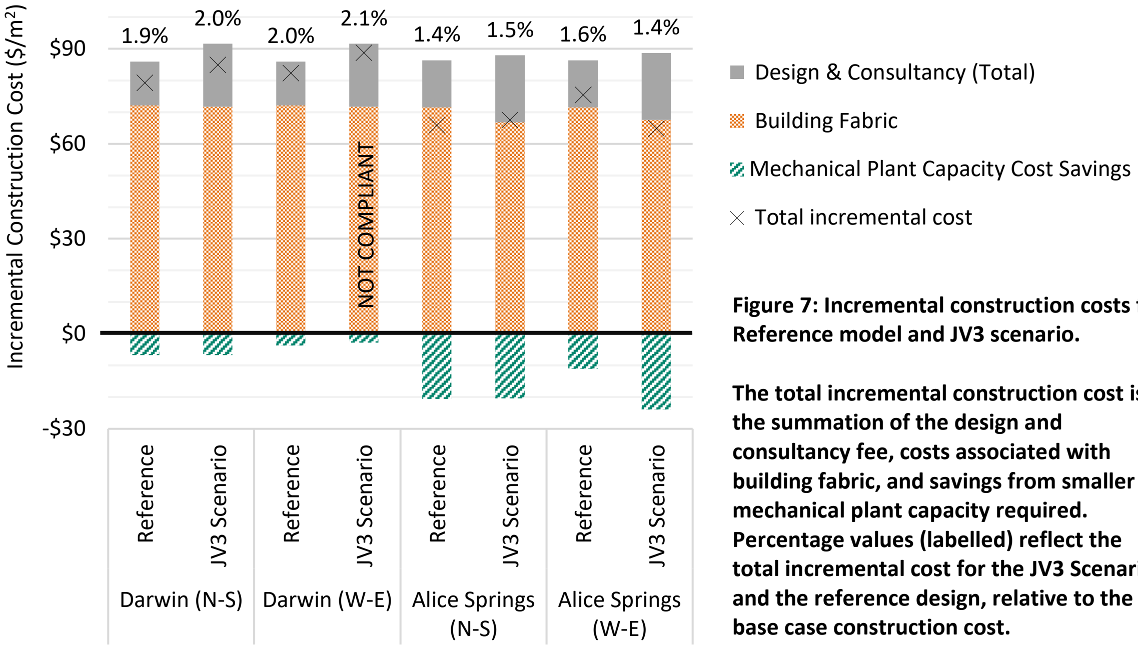


Figure 7: Incremental construction costs for Reference model and JV3 scenario.

The total incremental construction cost is the summation of the design and consultancy fee, costs associated with building fabric, and savings from smaller mechanical plant capacity required. Percentage values (labelled) reflect the total incremental cost for the JV3 Scenario and the reference design, relative to the base case construction cost.

2.5 How do building designs using the JV3 compliance pathway change the economic analysis results (from an owner-occupier perspective)?

For Alice Springs, the JV3 proposed building design in this case study is more cost-beneficial than the reference design (DTS core study) due mainly to the JV3 solution's lesser energy use. This is indicated by a higher BCR value for the JV3 design (3.2 for JV3 and 2.5 for the Core Study).

For Darwin, the JV3 proposed design was compliant for only one building orientation (N-S) and costs more than the reference case with only marginally less energy use. The proposed design achieved the same BCR as the core study (1.4).

2.6 Does the Proposed Design Comply using JV3?

Three of the proposed designs complied using JV3 (Alice Springs buildings oriented N-S and W-E, and single-storey office in Darwin oriented N-S). These three designs met thermal comfort requirements (complied with JVb and ANSI/ASHRAE Standard 140) and had lower annual GHG emissions than the reference case. The JV3 scenario design considered for the single-storey office in Darwin, oriented W-E, did not comply as the modelled energy intensity was higher than the reference building (0.88 kWh/m^2 more).