DELTA Q

NCC 2025 Chiller Plant Selections

Case Study

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Introduction

This case study presents two worked examples illustrating the process of selecting chillers according to the proposed NCC 2025 J6D11 update. This update introduces a largely revised approach to chiller efficiency requirements. The objectives of this case study are to:

- Test application of the methodology for practicality and ease of comprehension
- Provide industry stakeholders with a broad overview of the revised approach and the rationale behind the changes.
- Assist readers in understanding the procedural aspects of the revised approach.
- Explain the connection between the revised approach and certification bodies such as Eurovent and AHRI.

Background and context

The proposed NCC 2025 J6D11 is a subsection of Part J6, which covers energy efficiency of air-conditioning and ventilation. J6 covers the energy efficiency performance of refrigerant chillers in J6D11, alongside other subsections covering air conditioning systems and equipment such as fans, ductwork insulation, pumps and heat rejection equipment.

NCC 2022 J6D11 uses EER (Energy efficiency ratio at 100% load) and IPLV (Integrated Part Load Value, based on standard AHRI 551/591 part load conditions) to measure chiller efficiency. These metrics apply to individual chillers and are widely used internationally in energy efficiency regulation. In practice, however, neither of these factors necessarily guides installers to select a chiller suited to a given climate with a particular cooling load profile. As a result, it is possible to select chillers that are compliant with J6D11 but are not as suited to the installation conditions as they could be, potentially resulting in poorer performance than necessary.

Research in the lead up to NCC 2025 Public Comment Draft identified the potential to develop a regulatory minimum energy efficiency for chiller plant at the building level, as opposed to the current equipment-level requirement[1]. To capture more of the real-world factors determining chiller efficiency, this would be based on the expected performance of the entire chiller plant operating against a load profile that reflects the characteristics of cooling load for the building type and climate zone. This concept was developed and presented in the current Public Comment Draft. The purpose of this report is to test the application of the resultant methodology to assist with its refinement and explanation to stakeholders.

Methodology overview

The proposed NCC 2025 energy efficiency requirements for chillers introduces the concept of a CSPLV (Climate Specific Part Load Value). CSPLV calculates the combined part and full load performance of a given chiller or group of chillers, with weighting factors based on building class and climate zone.

$$CSPLV = \alpha_{100}EER_{100} + \alpha_{75}EER_{75} + \alpha_{50}EER_{50} + \alpha_{25}EER_{25}$$

[1] REP00777-A-01 Whole of HVAC COP, DeltaQ report for Department of Climate Change, Energy, the Environment and Water, November 2022.

EER_n = the average energy efficiency ratio of the chillers that operate (according to a design staging strategy for multiple chillers) to provide n% of the design cooling load determined in accordance with specific operating conditions depending on climate zone and building Class.

α_n = load weighting factors dependent on climate zone and building class.

This structure of equation mimics that of the AHRI 551/591 IPLV calculation but is different in the following critical details in the CSPLV calculation:

1. The part load values (100%, 75%, 50% and 25%) are calculated as a percentage of the design load being served by the chillers, as opposed to the sum of the chiller capacities. This effectively incorporates questions of optimal sizing into the assessment.
2. When evaluating efficiency EER_n at a load percentage n, one is assessing the combined efficiency of all chillers operating to meet that load. This figure has dependencies on the proposed chiller staging and the chiller sizes relative to the design load as well as the efficiency characteristics of the individual chillers.
3. When evaluating the EER_n figures, the conditions present at load n (ambient wet bulb, ambient dry bulb and chilled water temperature) are specific to the climate zone and the building type (daytime only or 24 hour).
4. The load weighting factors α_n are also specific to the climate zone and building type.

These differences mean that the results will be more reflective of real-world efficiency than the current EER/IPLV based requirements.

Demonstrating Compliance – Worked Example

The proposed Code text in NCC 2025 S47C2 covers a wide range of applications. Practitioners can demonstrate compliance for a chiller plant in the building using the process presented below:

1. Plant Design: Determine required chiller plant capacity and select proposed chiller(s) for assesment.

2. Determine required plant CSPLV performance.

3. Plant staging: Carry out an assessment to determine the options for operation of each chiller and chiller load at each building load point

4. Identify required performance assessment conditions for each chiller using Tables S47C2c through h, dependent on chiller type and building class.

5. Compile and issue request for data from chiller suppliers.

6. Review supplier performance submissions

7. Calculate the operating capacity weighted average CSPLV using the formula in S47C2 and the weighting factors in S47C2a or b.

8. Compare resulting plant CSPLV with the required efficiency in Table J6D11a or b.

9. Reselect plant with more efficient chillers if calculated CSPLV is less than the J6D11 requirements.

1. Plant Design

The worked example presents two different but common plant arrangements for a notional typical building application. The design parameters for these examples are as follows:

- Common to both examples:
  - Climate Zone: 5
  - Building Class: 5
  - Design cooling load: 1,000 kW
  - Design brief: 60% redundancy[2]
- Example Plant A:
  - Water-cooled
  - 2x 600 kW chillers (designated Chiller A.1 and A.2 for this example)
- Example Plant B:
  - Air-cooled
  - 1x 200 kW chiller (designated Chiller B.1)
  - 2x 400 kW chillers (designated Chiller B.2 and B.3)

[2] Both plant arrangements have the requirement for 60% redundancy (that is, if one chiller fails a minimum of 60% total cooling capacity must be supplied be the remaining chillers). This level of redundancy was selected to align with Property Council of Australia (PCA) Office Quality Premium requirements for new buildings.

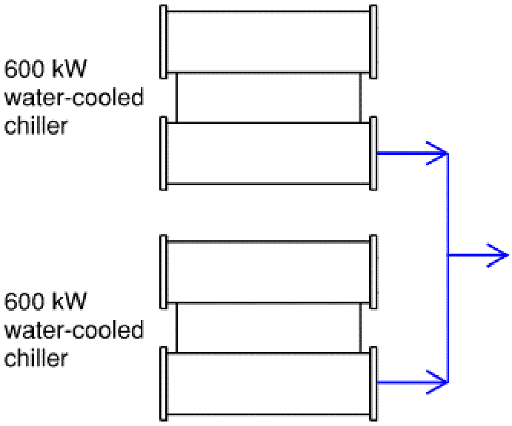

Figure 1: Plant A Arrangement

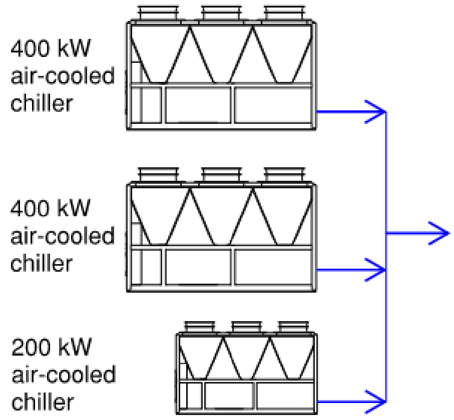

Figure 2: Plant B Arrangement

2. Determining Required CSPLV Performance

Clause J6D11 describes the efficiency requirements for each plant arrangement separating air-cooled (Table J6D11a) from water-cooled (Table J6D11b). Looking up the CSPLV requirements in these tables for each plant yields the results as demonstrated in Figure 3 and Figure 4.

Table J6D11a. Minimum climate specific part load value for a connected group of water-cooled chiller plant

Climate zone	Design load range (kWth)	*Climate specific part load value* – Class 2 common area, a Class 5, 6, 7, 8 or 9b building or a Class 9a building other than a *ward area*	*Climate specific part load value* - Class 3 or 9c building or a Class 9a *ward area*
1	0 to ≤440	4.82	4.76
1	>440 to ≤880	4.87	
1	>880 to ≤1760		
		5.54	5.58
5	>440 to ≤880	6.4	6.5
5	>880 to ≤1760	6.92	7.07
5	>1760 to ≤2345	6.98	6.98
5	>2345	7.68	7.68

Figure 3: Extract of Proposed Section J6D11 - CSPLV required for the Example Plant A

Table J6D11b. Minimum climate specific part load value for air-cooled chiller plant

Climate zone	Design load range (kWth)	*Climate specific part load value* – Class 2 common area, a Class 5, 6, 7, 8 or 9b building or a Class 9a building other than a *ward area*	*Climate specific part load value* – Class 3, 9c or 9a ward area
1	0–880kW	4.03	4.08
1	>880kW	3.76	[illegible]
[illegible]	0–880kW	[illegible]	
		[illegible]	4.92
[illegible]	0–880kW	5.26	5.36
5	>880kW	4.94	4.99
6	0–880kW	5.73	5.87
6	>880kW	5.33	5.39
7	0–880kW	5.54	5.6

Figure 4: Extract of Proposed Section J6D11 – CSPLV required for the Example Plant B

In summary, the CSPLV efficiency requirements have been determined as follows:

- Example Plant A CSPLV required = 6.92
- Example Plant B CSPLV required = 4.94

3. Plant Staging Assessment

To calculate the average efficiency ratio of the chillers operating at each building load point, an assessment of the possible combinations of chiller operation needs to be carried out. This is relatively simple for Example Plant A as it consists of only two chillers of equal capacity. When a chiller plant arrangement consists of more chillers of varying capacities (such as Example Plant B) the range of potential operating combinations can be much larger. One method to explore the possible arrangements is to list the various operating options for each load point, as detailed in the following tables.

Example Plant A

Table 1: Example Plant A Plant Staging Assessment

Load Point Staging Option ID	Building Cooling Load (%)	Building Cooling Load (kW_r)	Chiller A.1 load (%)[3]	Chiller A.1 load (kW_r)	Chiller A.2 load (%)	Chiller A.2 load (kW_r)
1.1	25	250	42	250	0	0
1.2	25	250	21	125	21	125
2.1	50	500	83.5	500	0	0
2.2	50	500	42	250	42	250
3.1	75	750	62.5	375	62.5	375
4.1	100	1000	83.5	500	83.5	500

[3] The chiller load point for Example Plant A is lower than the design load point due to the redundancy requirements of this plant. Each chiller will be capable of a full load of 600 kW_r.

Example Plant B

Table 2: Example Plant B Plant Staging Assessment

Load Point Staging Option ID	Building Cooling Load (%)	Building Cooling Load (kW_r)	Chiller B.1 load (%)	Chiller B.1 load (kW_r)	Chiller B.2 load (%)	Chiller B.2 load (kW_r)	Chiller B.3 load (%)	Chiller B.3 load (kW_r)
1.1	25	250	25	50	25	100	25	100
1.2	25	250	42	83.5	42	166.5	0	0
1.3	25	250	0	0	31	125	31	125
1.4	25	250	0	0	62.5	250	0	0
2.1	50	500	0	0	62.5	250	62.5	250
2.2	50	500	50	100	50	200	50	200
2.3	50	500	83.5	166.5	83.5	333.5	0	0
3.1	75	750	0	0	94	375	94	375
3.2	75	750	75	150	75	300	75	300
4.1	100	1000	100	200	100	400	100	400

Note that in these tables, the cooling load is the building cooling load, not the design capacity of the chiller plant.

4. Identify Required Assessment Conditions

With the array of potential load points determined by the previous step, the chiller operating conditions at each of the load points must be determined by referencing the conditions defined by Specification 47.

Example Plant A

The conditions used to assess the Example Plant A performance at each load point is provided by Table S47C2c (chilled water supply temperatures) and S47C2d (ambient wet bulb temperatures). Noting the latter provides ambient conditions rather than the condenser water entering temperature required for water-cooled chiller performance assessment, the associated cooling tower design must also be determined. For our example, we are using an assumed 6°C approach temperature (that is, the cooling towers selected will achieve a constant supply water temperature to the chiller of ambient wet bulb temperature minus 6°C).

Example Plant B

The conditions used to assess the Example Plant B performance at each load point is provided by the same Table S47C2c (chilled water supply temperatures) and S47C2e (outdoor dry bulb temperatures). The resulting performance assessment load points are compiled and issued to the chiller supplier(s), as summarised in the next section. Three suppliers were approached and coordinated with in developing this case study.

5. Compiling and Issuing Requests for Data from Chiller Suppliers

The data required to be compiled for issue to suppliers is a combination of building cooling load point (due to the unique assessment conditions) and the associated chiller load option. Combining these with the conditions required by S47C2c to e provides the range of required assessment points, as detailed in the following table. In total, this results in the request for 6 unique load point selections for Example Plant A and 16 for Example Plant B.

The data request letter used for this case study is provided as an example in Appendix C.

Example Plant A

Table 3: Chiller A.1 and A.2 Assessment Conditions

Load Point Staging Option ID	Total Building Load (%)	Chiller load (kW_r)	Chilled Water Supply Temperature (°C)	Condenser Water Entering Temperature (°C)[4]
1.1	25	250	10	20
1.2	25	125	10	20
2.1	50	500	8	26
2.2	50	250	8	26
3.1	75	375	7	29
4.1	100	500	6	31

Example Plant B

Table 4: Chiller B.1 Assessment Conditions

Load Point Staging Option ID	Total Building Load (%)	Chiller B.1 load (kW_r)	Chilled Water Supply Temperature (°C)	Ambient Air Temperature (°C)
1.1	25	50	10	19
1.2	25	83	10	19
2.2	50	100	8	25
2.3	50	167	8	25
3.2	75	150	7	28
4.1	100	200	6	27

Table 5: Chiller B.2 and B.3 Assessment Conditions

Load Point Staging Option ID	Total Building Load (%)	Chiller B.2 and B.3 load (kW_r)	Chilled Water Supply Temperature (°C)	Ambient Air Temperature (°C)
1.1	25	100	10	19
1.2	25	166	10	19
1.3	25	125	10	19
1.4	25	250	10	19
2.1	50	250	8	25
2.2	50	200	8	25
2.3	50	334	8	25
3.1	75	375	7	28
3.2	75	300	7	28
4.1	100	400	6	27

6. Reviewing Supplier Submissions

The format of responses from suppliers varies and is dependent on the differences in between each manufacturer's selection software, how the performance load point conditions are entered into the

[4] As noted previously, condenser water temperature is calculated using an assumed 6°C approach for a conceptual cooling tower design.

software, and how the resulting performance is calculated and reported. In general, the EER for each of the four load points is assessed through four separate software simulations, rather than one, due to the unique conditions at each load point. This contrasts with IPLV calculations, where the software can then automatically assess the part load points based on a standard set of unloading conditions following the full load input requirements.

The conditions used by the chiller supplier to calculate the EER at each load point require careful verification against the requested inputs before proceeding to the calculation step. Our experience in reviewing supplier responses demonstrated a wide range of results. Some suppliers returned a correct response, accurate to the request on first review, while others required up to two subsequent revisions and detailed discussions on required data.

Cooling

Ls [%]	Pf [kW]	Pa [kW]	Ef [W/W]	Gw [°C]	Gd [°C]	Uw [°C]	Ud [°C]
100	725.9	140.8	5.15	30.8	4.3	8.0	6.4
34	250.4	29.5	8.49	26.0	1.4	8.0	2.2

Ls: Load percentage; wE: Weight coefficients; Pf: Capacity; Pa: Input power; Ef: EER; Gw: Inlet water temperature (Source side circuit); Gd: Temperature difference (Source side circuit); Uw: Outlet water temperature (System side circuit); Ud: Temperature difference (System side ci
Water flow and glycol percentage are kept the same at all load percentages.

Figure 5: Sample of data submitted by a chiller supplier – Load Point Staging ID 2.2 for Example Plant A

7. Calculating Chiller Plant CSPLV Performance

With accurate performance data at each load point verified as required above, the EER for each chiller at each load point can be calculated to determine the most efficient operating combination at each of the four load points. This is again a simpler process for Example Plant A due to the equally-sized chillers, whereas the unequally-sized chillers in Example Plant B require an operating capacity weighted average calculation.

Once the highest EER is determined for each load point these can be substituted into the formula provided under S47C2 (1) in Specification 47 in combination with the load weighting factors provided by Table S47C2a.

Example Plant A

Table 6: Example Plant A Plant Staging Assessment. Selected operating points are highlighted in bold font

Load Point Staging Option ID	Chiller A.1 EER	Chiller A.2 EER	Weighted EER
1.1	12.2	-	**12.2**
1.2	11.94	11.94	11.94
2.1	7.6	-	7.6
2.2	8.49	8.49	**8.49**
3.1	7.01	7.01	**7.01**
4.1	5.68	5.68	**5.68**

Substituting the load factors and EER results for each chiller into S47C2(1) results in the following calculations.

CSPLV = (0 x 5.68) + (0.3 x 7.01) + (0.46 x 8.49) + (0.24 x 12.2) = **8.94**

Example Plant B

Table 7 below presents the EER results for each chiller and includes the operating weighted average EER calculation for the plant as a whole, at each load point option.

Table 7: Example Plant B Plant Staging Assessment. Selected operating points are highlighted in bold font.

Load Point Staging Option ID	Chiller B.1 EER	Chiller B.2 EER	Chiller B.3 EER	Weighted EER
1.1	5.34	5.8	5.8	5.71
1.2	6.06	6.15	-	**6.12**
1.3	-	5.96	5.96	5.95
1.4	-	5.84	-	5.84
2.1	-	4.72	4.72	4.72
2.2	5.10	4.97	4.97	**5.00**
2.3	4.67	4.54	-	4.58
3.1	-	4.04	4.04	4.04
3.2	4.06	4.12	4.12	**4.11**
4.1	3.83	3.9	3.9	**3.89**

The operating weighted average EER calculation for Load Point Staging Option 1.2, as an example, is provided as follows:

Operating weighted average EER at a given load point =

$$\frac{(\text{CH\_B.1 EER}) \text{ x } (\text{CH\_B.1 Load}) + (\text{CH\_B.2 EER}) \text{ x } (\text{CH\_B.2 Load}) + (\text{CH\_B.3 EER}) \text{ x } (\text{CH\_B.3 Load})}{\text{Total Plant Load}}$$

Operating weighted average EER at load point 1.2 = $\frac{(6.06) \text{ x } (83.5) + (6.15) \text{ x } (166.5) + (0) \text{ x } (0)}{250}$ = **6.12**

One weighted EER at each building load point must contribute to the CSPLV calculation. So, to assess the selected chiller plant's maximum possible CSPLV the highest EER for each load point should be selected and substituted in into S47C2(1). For Example Plant B, these selected load points are 1.2, 2.2, 3.2 and 4.1.

CSPLV = (0 x 3.89) + (0.3 x 4.11) + (0.46 x 5.00) + (0.24 x 6.12) = **5.00**

8. Comparing with Required Performance

Example Plant A

The CSPLV result of **8.94** can be compared with the required minimum plant CSPLV of **6.92** from Table J6D11a. This shows that the selected chiller plant for Example Plant A **is compliant** with the proposed NCC 2025 requirements.

Example Plant B

The CSPLV result of **5.00** can be compared with the required minimum plant CSPLV of **4.94** from Table J6D11b. This shows that the selected chiller plant for Example Plant B **is compliant** with the proposed NCC 2025 requirements.

Does the proposed requirement change the level of effort required to demonstrate compliance?

This case study has shown that the changes will require some upfront adjustments by chiller suppliers as well as practitioners (designers and contractors). However, it is likely that this reflects a learning curve facing the industry in the early stages rather than an ongoing increase in effort required. The building services and construction industries are continuously updating and evolving, so managing learning curves due to new materials, equipment, processes or standards are common. Essentially, the required data is available, but requires some upskilling and changes in process to extract the correct information to demonstrate compliance. The calculations required all fall within the range of current good to best practice, as this would require consideration of climate specific part load performance and staging during the chiller selection process.

Potentially, chiller selection software could be updated by manufacturers to facilitate producing CSPLV (just as the software easily produces IPLV figures), with the adoption of the proposed NCC 2025 Section J for Refrigerant Chillers efficiency.

Chiller suppliers

The current IPLV measurement has been used widely and internationally within the industry. As a result, chiller supplier software (and often marketing material) is designed to produce the required chiller IPLV with little effort. That said, the same software is capable of providing performance at customised conditions, such as those required by the CSPLV.

Standardised part load data is usually produced as a process automated via software, using full load inputs by the user. In contrast, the proposed NCC 2025 method requires custom performance to be entered for each of the four load points (25%, 50%, 75% and 100%) individually. Depending on the design of the software used by each supplier and design of the chiller plant to be assessed (particularly due to the range of different staging option) this could require at least four times the amount of data entry as a typical NCC 2022 selection. We note this is not widespread and is isolated to a subset of chiller suppliers' software.

During the case study, we found that there were errors in the first attempt at data response from two out of three of the suppliers due to the new requirement for multiple load point calculations. However, all suppliers were able to provide the data within three attempts. The difficulty experienced initially appeared to stem from the assumption that the proposed method required one iteration of performance based on a single set of conditions (similar to the existing method) rather than four or more.

Practitioners

The practitioner should allow time for detailed reviews and additional iterations with chiller suppliers for chiller performance data when the NCC 2025 requirements are first rolled out. This includes time required to consider the staging options for the proposed chiller plant, as well as potentially more detailed consideration of individual chiller selections than would have been the case for the current Code.

Identification and Verification of Supplier Performance Data

The current NCC 2022 requires chiller performance (IPLV and EER) to be determined and certified by AHRI in accordance with their standard AHRI 551/591. Our research has shown this typically accounts for chillers manufactured outside of Europe (most commonly Asia and the United States). However, it is also common for chillers to be supplied to Australia from Europe, which are most likely to be certified by Eurovent in accordance with the standards EN 14511 and EN 14825. Some chillers are certified by both AHRI and Eurovent.

While both the AHRI and EN standards include methods of determining chiller performance at 100% load and a weighted average based on seasonal conditions, direct translation between the standards is not possible due to differing assessment conditions and calculations. In brief, the differences are described in the following table:

Table 8: Comparison of AHRI and European Performance Assessment Standards

Full Load Performance: • **AHRI COP** • **EN 14511 EER**	**Part Load Performance:** • **AHRI IPLV** • **EN 14825 SEER**
• **Both AHRI COP and EN 14511 EER** use chiller cooling capacity output compared to chiller unit power input at full load. Assessment conditions (water and air temperatures) are slightly different. • **AHRI COP** specifies a fouling factor for chiller heat exchanger(s). • **EN 14511 EER** does not specify a fouling factor but requires hydraulic pump power to be included in the power input coverage.	• **AHRI IPLV** uses four discrete load points and calculates a weighted average based on one set of prescriptive weightings. • **EN 14825 SEER** calculation uses performance weighted by 'Bin Hours' for each of the reference climates. Also considers ancillary consumption such as standby loads.

The Australian Building Codes Board (ABCB) developed an advisory document in 2021 that demonstrated a Performance Solution pathway for chillers certified under Eurovent only, setting out equivalent and part load performance between the two certification schemes and standards[5].

The proposed NCC 2025 updates include unique and customized conditions for four specific load points. The public consultation draft text does not cite either AHRI or EN Standards, which is reasonable given that a primary purpose of such standards is to define load points. However, both standards also define background measurement conditions (such as fouling) while the certification by the AHRI or Eurovent organisations provides a degree of quality assurance on the measurements that produce the COP figures that would be used in the NCC2025 calculation. This creates some question as to whether a more detailed specification of Standards and certification is merited.

If such a requirement were to be added to Code text, it would need to say that:

1. Measurements underlying the figures used in compliance be certified by AHRI or Eurovent to either the AHRI 551/591 or EN14511/EN14825 measurement protocols; and
2. If using EN14511/EN14825, pump energy should be excluded for use in NCC calculations

This statement could alternatively be provided in the Guidance.

[5] Australian Building Codes Boards, "Eurovent Standards for Chillers", National Construction Code, (July 2021), *https://ncc.abcb.gov.au/sites/default/files/resources/2022/PBDS-eurovent-standards-chillers.PDF*.

Appendix A Literature Review

Appendix A.I.I Eurovent vs AHRI

In considering the question of Eurovent vs AHRI, it is essential to start with a clearer definition of what this comparison is intended to mean. Eurovent and AHRI are certification bodies that certify that chiller performance measurements and software are accurate. These measurements can be conducted to either AHRI551/591 or EN14511, both of which define the conditions of measurement for chiller performance and the calculation of the respective metrics[6]. The pertinent question for the NCC, however, is the extent to which the measurements under AHRI551/591 and EN14511 can be considered to be equivalent. This is important as the underlying analysis for the currently proposed Code text is based on data generated from AHRI551/591. It is necessary therefore to establish that chillers for which performance data was measured under EN14511 conditions can also use the proposed NCC methodology without undue bias in outcomes or additional difficulty applying the method.

Our research conducted when compiling this case study has found the key differences between the underlying measurement standards are as follows:

Table 9: Performance Results from Chosen Chiller Manufacturer for Each Chiller

Standard	Pump Energy	Fouling Factor	Elevation (ambient air pressure/density)
AHRI 551/591	Does not include pumping energy.	Specifies fouling factor for evaporator and condenser (for water-cooled chillers) heat exchangers.	Specifies elevation for test conditions at sea level.
EN 14511	Accounts for pump power, added to chiller power.	Does not specify a fouling factor.	Does not specify an ambient air pressure for non-ducted units.

Pump Energy

During our data gathering exercise, one supplier noted they were able to demonstrate performance and software selection capabilities for the same chiller under both Eurovent and AHRI certification. This enabled an exploration as to the impact of pumping energy on the performance of the chiller. The following two selection extracts illustrate an increase in pumping energy at full load of 0.9 kW, resulting in an increase of less than 1% to power input, and corresponding decrease to the full load EER.

[6] Confusingly, Eurovent can and does certify measurements under the AHRI standards and AHRI can and does certify measures under the EN standard.

Part loads information	
Calculation type: custom	
Load [%]	100
Power Input [kW]	129.6
Cooling Capacity [kW]	400.0
EER [kW/kW]	3.086
Evap. fluid IN/OUT [°C]	12.00/7.00
Evap. Water flow [l/s]	18.52
Evap. pressure drops [kPa]	27.3
Ambient temp. [°C]	35.0
Running Current [A]	217.77
Lw [db(A)]	101

Figure 6: Submission of the 400 kW air-cooled chiller with pump power included at full load EER

Part loads information	
Calculation type: custom	
Load [%]	100
Power Input [kW]	128.7
Cooling Capacity [kW]	400.0
EER [kW/kW]	3.109
Evap. fluid IN/OUT [°C]	12.00/7.00
Evap. Water flow [l/s]	18.52
Evap. pressure drops [kPa]	27.3
Ambient temp. [°C]	35.0
Running Current [A]	217.77
Lw [db(A)]	101

Figure 7: Submission of the 400 kW air-cooled chiller without pump power included at full load EER

While this is a seemingly small increase, the impact of pump power becomes much larger at low load (which also receives a much higher weighting in the CSPLV calculation). The same chiller used in the above example has a power input of 16.62 kW at 25% load, resulting in an EER of 6.018. If the same 0.9 kW pump power was accounted for this example the EER would reduce to 5.708, a reduction in EER of greater than 5%.

Part loads information	
Calculation type: custom	
Load [%]	25
Power Input [kW]	16.62
Cooling Capacity [kW]	100.0
EER [kW/kW]	6.018
Evap. fluid IN/OUT [°C]	11.25/10.00
Evap. Water flow [l/s]	18.52
Evap. pressure drops [kPa]	30.1
Ambient temp. [°C]	19.0
Running Current [A]	32.36
Lw [db(A)]	82

Figure 8: Submission of the 400 kW air-cooled chiller without pump power at 25% load

Fouling Factor

The impact of fouling factor for both air- and water-cooled chillers was tested via multiple selections (both chiller types were tested due to fouling factor also applying to water-side condenser heat exchangers for water-cooled chillers). Equivalent selections were produced while making an adjustment to fouling factor only between zero and the AHRI specified requirement. No changes to the output figures were observable, leading to the conclusion that the impacts of fouling factor when comparing between AHRI and EN standards is too small to be perceivable by the chiller manufacturer software.

Elevation (ambient air pressure/density)

The same approach as fouling factor was taken for testing the impacts of elevation on chiller performance. However, for this iteration, only air-cooled chillers were tested as elevation will have no impact to water-cooled chiller performance. It is primarily concerned with the impact to air density, which in turn has an impact to the air flow capabilities of the chiller along with the heat capacity of air. This alters the quantity of heat that can be physically rejected by a chiller.

Equivalent selections were produced while making an adjustment to elevation only. 1000m was selected as the upper limit to simulate the range of reasonably likely outcomes for a chiller selection in Australia. Three iterations for different air-cooled chillers were used, resulting in a slight reduction in cooling capacity and slight increase to input power. The net result was a corresponding EER reduction of approximately 5%.

While this proves there is a material difference to performance, our research showed that sea level was the default software input, already maximising the chillers performance at the given conditions. We believe it is unlikely that chiller suppliers will deviate from sea level as the reference elevation for performance calculations to reduce their chiller's performance. By association, no opportunity for gaming of results exists by altering this metric.

EN14511 vs AHRI551/591: Conclusions

The above discussion shows that, aside from the treatment of pump power, the two measurement standards are functionally equivalent. This means that either measurement standard can be used in performing the proposed Code calculations almost interchangeably. To implement this, Code text would need to specify that chiller performance figures used in the calculation –

1. can be based on measurements made to either EN14511 or AHRI 551/591; and
2. where based on measurements made to EN14511, should be adjusted to remove pump power.

This is discussed further and confirmed in Appendix B.

Appendix A.I.II Manufacturer Software

The chiller suppliers we spoke with, during our research and data gathering, all made reference to their software being supplied and managed by the chiller manufacturers themselves. They were generally provided little information from the chiller manufacturers regarding how the software works or how it was developed. One senior member of a supplier that we spoke to explained that their software derives performance for custom and unique load points via interpolation of an array of tested performance conditions. Reviewing the AHRI and Eurovent certification method and operations manual documentation corroborates these statements by describing how each supplier's software tool forms part of the certification process.

During this process, our discussions with the various suppliers lead to the understanding that the proposed NCC 2025 method would increase the required effort by suppliers by up to four times. It is recognised that part of this impact can be attributed to the typical learning curve with new code processes and revisions. Another, possibly larger, impact can be attributed to manufacturer software design, as current software versions will be designed in coordination with current supplier requirements (including code compliance).

One supplier advised that they commonly receive minor update “patches” approximately every 6 weeks, and more major software updates every six months.

Appendix B Recommended Updates to Code Text

Appendix B.I.I AHRI/EN standards and AHRI/Eurovenet certification

As described in the body of the report, AHRI and Eurovent are certification bodies that certify measurements undertaken to AHRI and EN Standards. The AHRI and EN Standards are useful for the purposes of NCC because they provide a measurement methodology for determining the figures that would be used in compliance with the revised chiller measure. These measurement methodologies are functionally equivalent for the intended Code purpose, except for the treatment of pump energy under the EN standards.

We recommend that either the Code text or the guidance is updated to include the following requirements:

1. *Measurements underlying the figures used in compliance must be certified by AHRI or Eurovent to either the AHRI 551/591 or EN14511/EN14825 measurement protocols; and*
2. *If using EN14511/EN14825, pump energy should be excluded for use in NCC calculations.*

Appendix B.I.II CSPLV Weighted Average Calculation

Specification 47 requires the calculation of EER_n, the *average energy efficiency ratio of the chillers that operate to provide n% of the design cooling load, determined in accordance with* the conditions presented in the tables later in the Specification. This section does not account for chiller plant designs that include chillers of different capacities, which should contribute to the plant CSPLV calculation based on their proportion of total plant capacity. Using a weighted average calculation, as opposed to average only, will ensure that the CSPLV calculation is more accurately representative of the designed chiller plant arrangement.

It should be noted that the worked example within this report assumes this proposed change is accepted and included in the final NCC 2025 text.

Proposed update to text below in ***bold, italics and underlined***:

S47C2 Calculation of climate specific part load value for chillers

(1) The climate specific part load value for a group of one or more chillers must be calculated in accordance with the following formula:

$$CSPLV = \alpha_{100}EER_{100} + \alpha_{75}EER_{75} + \alpha_{50}EER_{50} + \alpha_{25}EER_{25}$$

where —

(a) $CSPLV$ = climate specific part load value; and

*(b) EER_n = the **operating capacity weighted** average energy efficiency ratio of the chillers that operate to provide n% of the design cooling load, determined in accordance with (2); and*

(c) α_n = load weighting factors specified in—

(i) Table S47C2a for chillers serving a Class 2 common area, a Class 5, 6, 7, 8 or 9b building or a Class 9a building other than a ward area; or

(ii) Table S47C2b for chillers serving a Class 3 or 9c building or a Class 9a ward area.

(2) EER_n is determined as the ***<u>operating capacity weighted</u>*** *average energy efficiency ratio of the chillers operating to meet n% of the design load, allowing for the part-load efficiencies at—*

Appendix B.I.III Plant Staging Consideration

The definition for EER_n in Specification 47 section S47C2 (b) (expanded in Appendix B.I.II above) contains the description "*…average energy efficiency ratio of the chillers that operate to provide n% of the design cooling load…*". In practice, this component of the EER_n calculation requires detailed consideration of various chiller plant staging combinations as can be seen in the sections "Plant Staging Assessment" and "Calculating Chiller Plant CSPLV Performance" within the main report. This is a process that does not usually receive this level of consideration until later stages of a design, if at all. The true level of consideration and assessment required for this aspect of the process should be reflected within the Code text with an accompanying explanation as a minimum.

Proposed update to text below in ***<u>bold, italics and underlined</u>***:

(2) EER_n is determined as the average energy efficiency ratio of the chillers operating to meet n% of the design load, allowing for the part-load efficiencies ***<u>~~at~~</u>****—*

<u>(a) for each chiller's operating capacity contribution to the load as a result of the staging strategy to be deployed at a given load point n; and</u>

<u>(b)</u> *for chillers serving a Class 2 common area, a Class 5, 6, 7, 8 or 9b building or a Class 9a building other than a ward area—*

(i) the chilled water leaving temperatures listed in Table S47C2c; and

(ii) the entering condenser water temperature for water-cooled chillers that is determined by adding the design approach temperature to the outside wet-bulb temperatures listed in Table S47C2d; and

(iii) the outside dry bulb temperatures listed in Table S47C2e for air-cooled chillers; and

<u>(c)</u> *for chillers serving a Class 3 or 9c building or a Class 9a ward area—*

(i) the chilled water leaving temperatures listed in Table S47C2f; and

(ii) the entering condenser water temperature for water-cooled chillers that is determined by adding the design approach temperature to the outside wet-bulb temperatures listed in Table S47C2g; and

(iii) the outside dry bulb temperatures in Table S47C2h for a Class 3 or 9c building or a Class 9a ward area for air-cooled chillers.

Appendix B.I.IV Chilled and Condenser Water Flow Rates

The chilled and condenser water flow rates were required by chiller suppliers to calculate performance. As the chosen flow rates had an impact on chilled and condenser water return temperatures each supplier noted this will have an impact on the performance calculations (due to difference in average temperatures through chiller evaporators and condensers, although supply water temperature has a larger impact).

We recommend that a chilled and condenser water flow rate methodology is required by the proposed Code text. A method that aligns with the current AHRI 551/591 standard would prove sound for the purposes of technical significance and supplier/practitioner ease of understanding. This would require rated water flow *to be determined by a 6°C entering/leaving temperature difference at the design (100% cooling load) cooling capacity.*

Appendix B.I.V CSPLV Assessment Software/Spreadsheet Tool Development

The required effort added when two or more chillers (particularly of unequal capacity) make up a proposed chiller plant is relatively significant largely due to the staging assessment and operating weighted average calculations. The calculations are not necessarily complex, but mostly laborious and repetitive in nature due to the requirement to assess numerous options under the same process. Because of this, it would be expected that practitioners who carry out these assessments and calculations to ultimately develop their own 'in-house' spreadsheet tools to assist and save processing times when developing designs.

It would be prudent to develop a tool designed to be distributed for use alongside the NCC 2025, which would assist to:

- Minimise additional time required by practitioners to carry out assessments.
- Standardise and direct industry practices to within the intended process.
- Minimise time required for industry uptake and flatten the learning curve.

Appendix C Data request to chiller supplier

Hi,
We're carrying out an exercise to select chillers. The key is that these will be selected at specific *cooling design* part loads (each with a unique Chilled water/Condenser water combination) rather than *chiller* loads.
We're testing two scenarios: a water-cooled plant (Plant A) and an air-cooled plant (Plant B). Total design load is 1000kW total in both scenarios.
All noted chiller sizes are nominal capacities.
For each of the 3 unique chillers selected (1 water-cooled model and 2 different air-cooled models) we require the following information:

- For Euro chillers
    - EER
    - SEER
- For non-Euro chillers
    - COP
    - IPLV
- For all chillers
    - COP/EER at each of the four unique load points

Plant A – 2 Chillers

- 2 equally sized water-cooled chillers – 600kW each

Unique load points for each chiller:

Cooling capacity (kW)	***Chiller*** load point (%)	***Design*** load point (%)	CHW Supply temp (°C)	CDW entering temp (°C)*
500	83	100	6	31
375	62.5	75	7	29
250	42	50	8	26
125	21	25	10	20

*Assumes a 6°C design CT approach

Plant B – 3 Chillers

- 2 equally sized air-cooled chillers – 400kW each
- 1 air-cooled chiller at 200kW

Unique load points for the 400kW chiller

Cooling capacity (kW)	***Chiller*** load point (%)	***Design*** load point (%)	CHW Supply temp (°C)	Ambient air temp (°C)
400	100	100	6	27
300	75	75	7	28
200	50	50	8	25
100	25	25	10	19

Unique load points for the 200kW chiller

Cooling capacity (kW)	***Chiller*** load point (%)	***Design*** load point (%)	CHW Supply temp (°C)	Ambient air temp (°C)
200	100	100	6	27
150	75	75	7	28
100	50	50	8	25
50	25	25	10	19

The nominal chiller selections can increase in size (because I presume we wont have chiller selections for the exact capacities we've nominated) but they cannot reduce. If the chiller sizes need to be adjusted (increase), it means that the "Chiller load point %" will change (decrease), but each chiller must be rated at the cooling capacities we've nominated.