UNIVERSITY of TASMANIA

MOISTURE ACCUMULATION AND MOULD GROWTH FOR 6 STAR AND 7 STAR HOUSING

Research Report 3: Enhancements to 6 Star and 7 Star external wall systems for Class 1 and Class 2 housing in Victoria

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Acronyms

@n50	@n50 or @50 is often combined with ACH, ACR, or AEH. This signifies the data refers to a 50 Pascal pressure difference between the interior and exterior of the building envelope under test.
AAC	Autoclaved Aerated Concrete
ACH	Air Change per Hour
ACR	Air Change Rate
ACR(1h)	Air Change Rate in 1 hour
AEH	Air Exchange per Hour – It is expected that habitable spaces have at least 5 air exchanges per hour
BCA	Building Code of Australia – The NCC was called the Building Code of Australia between 1988 and 2010
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
CZ	Climate Zone.
FWPA	Forest and Wood Products Australia
MI	Mould Index
MBV	Master Builders Association of Victoria
NatHERS	Nationwide House Energy Rating Scheme
NCC	National Construction Code
RH	Relative Humidity
VBA	Victorian Building Authority
WDR	Wind Driven Rain
WUFI	Wärme Und Feuchte Instationär
VTT	VTT Technical Research Centre of Finland

Terms

AAC	Autoclaved Aerated concrete – A light weight masonry product used to clad buildings.
ACH	Air Changes per Hour - This is the traditional method to quantify air quality and minimum rates of ventilation. This was originally achieved by conducting experiments with Tracer Gas to establish rates of air changes per hour within a room, or a building. Due to the complexity of this method and the development of building pressurisation testing in the 1970s, this method has generally been replaced by the ACR method.
ACR	Air Change Rate. This is based on the amount of infiltration and exfiltration that results through a building's external envelope, per hour. An internationally accepted 'rule-of-thumb' to convert ACRn50 to ACR/ACH/AEH is to divide the ACR value by 20 (ACRn50/20 = ACH). ACRn50 of 10 = ACH of 0.5.
ACRn50	This is based on the amount of infiltration and exfiltration that result from a 50 Pascal building pressurisation or depressurisation. This is different to the traditional ACH (air changes per hour), that exists in most older standards and regulation. Some documents may refer to AEHn50 and ACHn50, which are generally the same metric.
AEH	Air Exchange per Hour. The hygrothermal simulation software requires an input for AEH. For ACH values from 0.25 to infinite can be used within this function. When an AEH value becomes less than 0.25, a building is required to have mechanical ventilation for fresh air within habitable spaces. Within this context, the simulated AEH should not be less than 0.25.
ACR(1h)	Air Change Rate in 1 hour – This is a very similar term to ACH/AEH/ACR and is commonly used when calculating the required mechanical ventilation to ensure an adequate interior air quality. Typically, building simulation software include an ACR(1h) data input.
BCA	Building Code of Australia – The NCC was called the Building Code of Australia between 1988 and 2010.
Bio-Hygrothermal	An analysis method that considers moisture and heat conditions, combined with material properties, that may promote mould growth on the surfaces of and within wall, floor or roof systems.
Built fabric	Built fabric refers to manufactured elements that are used to create constructed spaces, such as buildings, landscapes or a bush shelter.
CZ	Climate zone. The National Construction Code has eight climate types, whilst the Nationwide House Energy Rating Scheme (NatHERS) has sixty-nine climate types.
Dew point	When the relative humidity, discussed below, reaches 100%, the air can no longer hold the moisture in vapour form and the moisture condenses. A simplified formula to calculate the dew point temperature under normal conditions is; Td = T - ((100-RH)/5).

	Applying this formula to a room in a home when the interior temperate is 230C, and the relative humidity is 75%: Td = T – ((100 – RH) / 5) Td = 23 – ((100 – 75) / 5) Td = 18.00C Moisture will form on any surface within the room that is less than, or equal, to 18.00C. An example of this is phenomena is condensation of single glazed window or on a can of soft-drink that has just been taken out of a refrigerator.
Empirical Validation	The comparison of simulated and measured results to inform software calibration.
External wall system	All modern building envelopes incorporate several elements combined to make a system. For example, a brick veneer wall may include from the outside to the inside: A 110mm unpainted extruded clay brick, A 40mm vented air cavity, A 1mm pliable building membrane, A 90mm timber or steel wall frame that contains compressible wall bat insulation, A 10mm paper faced plasterboard board lining, and An Acrylic painted surface. Each of these elements will have different structural, durability, conductivity, water vapour resistivity, thermal capacitance and density properties. When considering the hygrothermal performance of a wall system, the flow of energy and water vapour needs to consider all these different physical attributes.
Hygrothermal	The combination of heat and moisture.
Interstitial	As described above, wall systems, (and floor and roof systems) comprise many elements with different physical properties. The space and materials between in the interior surface and exterior surface are classed as Interstitial. Interstitial mould growth, is mould growth that is occurring somewhere within the wall system.
Mould Index	Developed by Hannu Viitanen and Tuomo Ojanen, the Mould Index refers to the amount and mould that may grow on, and within a wall, floor, or roof system. It should be noted that most mould growth calculation methods can't calculate a MI greater than 5.0. For this reason, no graphs show a MI greater than 5.0.
NatHERS	Nationwide House Energy Rating Scheme
NCC	"The National Construction Code is Australia's primary set of technical design and construction provisions for buildings. As a performance-based code, it sets minimum required levels for the safety, health,

	amenity, accessibility and sustainability of certain buildings." (ABCB 2022).
Relative Humidity	All air contains moisture in the form of water vapour. As air temperature increases, it can contain hold more water vapour, and as it cools, it needs to hold less water vapour. Generally, the term Relative Humidity indicates the amount of water vapour the air can contain. O% RH = no water vapour in the air, 100%RH = saturation or dew point conditions.
Thermal Bridge	All elements used to construct a floor, roof or wall system have a conductivity value. This is the rate at which a material conducts energy. Whilst steel has a very high conductivity value, insulation products have a very low conductivity value. Within a wall system some elements may have a higher conductivity value than others, leading to 'thermal bridges' within the built fabric.
WUFI	Wärme Und Feuchte Instationär, when translated means the transient calculation-based analysis of heat and moisture transport through elements and systems. An 'element' is an item (such as a concrete block), while a 'system' is a collection of elements that make up a component of a building envelope (i.e., acrylic paint, plasterboard, insulation, building membrane, vented air space, extruded clay brick). The WUFI software was developed and owned by the Fraunhofer Institute of Building Physics (IBP). The Fraunhofer Institute is very similar in nature to the CSIRO in Australia. The WUFI software has undergone empirical validation in Europe, United Kingdom, Canada and the United States of America.
WUFI VTT	The WUFI software includes internationally tested and empirically validated 'add-ons' for graphing data, mould risk and corrosion risk. The WUFI VTT Acronym stands for the WUFI software that incorporates the VTT Technical Research Centre of Finland's mould growth calculation method developed by Hannu Viitanen and Tuomo Ojanen.

Preamble

This research is not being undertaken to undermine or diminish the need for net zero homes and non-residential buildings. This research highlights the need for the co-development of energy efficiency and hygrothermal building regulations. This research activity is conducted in response to national and Victorian concerns about the increased presence of moisture and mould within new buildings. The activities within this research project include the hygrothermal simulation-based assessment of mould growth risk in regulatory compliant 6 Star and 7 Star new homes in Victoria. The full Moisture Accumulation and Mould Growth research program includes four key outputs (to be delivered across 2022 and 2023), namely:

- Research report 1 - Moisture accumulation and mould growth risk for 6 Star housing,
- Research report 2 - Moisture accumulation and mould growth risk for 7 Star housing,
- Research report 3 - Moisture accumulation and mould growth risk for 6 Star and 7 Star housing based on 2022 NCC NatHERS RMY climate data with precipitation data added (this report), and
- Research report 4 – Provides research program report that summarises the research background, research methods, research results and recommendations.

This report focusses on mould growth risks that may be present in the external walls of Class 1 and Class 2 buildings, as constructed to the 6 Star and 7 Star energy efficiency standard and the health and amenity requirements of National Construction Code (NCC) 2022. Whereas research report 1 and research report 2 explored these risks, the external climate data used for the simulations comprised the NCC 2002-2021 NatHERS Reference Meteorological Year (RMY) climate data, which did not include precipitation data. In November 2022, the National Construction Code 2022 was approved. The NCC 2022 is to be adopted in Victoria on May 1, 2023. The NatHERS component of the NCC 2022 included updated RMY climate files. These files do not include precipitation data. In this report the 6 Star and 7 Star hygrothermal and bio-hygrothermal simulations utilise the NCC2022 NatHERS climate files, with precipitation data added.

Since 2008, national research conducted by the University of Tasmania has highlighted the connection between the energy efficiency regulations and the presence of condensation and mould in buildings. Since 2014, this has included the study of existing buildings and desktop based hygrothermal calculations and simulation. One of the recent University of Tasmania PhD projects explored condensation and mould risk that may exist in Hobart, Melbourne and Brisbane [1]. The research explored the changes in risk that have occurred between 2002 (pre- energy efficiency regulation) through to 2022 (7 Star regulation). That research highlighted the greater risk of moisture accumulation and mould growth in housing located in Melbourne. This made the university research team aware of the urgent need for a greater analysis of the specific needs for informed envelope (floor, external wall, and roof) systems for housing in Victoria.

Mould growth in housing is internationally recognised as a cause of many short-term and life-long human health conditions [2-6]. Based on the international experiences and what was being observed in Australian buildings, concerned individuals, industry representatives and researchers have raised concerns since 2013. University of Tasmania research in 2019 highlighted that Australia had twice the Asthma rate of other developed nations that have had condensation and mould related building regulations for between two and six decades [7, 8]. For this reason, the first stage of regulatory development focussed on new clauses within Health and Amenity, and not Energy Efficiency sections of the National Construction Code. This is an important recognition of two key differences between condensation and mould growth, namely:

- Condensation occurs when the relative humidity reaches 100% or the mix of moisture in the air and air temperature reach saturation temperature.
- Mould growth occurs in areas of low ventilation when the relative humidity reaches 60% and in well-ventilated areas when the relative humidity is above 70%. (e.g., a room may be well ventilated by cross ventilation when windows and doors are open but be poorly ventilated if only a single window is open. Similarly, the air in the middle of a room may be easily exchanged via ventilation,

whilst low corners and areas around some furnishings or cupboards may be poorly ventilated).

This shows that mould growth occurs well before condensation occurs and also that a house may have no presence of condensation but have the visible and unhealthy presence of mould. The World Health Organisation states that the visible presence of mould within buildings has been linked to increases in medical conditions [9].

Within this context, this research will analyse the risk of surface and interstitial mould growth within typical external wall systems used in the construction of new housing in Victoria.

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Executive Summary

This research explores via simulation the hygrothermal (heat and moisture) and bio-hygrothermal (mould growth) actions that occur within selected external wall systems, located within Victoria. The use of hygrothermal and bio-hygrothermal simulation to inform building envelope design is quite common in North America, Japan, Korea, the United Kingdom, and many nations within Europe. Recently, Australia has adopted a similar regime with the first 'condensation' regulations included within the Health and Amenity clauses of NCC 2019, followed by some enhancements in NCC 2022. Whereas NCC 2019 focussed on condensation, NCC 2022 has moved the focus to a simulated Mould Index (MI) value. Internationally a building envelope system that has a simulated MI of 3, or more, should not be constructed. In some nations, an envelope system with a simulated interstitial MI of 2, or more, should not be constructed. Envelope systems with a simulated MI <1.0 and <3 generally require further analysis and investigation. Generally, a Mould Index of 3 or more, indicates the visible presence of mould to the unassisted human eye. This scale relates to the World Health Organisation recommendations that describe any visible presence of mould as a risk to human health.

Research Report 1 and Research Report 2 identified mould growth risks associated with the nine selected wall systems within the eight selected climate types. Research Report 1 explored these issues applying the principles of NCC 2019 and typical 6 Star external wall system construction. That report highlighted a significant number of wall system scenarios with a MI of $\geqslant$3 and many with a MI of $\geqslant$1 and <3. Research Report 2 explored these issues applying the principles of NCC 2022 and typical 7 Star external wall system constructions. That report highlighted an improvement due to the new requirement of a Class 3 vapour permeable weather control layer in NCC Climate Zone 4, and a Class 4 vapour permeable weather control layer in NCC Climate Zones 6-8. However, a significant number of southern orientated external wall system scenarios still documented a simulated MI of $\geqslant$3 and with many others showing a MI of $\geqslant$1 and <3.

The function of Research Report 3 was to explore built fabric assemblages that may reduce the simulated mould growth risks from Research Report 1 and Research Report 2.

A parallel activity included the Victorian adoption of NCC 2022, which included a revised set of NatHERS RMY climate files. As a result, the climate data adopted for Research Report 3 included the NCC 2022 NatHERS RMY climate data. However, Research Report 1 and Research Report 1 also highlighted the conservative nature of the results as the NatHERS RMY climate data did not include any hourly data for precipitation (rainfall) which has been internationally identified as a critical hygrothermal and bio-hygrothermal simulation input. Recognising this limitation, hourly precipitation data was added to the NatHERS 2022 RMY climate data for the simulations completed in this report.

Research Report 1 and Research Report 2 identified that the wall orientation that posed the greatest risk was the southern oriented wall (non-equatorial facing). All simulations for this report only considered the non-equatorial southern oriented wall.

To ascertain if changes to the NatHERS RMY climate impact simulation results the results in this report include key results from Research Report 1 and Research Report 2. In all cases, the 2022 NatHERS RMY climate data, with hourly precipitation data added, provided a higher simulated Mould Index value.

As a key focus of this report was to explore actions that may reduce the simulated Mould Index value, enhancements were made to each wall system, as shown in Table 1. Generally, the enhancements included increasing the water vapour diffusion properties of the exterior weather resistive pliable membrane, adding a vented and drained cavity between the weather resistive pliable membrane and the cladding system, and adding a water vapour control membrane to the interior side of the insulated timber framed wall system.

Table 1: NCC CZ 4, 6 & 7 Star external wall system enhancements.

Enhancement 1	Research Report 1 and Research Report 2 versions of the nine external wall systems with the weather resistive pliable membrane modified to the minimum requirements of NCC 2022 (Class 3 for NCC climate zone 4 and Class 4 for NCC climate zone 6)
Enhancement 2	The weather resistive pliable membrane was then simulated with increasing water vapour diffusion permeance properties.
Enhancement 3	The external wall systems from Research Report 1 and Research Report 2 that did not have a vented and drained cavity, had a vented and drained cavity added to the simulated wall systems.
Enhancement 4	In a similar pattern to Enhancement 2, the external wall systems were simulated with a vented and drained cavity and weather resistive pliable membranes with increased water vapour diffusion permeance properties.
Enhancement 5	A water vapour diffusion control layer was added to the interior side of the external wall insulation layer. This type of product controls how and when water vapour may diffuse into the timber framed wall system.

The results of 4,310 hygrothermal and 4,310 bio-hygrothermal simulations of nine external wall systems, within eight of the NatHERS climates, with NCC Climate Zone 4 and Climate Zone 6 & 7 variables applied for Victoria identified several trends, namely:

- The increasing of the water vapour permeability of the weather resistive pliable membrane always reduced the simulated MI value.
- The addition of a vented and drained cavity in most cases significantly reduced the simulated MI value.
- The combining of an increased vapour permeable weather resistive pliable membrane with a vented and drained cavity provided reduced simulated MI values.
- The incorporation of an interior vapour control membrane, paired with a minimum Class 4 weather resistive pliable membrane and a vented and drained cavity system often provided the most robust external wall system with the lowest simulated MI values.
- Many code compliant wall systems failed to provide a Mould Index of <3, as prescribed within the verification method H4V5 of NCC 2022.

The climate type that each wall system was located within also played a significant role. In the warmer climate types for Victoria, many external wall variations provided suitable results with a simulated MI of ≤1. However, in the cooler climate types for Victoria, the external wall systems that provided suitable results increasingly required a vented and drained cavity, a vapour permeable external membrane and an interior vapour control membrane.

Many wall systems performed suitably in most climate types when the hourly air exchange rate was set to 10, which is the maximum air exchange rate allowed in a modern 6 Star or 7 Star home. When the hourly air change rate was reduced to 7.5@n50, wall systems generally required a vented and drained cavity and a greater water vapour permeance properties for the weather resistive pliable membrane. When the hourly air change rate was reduced to 5.0@n50, the most suitable wall systems often included a vented and drained cavity, a vapour permeable weather resistive pliable membrane and an interior vapour control membrane. Habitable spaces with an air change rate of <5@n50 are expected to include mechanical ventilation.

Table 170 and Table 171, within the results section, summarises the bio-hygrothermal simulation results for the NCC climate zone 4 and the NCC climate zone 6-7 respectively. Surprisingly, many southern oriented

7 Star external wall systems required the trio of an interior vapour control membrane, paired with a minimum Class 4 weather resistive pliable membrane and a vented and drained cavity system.

Contrary to expectations, in some climate types, some wall systems struggled to achieve a suitable MI. This has been linked to the adoption of the new NatHERS RMY data with hourly precipitation data added. A sample analysis identified that most climatic variables were very similar except for radiation data and the additional precipitation data. Subject to the external wall systems ability to adsorb moisture, combined with the addition of precipitation data, some external wall systems did increase in moisture content. The reduced amount of annual solar radiation then compromised the wall system's ability to dry.

The research report findings raise a few areas of immediate concern, namely:

- For the external wall systems that did not achieve an appropriate simulated MI value, further simulation-based research needs to occur to establish likely built fabric arrangements that do provide an appropriate simulated MI. This may include adding an insulation layer on the outside of the timber frame.
- This research has utilized the NatHERS 2022 RMY data, with hourly precipitation data added. At this stage there is no regulatory guidance regarding the choice, or source, of climate data for hygrothermal and bio-hygrothermal simulation purposes. As the results from this report and Research Report 1 and Research Report 2 document, the selection of climate data plays a pivotal role in the simulation process and the resultant MI values. To ensure all simulations are comparable, the climate data used for this type of analysis should be regulated.
- The construction material physical properties selected for the simulations completed in this report included measured values for a few products and estimated values for others. At this stage, the only construction materials that require a water vapour diffusion permeance classification are pliable membranes. Aside from all materials used to construct an external wall needing to have a published water vapour diffusion permeance value, these values need to be reasonably precise, as demonstrated by the significant difference in results for the three types of AS4200 Class 4 pliable membranes.
- Building regulators, builders and building surveyors are increasingly being made aware of problem buildings. Data needs to be collected that allows for a comparison between the simulation results and what is occurring in real buildings.
- This research has highlighted confusion between the ventilation, condensation and energy efficiency expectations and requirements within the NCC. Careful curation needs to occur to recognize the key differences and update and harmonise aspects of the NCC that increasingly affect occupant health.

Introduction

The purpose of this stage of the research was to explore a limited set of enhancements to external wall system configurations and components that may address the simulated interstitial moisture and mould growth risks identified in Research Report 1 and Research Report 2. Research Report 1 explored moisture and mould growth risks associated with National Construction Code (NCC) compliant 6 Star external wall systems. Research Report 2 explored moisture and mould growth risks associated with NCC compliant 7 Star external wall systems. Both previous research activities utilised the 2002-2022 NCC sanctioned Nationwide House Energy Rating Scheme (NatHERS) Reference Meteorological Year (RMY) climate data. It was noted within these reports that the NatHERS RMY climate files did not include rain data. It was also noted that international research has recommended the incorporation of precipitation data as best practice for hygrothermal and bio-hygrothermal simulation [10-13]. Within this context, it was further noted, that as precipitation data was not included, that the results discussed in Research Reports 1 and Research Report 2 were conservative. The hygrothermal and bio-hygrothermal simulations for this report (Research Report 3) were to include precipitation data.

Parallel to this research, the 2022 edition of the NCC was approved for adoption in May 2023. The 2022 NCC included the adoption of the 7 Star requirement for new Class 1 and Class 2 buildings, some improvements to the CHENATH calculation software, (the back-bone to the NatHERS envelope calculation software), and updated NatHERS RMY climate files. Recognising these updates, the revised brief for Research Report 3 included:

- The adoption of the 2022 NCC NatHERS RMY climate data for the hygrothermal and bio-hygrothermal simulations
- The addition of measured precipitation data to the 2022 NCC NatHERS RMY climate data for the hygrothermal and bio-hygrothermal simulations
- The testing of enhancements to pliable membranes and drained and vented cavities such that simulated mould growth risks were mitigated.

For further background information, please refer to Research Report 4.

The format for this report includes the methodology, hygrothermal and bio-hygrothermal simulation results, conclusion and recommendations. Each of these sections includes a brief introduction followed by relevant content.

Methodology

This section describes the methodology adopted for Research Report 3. This includes the selection of various forms of input data and simulation methods undertaken in this research. In some instances, reference will be made to other reports, where more expanded information is available. The software used in this research was the WUFI Pro one-dimensional (1D) hygrothermal analysis software that has been developed by the Fraunhofer Institute of Building Physics, is in use by regulatory developers and researchers in Canada, United States, Japan, South Korea, New Zealand, Germany, France, Italy, Norway, Sweden, Finland, Poland, Bosnia, Austria, Belgium, Spain, United Kingdom, and Portugal. The basis for the simulation methodology used within this research combines the consideration of NatHERS thermostat settings, combined with collaborative method established by Nath and researchers from the Fraunhofer Institute of Building Physics in 2019 [14, 15]. More recently, the Australian Institute of Refrigeration, Air-conditioning and Heating (AIRAH) has entered a data sharing arrangement with the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) and published DA-07- Criteria for moisture control in buildings [16], which is very similar to the ASHRAE Standard 160, of the same name [17]. The methodology described within ASHRAE Standard 160 and AIRAH DA-07 follows the same principles as developed by Nath. Finally, the method described below only applies to this report: Research Report 3: Enhancements to 6 Star and 7 Star external wall systems housing in Victoria.

3.1 External wall types

This research has comprised the same nine external wall systems as described in Research Report 1 and Research Report 2. These nine external wall systems are commonly constructed for low to mid rise Class 1 and Class 2 buildings in Victoria. The external wall systems comprise:

- Wall 1: Timber cladding, with insulated timber structural frame
- Wall 2: Compressed fibre cement sheet cladding, with insulated timber structural frame
- Wall 3: Clay masonry veneer, with insulated timber structural frame
- Wall 4: Concrete blockwork masonry, with insulated timber structural frame
- Wall 5: Externally insulated clay masonry, with insulated timber structural frame
- Wall 6: Extruded polystyrene cladding, with insulated timber structural frame
- Wall 7: Expanded polystyrene cladding, with insulated timber structural frame
- Wall 8: Autoclaved Aerated concrete masonry cladding, with insulated timber structural frame
- Wall 9: Flat metal cladding, with insulated timber structural frame

The sources of the physical properties of each element in the nine selected external wall systems was sourced from either:

- manufacturer's data, and/or
- NatHERS material properties database and/or
- AIRAH Handbook [18] and/or
- National databases within the WUFI Pro software.

The physical properties of these wall systems are defined within Appendix 1 of Research Report 1 and Appendix 1 of Research Report 2, for the 6 Star and 7 Star insulation requirements respectively.

The sensitivity analysis explored in Research Report 1 demonstrated benefits from increasing the vapour permeance of the weather resistive pliable membrane and the addition of a vapour cavity. Internationally, the application of a vapour control membrane on the interior of the insulation layer is common in high performance external wall systems. Recognising these possible improvements to mould risk mitigation, this research has applied these enhancements. Table 2 shows the enhancement process for the 6 Star external wall systems that are not required to include a vented and drained cavity, namely, wall 1: timber cladding, wall 2: compressed fibre cement sheet cladding, wall 4: concrete blockwork masonry, wall 5: externally insulated clay masonry, wall 6: extruded polystyrene cladding, wall 7: expanded polystyrene cladding, and wall 9: flat metal cladding. More detail regarding the enhancements is shown within the results section for each wall type.

Table 2: Enhancements explored for typical 6 Star external wall system, that are not required to include a vented and drained cavity.

Enhancements	External wall system composition
Stage 1	As per 6 Star Research Report 1 with NCC 2019 requirements for the external weather resistive pliable membrane
Stage 2	As per 6 Star Research Report 1, with three to four steps of increased water vapour diffusion permeance properties for the external weather resistive pliable membrane
Stage 3	As per 6 Star Research Report 1 with NCC 2019 requirements for the external weather resistive pliable membrane, and the addition of a vented and drained cavity, with an ACR of 20, between the cladding system and the external pliable membrane
Stage 4	As per Stage 3, with three to four steps of increased water vapour diffusion permeance properties for the external weather resistive pliable membrane
Stage 5	As per Stage 1 and Stage 3, with the addition of an interior vapour control layer.

Table 3 shows the enhancements for the 6 Star external wall systems that are required to include a vented and drained cavity, namely, wall 3: clay masonry veneer, and wall 8: autoclaved Aerated concrete masonry cladding. More detail regarding the enhancements is shown within the results section for each wall type.

Table 3: Enhancements explored for 6 Star external wall system, with a vented and drained cavity.

Enhancements	External wall system composition
Stage 1	As per 6 Star Research Report 1 with NCC 2019 requirements for the water vapour diffusion properties of the external weather resistive pliable membrane
Stage 2	As per 6 Star Research Report 1, with three to four steps of increased water vapour diffusion permeance properties for the external weather resistive pliable membrane
Stage 3	As per Stage 1, with the addition of an interior slightly vapour permeable vapour control layer.

The 7 Star wall systems apply the principles of NCC 2022. These wall systems are identical in most cases to the 6 Star wall systems, with three exceptions, namely:

- NCC 2022 requires a minimum Class 3 weather resisting pliable membrane for NCC Climate Zone 4, whereas NCC 2019 had no requirement.
- NCC 2022 requires a minimum Class 4 weather resisting pliable membrane for NCC Climate Zone 6 to 8, whereas NCC 2019 required a minimum Class 3 weather resisting pliable membrane.
- The amount of required wall insulation does vary for some wall systems between the 6 Star and 7 Star external wall systems. This data is summarized in Table 4.

Table 4: External wall insulation values for 6 Star and 7 Star hygrothermal and bio-hygrothermal simulations.

NatHERS Climate	21	22	27	60	61	63	64 (&62)	66
Wall 1 - Weatherboard								
6 Star NCC	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5
7 Star NatHERS	R2.7	R2.7	R2.0	R2.0	R2.5	R2.7	R2.7	R2.7
Wall 2 – Compressed fibre cement sheet								
6 Star NCC	CZ6: R2.5	CZ6: R2.5	CZ4: R2.5 CZ6: R2.5	CZ6: R2.5	CZ4: R2.5 CZ6: R2.5	CZ6: R2.5	CZ6: R2.5	CZ4: R2.5 CZ6: R2.5
7 Star NatHERS	R2.7	R2.7	R2.0	R2.0	R2.5	R2.7	R2.7	R2.7
Wall 3 – Clay masonry veneer								
6 Star NCC	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5
7 Star NatHERS	R2.7	R2.7	R2.7	R2.0	R2.5	R2.7	R2.7	R2.7
Wall 4 – Concrete block masonry								
6 Star NCC	CZ6: R1.5	CZ6: R1.5	CZ4: R1 CZ6: R1.5	CZ6: R1.5	CZ4: R1 CZ6: R1.5	CZ6: R1.5	CZ6: R1.5	CZ4: R1 CZ6: R1.5
7 Star NatHERS	R2.5	R2.5	R2.5	R2.5	R2.5	R2.7	R2.5	R3
Wall 5 – Externally insulated clay masonry								
6 Star NCC	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5
7 Star NatHERS	R2.5	R2.7	R2.5	R2.5	R2.5	R2.5	R2.5	R2.7
Wall 6 – Extruded polystyrene cladding (XPS)								
6 Star NCC	CZ6: R1	CZ6: R1	CZ4: R1 CZ6: R1	CZ6: R1	CZ4: R1 CZ6: R1	CZ6: R1	CZ6: R1	CZ4: R1 CZ6: R1
7 Star NatHERS	R2.5	R2.7	R2.7	R2.7	R2.5	R2.5	R2.0	R2.5
Wall 7 - Expanded polystyrene cladding (EPS)								
6 Star NCC	CZ6: R1	CZ6: R1	CZ4: R1 CZ6: R1	CZ6: R1	CZ4: R1 CZ6: R1	CZ6: R1	CZ6: R1	CZ4: R1 CZ6: R1
7 Star NatHERS	R2.5	R2.7	R2.7	R2.7	R2.5	R2.5	R2.0	R2.5
Wall 8 – Autoclaved Aerated concrete (AAC) cladding								
6 Star NCC	CZ6: R2.0	CZ6: R2.0	CZ4: R1.5 CZ6: R2.0	CZ6: R2.0	CZ4: R1.5 CZ6: R2.0	CZ6: R2.0	CZ6: R2.0	CZ4: R1.5 CZ6: R2.0
7 Star NatHERS	R2.7	R2.7	R2.7	R2.0	R2.0	R2.7	R2.7	R2.7
Wall 9 – Sheet-metal cladding								
6 Star NCC	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5	CZ6: 2.5	CZ4: R2.0 CZ6: R2.5	CZ6: R2.5	CZ6: R2.5	CZ4: R2.0 CZ6: R2.5
7 Star NatHERS	R2.7	R2.7	R2.7	R2.5	R2.7	R2.7	R2.7	R2.7

The properties of external weather resistive pliable membranes applied to the external wall systems in this report are shown in Table 5. This shows that the order of magnitude of difference for water vapour diffusion between a Class 1 and a Class 4 membrane is in the order of 1000. Whilst the order of magnitude for water vapour diffusion properties of the three types of Class 4 membranes simulated is 10. That is, a Class 4 has between 1000 and 10, 000 times the water vapour diffusion properties of a class 1 pliable membrane.

Table 5: Physical properties of vapour control membranes

AS4200.1 classification	R Value	Non-reflective	Vapour Permeance	Water vapour diffusion resistance factor
Class 1	0.001	Yes	0.001	200,000
Class 3	0.001	Yes	0.143	1,398
Class 4-1	0.001	Yes	1.1403	175
Class 4-2	0.001	Yes	2.0	100
Class 4-3	0.001	Yes	9.5	21

The pliable membrane vapour diffusion properties are classified within Australian Standard AS4200.1 [19]. A summary of the classification properties is shown in Table 6.

Table 6: AS4200.1 water vapour diffusion classifications.

	Min ≥ (µg/N.s)	Max < (µg/N.s)	Corresponding water vapour diffusion resistance factor
Class 1	0.0000	0.0022	≥90909.0909 to infinite
Class 2	0.0022	0.1429	≥1399.5801 to <90909.0909
Class 3	0.1429	1.1403	≥175.4078 to <1399.5801
Class 4	1.1403	No Max	0.0000 to <175.4

Finally, Research Report 1 and Research Report 2 identified that the southern, non-equatorial, external wall system demonstrated the greatest risks of moisture accumulation and mould growth. In this report, the only orientation simulated was non-equatorial south facing.

3.2 External climate data

Research Report 1 identified eight (8) NatHERS climate types which accounted for most areas of development where Class 1 and Class 2 buildings may be constructed in Victoria. A summary of this data is shown in Table 7.

Table 7: NatHERS climate zones selected for simulation

NatHERS climate zone	Source of NatHERS climate data	Number of postcodes using climate data	Percentage postcodes using climate data
21	Melbourne	94	6%
22	East Sale	211	12%
27	Mildura	149	9%
60	Tullamarine	199	12%

61	Mt Gambier	30	2%
63	Warrnambool	68	4%
64 (+62)	Cape Otway (+Moorabbin)	70+349=419	25%
66	Ballarat	512	30%
TOTAL		1682	100%

The climate types also need to overlayed with the Climate classifications within the NCC. Figure 1 shows the NCC climate map for Victoria, which includes NCC climate zones 4, 6, 7 and 8. Aside from the impact of climatic conditions, these classifications also prescribe the minimum water vapour permeance properties for the weather resistive pliable membranes. NCC 2019 required a minimum class 3 membrane for NCC climate zones 6, 7 & 8. NCC 2022 requires a minimum Class 3 pliable membrane for NCC Climate zone 4, and a minimum Class 4 pliable for NCC climate zones 6, 7 & 8.

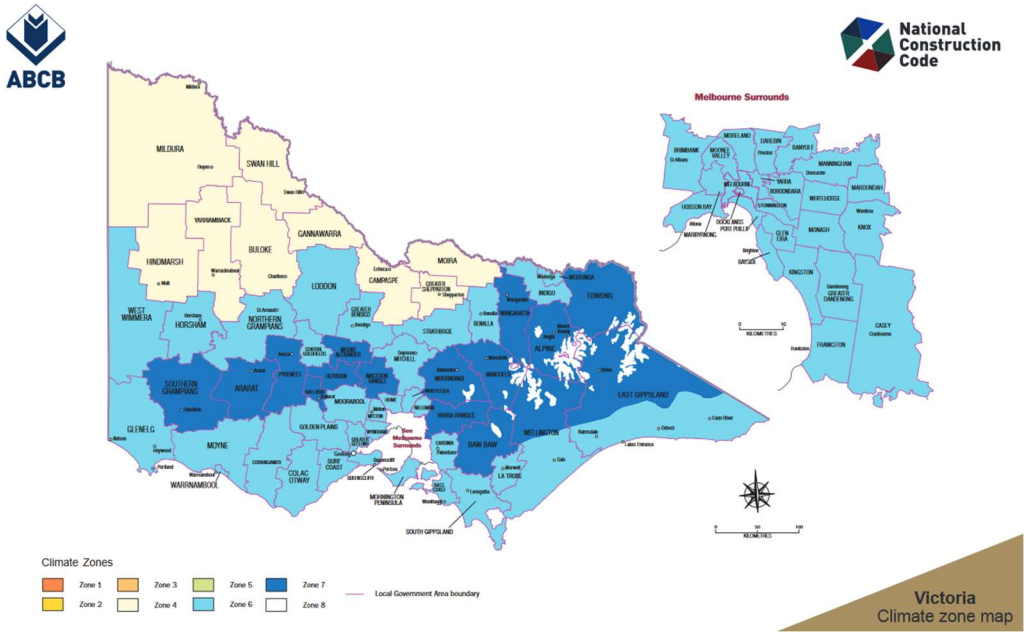

Figure 1: ABCB NCC Climate map for Victoria (ABCB 2022)

The NatHERS climate data that was used in Research Report 1 and Research Report 2 did not include and precipitation (rain) data. Previous research has identified the need for precipitation data to be included in hygrothermal simulation for Australian buildings [10-12, 20, 21]. It had been intended to add precipitation data to the existing NatHERS climate files. However, and a benefit for this research, the NCC 2022 included the adoption of the 7 Stars NatHERS requirements, which included enhancements to the CHENATH calculation software and updated NatHERS RMY climate files. These changes required:

- the reformatting of the new NatHERS RMY climate data into an appropriate format for the hygrothermal simulation software (EPW),
- the sourcing of new precipitation data that corresponded with the RMY climate file month and years, and
- the addition of hourly precipitation data to the newly created EPW climate files

The updated NatHERS RMY climate data has been sourced from observed climate data from 1 January 1990 to 31 December 2015; a period of 26 years. The standard NatHERS 2022 data file consists of 8760 rows of data, representing average hourly observations over one year. The methodology for the creation of the RMY file uses the Finkelstein-Shafer statistical method and is outlined in NIWA's 2016 report [22]. The NatHERS 2022 data files do not include precipitation. The very act of adding precipitation to the RMY data schema diverges it from the source requiring a different naming convention. In this research the file names included RMY+Precipitation. The precipitation observations were obtained from the Australian Bureau of Meteorology. The data was manipulated due to the unevenness of records. The data collection and some weather stations did not operate for the entire period record. For those climate zones affected, more than one weather station was used to collate precipitation data. Hourly precipitation data is unavailable for the entire period of record. Hourly readings of weather observations were only made possible when automated weather stations (AWS) were established by the Bureau of Meteorology, in a staggered schedule from 1995. However, daily measured precipitation is available for almost every staffed weather station from the advent of meteorological observations in the late 1880s. To manage this difference in data collection and to ensure a commonality of process, the daily measured precipitation was divided by 24 and added to the NatHERS 2022 RMY file for each hour of each day. Although this is not at all realistic, a compromise was made to achieve data consistency across every year of the period of record. By ignoring hourly observations, the days with missing hourly precipitation observations would have the same quality of data as those days that did have hourly precipitation observations.

It is noted that averaging out rainfall over the 24 hours leads to a flattening of wetting and saturation potential that may occur during periods of intense precipitation. This is recognised as a shortcoming of this method of adding precipitation. This is an area that requires further research.

3.3 Interior Climate

Following the same principles as discussed in Research Report 1 and Research Report 2, the interior heating thermostat was set to 20.0°C and the cooling thermostat was set to 24.0°C, as per the NatHERS protocol. This is different to the requirements within DA-07 and ASHRAE 160 which include a heating thermostat of 21.1°C and a cooling thermostat of 23.9°C. In cool-temperate climates the additional 1.1°C heating requirements may increase interstitial moisture and mould growth risk.

The Air Change Rate (ACR) for the simulations has applied three variables that reflect three possible scenarios in new Class 1 and Class 2 residential buildings. The ACR refers to the number of times the volume of air within the building changes per hour. This is a reflects the amount of air that may leak out-of and in-to the building due to infiltration and exfiltration, and the need for ventilation to manage air contaminants, including relative humidity. The highest simulated ACR is 10, which reflects the maximum leakiness of the built fabric, as specified in NCC 2022 [23]. The minimum ACR that is simulated is 5, which reflects the minimum requirements as specified within the Ventilation section of Health and Amenity, NCC 2022 [23]. If a building has an ACR of less than 5, it should have supplementary mechanical ventilation. The third option selected is ACR 7.5, which anecdotally may reflect the condition in many new homes in Victoria.

Due to the international nature of the hygrothermal simulation software, the relative humidity is set at 70% [17, 24, 25]. As mentioned above, one of the fundamental requirements of ventilation is to manage relative humidity. International research suggests that an ACR of 5 will manage this risk in most cases. Additional ventilation may be needed to manage water vapour from washing, bathing and cooking activities.

The interior volume adopted in this research reflects the house plan documented in Research Report 1 and Research Report 2, with an interior volume of 366m^3.

3.4 Hygrothermal and bio-hygrothermal simulation

In this research, adopting the principles of ASHRAE Standard 160 [17] and the most recent version of the German Standard DIN-4108 [24], hygrothermal simulations were completed for a ten-year period. Internationally, the minimum of a ten-year simulation period is increasingly being required due to the expected long-term performance of buildings [15]. The results from the ten-year hygrothermal simulations were then post processed by the WUFI VTT mould growth software. It should be noted that these two international standards provided regulatory verification in North America and Europe.

3.5 External Wall orientation

The hygrothermal and bio-hygrothermal simulations completed for the external wall systems analysed and discussed in Research Report 1 and Research Report 2 identified general trends, namely:

- Northern (equatorial) oriented external wall systems showed the lowest Mould Index values, which were often Nil to <1.0. This is due to the impact of solar radiation based drying potential.
- Eastern oriented wall systems often performed slightly worse than the northern oriented wall system. This is due to the impact of solar radiation based drying potential between sunrise and midday.
- Western oriented wall systems often performed worse that northern and eastern oriented wall systems. This is due to the impact of the limited solar radiation based drying potential, which only occurred after midday, leaving the wall system quite cool for most of the daily cycle.
- The southern (non-equatorial) oriented external wall systems always had the highest simulated mould growth index. From late March to late September, the only climatic elements that can assist the drying potential for this orientation of external wall systems are diffuse radiation, air temperature and ventilation.

Recognising this trend, for this report, only the southern (non-equatorial) orientation of each external wall system, within each climate type, was hygrothermally and bio-hygrothermally simulated.

3.6 Summary

This section has described the methodology adopted for Research Report 3. This has included the selection of wall systems and their components (cladding, insulation, lining), the selection of exterior and interior climates, the selection of material properties for simulation purposes, the simulation method and orientation of the external wall systems that were simulated.

It is important to note that this report is focussing on enhancements to the external wall systems that were simulated and analysed in Research Report 1 (6 Star), and Research Report 2 (7Star), Class 1 and Class 2 buildings, in the NatHERS climates of Victoria.

Simulation Results

This section contains the summarised results for each of the nine selected 6 Star and 7 Star external wall system hygrothermal and bio-hygrothermal simulations. The Appendices for each external wall type contain a more comprehensive compilation of mould growth Mould Index simulation results for each wall type. Each wall type will be addressed as a separate sub-section, namely:

- 4.1 Timber clad wall
- 4.2 Compressed fibre cement sheet clad wall
- 4.3 Clay masonry veneer
- 4.4 Concrete block with interior insulation
- 4.5 Externally insulated frame with interior clay masonry (reverse brick veneer)
- 4.6 Extruded polystyrene clad wall (XPS)
- 4.7 Expanded polystyrene clad wall (EPS)
- 4.8 Autoclaved Aerated concrete masonry clad wall (AAC)
- 4.9 Sheet-metal clad wall

The results for each external wall system are provided in a table format. The table lists each NatHERS climate and corresponding NCC climates. Each wall system has separate tables for hygrothermal (heat and moisture) and bio-hygrothermal (mould growth) results. The hygrothermal simulations calculate if there is moisture accumulation. If moisture has accumulated, a table will document this, and if there is no moisture accumulation, this will be noted within the general text. The bio-hygrothermal simulations calculate if the conditions within the wall system can promote mould growth. The mould growth Mould Index (MI) is presented in these results. In this research the bio-hygrothermal simulation results have been categorised as shown in Table 8 below, where:

- A MI of less than <1 may be suitable to construct if the MI does not increase.
- A MI that is ≥1 but is <3 is not ideal and should be investigated further.
- A MI of ≥3, does not achieve the minimum performance requirements within NCC 2022 [23].

Table 8: Mould growth Mould Index (MI) categories

Mould Index	Definition	Explanation [26]
<1	Acceptable level of mould growth was simulated	Mould growth just starting, invisible growth acceptable in indoor and interstitial spaces.
>1 to <3	An amount of mould growth was simulated that requires further investigation	MI >1 to < 2: invisible growth, recognizable only by microscope, and MI ≥2 to < 3: growth starts to become visible to the naked eye.
>3	Unacceptable amount of mould growth was simulated	MI ≥ 3: growth is visible to the naked eye and starts covering the surface.

It should be noted that some other developed nations require a MI no greater than 2.0 within interstitial spaces, which includes floors, external wall and roof systems.

Many of the MI simulation graphs within the Appendices show the seasonal patterns of moist conditions that promote mould growth during the cooler months and drier periods when the mould growth may

recede or stay stagnant during the warmer months. This is a critical aspect to understand, as subject to the interior relative humidity and air temperature conditions the dewpoint temperature and relative humidity conditions within external wall systems is continually changing. This indicates that moisture may form and that the conditions in the wall will have periods where the Relative Humidity is greater than 70%, which promotes mould growth. What is required, is that the year-on-year performance does not promote an ongoing and increasing amount of mould growth that will lead to mould spores entering a home and long term wall system structural failure.

4.1. Timber cladding with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star timber clad external wall systems. The complete set of MI graphs for this wall system are in Appendix 1. The results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star and 7 Star timber clad external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 9 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, Cases 2, 3, 4, 6, 7, 8, 9 and 10 provided a MI of <1.
- For ACR 7.5, Cases 6 to 10 provided a MI of <1.
- For ACR 5, Cases 8, 9 and 10 provided an MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which include the new NatHERS climate data (with precipitation data added), the results show a higher MI.

Table 9: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	5		
RR2 7 Star	No	Class 3 (1398)	Nil	>1	>4	>5
Case 1	No	Class 3 (1398)	Nil	>3	>5	6
Case 2	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 3	No	Class 4-2 (100)	Nil	<1	>4	6
Case 4	No	Class 4-3 (21)	Nil	<1	>3	6
Case 5	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	5
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	4
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC Climate Zone 4, NatHERS Climate Zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 10 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 7 to 10 provided and MI of <3.0 and cases 8 and 10 provided a MI of <1.
- For ACR 7.5, Case 8, a Class 4-3 (21) membrane with a vented and drained cavity and Case 10, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3. No wall systems provided a MI of <3.
- For ACR 5, no wall systems provided a MI of <3 or <1.
- Further options with a Class 4 membrane need to be explored for this wall system in this climate.
- Comparing the results from report 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 10: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 61, NCC CZ4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil			
RR2 7 Star	No	Class 3 (1398)	Nil	>4	5	5
Case 1	No	Class 3 (1398)	Nil	6	6	6
Case 2	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 3	No	Class 4-2 (100)	Nil	>5	6	6
Case 4	No	Class 4-3 (21)	Nil	5	6	6
Case 5	Yes	Class 3 (1398)	Nil	>5	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>3	5	6
Case 7	Yes	Class 4-2 (100)	Nil	>1 to <3	>4	>5
Case 8	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 9	No	Class 3 (1398)	Yes	>1 to <3	>3	>5
Case 10	Yes	Class 3 (1398)	Yes	<1	>1 to <3	4

6 Star and 7 Star timber clad external wall: NCC Climate Zone 4 NatHERS Climate Zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 11 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 8, 9 and 10 provided a MI of <3 and Case 10, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Case 10, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3. No wall systems provided a MI of <3.
- For ACR 5, no wall systems provided a MI of <3 or <1.
- Further options with a Class 4 membrane need to be explored for this wall system in this climate.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 11: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>5		
RR2 7 Star	No	Class 3 (1398)	Nil	<4	>5	>5
Case 1	No	Class 3 (1398)	Nil	6	6	6
Case 2	No	Class 4-1 (175.4)	Nil	6	6	6
Case 3	No	Class 4-2 (100)	Nil	6	6	6
Case 4	No	Class 4-3 (21)	Nil	>5	6	6
Case 5	Yes	Class 3 (1398)	Nil	6	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 7	Yes	Class 4-2 (100)	Nil	4	>5	6
Case 8	Yes	Class 4-3 (21)	Nil	>1 to <3	4	>5
Case 9	No	Class 3 (1398)	Yes	>1 to <3	>3	>5
Case 10	Yes	Class 3 (1398)	Yes	<1	>1 to <3	>5

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 12 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, All Cases provided a MI of <3, and Cases 2 to 8 provided a MI of <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3 and an MI of <1.
- For ACR 5, Cases 5 to 8 provided a MI of <3, and Cases 6 to 8 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 12: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 1	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	6
Case 2	No	Class 4-2 (100)	Nil	<1	>4	6
Case 3	No	Class 4-3 (21)	Nil	<1	>3	>5
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 13 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 5 to 8 provided a MI of <3, and Cases 6 to 8 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 5, Case 7 and 8, a Class 4-1 (175.4) membrane without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 13: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>3	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>3	>4	6
Case 5	Yes	Class 4-2 (100)	Nil	>1 to <3	4	>5
Case 6	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 14 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all scenarios provided a MI of < 3 and <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3 and <1
- For ACR 5, Case 6, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 7 and 8, a Class 4-1 (175.4) without/with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3.0 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 14: Bio-hygrothermal simulation (mould growth) from 6 Star and 7 Star timber clad wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 1	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 2	No	Class 4-2 (100)	Nil	<1	>4	6
Case 3	No	Class 4-3 (21)	Nil	<1	4	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	5
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 15 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3 and <1.
- For ACR 7.5, Cases 5 to 8 provided an MI of <3, and Case 6 to 8 provided a MI of <1.
- For ACR 5, Case 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with or without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 15: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>1 to <3	>5
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	4	>5	6
Case 3	No	Class 4-3 (21)	Nil	>3	>5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 5	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	>1 to <3
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 16 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 5 to 8 provided a MI of <3, and Cases 6 to 8 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity and an interior vapour control membrane provided a MI of <3, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 16: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<4	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>3	5	>5
Case 5	Yes	Class 4-2 (100)	Nil	>1 to <3	>4	>5
Case 6	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 17 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity and an interior vapour control membrane provided a MI of <3, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 17: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<4	<5	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 5	Yes	Class 4-2 (100)	Nil	4	>4	6
Case 6	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>4
Case 7	No	Class 4-1 (175.4)	Yes	<1	>1 to <3	>3
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 18 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <30 and <1.
- For ACR 7.5, Cases 5 to 8 provided a MI of <3, and Cases 6 to 8 provided a MI of <1.
- For ACR 5, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane without/with a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 18: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	4	>5	6
Case 3	No	Class 4-3 (21)	Nil	>3	5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>3	>4
Case 5	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	>1 to <3
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star timber clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 19 shows the results for enhancements to the 6 Star and 7 Star timber clad wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane without/with a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Cases 7 and 8, a Class 4-1 (175.4) membrane without/with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 19: Bio-hygrothermal simulation (mould growth) results from southern oriented 6 Star and 7 Star timber clad wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>4	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	6	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 5	Yes	Class 4-2 (100)	Nil	4	>5	6
Case 6	Yes	Class 4-3 (21)	Nil	>1 to <3	4	>5
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	>5
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star timber clad external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star timber clad external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 20 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star timber clad wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 20 shows that:

- For ACR 10, three external wall systems scenarios in the three simulated climates had a MI of <3.0
- For ACR 7.5, one external wall system scenario in the three simulated climates had an MI of <3.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 20 shows that:

- For ACR 10, one external wall system scenarios in the three simulated climates had a MI of <1.0
- For ACR 7.5, nil external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 20: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star timber clad wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 3 (1398)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	No	Nil	33%	0%	0%		33%	0%	0%
Class 4-2 (100)	No	Nil	33%	0%	0%		33%	0%	0%
Class 4-3 (21)	No	Nil	33%	0%	0%		33%	0%	0%
Class 3 (1398)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	Yes	Nil	33%	33%	0%		33%	33%	0%
Class 4-2 (100)	Yes	Nil	67%	33%	0%		33%	33%	0%
Class 4-3 (21)	Yes	Nil	100%	67%	33%		67%	33%	33%
Class 3 (1398)	No	Yes	100%	33%	33%		33%	33%	33%
Class 3 (1398)	Yes	Yes	100%	100%	33%		100%	33%	33%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and timber clad external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria.

NCC climate zone 6 & 7

Table 21 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 Star timber clad wall system located within NCC climate zone 6 & 7. Table 21 shows that:

- For ACR 10, three external wall system scenarios in the simulated climates had a MI of <3.0,
- For ACR 7.5, two external wall system scenarios in the simulated climates had a MI of <3.0, and
- For ACR 5, one external wall system scenarios in the simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 21 shows that:

- For ACR 10, two external wall system scenarios in the simulated climates had a MI of <1.0,
- For ACR 7.5, one external wall system scenarios in the simulated climates had a MI of <1.0, and
- For ACR 5, one external wall system scenarios in the simulated climates had a MI of <1.0.

Table 21: Summary of Bio-hygrothermal simulation mould index results <3.0 from southern oriented 6 Star and 7 Star timber clad wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 4-1 (175.4)	No	Nil	25%	0%	0%		13%	0%	0%
Class 4-2 (100)	No	Nil	25%	0%	0%		25%	0%	0%
Class 4-3 (21)	No	Nil	25%	0%	0%		25%	0%	0%
Class 4-1 (175.4)	Yes	Nil	50%	25%	0%		50%	25%	0%
Class 4-2 (100)	Yes	Nil	75%	50%	13%		50%	25%	0%
Class 4-3 (21)	Yes	Nil	100%	75%	50%		75%	50%	25%
Class 4-1 (175.4)	No	Yes	100%	100%	75%		100%	88%	50%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and timber clad external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria.

4.2 Compressed fibre cement sheet (CFCS) cladding with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star compressed fibre cement sheet (CFCS) clad external wall systems. The complete set of MI graphs for this wall system are in Appendix 2. The results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star and 7 Star CFCS clad external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 22 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, Cases 1 to 4 and 6 to 10 provided a MI of <3 and <1.
- For ACR 7.5, Cases 3, 4 and 6 to 10 provided a MI of <3 and <1.
- For ACR 5, Cases 8 to 10 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding are similar.

Table 22: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>1 to <3		
RR2 7 Star	No	Class 3 (1398)	Nil	<1	>3	>5
Case 1	No	Class 3 (1398)	Nil	<1	>5	6
Case 2	No	Class 4-1 (175.4)	Nil	<1	3	>5
Case 3	No	Class 4-2 (100)	Nil	<1	<1	5
Case 4	No	Class 4-3 (21)	Nil	<1	<1	4
Case 5	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	5
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 23 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 7 to 10 provided a MI of <3, and Cases 8 to 10 provided a MI of <1.
- For ACR 7.5, Cases 8 to 10 provided a MI of <3. No Cases provided a MI of <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- Class 4 external membranes need to be further explored for this wall system in this climate.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 23: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>5		
RR2 7 Star	No	Class 3 (1398)	Nil	>4	>5	>5
Case 1	No	Class 3 (1398)	Nil	6	6	6
Case 2	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 3	No	Class 4-2 (100)	Nil	>4	>5	6
Case 4	No	Class 4-3 (21)	Nil	>3	>4	>5
Case 5	Yes	Class 3 (1398)	Nil	>5	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>3	5	6
Case 7	Yes	Class 4-2 (100)	Nil	>1 to <3	4	>5
Case 8	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>3
Case 7	No	Class 3 (1398)	Yes	<1	>1 to <3	5
Case 10	Yes	Class 3 (1398)	Yes	<1	>1 to <3	>4

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 24 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 8 to 10 provided a MI of <3 and <1.
- For ACR 7.5, Cases 9 and 10, a Class 3 (1398) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3. No Cases provided a MI of <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- Class 4 external membranes need to be further explored for this climate.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 24: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>5		
RR2 7 Star	No	Class 3 (1398)	Nil	>4	>5	>5
Case 1	No	Class 3 (1398)	Nil	6	6	6
Case 2	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 3	No	Class 4-2 (100)	Nil	>5	6	6
Case 4	No	Class 4-3 (21)	Nil	>4	>5	6
Case 5	Yes	Class 3 (1398)	Nil	6	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	5	>5	6
Case 7	Yes	Class 4-2 (100)	Nil	4	>5	6
Case 8	Yes	Class 4-3 (21)	Nil	<1	>3	>4
Case 9	No	Class 3 (1398)	Yes	<1	>1 to<3	>5
Case 10	Yes	Class 3 (1398)	Yes	<1	>1 to <3	>5

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 25 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, All Cases provided a MI of <3, and Cases 3 to 8 provided a MI of <1.
- For ACR 5, Cases 5 to 8 provided a MI of <3, and Cases 6 to 8 cavity provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a comparable MI for ACR 10 and a higher MI for ACRH 7.5 and ACR 5.

Table 25: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	<4
Case 1	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 2	No	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 3	No	Class 4-3 (21)	Nil	<1	<1	>3
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 26 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 3 and 5 to 8 provided a MI of <3, and Cases 5 to 8 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 provided a MI of <3 and <1.
- For ACR 5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 26: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	4		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	>3	>5	6
Case 3	No	Class 4-3 (21)	Nil	>1 to <3	>4	>5
Case 4	Yes	Class 4-1 (175.4)	Nil	>3	5	6
Case 5	Yes	Class 4-2 (100)	Nil	<1	>3	>5
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	>3
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 27 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 2 to 8 provided a MI of <3 and <1.
- For ACR 5, Cases 6 to 8 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results comparable MI values.

Table 27: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 1	No	Class 4-1 (175.4)	Nil	<1	3	>5
Case 2	No	Class 4-2 (100)	Nil	<1	<1	5
Case 3	No	Class 4-3 (21)	Nil	<1	<1	4
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 28 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and Cases 3 to 8 provided a MI of <1.
- For ACR 7.5, Cases 5 to 8 provided a MI of <3 and <1.
- For ACR 5, Case 6, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 7 and 8, a Class 4-1 (175.4) without/with a vented and drained cavity and with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 28: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 1	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	6
Case 2	No	Class 4-2 (100)	Nil	>1 to <3	>4	>5
Case 3	No	Class 4-3 (21)	Nil	<1	3	5
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>4
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 29 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 5 to 8 provided a MI of <3, and Cases 6 to 8 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 29: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	>4	>5	6
Case 3	No	Class 4-3 (21)	Nil	>3	>4	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>3	>5	>5
Case 5	Yes	Class 4-2 (100)	Nil	>1 to <3	>4	>5
Case 6	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>3
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 30 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 30: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	5	>5	6
Case 3	No	Class 4-3 (21)	Nil	>4	5	>5
Case 4	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 5	Yes	Class 4-2 (100)	Nil	>3	>4	>5
Case 6	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>4
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 31 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, Cases 2 to 8 provided a MI of <3, and Cases 3 to 8 provided a MI of <1.
- For ACR 7.5, Cases 5 to 8 provided a MI of <3 and <1.
- For ACR 5, Cases 6 to 8 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 31: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 1	No	Class 4-1 (175.4)	Nil	>3	>4	>5
Case 2	No	Class 4-2 (100)	Nil	>1 to <3	4	>5
Case 3	No	Class 4-3 (21)	Nil	<1	>3	>4
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>3	>4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star compressed fibre cement sheet clad external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 32 shows the results for enhancements to the 6 Star and 7 Star compressed fibre cement sheet clad external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 6 to 8 provided a MI of <3, and Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, Cases 7 and 8, a Class 4-1 (175.4) membrane with/without a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 32: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>4	5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 5	Yes	Class 4-2 (100)	Nil	4	>5	6
Case 6	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>4
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star compressed fibre cement sheet clad external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star compressed fibre cement sheet clad external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 33 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star compressed fibre cement sheet clad external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 33 shows that:

- For ACR 10, three external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, two external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 33 shows that:

- For ACR 10, three external wall systems scenarios in the simulated climates had a MI of <1.0,
- For ACR 7.5, nil external wall systems scenarios in the simulated climates had a MI of <1.0, and
- For ACR 5, nil external wall systems scenarios in the simulated climates had a MI of <1.0.

Table 33: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 3 (1398)	No	Nil	33%	0%	0%		33%	0%	0%
Class 4-1 (175.4)	No	Nil	33%	0%	0%		33%	0%	0%
Class 4-2 (100)	No	Nil	33%	33%	0%		33%	33%	0%
Class 4-3 (21)	No	Nil	33%	33%	0%		33%	33%	0%
Class 3 (1398)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	Yes	Nil	33%	33%	0%		33%	33%	0%
Class 4-2 (100)	Yes	Nil	67%	33%	0%		33%	33%	0%
Class 4-3 (21)	Yes	Nil	100%	67%	33%		100%	33%	33%
Class 3 (1398)	No	Yes	100%	100%	33%		100%	33%	33%
Class 3 (1398)	Yes	Yes	100%	100%	33%		100%	33%	33%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and compressed fibre cement sheet clad external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria.

NCC climate zone 6 & 7

Table 34 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 Star compressed fibre cement sheet clad external wall system located within NCC climate zone 6 & 7. Table 34 shows that:

- For ACR 10, three external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, two external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, two external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 34 shows that:

- For ACR 10, two external wall systems scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, two external wall systems scenarios in all three simulated climates had a MI of <1.0, and
- For ACR 5, two external wall systems scenarios in all three simulated climates had a MI of <1.0.

Table 34: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star compressed fibre cement sheet clad wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 4-1 (175.4)	No	Nil	38%	13%	0%		25%	0%	0%
Class 4-2 (100)	No	Nil	50%	25%	0%		25%	13%	0%
Class 4-3 (21)	No	Nil	63%	25%	0%		50%	25%	0%
Class 4-1 (175.4)	Yes	Nil	50%	25%	0%		50%	25%	0%
Class 4-2 (100)	Yes	Nil	75%	50%	13%		63%	50%	0%
Class 4-3 (21)	Yes	Nil	100%	75%	50%		75%	63%	50%
Class 4-1 (175.4)	No	Yes	100%	100%	100%		100%	100%	100%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and compressed fibre cement sheet clad external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria.

4.3 Clay masonry veneer with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star clay masonry veneer external wall systems. The complete set of MI graphs for this wall system are in Appendix 3. The results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 35 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, Cases 3 to 8 provided a MI of <3 and <1.
- For ACR 7.5, Cases 3, 4, 5, 7 and 8 provided a MI of <3 and <1.
- For ACR 5, Cases 4, 5, 7 and 8 provided a MI of <3, and Cases 5, 7 and 8 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 35: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	<1		5
Case 1	Yes	Class 1 (200000)	Nil	>4	6	6
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 2	Yes	Class 3 (1398)	Nil	3	>5	6
Case 3	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 4	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 5	Yes	Class 4-3 (21)	Nil	Nil	<1	<1
Case 6	Yes	Class 1 (200000)	Yes	<1	>3	6
Case 7	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was significant moisture accumulation within the clay masonry in all eight scenarios. This requires further investigation.

Bio-hygrothermal simulation (mould growth)

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Table 36 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, no Cases provided a MI of <3 or <1.
- For ACR 7.5, no Cases provided a MI of <3 or <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

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Table 36: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil			
Case 1	Yes	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	Yes	Class 3 (1398)	Nil	<4	6	>5
Case 2	Yes	Class 3 (1398)	Nil	>5	6	6
Case 3	Yes	Class 4-1 (175.4)	Nil	>5	>5	6
Case 4	Yes	Class 4-2 (100)	Nil	5	>5	6
Case 5	Yes	Class 4-3 (21)	Nil	>4	>5	>5
Case 6	Yes	Class 1 (200000)	Yes	>5	6	6
Case 7	Yes	Class 3 (1398)	Yes	>5	6	6
Case 8	Yes	Class 4-1 (175.4)	Yes	>4	5	>5

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 37 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 5, 7 and 8 provided a MI of <3, and Cases 7 and 8, a Class 3 /Class 4 membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results comparable MI values.

Table 37: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>4		5
Case 1	Yes	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	Yes	Class 3 (1398)	Nil	>4	>5	>5
Case 2	Yes	Class 3 (1398)	Nil	6	6	6
Case 3	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 4	Yes	Class 4-2 (100)	Nil	>3	5	6
Case 5	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>4
Case 6	Yes	Class 1 (200000)	Yes	>5	6	6
Case 7	Yes	Class 3 (1398)	Yes	<1	>3	>5
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 38 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 2, 3 and 4 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results comparable MI values.

Table 38: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	<1		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 1	Yes	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 2	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 3	Yes	Class 4-3 (21)	Nil	Nil	<1	<1
Case 4	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 39 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 2, 3 and 4 provided a mi of <3 and Cases 3 and 4 provided a MI of <1.
- For ACR 7.5, Cases 3 and 4 provided a MI of <3 and <1.
- For ACR 5, Case 4, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 39: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>1 to <3		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	>1	<4	>5
Case 1	Yes	Class 4-1 (175.4)	Nil	>3	>4	6
Case 2	Yes	Class 4-2 (100)	Nil	>1 to <3	>3	>5
Case 3	Yes	Class 4-3 (21)	Nil	<1	<1	>3
Case 4	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 40 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 2, 3 and 4 provided an MI of <3, and Cases 3 and 4 provided a MI of <1.

Table 40: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	<1		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 1	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 2	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 3	Yes	Class 4-3 (21)	Nil	Nil	Nil	<1
Case 4	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was significant moisture accumulation within the clay masonry in all scenarios. This requires further investigation.

Bio-hygrothermal simulation (mould growth)

Table 41 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, no Cases provided a MI of <3, or <1.
- For ACR 7.5, no Cases provided a MI of <3 or <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 41: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>1 to <3		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 1	Yes	Class 4-1 (175.4)	Nil	5	>5	6
Case 2	Yes	Class 4-2 (100)	Nil	5	>5	6
Case 3	Yes	Class 4-3 (21)	Nil	5	5	>5
Case 4	Yes	Class 4-1 (175.4)	Yes	5	5	>5

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was significant moisture accumulation within the clay masonry in all scenarios. This requires further investigation.

Bio-hygrothermal simulation (mould growth)

Table 42 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, no Cases provided a MI of <3 or <1.
- For ACR 7.5, no Cases provided a MI of <3 or <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
-

Table 42: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>3		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>1 to <3	>5
Case 1	Yes	Class 4-1 (175.4)	Nil	>5	>5	6
Case 2	Yes	Class 4-2 (100)	Nil	5	>5	6
Case 3	Yes	Class 4-3 (21)	Nil	>4	5	>5
Case 4	Yes	Class 4-1 (175.4)	Yes	>4	5	>5

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was significant moisture accumulation within the clay masonry in all scenarios. This requires further investigation.

Bio-hygrothermal simulation (mould growth)

Table 43 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, no Cases provided a MI of <3 or <1.
- For ACR 7.5, no Cases provided a MI of <3 or <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 43: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>3		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 1	Yes	Class 4-1 (175.4)	Nil	>5	>5	6
Case 2	Yes	Class 4-2 (100)	Nil	>5	>5	6
Case 3	Yes	Class 4-3 (21)	Nil	5	5	>5
Case 4	Yes	Class 4-1 (175.4)	Yes	>5	>5	>5

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was significant moisture accumulation within the clay masonry in all scenarios. This requires further investigation.

Bio-hygrothermal simulation (mould growth)

Table 44 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, no Cases provided a MI of <3 or <1.
- For ACR 7.5, no Cases provided a MI of <3 or <1.
- For ACR 5, no Cases provided a MI of <3 or <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 44: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	<1		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 1	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	Yes	Class 4-2 (100)	Nil	>4	5	>5
Case 3	Yes	Class 4-3 (21)	Nil	>4	5	>5
Case 4	Yes	Class 4-1 (175.4)	Yes	>4	>4	>4

-

6 Star and 7 Star clay masonry veneer external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was significant moisture accumulation within the clay masonry in all scenarios. This requires further investigation.

Bio-hygrothermal simulation (mould growth)

Table 45 shows the results for enhancements to the 6 Star and 7 Star clay masonry veneer external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Case 4, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, Case 4, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, Case 4, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of<3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 45: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star clay masonry veneer clad wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>4		5
RR2 7 Star	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 1	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	Yes	Class 4-2 (100)	Nil	>3	5	6
Case 3	Yes	Class 4-3 (21)	Nil	>3	>3	>4
Case 4	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star clay masonry veneer external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star clay masonry veneer external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 46 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star clay masonry veneer external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 52 shows that:

- For ACR 10, nil external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, nil external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 52 shows that:

- For ACR 10, nil external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, nil external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 46: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star clay masonry veneer external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	Yes	Nil	33%	33%	0%		33%	33%	0%
Class 4-2 (100)	Yes	Nil	33%	33%	33%		33%	33%	0%
Class 4-3 (21)	Yes	Nil	67%	33%	33%		33%	33%	33%
Class 1 (200000)	Yes	Yes	33%	0%	0%		33%	0%	0%
Class 3 (1398)	Yes	Yes	67%	33%	33%		67%	33%	33%
Class 4 (175.4)	Yes	Yes	67%	67%	33%		67%	67%	67%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and clay masonry veneer external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria. These results were initially surprising, however recent research in Belgium, Canada and New Zealand, has highlighted mould growth problems within external wall systems, which can store unwanted moisture.

NCC climate zone 6 & 7

Table 53 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 Star clay masonry veneer external wall system located within NCC climate zone 6 & 7. Table 53 shows that:

- For ACR 10, nil external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, nil external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, nil external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 53 shows that:

- For ACR 10, nil external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, nil external wall system scenarios in the eight simulated climates had a MI of <1.0, and
- For ACR 5, nil external wall system scenarios in the eight simulated climates had a MI of <1.0.

Table 47: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star clay masonry veneer external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 4-1 (175.4)	Yes	Nil	25%	25%	0%		25%	25%	0%
Class 4-2 (100)	Yes	Nil	38%	25%	25%		25%	25%	13%
Class 4-3 (21)	Yes	Nil	38%	38%	25%		38%	38%	25%
Class 4-1 (175.4)	Yes	Yes	50%	50%	50%		50%	50%	50%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and clay masonry veneer external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria. These results were initially surprising, however recent research in Belgium, Canada and New Zealand, has highlighted mould growth problems within external wall systems, which can store unwanted moisture.

4.4 Concrete block masonry, internally insulated

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star concrete block masonry, internally insulated external wall systems. The complete set of MI graphs for this wall system are in Appendix 4. As the external wall insulation levels are significantly different, the 6 Star scenarios are presented first followed by the 7 Star scenarios. In each case the results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star concrete block masonry external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 48 shows the results for enhancements to the 6 Star concrete block masonry external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 8 to 10 and 12 to 14 provided a MI of <3 and <1.
- For ACR 5, Cases 9, 10, 12, 13 and 14 provided a MI of <3, and Cases 10 and 14 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 48: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block masonry wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1	Nil	Nil		5
Case 1	No	Class 1 (200000)	Nil	<1	>4	6
Case 2	No	Class 3 (1398)	Nil	<1	>4	6
Case 3	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 4	No	Class 4-2 (100)	Nil	<1	>4	6
Case 5	No	Class 4-3 (21)	Nil	<1	>3	6
Case 6	Yes	Class 1	Nil	<1	>4	6
Case 7	Yes	Class 3 (1398)	Nil	<1	>3	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	3
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1	Yes	<1	>4	6
Case 12	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 13	Yes	Class 1	Yes	<1	<1	>1 to <3
Case 14	Yes	Class 3 (1398)	Yes	Nil	Nil	Nil

6 Star concrete block masonry external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 49 shows the results for enhancements to the 6 Star concrete block masonry external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 8 to 10 and 12 to 14 provided a MI of <3, and Cases 8 to 10 and 14 provided a MI of <1.
- For ACR 7.5, Cases 9, 10 and 14 provided a MI of <3, and Cases 10 and 12 provided a MI of <1.
- For ACR 5, Case 14, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control layer provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 49: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block masonry wall NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1	Nil	>3		5
Case 1	No	Class 1	Nil	>5	6	6
Case 2	No	Class 3 (1398)	Nil	>4	6	6
Case 3	No	Class 4-1 (175.4)	Nil	>4	6	6
Case 4	No	Class 4-2 (100)	Nil	>4	6	6
Case 5	No	Class 4-3 (21)	Nil	>4	>5	6
Case 6	Yes	Class 1	Nil	>4	6	6
Case 7	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 9	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	3
Case 11	No	Class 1	Yes	>4	>5	6
Case 12	No	Class 3 (1398)	Yes	>1 to <3	>4	6
Case 13	Yes	Class 1	Yes	>1 to <3	>3	>5
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star concrete block masonry external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 50 shows the results for enhancements to the 6 Star concrete block masonry external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 8 to 10 and 12 to 14 provided a MI of <3, and Cases 9, 10 and 14 provided a MI of <1.
- For ACR 7.5, Cases 10, 13 and 14 provided a MI of <3, and Cases 10 and 14 provided a MI of <1..
- For ACR 5, Case 14, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control layer provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 50: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block masonry wall NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1	Nil	>3		5
Case 1	No	Class 1	Nil	>5	6	6
Case 2	No	Class 3 (1398)	Nil	>5	6	6
Case 3	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 4	No	Class 4-2 (100)	Nil	>5	6	6
Case 5	No	Class 4-3 (21)	Nil	>5	6	6
Case 6	Yes	Class 1	Nil	>5	6	6
Case 7	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 9	Yes	Class 4-2 (100)	Nil	<1	>4	>5
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	>4
Case 11	No	Class 1	Yes	5	>5	6
Case 12	No	Class 3 (1398)	Yes	>1 to <3	>4	6
Case 13	Yes	Class 1	Yes	>1 to <3	>1 to <3	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 51 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3 and <1.
- For ACR 5, Cases 4 to 8 provided a MI of <3, and Cases 5, 6 and 8 provided a MI of <1.

Table 51: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		5
Case 1	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 2	No	Class 4-2 (100)	Nil	<1	>4	6
Case 3	No	Class 4-3 (21)	Nil	<1	>4	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 52 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3, and Cases 5, 6 and 8 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 provided a MI of <3, and Cases 6 and 8 provided a MI of <1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 52: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	4		5
Case 1	No	Class 4-1 (175.4)	Nil	>4	6	6
Case 2	No	Class 4-2 (100)	Nil	>4	6	6
Case 3	No	Class 4-3 (21)	Nil	5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>1 to <3	4	>5
Case 5	Yes	Class 4-2 (100)	Nil	<1	>3	5
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	>3
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	>5
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 53 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 4 to 8 cavity provided a MI of < 3 and <1.
- For ACR 5, Cases 6 to 8 provided a MI of <3, and Cases 6 and 8 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 53: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		5
Case 1	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 2	No	Class 4-2 (100)	Nil	<1	5	6
Case 3	No	Class 4-3 (21)	Nil	<1	>4	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 54 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, Cases 5 to 8 provided a MI of <3 and Cases 5, 6 and 8 provided a MI of <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3, and Cases 5, 6 and 8 provided a MI of <1.
- For ACR 5, Cases 6 and 8 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 54: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
Case 1	No	Class 4-1 (175.4)	Nil	4	>5	6
Case 2	No	Class 4-2 (100)	Nil	4	>5	6
Case 3	No	Class 4-3 (21)	Nil	>3	>5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>3	>1 to <3	5
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	4
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	>4
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 55 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3 and Cases 5, 6 and 8 provided a MI of <1.
- For ACR 7.5, Cases 6 and 8 provided a MI of <3 and 0<1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 55: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	4		5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 5	Yes	Class 4-2 (100)	Nil	<1	>3	>5
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	>3
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>3	6
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 56 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 6 to 8 provided a MI of <3, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 56: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3		5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>3	6	6
Case 5	Yes	Class 4-2 (100)	Nil	>3	>4	6
Case 6	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>5
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>4	6
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 57 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3, and Cases 5, 5, 6 and 8 provided a MI of <1.
- For ACR 7.5, Cases 5 to 8 provided a MI of <3, and Cases 6 and 8 provided a MI of <1.
- For ACR 5, Cases 6, a Class 4-3 (21) membrane, with a vented and drained cavity, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 57: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	>4	>5	6
Case 3	No	Class 4-3 (21)	Nil	>4	>5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>3	>4
Case 5	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	>4
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 58 shows the results for enhancements to the 6 concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 6 to 8 provided a MI of <3, and Cases 6 and 8 provided a MI of <1.
- For ACR 7.5, Cases 7 and 8 provided an MI of <3, and Case 8, s Class 4-1 (175.4) membrane without a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 5, Case 8, a Class 4-1 (175.4) membrane with a vented and drained and cavity and with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 58: Bio-hygrothermal simulation results from southern oriented 6 Star concrete block, internally insulated wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		5
Case 1	No	Class 4-1 (175.4)	Nil	6	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	6	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	4	>5	6
Case 5	Yes	Class 4-2 (100)	Nil	>3	>4	>5
Case 6	Yes	Class 4-3 (21)	Nil	<1	3	>5
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	6
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star concrete block masonry external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 59 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, Cases 3 to 5 and 7 to 14 provided a MI of <3, and Cases 8 to 14 provided a MI of <1.
- For ACR 7.5, Cases 8 to 10 and 12 to 14 provided a MI of <3 and <1.
- For ACR 5, Case 9, 10 and 14 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 59: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block masonry wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1	Nil	Nil		5
Case 1	No	Class 1	Nil	>4	>5	6
RR2 7 Star	No	Class 3 (1398)	Nil	>1 to <3	>4	>5
Case 2	No	Class 3 (1398)	Nil	>3	>5	6
Case 3	No	Class 4-1 (175.4)	Nil	>1 to <3	>5	6
Case 4	No	Class 4-2 (100)	Nil	>1 to <3	>5	6
Case 5	No	Class 4-3 (21)	Nil	>1 to <3	>5	6
Case 6	Yes	Class 1	Nil	4	>5	6
Case 7	Yes	Class 3 (1398)	Nil	>1 to <3	5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1	Yes	<1	>3	6
Case 12	No	Class 3 (1398)	Yes	<1	<1	>3
Case 13	No	Class 4-1 (175.4)	Yes	<1	<1	>3
Case 14	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

7 Star concrete block masonry external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 60 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 8 to 10 and 12 to 14 provided a MI of >3, and Cases 9, 10 and 14 provided a MI of <1.
- For ACR 7.5, only Case 10, a Class 4-3 (21) membrane with a vented and drained cavity, and Case 14, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 14, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 60: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block masonry wall NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1	Nil	>3		5
Case 1	No	Class 1	Nil	6	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	>4	>5	>5
Case 2	No	Class 3 (1398)	Nil	>5	6	6
Case 3	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 4	No	Class 4-2 (100)	Nil	>5	6	6
Case 5	No	Class 4-3 (21)	Nil	>5	6	6
Case 6	Yes	Class 1	Nil	>5	6	6
Case 7	Yes	Class 3 (1398)	Nil	5	6	6
Case 8	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 9	Yes	Class 4-2 (100)	Nil	<1	>3	>4
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	3
Case 11	No	Class 1	Yes	>5	6	6
Case 12	No	Class 3 (1398)	Yes	>1 to <3	>4	6
Case 13	No	Class 4-1 (175.4)	Yes	>1 to <3	>3	6
Case 14	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star concrete block masonry external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 61 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 10, 13 and 14 provided an MI of >3, and Case 10, a Class 4-3 (21) membrane, with a vented and drained cavity, or Case 14, a Class 4-1 (175.4) membrane, with a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 14, a Class 4-1 (175.4) membrane, with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 14, a Class 4-1 (175.4) membrane, with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.

Table 61: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block masonry wall NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1	Nil	>3		5
Case 1	No	Class 1	Nil	6	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	<5	>5	>5
Case 2	No	Class 3 (1398)	Nil	6	6	6
Case 3	No	Class 4-1 (175.4)	Nil	6	6	6
Case 4	No	Class 4-2 (100)	Nil	6	6	6
Case 5	No	Class 4-3 (21)	Nil	6	6	6
Case 6	Yes	Class 1	Nil	6	6	6
Case 7	Yes	Class 3 (1398)	Nil	6	6	6
Case 8	Yes	Class 4-1 (175.4)	Nil	4	>5	6
Case 9	Yes	Class 4-2 (100)	Nil	>3	>4	6
Case 10	Yes	Class 4-3 (21)	Nil	<1	>3	>4
Case 11	No	Class 1	Yes	>5	6	6
Case 12	No	Class 3 (1398)	Yes	>3	>4	6
Case 13	No	Class 4-1 (175.4)	Yes	>1 to <3	>3	6
Case 14	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 62 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and Cases 4 to 8 provided a MI of <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3, and Cases 4, 5, 6 and 8 provided a MI of <1.
- For ACR 5, Cases 4, 5, 6 and 8 provided a MI of <3, and Cases 5, 6 and 8 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 62: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1	>4	>5
Case 1	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	6
Case 2	No	Class 4-2 (100)	Nil	>1 to <3	>4	6
Case 3	No	Class 4-3 (21)	Nil	>1 to <3	>4	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	>1 to <3	>3
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 63 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3, and Cases 5, 6 and 8 provided a MI of <1.
- For ACR 7.5, Case 6, a Class 4-3 (21) membrane with a vented and drained cavity, or Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 63: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	4		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>4.5	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 5	Yes	Class 4-2 (100)	Nil	<1	>3	6
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	5
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>3	6
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 64 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and Cases 4 to 8 provided a MI of <1.
- For ACR 7.5, Cases 4 to 8 cavity provided a MI of <3 and <1.
- For ACR 5, Cases 5, 6 and 8 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 64: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1	>4	>5
Case 1	No	Class 4-1 (175.4)	Nil	>1 to <3	>5	6
Case 2	No	Class 4-2 (100)	Nil	>1 to <3	>5	6
Case 3	No	Class 4-3 (21)	Nil	>1 to <3	5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	<1	4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	<1	>3
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 65 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3 and <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3, and Cases 5, 6 and 8 provided a MI of <1.
- For ACR 5, only Case 6, a Class 4-3 (21) membrane with a vented and drained cavity, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 65: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>3	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	4	>5	6
Case 3	No	Class 4-3 (21)	Nil	4	>3	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	4
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	<1	>1 to <3	>4
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 66 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3 and Cases 6 and 8 provided a MI of <1.
- For ACR 7.5, only Case 6, a Class 4-3 (21) membrane with a vented and drained cavity, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.

Table 66: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	4		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>4.5	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 2	No	Class 4-2 (100)	Nil	>5	6	6
Case 3	No	Class 4-3 (21)	Nil	>5	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 5	Yes	Class 4-2 (100)	Nil	>1 to <3	>3	5
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	>3
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>3	6
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 67 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 6 and 8 provided a MI of <3, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 67: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3		5
RR1 7 Star	No	Class 4-1 (175.4)	Nil	>4.5	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	6	6	6
Case 2	No	Class 4-2 (100)	Nil	6	6	6
Case 3	No	Class 4-3 (21)	Nil	6	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>5	6	6
Case 5	Yes	Class 4-2 (100)	Nil	>3	6	6
Case 6	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	6
Case 7	No	Class 4-1 (175.4)	Yes	>3	>4	6
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 68 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, Cases 4 to 8 provided a MI of <3, and Cases 4, 5, 6 and 8 provided a MI of <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3, and Cases 4, 5, 6 and 8 provided a MI of <1.
- For ACR 5, only Case 6, a Class 4-3 (21) membrane, with a vented and drained cavity, and Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 68: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1.5	>4	>4
Case 1	No	Class 4-1 (175.4)	Nil	>4	>5	6
Case 2	No	Class 4-2 (100)	Nil	>4	>5	6
Case 3	No	Class 4-3 (21)	Nil	>4	>5	6
Case 4	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>3
Case 5	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 6	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	>4
Case 8	Yes	Class 4-1 (175.4)	Yes	Nil	Nil	Nil

7 Star concrete block masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 69 shows the results for enhancements to the 7 Star concrete block masonry external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 6 to 8 provided an MI of <3, and Cases 6 and 8 provided a MI of <1.
- For ACR 7.5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity, with an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 69: Bio-hygrothermal simulation results from southern oriented 7 Star concrete block, internally insulated wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>4		5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>4.5	>5	>5
Case 1	No	Class 4-1 (175.4)	Nil	6	6	6
Case 2	No	Class 4-2 (100)	Nil	6	6	6
Case 3	No	Class 4-3 (21)	Nil	6	6	6
Case 4	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 5	Yes	Class 4-2 (100)	Nil	>3	>4	6
Case 6	Yes	Class 4-3 (21)	Nil	<1	>3	>4
Case 7	No	Class 4-1 (175.4)	Yes	>1 to <3	>3	6
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star concrete block masonry external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star concrete block masonry external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table *70* shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star concrete block masonry external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 70 shows that:

- For ACR 10, two external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, one external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, one external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 70 shows that:

- For ACR 10, one external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, one external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, one external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 70: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 concrete block masonry external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	No	Nil	17%	0%	0%		17%	0%	0%
Class 3 (1398)	No	Nil	17%	0%	0%		17%	0%	0%
Class 4-1 (175.4)	No	Nil	33%	0%	0%		17%	0%	0%
Class 4-2 (100)	No	Nil	33%	0%	0%		17%	0%	0%
Class 4-3 (21)	No	Nil	33%	0%	0%		17%	0%	0%
Class 1 (200000)	Yes	Nil	17%	0%	0%		17%	0%	0%
Class 3 (1398)	Yes	Nil	33%	0%	0%		17%	0%	0%
Class 4-1 (175.4)	Yes	Nil	83%	33%	0%		50%	33%	0%
Class 4-2 (100)	Yes	Nil	83%	50%	33%		83%	33%	17%
Class 4-3 (21)	Yes	Nil	100%	83%	33%		83%	83%	33%
Class 1 (200000)	No	Yes	33%	0%	0%		33%	0%	0%
Class 3 (1398)	No	Yes	83%	33%	17%		33%	33%	0%
Class 1 (200000)	Yes	Yes	67%	67%	33%		67%	67%	0%
Class 3 (1398)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and

the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and concrete block masonry external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria. These results were initially surprising, however recent research in Belgium, Canada and New Zealand, has highlighted mould growth problems within external wall systems, which can store unwanted moisture.

NCC climate zone 6 & 7

Table 71 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 concrete block masonry external wall system located within NCC climate zone 6 & 7. Table 71 shows that:

- For ACR 10, two external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, one external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, one external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 71 shows that:

- For ACR 10, one external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, one external wall system scenarios in the eight simulated climates had a MI of <1.0, and
- For ACR 5, one external wall system scenarios in the eight simulated climates had a MI of <1.0.

Table 71: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star concrete block masonry external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 4-1 (175.4)	No	Nil	25%	0%	0%		13%	0%	0%
Class 4-2 (100)	No	Nil	25%	0%	0%		13%	0%	0%
Class 4-3 (21)	No	Nil	25%	0%	0%		13%	0%	0%
Class 4-1 (175.4)	Yes	Nil	69%	44%	13%		44%	25%	0%
Class 4-2 (100)	Yes	Nil	75%	50%	19%		69%	44%	19%
Class 4-3 (21)	Yes	Nil	100%	81%	50%		88%	75%	50%
Class 4-1 (175.4)	No	Yes	94%	63%	19%		31%	19%	0%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of improved air-tightness measures on the external wall systems ability to passively minimise interstitial mould growth. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and concrete block masonry external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria. These

results were initially surprising, however recent research in Belgium, Canada and New Zealand, has highlighted mould growth problems within external wall systems, which can store unwanted moisture.

4.5 Externally insulated clay masonry (reverse brick veneer)

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star externally insulated clay masonry external wall systems. The complete set of MI graphs for this wall system are in Appendix 5. The results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 72 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, except for Cases 1 and 6, all Cases provided a MI of <3, and except for Cases 1, 6 and 11, all Cases provided a MI of <1.
- For ACR 7.5, except for Cases 1 and 6, all Cases provided a MI of <3, and except for Cases 1, 6, 11 and 14, all Cases provided a MI of <1.
- For ACR 5, Cases 3 to 5, 8 to 10, 12, 13, 15 and 16 provided a MI of <3, and Cases 5, 8 to 10, 12, 13, 15 and 16 provided a MI of <1.

Table 72: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>1 to <3		5
Case 1	No	Class 1 (200000)	Nil	>4	>5	6
RR2 7 Star	No	Class 3 (1398)	Nil	<1	<1	<4
Case 2	No	Class 3 (1398)	Nil	<1	<1	>5
Case 3	No	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 4	No	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 5	No	Class 4-3 (21)	Nil	<1	<1	<1
Case 6	Yes	Class 1 (200000)	Nil	>3	>5	6
Case 7	Yes	Class 3 (1398)	Nil	<1	<1	>5
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	>1 to <3	>1 to <3	6
Case 12	No	Class 3 (1398)	Yes	<1	<1	<1
Case 13	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 14	Yes	Class 1 (200000)	Yes	<1	>1 to <3	6
Case 15	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 16	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 73 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 3 to 5, 8 to 10 and 13 to 16 provided a MI of <3, and Cases 8 to 10 and 14 to 16 provided a MI of <1.
- For ACR 7.5, Cases 8 to 10 and 13 to 16 provided a MI of <3 and Cases 8 to 10 and 14 to 16 provided a MI of <1.
- For ACR 5, Cases 8 to 10 and 15 to 16 provided a MI of <3, and Cases 8 to 10 and 16 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 73: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 61, NCC CZ 4 with rain data..

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	5		
Case 1	No	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	>1 to <3	>4	>5
Case 2	No	Class 3 (1398)	Nil	5	6	6
Case 3	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	6
Case 4	No	Class 4-2 (100)	Nil	>1 to <3	4	>5
Case 5	No	Class 4-3 (21)	Nil	>1 to <3	4	>5
Case 6	Yes	Class 1 (200000)	Nil	6	6	6
Case 7	Yes	Class 3 (1398)	Nil	>3	5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	6	6	6
Case 12	No	Class 3 (1398)	Yes	>4	>5	6
Case 13	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	>4
Case 14	Yes	Class 1 (200000)	Yes	<1	<1	>3
Case 15	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 16	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 74 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 4, 5, 8, 9, 10 and 13 to 16 provided a MI of <3, and Cases 8 to 10 and 14 to 16 provided a MI of <1.
- For ACR 7.5 Cases 8 to 10 and 14 to 16 provided a MI of <3 and <1.
- For ACR 5, Cases 8 to 10, 15 and 16 provided a MI of <3, and Cases 9, 10 and 16 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 74: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	5		5
Case 1	No	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	>1 to <3	>4	>5
Case 2	No	Class 3 (1398)	Nil	>5	6	6
Case 3	No	Class 4-1 (175.4)	Nil	>3	5	6
Case 4	No	Class 4-2 (100)	Nil	>1 to <3	5	6
Case 5	No	Class 4-3 (21)	Nil	>1 to <3	4	6
Case 6	Yes	Class 1 (200000)	Nil	6	6	6
Case 7	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	>5	6	6
Case 13	No	Class 3 (1398)	Yes	>1 to <3	>3	6
Case 15	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 12	Yes	Class 1 (200000)	Yes	>4	6	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	>4
Case 16	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 75 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 3, 4 and 6 to 12 provided a MI of <3, and Cases 6 to 8 and 10 to 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI for the ACR 5.0 simulation.

Table 75: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>4
Case 1	No	Class 3 (1398)	Nil	>1 to <3	>1 to <3	5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	Nil	<1	<1
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 3	No	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 4	No	Class 4-3 (21)	Nil	<1	<1	>1 to <3
Case 5	Yes	Class 3 (1398)	Nil	<1	<1	4
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 76 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, except for Case 5, all Cases provided a MI of <3, and Cases 6 to 8 and 10 to 12 provided a MI of <1.
- For ACR 7.5, Cases 6 to 12 provided MI of <3, and Cases 6 to 8 and 10 to 12 provided a MI of <1.
- For ACR 5, Cases 6 to 8, 10 and 12 provided a MI of <3, and Cases 6 to 8 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 76: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
Case 1	No	Class 3 (1398)	Nil	5	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>3
Case 2	No	Class 4-1 (175.4)	Nil	>1 to <3	4	>5
Case 3	No	Class 4-2 (100)	Nil	>1 to <3	4	>5
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	>3	5
Case 5	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>1 to <3	>1 to <3	>4
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	4
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 77 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, except for Cases 1 and 5, all Cases provided a MI of <3, and except for Cases 1, 2 and 5, all Cases provided a MI of <1.

Table 77: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>4
Case 1	No	Class 3 (1398)	Nil	<1	<1	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	Nil	<1	<1
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 3	No	Class 4-2 (100)	Nil	<1	<1	<1
Case 4	No	Class 4-3 (21)	Nil	<1	<1	<1
Case 5	Yes	Class 3 (1398)	Nil	<1	<1	5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 78 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and Cases 2 to 12 provided a MI of <1.
- For ACR 7.5, Except for case 5, all Cases provided a MI of <3, and Cases 6 to 8 and 10 to 12 provided a MI of <1.
- For ACR 5, Cases 6 to 8 and 10 to 12 provided a MI of <3, and Cases 6 to 8, 11 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 78: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
Case 1	No	Class 3 (1398)	Nil	>1 to <3	5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>1 to <3	>3
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	5
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	5
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	4
Case 5	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	>1 to <3	>3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 79 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Except for Case 5, all Cases provided a MI of <3, and Cases 6 to 8 and 10 to 12 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 and 10 to 12 provided a MI of <3, and Cases 6 to 8, 10 and 12 provided a MI of <1.
- For ACR 5, Cases 6 to 8, 10 and 12 provided a MI of <3, and Cases 6 to 8 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 79: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>1 to <3		5
Case 1	No	Class 3 (1398)	Nil	5	>5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1 to <3	>1 to <3	>3
Case 2	No	Class 4-1 (175.4)	Nil	>1 to <3	4	6
Case 3	No	Class 4-2 (100)	Nil	>1 to <3	4	5
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	4	5
Case 5	Yes	Class 3 (1398)	Nil	4	5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>1 to <3	>3	5
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	<1	>1 to <3	>3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 80 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 4 and 6 to 12 provided an MI of <3, and Cases 6 to 8, 10 and 12 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8, 10 and 12 provided a MI of <3, and Cases 7, 8, 10 and 12 provided a MI of <1.
- For ACR 5, Cases 6 to 8, 10 and 12 provided a MI of <3, and Cases 7, 8 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 80: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>2.5		5
Case 1	No	Class 3 (1398)	Nil	5	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>1	>2	>3.5
Case 2	No	Class 4-1 (175.4)	Nil	4	5	6
Case 3	No	Class 4-2 (100)	Nil	>3	5	5
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	4	5
Case 5	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>1 to <3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>1 to <3	5	5
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	>1 to <3	3	4
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 81 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Case 5, all Cases provided a MI of <3, and Cases 6 to 8 and 1- to 12 provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3, and Cases 6 to 8 and 1- to 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 81: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	1.2		5
Case 1	No	Class 3 (1398)	Nil	>1 to <3	5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	>2
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	4
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	4
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	>3
Case 5	Yes	Class 3 (1398)	Nil	<1	>3	5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	>1 to <3	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star externally insulated clay masonry external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 82 shows the results for enhancements to the 6 Star and 7 Star externally insulated clay masonry wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 3, 4 and 6 to 12 provided a MI of <3, and Cases 6 to 8 and 10 to 12 provided a MI of <1.
- For ACR 7.5, Cases 6 to 8 and 10 to 12 provided a MI of <3 and <1.
- For ACR 5, Cases 7, 8, 10 and 12 provided a MI of <3, and Cases 7, 8 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 82: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star externally insulated clay masonry wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>2		5
Case 1	No	Class 3 (1398)	Nil	5	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>1.5	>4
Case 2	No	Class 4-1 (175.4)	Nil	3	5	6
Case 3	No	Class 4-2 (100)	Nil	>1 to <3	5	6
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	4	6
Case 5	Yes	Class 3 (1398)	Nil	5	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>1 to <3	4	6
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	5
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star externally insulated clay masonry external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star externally insulated clay masonry external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 83 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star externally insulated clay masonry external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 83 shows that:

- For ACR 10, seven external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, five external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, four external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 83 shows that:

- For ACR 10, five external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, five external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, three external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 83: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 externally insulated clay masonry external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	No	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	No	Nil	33%	33%	0%		33%	33%	0%
Class 4-1 (175.4)	No	Nil	67%	33%	33%		33%	33%	0%
Class 4-2 (100)	No	Nil	100%	33%	33%		33%	33%	0%
Class 4-3 (21)	No	Nil	100%	33%	33%		33%	33%	33%
Class 1 (200000)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	Yes	Nil	33%	33%	0%		33%	33%	0%
Class 4-1 (175.4)	Yes	Nil	100%	100%	100%		100%	100%	67%
Class 4-2 (100)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 4-3 (21)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 1 (200000)	No	Yes	33%	33%	0%		0%	0%	0%
Class 3 (1398)	No	Yes	67%	33%	33%		33%	33%	33%
Class 1 (200000)	Yes	Yes	67%	67%	0%		67%	33%	0%
Class 3 (1398)	Yes	Yes	100%	100%	67%		100%	100%	33%
Class 4 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the moisture buffering impact of the interior clay masonry material. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and externally insulated clay masonry external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria.

NCC climate zone 6 & 7

Table 84 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 externally insulated clay masonry external wall system located within NCC climate zone 6 & 7. Table 84 shows that:

- For ACR 10, eight external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, five external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, four external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 84 shows that:

- For ACR 10, five external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, four external wall system scenarios in the eight simulated climates had a MI of <1.0, and
- For ACR 5, three external wall system scenarios in the eight simulated climates had a MI of <1.0.

Table 84: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star externally insulated clay masonry external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 3 (1398)	No	Nil	50%	25%	0%		13%	13%	0%
Class 4-1 (175.4)	No	Nil	75%	50%	13%		50%	25%	0%
Class 4-2 (100)	No	Nil	88%	50%	25%		50%	25%	25%
Class 4-3 (21)	No	Nil	100%	50%	25%		50%	25%	25%
Class 3 (1398)	Yes	Nil	50%	25%	0%		50%	25%	0%
Class 4-1 (175.4)	Yes	Nil	100%	100%	88%		100%	88%	75%
Class 4-2 (100)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 4-3 (21)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 3 (1398)	No	Yes	100%	63%	38%		50%	25%	0%
Class 4-1 (175.4)	No	Yes	100%	100%	100%		100%	100%	38%
Class 3 (1398)	Yes	Yes	100%	88%	50%		88%	75%	50%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and

the inclusion of an interior vapour control layer. The results also clearly show the moisture buffering impact of the interior clay masonry material. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and externally insulated clay masonry external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria.

4.6 Extruded polystyrene with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star extruded polystyrene external wall systems. The complete set of MI graphs for this wall system are in Appendix 6. As the external wall insulation levels are significantly different, the 6 Star scenarios are presented first followed by the 7 Star scenarios. In each case the results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 85 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all scenarios provided a MI of <3 and <1.
- For ACR 7.5, Except for Case 4, all cases provided a MI of <3, and except for Cases 4 and 6 all cases provided a MI of <1.
- For ACR 5, Cases 8, 9, 10, 12 and 14 provided an MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 85: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 27, BNCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>2.5
Case 1	No	Class 1 (200000)	Nil	< 1	< 1	>4
Case 2	No	Class 3 (1398)	Nil	< 1	< 1	>4
Case 3	No	Class 4-1 (175.4)	Nil	< 1	< 1	>4
Case 4	No	Class 4-2 (100)	Nil	< 1	>4	>4
Case 5	No	Class 4-3 (21)	Nil	< 1	< 1	>4
Case 6	Yes	Class 1 (200000)	Nil	< 1	>1 to <3	>5
Case 7	Yes	Class 3 (1398)	Nil	< 1	< 1	5
Case 8	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	< 1
Case 9	Yes	Class 4-2 (100)	Nil	< 1	< 1	< 1
Case 10	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 11	No	Class 1 (200000)	Yes	< 1	< 1	4
Case 12	No	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 13	Yes	Class 1 (200000)	Yes	< 1	< 1	5
Case 14	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 86 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Except for Case 6 all vases provided a MI of <3, and except for Cases 6, 7 and 13 all cases provided a MI of <1.
- For ACR 7.5, Cases 8, 9, 10, 12 and 14 provided a MI of <3 and <1.
- For ACR 5, Cases 9, 10 and 14 provided a MI of >3, and Case 10, a Class 4-3 (21) membrane with a vented and drained cavity, or Case 14, a Class 3 (1398) with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 86: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>4
Case 1	No	Class 1 (200000)	Nil	< 1	>3	>5
Case 2	No	Class 3 (1398)	Nil	< 1	>3	>5
Case 3	No	Class 4-1 (175.4)	Nil	< 1	>3	>5
Case 4	No	Class 4-2 (100)	Nil	< 1	>5	>5
Case 5	No	Class 4-3 (21)	Nil	< 1	>3	>5
Case 6	Yes	Class 1 (200000)	Nil	>3	5	6
Case 7	Yes	Class 3 (1398)	Nil	>1 to <3	>4	>5
Case 8	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	>3
Case 9	Yes	Class 4-2 (100)	Nil	< 1	< 1	>1 to <3
Case 10	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 11	No	Class 1 (200000)	Yes	< 1	>3	5
Case 12	No	Class 3 (1398)	Yes	< 1	< 1	>4
Case 13	Yes	Class 1 (200000)	Yes	>1 to <3	>4	6
Case 14	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 87 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, all Cases provided a MI of >3, and except for cases 6, 7 and 13 all Cases provided an MI of <1.
- For ACR 7.5, Cases 8, 9, 10, 12 and 14 provided a MI of <3 and <1.
- For ACR 5, Cases 9, 10 and 14 provided a MI of <3, and Case 10, a Class 4-3 (21) membrane with a vented and drained cavity, or Case 14, a Class 3 (1398) with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 87: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>4
Case 1	No	Class 1 (200000)	Nil	< 1	>3	>5
Case 2	No	Class 3 (1398)	Nil	< 1	>3	>5
Case 3	No	Class 4-1 (175.4)	Nil	< 1	>3	>5
Case 4	No	Class 4-2 (100)	Nil	< 1	>5	>5
Case 5	No	Class 4-3 (21)	Nil	< 1	>3	>5
Case 6	Yes	Class 1 (200000)	Nil	>1 to <3	5	6
Case 7	Yes	Class 3 (1398)	Nil	>1 to <3	>4	6
Case 8	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	4
Case 9	Yes	Class 4-2 (100)	Nil	< 1	< 1	>1 to <3
Case 10	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 11	No	Class 1 (200000)	Yes	< 1	>3	>5
Case 12	No	Class 3 (1398)	Yes	< 1	< 1	>4
Case 13	Yes	Class 1 (200000)	Yes	>1 to <3	>4	6
Case 14	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 88 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided an MI of <3 and <1.
- For ACR 7.5, all Cases provided an MI of <3 and <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 88: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2
Case 1	No	Class 3 (1398)	Nil	< 1	< 1	4
Case 2	No	Class 4-1 (175.4)	Nil	< 1	< 1	4
Case 3	No	Class 4-2 (100)	Nil	< 1	< 1	4
Case 4	No	Class 4-3 (21)	Nil	< 1	< 1	4
Case 5	Yes	Class 3 (1398)	Nil	< 1	< 1	>4
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	< 1
Case 7	Yes	Class 4-2 (100)	Nil	< 1	< 1	< 1
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	< 1
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 89 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 4 and 7 to 12 provided a MI of >3, and Cases 7 to 12 provided a MI of <1.
- For ACR 5, Case 7, 8, 11 and 12 a MI of <3, and Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 11 and 12, which include a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 89: Bio-hygrothermal results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3
Case 1	No	Class 3 (1398)	Nil	< 1	3	5
Case 2	No	Class 4-1 (175.4)	Nil	< 1	3	5
Case 3	No	Class 4-2 (100)	Nil	< 1	3	5
Case 4	No	Class 4-3 (21)	Nil	< 1	>1 to <3	5
Case 5	Yes	Class 3 (1398)	Nil	< 1	4	6
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	<1	6
Case 7	Yes	Class 4-2 (100)	Nil	< 1	<1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	4
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	4
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 90 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5 all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 90: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		2.5
Case 1	No	Class 3 (1398)	Nil	< 1	< 1	>4
Case 2	No	Class 4-1 (175.4)	Nil	< 1	< 1	>4
Case 3	No	Class 4-2 (100)	Nil	< 1	< 1	>4
Case 4	No	Class 4-3 (21)	Nil	< 1	< 1	>4
Case 5	Yes	Class 3 (1398)	Nil	< 1	< 1	5
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	< 1
Case 7	Yes	Class 4-2 (100)	Nil	< 1	< 1	< 1
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	< 1
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 91 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all cases provided a MI of <3, and except for Case 5 all Cases provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 91: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3
Case 1	No	Class 3 (1398)	Nil	< 1	< 1	5
Case 2	No	Class 4-1 (175.4)	Nil	< 1	< 1	5
Case 3	No	Class 4-2 (100)	Nil	< 1	< 1	5
Case 4	No	Class 4-3 (21)	Nil	< 1	< 1	>4
Case 5	Yes	Class 3 (1398)	Nil	< 1	>1 to <3	5
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	>1 to <3
Case 7	Yes	Class 4-2 (100)	Nil	< 1	< 1	<1
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 92 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and except for Case 5, all other cases provided a MI of <1.
- For ACR 7.5, all Cases provided a MI of <3, and except for Case 5, all other cases provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 92: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		4
Case 1	No	Class 3 (1398)	Nil	< 1	< 1	>4
Case 2	No	Class 4-1 (175.4)	Nil	< 1	< 1	>4
Case 3	No	Class 4-2 (100)	Nil	< 1	< 1	>4
Case 4	No	Class 4-3 (21)	Nil	< 1	< 1	>4
Case 5	Yes	Class 3 (1398)	Nil	>1 to <3	>1 to<3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	>1 to <3
Case 7	Yes	Class 4-2 (100)	Nil	< 1	< 1	< 1
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 93 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, except for Case 5, all other cases provided a MI of <3, and Cases 3 and 6 to 12 provided a MI of <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3 and <1.
- For ACR 5, Cases 7, 8, 11 and 12 provided a MI of <3, and Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 11 and 12 which include a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 93: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		4
Case 1	No	Class 3 (1398)	Nil	>1 to <3	>3	5
Case 2	No	Class 4-1 (175.4)	Nil	>1 to <3	>3	5
Case 3	No	Class 4-2 (100)	Nil	<1	>3	5
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	>3	5
Case 5	Yes	Class 3 (1398)	Nil	>3	>4	5
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	>3
Case 7	Yes	Class 4-2 (100)	Nil	< 1	< 1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	4
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	>3
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 94 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Case 5, all Cases provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 5, Cases 7, 8, 11 and 12 provided a MI of <3, and Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 11 and 12 which include a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 94: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2
Case 1	No	Class 3 (1398)	Nil	< 1	>1 to<3	>5
Case 2	No	Class 4-1 (175.4)	Nil	< 1	>1 to<3	>5
Case 3	No	Class 4-2 (100)	Nil	< 1	>1 to<3	>5
Case 4	No	Class 4-3 (21)	Nil	< 1	>1 to<3	>5
Case 5	Yes	Class 3 (1398)	Nil	< 1	3	6
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	4
Case 7	Yes	Class 4-2 (100)	Nil	< 1	< 1	>1 to<3
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	<1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	>4
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	>4
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	< 1

6 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 95 shows the results for enhancements to the 6 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, all Cases provided an MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and Casea 2 and 6 to 12 provided an MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 95: Bio-hygrothermal simulation results from southern oriented 6 Star extruded polystyrene wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>4
Case 1	No	Class 3 (1398)	Nil	< 1	>1 to <3	>4
Case 2	No	Class 4-1 (175.4)	Nil	< 1	<1	>4
Case 3	No	Class 4-2 (100)	Nil	< 1	>1 to <3	>4
Case 4	No	Class 4-3 (21)	Nil	< 1	>1 to <3	>4
Case 5	Yes	Class 3 (1398)	Nil	< 1	>1 to <3	5
Case 6	Yes	Class 4-1 (175.4)	Nil	< 1	<1	>1 to <3
Case 7	Yes	Class 4-2 (100)	Nil	< 1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	< 1	< 1	<1
Case 9	No	Class 3 (1398)	Yes	< 1	< 1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	< 1	< 1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	< 1	< 1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	< 1	< 1	<1

7 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 96 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Case 8 to 14 provided a MI of <3, and Cases 8 to 12 and 14 provided a MI of <1.
- For ACR 5, Case 8, 9, 10, 12 and 14 provided a MI of <3, and Cases 8, 9, 10 and 14 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 96: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>2.5
Case 1	No	Class 1 (200000)	Nil	< 1	>3	6
RR2 7 Star	No	Class 3 (1398)	Nil	<1	<1	>5
Case 2	No	Class 3 (1398)	Nil	< 1	>3	6
Case 3	No	Class 4-1 (175.4)	Nil	< 1	>3	>5
Case 4	No	Class 4-2 (100)	Nil	< 1	>5	>5
Case 5	No	Class 4-3 (21)	Nil	< 1	>3	>5
Case 6	Yes	Class 1 (200000)	Nil	< 1	5	6
Case 7	Yes	Class 3 (1398)	Nil	< 1	>3	6
Case 8	Yes	Class 4-1 (175.4)	Nil	< 1	< 1	< 1
Case 9	Yes	Class 4-2 (100)	Nil	< 1	< 1	< 1
Case 10	Yes	Class 4-3 (21)	Nil	< 1	< 1	< 1
Case 11	No	Class 1 (200000)	Yes	< 1	< 1	>4
Case 12	No	Class 3 (1398)	Yes	< 1	< 1	>1 to <3
Case 13	Yes	Class 1 (200000)	Yes	< 1	>1 to <3	>5
Case 14	Yes	Class 3 (1398)	Yes	< 1	< 1	< 1

7 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 97 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 8, 9, 10 12 and 14 provided a MI of <3 and <1.
- For ACR 7.5, Cases 8, 9, 10 and 14 provided a MI of <3, and Cases 9, 10 and 14 provided a MI of <1.
- For ACR 5, Cases 10 and 14 provided a MI of <3, and Case 10, Class 4-3 (21) membrane with a vented and drained cavity was the only scenario that provided a MI of <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 97: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil	NA	>2
Case 1	No	Class 1 (200000)	Nil	>3	>5	6
RR2 7 Star	No	Class 3 (1398)	Nil	< 1	>3	>5
Case 2	No	Class 3 (1398)	Nil	>3	>5	6
Case 3	No	Class 4-1 (175.4)	Nil	>3	>5	6
Case 4	No	Class 4-2 (100)	Nil	>3	>6	6
Case 5	No	Class 4-3 (21)	Nil	>3	5	6
Case 6	Yes	Class 1 (200000)	Nil	>4	>5	6
Case 7	Yes	Class 3 (1398)	Nil	4	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	3	>5	6
Case 12	No	Class 3 (1398)	Yes	<1	>3	>5
Case 13	Yes	Class 1 (200000)	Yes	4	>5	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3

7 Star extruded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 98 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, except for Case 6, all Cases provided a MI of <3, and except for Cases 6 and 13 all cases provided a MI of <1.
- For ACR 7.5, Cases 9, 10, 12 and 14 provided a MI of <3, and Cases 9, 10 and 14 provided a MI of <1.
- For ACR 5, Case 10, a Class 4-3 (21) membrane with a vented and drained cavity was the only scenario that provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 98: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>4
Case 1	No	Class 1 (200000)	Nil	<1	>5	6
RR2 7 Star	No	Class 3 (1398)	Nil	<1	>3	>5
Case 2	No	Class 3 (1398)	Nil	<1	>5	6
Case 3	No	Class 4-1 (175.4)	Nil	<1	>5	6
Case 4	No	Class 4-2 (100)	Nil	<1	6	6
Case 5	No	Class 4-3 (21)	Nil	<1	>5	6
Case 6	Yes	Class 1 (200000)	Nil	>3	6	6
Case 7	Yes	Class 3 (1398)	Nil	<1	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	>3	5
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	4
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	<1	>5	6
Case 12	No	Class 3 (1398)	Yes	<1	>1 to <3	6
Case 13	Yes	Class 1 (200000)	Yes	>1 to <3	>5	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	>3

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 99 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3, and Cases 6, 7, 8, 11 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 99: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2
Case 1	No	Class 3 (1398)	Nil	<1	>1 to <3	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	>5
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	>5
Case 5	Yes	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 100 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 3 and 6 to 12 provided a MI of <3 and Cases 6 to 12 provided a MI of <1.
- For ACR 7.5, Cases 6, 7, 8, 11 and 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- For ACR 5, Case 8, a Class 4-3 (21) membrane with a vented and drained cavity and a Cases 11 and 12 which include a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 100: Bio-hygrothermal results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2
Case 1	No	Class 3 (1398)	Nil	>3	>5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>2.5	>5
Case 2	No	Class 4-1 (175.4)	Nil	>3	>5	6
Case 3	No	Class 4-2 (100)	Nil	>1 to <3	>5	6
Case 4	No	Class 4-3 (21)	Nil	>3	>5	6
Case 5	Yes	Class 3 (1398)	Nil	4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	>3	>5
Case 10	No	Class 4-1 (175.4)	Yes	<1	>3	>5
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 101 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3 and <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3, and Cases 6, 7, 8, 11 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 101: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		2.5
Case 1	No	Class 3 (1398)	Nil	<1	>3	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	>5
Case 2	No	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 3	No	Class 4-2 (100)	Nil	<1	>3	>5
Case 4	No	Class 4-3 (21)	Nil	<1	>3	>5
Case 5	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>1 to <3
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 102 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and except for Case 5 all Cases provided an MI of <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3 and <1.
- For ACR 5, Cases 6, 7, 8, 11 and 12 provided a MI of <3, and Casea 7, 8, 11 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 102: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		3
Case 1	No	Class 3 (1398)	Nil	<1	>4	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>1.5	>5
Case 2	No	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 3	No	Class 4-2 (100)	Nil	<1	>3	>5
Case 4	No	Class 4-3 (21)	Nil	<1	4	>5
Case 5	Yes	Class 3 (1398)	Nil	>1 to <3	>4	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>4
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>4
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 103 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 3 and 6 to 12 provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 7.5, Cases 7 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- For ACR 5, Cases 7, 8, 11 and 12 provided a MI of <3, and Case 8, Class 4-3 (21) membrane with a vented and drained cavity or Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 103: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		4
Case 1	No	Class 3 (1398)	Nil	>3	>5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<3	>5
Case 2	No	Class 4-1 (175.4)	Nil	>3	>5	6
Case 3	No	Class 4-2 (100)	Nil	>1 to <3	>5	6
Case 4	No	Class 4-3 (21)	Nil	>3	5	6
Case 5	Yes	Class 3 (1398)	Nil	4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>5	>4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	>1 to <3	>5
Case 10	No	Class 4-1 (175.4)	Yes	<1	>1 to <3	>5
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 104 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 6 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- For ACR 7.5, Cases 7 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- For ACR 5, Cases 8, 11 and 12 provided an MI of <3, and Case 8, Class 4-3 (21) membrane with a vented and drained cavity or Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 104: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		4
Case 1	No	Class 3 (1398)	Nil	4	>5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 2	No	Class 4-1 (175.4)	Nil	4	>5	6
Case 3	No	Class 4-2 (100)	Nil	>3	>5	6
Case 4	No	Class 4-3 (21)	Nil	>3	>5	6
Case 5	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>3	>3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>1 to <3	>1 to <3	>5
Case 10	No	Class 4-1 (175.4)	Yes	>1 to <3	>1 to <3	>5
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 105 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3 and <1.
- For ACR 5, Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 11 and 12 which include a vented and drained cavity, and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 105: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2
Case 1	No	Class 3 (1398)	Nil	<1	>3	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 2	No	Class 4-1 (175.4)	Nil	<1	>3	6
Case 3	No	Class 4-2 (100)	Nil	<1	>3	6
Case 4	No	Class 4-3 (21)	Nil	<1	>3	6
Case 5	Yes	Class 3 (1398)	Nil	<1	>3	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>5
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	>5
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star extruded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 106 shows the results for enhancements to the 7 Star extruded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 6 to 12 provided a MI of <3 and <1.
- For ACR 7.5, Cases 7 to 12 provided a MI of <3, and Cases 7, 8, 11 and 12 provided a MI of <1.
- For ACR 5, Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, and Case 12 a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 106: Bio-hygrothermal simulation results from southern oriented 7 Star extruded polystyrene wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>4
Case 1	No	Class 3 (1398)	Nil	>3	>5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 2	No	Class 4-1 (175.4)	Nil	>3	>5	6
Case 3	No	Class 4-2 (100)	Nil	>3	>5	6
Case 4	No	Class 4-3 (21)	Nil	>3	>5	6
Case 5	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>3	5
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	4
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	>1 to <3	>5
Case 10	No	Class 4-1 (175.4)	Yes	<1	>1 to <3	>5
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star extruded polystyrene (XPS) clad external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star extruded polystyrene (XPS) clad external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 107 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star extruded polystyrene (XPS) clad external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 107 shows that:

- For ACR 10, five external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, three external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, one external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 107 shows that:

- For ACR 10, five external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, three external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, one external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 107: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 extruded polystyrene (XPS) clad external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	No	Nil	83%	17%	0%		83%	17%	0%
Class 3 (1398)	No	Nil	83%	17%	0%		83%	17%	0%
Class 4-1 (175.4)	No	Nil	83%	17%	0%		83%	17%	0%
Class 4-2 (100)	No	Nil	83%	0%	0%		83%	0%	0%
Class 4-3 (21)	No	Nil	83%	17%	0%		83%	17%	0%
Class 1 (200000)	Yes	Nil	50%	17%	0%		33%	0%	0%
Class 3 (1398)	Yes	Nil	83%	17%	0%		50%	17%	0%
Class 4-1 (175.4)	Yes	Nil	100%	83%	33%		100%	67%	33%
Class 4-2 (100)	Yes	Nil	100%	100%	67%		100%	100%	33%
Class 4-3 (21)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 1 (200000)	No	Yes	83%	33%	0%		83%	67%	0%
Class 3 (1398)	No	Yes	100%	83%	33%		100%	67%	17%
Class 1 (200000)	Yes	Yes	83%	33%	0%		33%	17%	0%
Class 3 (1398)	Yes	Yes	100%	100%	83%		100%	100%	67%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and

the inclusion of an interior vapour control layer. The results also clearly show the impact of building airtightness and its link to risks of interstitial mould. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and extruded polystyrene (XPS) clad external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria.

NCC climate zone 6 & 7

Table 108 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 extruded polystyrene (XPS) clad external wall system located within NCC climate zone 6 & 7. Table 108 shows that:

- For ACR 10, seven external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, four external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, two external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 108 shows that:

- For ACR 10, four external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, four external wall system scenarios in the eight simulated climates had a MI of <1.0, and
- For ACR 5, two external wall system scenarios in the eight simulated climates had a MI of <1.0.

Table 108: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star extruded polystyrene (XPS) clad external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 3 (1398)	No	Nil	75%	44%	0%		56%	25%	0%
Class 4-1 (175.4)	No	Nil	75%	44%	0%		69%	31%	0%
Class 4-2 (100)	No	Nil	88%	44%	0%		75%	25%	0%
Class 4-3 (21)	No	Nil	75%	50%	0%		69%	25%	0%
Class 3 (1398)	Yes	Nil	69%	38%	0%		56%	13%	0%
Class 4-1 (175.4)	Yes	Nil	100%	75%	50%		94%	69%	25%
Class 4-2 (100)	Yes	Nil	100%	100%	75%		100%	100%	50%
Class 4-3 (21)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 3 (1398)	No	Yes	100%	94%	44%		94%	75%	13%
Class 4-1 (175.4)	No	Yes	100%	94%	44%		94%	75%	13%
Class 3 (1398)	Yes	Yes	100%	100%	94%		100%	100%	81%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and

mould free timber framed, and extruded polystyrene (XPS) clad external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria.

4.7 Expanded polystyrene with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star expanded polystyrene external wall systems. The complete set of MI graphs for this wall system are in Appendix 7. As the external wall insulation levels are significantly different, the 6 Star scenarios are presented first followed by the 7 Star scenarios. In each case the results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star expanded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 109 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 8, 9, 10, 12 and 14 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 109: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>2
Case 1	No	Class 1 (200000)	Nil	<1	<1	>4
Case 2	No	Class 3 (1398)	Nil	<1	<1	>4
Case 3	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 4	No	Class 4-2 (100)	Nil	<1	<1	>3
Case 5	No	Class 4-3 (21)	Nil	<1	<1	>3
Case 6	Yes	Class 1 (200000)	Nil	<1	<1	>5
Case 7	Yes	Class 3 (1398)	Nil	<1	<1	>5
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	<1	<1	>3
Case 12	No	Class 3 (1398)	Yes	<1	<1	<1
Case 13	Yes	Class 1 (200000)	Yes	<1	<1	5
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 110 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and except for Cases 6, 7 and 13 all cases provided a MI of <1.
- For ACR 7.5, Cases 3 to 5, 8 to 12 and 14 provided a MI of <3, and Cases 8 to 10, 12 and 14 provided a MI of <1.
- For ACR 5, Cases 8 to 10, 12 and 14 provided a MI of <3, and Cases 9, 10, 12 and 14 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 110: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>4
Case 1	No	Class 1 (200000)	Nil	<1	>3	5
Case 2	No	Class 3 (1398)	Nil	<1	3	5
Case 3	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 4	No	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 5	No	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 6	Yes	Class 1 (200000)	Nil	>1 to <3	>4	6
Case 7	Yes	Class 3 (1398)	Nil	>1 to <3	4	>5
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	<1	>1 to <3	5
Case 12	No	Class 3 (1398)	Yes	<1	<1	<1
Case 13	Yes	Class 1 (200000)	Yes	>1 to <3	4	>5
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 111 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and except for Case 6, all cases provided an MI of <1.
- For ACR 7.5, Cases 2 to 5, 8 to 10, 12 and 14 provided a MI of <3, and Cases 8 to 10, 12 and 14 provided a MI of <1.
- For ACR 5, Cases 9, 10, 12 and 14 provided a MI of <3, and Case 10, a Class 4-3 (21) membrane with a vented and drained cavity, or Cases 12 and 14 which include a Class 3 (1398) membrane without/with a cavity, with an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 111: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		4
Case 1	No	Class 1 (200000)	Nil	<1	>3	>5
Case 2	No	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 3	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 4	No	Class 4-2 (100)	Nil	<1	>1 to <3	5
Case 5	No	Class 4-3 (21)	Nil	<1	>1 to <3	5
Case 6	Yes	Class 1 (200000)	Nil	>1 to <3	>4	6
Case 7	Yes	Class 3 (1398)	Nil	<1	>4	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	<1	3	5
Case 12	No	Class 3 (1398)	Yes	<1	<1	<1
Case 13	Yes	Class 1 (200000)	Yes	<1	4	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 112 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, All Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 4 and 6 to 12 provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 112: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>1.25
Case 1	No	Class 3 (1398)	Nil	<1	<1	>3
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	3
Case 3	No	Class 4-2 (100)	Nil	<1	<1	3
Case 4	No	Class 4-3 (21)	Nil	<1	<1	>1 to <3
Case 5	Yes	Class 3 (1398)	Nil	<1	<1	>4
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 113 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Case 5, all Cases provided a MI of <3, and except for Cases 1 and 5 all Cases provided a MI of <1.
- For ACR 5, Cases 7 to 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 113: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2.5
Case 1	No	Class 3 (1398)	Nil	<1	>1 to <3	5
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	5
Case 3	No	Class 4-2 (100)	Nil	<1	<1	5
Case 4	No	Class 4-3 (21)	Nil	<1	<1	5
Case 5	Yes	Class 3 (1398)	Nil	<1	4	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 114 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3 and <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 114: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>1.2
Case 1	No	Class 3 (1398)	Nil	<1	<1	4
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 3	No	Class 4-2 (100)	Nil	<1	<1	>3
Case 4	No	Class 4-3 (21)	Nil	<1	<1	>3
Case 5	Yes	Class 3 (1398)	Nil	<1	<1	5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 115 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and except for Case 5, all Cases provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 115: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 60. NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2
Case 1	No	Class 3 (1398)	Nil	<1	<1	4
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	4
Case 3	No	Class 4-2 (100)	Nil	<1	<1	4
Case 4	No	Class 4-3 (21)	Nil	<1	<1	4
Case 5	Yes	Class 3 (1398)	Nil	<1	>1 to <3	5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 116 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and except for Case 5, all Cases provided a MI of <1.
- For ACR 7.5, except for Case 5 all Cases provided a MI of <3, and Vases 6 to 12 provided a MI of <1.
- For ACR 5, Cases 7 to 12 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 116: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3
Case 1	No	Class 3 (1398)	Nil	<1	>1 to <3	5
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 5	Yes	Class 3 (1398)	Nil	>1 to <3	4	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 117 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, except for Case 5, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 2, 4 and 6 to 12 provided a MI of <3, and Cases 7 to 12 provided a MI of <1.
- For ACR 5, Cases 7 to 12 provided a MI of <3, and Cases 8 to 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 117: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3
Case 1	No	Class 3 (1398)	Nil	<1	>3	5
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 3	No	Class 4-2 (100)	Nil	<1	3	>4
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 5	Yes	Class 3 (1398)	Nil	3	>4	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 118 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and except for Case 5, all Cases provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 118: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>1.5
Case 1	No	Class 3 (1398)	Nil	<1	<1	>3
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 3	No	Class 4-2 (100)	Nil	<1	<1	>3
Case 4	No	Class 4-3 (21)	Nil	<1	<1	>3
Case 5	Yes	Class 3 (1398)	Nil	<1	>1 to <3	>4
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 119 shows the results for enhancements to the 6 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Case 5, all Cases provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 5, Cases 7 to 12 provided a MI of <3, and Cases 8 to 12 provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 119: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3
Case 1	No	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	>5
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	5
Case 5	Yes	Class 3 (1398)	Nil	<1	>4	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 120 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 2 to 5 and 8 to 14 provided a MI of <3, and Cases 3 to 5 and 8 to 14 provided a MI of <1.
- For ACR 5, Cases 8, 9, 10, 12 and 14 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 120: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>1.25
Case 1	No	Class 1 (200000)	Nil	<1	>3	>5
RR2 7 Star	No	Class 3 (1398)	Nil	Nil	<1.0	>4.0
Case 2	No	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 3	No	Class 4-1 (175.4)	Nil	<1	<1	>5
Case 4	No	Class 4-2 (100)	Nil	<1	<1	>5
Case 5	No	Class 4-3 (21)	Nil	<1	<1	>5
Case 6	Yes	Class 1 (200000)	Nil	<1	5	6
Case 7	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	<1	<1	5
Case 12	No	Class 3 (1398)	Yes	<1	<1	<1
Case 13	Yes	Class 1 (200000)	Yes	<1	<1	>5
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 121 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 2 to 5, 8 to 12 and 14 provided a MI of <3, and Cases 3 to 5, 8 to 10, 12 and 14 provided a MI of <1.
- For ACR 7.5, Cases 8 to 10, 12 and 14 provided a MI of <3, and Cases 9, 10, 12 and 14 provided a MI of <1.
- For ACR 5, Cases 9, 10, 12 and 14 provided a MI of <3, and Case 10, a Class 4-3 (21) membrane with a vented and drained cavity provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 121: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>1.25
Case 1	No	Class 1 (200000)	Nil	>3	>5	6
RR2 7 Star	No	Class 3 (1398)	Nil	<1.0	<2.5	>5
Case 2	No	Class 3 (1398)	Nil	>1 to <3	>4	6
Case 3	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 4	No	Class 4-2 (100)	Nil	<1	>4	>5
Case 5	No	Class 4-3 (21)	Nil	<1	>4	>5
Case 6	Yes	Class 1 (200000)	Nil	>4	>5	6
Case 7	Yes	Class 3 (1398)	Nil	4	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	4
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	>1 to <3	>4	6
Case 12	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 13	Yes	Class 1 (200000)	Yes	>4	>5	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3

7 Star expanded polystyrene external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 122 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Cases 3 to 5, 8 to 12 and 14 provided a MI of <3, and Cases 8, 9, 10, 12 and 14 provided a MI of <1.
- For ACR 7.5, Case 8, 9, 10, 12 and 14 provided a MI of <3, and Cases 9, 10, 12 and 14 provided a MI of <1.
- For ACR 5, Cases 10, 12 and 14 provided a MI of <3, and Case 10, a Class 4-3 (21) membrane with a vented and drained cavity provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 122: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		>3
Case 1	No	Class 1 (200000)	Nil	>3	>5	6
RR2 7 Star	No	Class 3 (1398)	Nil	<1.0	>2.5	>5
Case 2	No	Class 3 (1398)	Nil	3	>5	6
Case 3	No	Class 4-1 (175.4)	Nil	>1 to <3	>5	6
Case 4	No	Class 4-2 (100)	Nil	>1 to <3	>4	6
Case 5	No	Class 4-3 (21)	Nil	>1 to <3	>4	6
Case 6	Yes	Class 1 (200000)	Nil	>5	6	6
Case 7	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	>4
Case 10	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 11	No	Class 1 (200000)	Yes	>1 to <3	5	6
Case 12	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 13	Yes	Class 1 (200000)	Yes	>3	>5	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 123 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and except for Case 5 all Cases provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a similar MI.

Table 123: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>1.25
Case 1	No	Class 3 (1398)	Nil	<1	<1	>4
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	<1	<3.0
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 3	No	Class 4-2 (100)	Nil	<1	<1	>4
Case 4	No	Class 4-3 (21)	Nil	<1	<1	>4
Case 5	Yes	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 124 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, except for Case all Cases provided a MI of <3, and except for Cases 1 and 5 all Cases provided a MI of <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3 and <1.
- For ACR 5, Cases 7, 8, 10, 11 and 12 provided a MI of <3, and Cases 8, 10, 11 and 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 124: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2.5
Case 1	No	Class 3 (1398)	Nil	>1 to <3	>4	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	>1.0	<5.0
Case 2	No	Class 4-1 (175.4)	Nil	<1	>4	6
Case 3	No	Class 4-2 (100)	Nil	<1	>4	6
Case 4	No	Class 4-3 (21)	Nil	<1	>4	6
Case 5	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 125 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Case 5 all Cases provided a MI of <3, and except for Cases 1 and 5 all Cases provided a MI of <1.
- For ACR 5, Cases 6 to 12 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a comparable MI.

Table 125: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>1.2
Case 1	No	Class 3 (1398)	Nil	<1	>1 to <3	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	Nil	<1.0	>3.0
Case 2	No	Class 4-1 (175.4)	Nil	<1	<1	>5
Case 3	No	Class 4-2 (100)	Nil	<1	<1	>5
Case 4	No	Class 4-3 (21)	Nil	<1	<1	>5
Case 5	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 126 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and except for Case 5 all Cases provided a MI of <1.
- For ACR 7.5, except for Case 5 all Cases provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 5, Cases 6 to 12 cavity provided a MI of <3, and Cases 7 to 12 provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a comparable MI.

Table 126: Bio-hygrothermal simulation from 6 Star expanded polystyrene wall systems NatHERS CZ 60. NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>2.0
Case 1	No	Class 3 (1398)	Nil	<1	>3	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	<1.0	<5.0
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	>5
Case 4	No	Class 4-3 (21)	Nil	<1	>1 to <3	>5
Case 5	Yes	Class 3 (1398)	Nil	>1 to <3	>4	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>1 to <3
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 127 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, except for Case 5 all Cases provided a MI of <3, and except for Cases 1, 2 and 5 all Cases provided a MI of <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3, and Cases 7 to 12 provided a MI of <1.
- For ACR 5, Cases 7 to 12 provided a MI of <3, and Cases 8, a Class 4-3 (21) membrane with a vented and drained cavity, and Cases 10, 11 and 12 which include an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 127: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3.0
Case 1	No	Class 3 (1398)	Nil	>1 to <3	>4	>5
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	>1.5	>4.5
Case 2	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	>5
Case 3	No	Class 4-2 (100)	Nil	<1	>4	>5
Case 4	No	Class 4-3 (21)	Nil	<1	>4	>5
Case 5	Yes	Class 3 (1398)	Nil	>3	>4	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>1 to <3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 128 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, Cases 4 and 6 to 12 provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 7.5, Cases 7 to 12 provided a MI of <3, and Cases 8 to 12 provided a MI of <1.
- For ACR 5, Cases 8, 10, 11 and 12 provided a MI of <3, and Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, and Cases 10 and 12 which include vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 128: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3.0
Case 1	No	Class 3 (1398)	Nil	>3	>4	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	>1.5	>4.5
Case 2	No	Class 4-1 (175.4)	Nil	>3	>4	>5
Case 3	No	Class 4-2 (100)	Nil	3	>4	>5
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	>4	>5
Case 5	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>3	4
Case 7	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 129 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Case 5 all Cases provided a MI of <3, and Cases 4 and 6 to 12 provided a MI of <1.
- For ACR 5, Cases 6 to 12 cavity provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 129: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>1.5
Case 1	No	Class 3 (1398)	Nil	<1	>1 to <3	>4
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	<1.0	<2.0
Case 2	No	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 3	No	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 4	No	Class 4-3 (21)	Nil	<1	<1	4
Case 5	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	<1
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	<1
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	<1
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star expanded polystyrene external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 130 shows the results for enhancements to the 7 Star expanded polystyrene external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, except for Cases 1 and 4 all Cases provided a MI of <3, and Cases 6 to 12 provided a MI of <1.
- For ACR 7.5, Cases 6 to 12 provided a MI of <3, and Cases 7 to 12 provided a MI of <1.
- For ACR 5, Cases 8, 10, 11 and 12 provided a MI of <3, and Case 8, a Class 4-3 (21) membrane with a vented and drained cavity, and Cases 10 and 12 which include a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 130: Bio-hygrothermal simulation from 7 Star expanded polystyrene wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	Nil		>3.0
Case 1	No	Class 3 (1398)	Nil	>3	>5	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<1.0	>1.5	<5.0
Case 2	No	Class 4-1 (175.4)	Nil	>1 to <3	>4	6
Case 3	No	Class 4-2 (100)	Nil	>1 to <3	>4	6
Case 4	No	Class 4-3 (21)	Nil	>1 to <3	>4	6
Case 5	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	<1	<1	>3
Case 10	No	Class 4-1 (175.4)	Yes	<1	<1	<1
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star expanded polystyrene (EPS) clad external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star expanded polystyrene (EPS) clad external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 131 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star expanded polystyrene (EPS) clad external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 131 shows that:

- For ACR 10, nine external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, five external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, three external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 131 shows that:

- For ACR 10, five external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, four external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, one external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 131: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 expanded polystyrene (EPS) clad external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	No	Nil	67%	17%	0%		67%	17%	0%
Class 3 (1398)	No	Nil	83%	50%	0%		67%	33%	0%
Class 4-1 (175.4)	No	Nil	100%	67%	0%		83%	17%	0%
Class 4-2 (100)	No	Nil	100%	67%	0%		83%	33%	0%
Class 4-3 (21)	No	Nil	100%	67%	0%		83%	33%	0%
Class 1 (200000)	Yes	Nil	67%	17%	0%		33%	17%	0%
Class 3 (1398)	Yes	Nil	67%	17%	0%		50%	17%	0%
Class 4-1 (175.4)	Yes	Nil	100%	100%	50%		100%	67%	33%
Class 4-2 (100)	Yes	Nil	100%	100%	83%		100%	100%	50%
Class 4-3 (21)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 1 (200000)	No	Yes	100%	50%	0%		67%	33%	0%
Class 3 (1398)	No	Yes	100%	100%	100%		100%	100%	67%
Class 1 (200000)	Yes	Yes	67%	33%	0%		50%	33%	0%
Class 3 (1398)	Yes	Yes	100%	100%	100%		100%	100%	67%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of building airtightness and its link to risks of interstitial mould. The results clearly indicate that further research needs

to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and expanded polystyrene (EPS) clad external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria.

NCC climate zone 6 & 7

Table 132 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 expanded polystyrene (EPS) clad external wall system located within NCC climate zone 6 & 7. Table 132 shows that:

- For ACR 10, eight external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, six external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, four external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 132 shows that:

- For ACR 10, seven external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, five external wall system scenarios in the eight simulated climates had a MI of <1.0, and
- For ACR 5, three external wall system scenarios in the eight simulated climates had a MI of <1.0.

Table 132: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star expanded polystyrene (EPS) clad external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 3 (1398)	No	Nil	88%	69%	0%		75%	31%	0%
Class 4-1 (175.4)	No	Nil	94%	75%	0%		81%	44%	0%
Class 4-2 (100)	No	Nil	94%	69%	0%		88%	44%	0%
Class 4-3 (21)	No	Nil	100%	75%	6%		88%	50%	0%
Class 3 (1398)	Yes	Nil	69%	25%	0%		56%	13%	0%
Class 4-1 (175.4)	Yes	Nil	100%	94%	50%		100%	75%	63%
Class 4-2 (100)	Yes	Nil	100%	100%	88%		100%	94%	63%
Class 4-3 (21)	Yes	Nil	100%	100%	100%		100%	100%	100%
Class 3 (1398)	No	Yes	100%	100%	81%		100%	100%	75%
Class 4-1 (175.4)	No	Yes	100%	100%	100%		100%	100%	100%
Class 3 (1398)	Yes	Yes	100%	100%	100%		100%	100%	88%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and expanded polystyrene (EPS) clad external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria.

4.8 Autoclaved aerated concrete with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star autoclaved Aerated concrete (AAC) external wall systems. The complete set of MI graphs for this wall system are in Appendix 8. As the external wall insulation levels are significantly different, the 6 Star scenarios are presented first followed by the 7 Star scenarios. In each case the results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star autoclaved aerated concrete external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 133 shows the results for enhancements to the 6 Star autoclaved Aerated concrete external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, except for Cases 1 and 2 all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 4 to 8 provided a MI of <3, and Cases 5 to 8 provided a MI of <1.
- For ACR 5, Cases 7 and 8, which include a Class 3 (1398) or Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 133: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		5
Case 1	Yes	Class 1 (200000)	Nil	>3	>5	6
Case 2	Yes	Class 3 (1398)	Nil	6	>4	6
Case 3	Yes	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 4	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>5
Case 5	Yes	Class 4-3 (21)	Nil	<1	<1	>4
Case 6	Yes	Class 1 (2000000)	Yes	<1	<1	>5
Case 7	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 134 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Cases 7 and 8, which include a Class 3 (1398) or Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 134: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
Case 1	Yes	Class 1 (200000)	Nil	>5	6	6
Case 2	Yes	Class 3 (1398)	Nil	6	6	6
Case 3	Yes	Class 4-1 (175.4)	Nil	4	>5	6
Case 4	Yes	Class 4-2 (100)	Nil	>3	>5	6
Case 5	Yes	Class 4-3 (21)	Nil	3	>4	5
Case 6	Yes	Class 1 (2000000)	Yes	4	6	6
Case 7	Yes	Class 3(1398)	Yes	4	<1	3
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 135 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, only Cases 7 and 8, which include a Class 3 (1398) or Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Cases 7 and 8, which include a Class 3 (1398) or Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 135: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
Case 1	Yes	Class 1 (200000)	Nil	6	6	6
Case 2	Yes	Class 3 (1398)	Nil	6	6	6
Case 3	Yes	Class 4-1 (175.4)	Nil	>4	6	6
Case 4	Yes	Class 4-2 (100)	Nil	>4	>5	6
Case 5	Yes	Class 4-3 (21)	Nil	>3	>4	>5
Case 6	Yes	Class 1 (2000000)	Yes	>4	6	6
Case 7	Yes	Class 3(1398)	Yes	<1	<1	>4
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 136 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and Cases 4 to 6 provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 136: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	Nil		5
Case 1	Yes	Class 3 (1398)	Nil	<1	>1 to <3	5
Case 2	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	5
Case 3	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 4	Yes	Class 4-3 (21)	Nil	<1	<1	>4
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 137 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 3 to 6 provided a MI of <3, and Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane or Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 137: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>2		5
Case 1	Yes	Class 3 (1398)	Nil	3	5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	3	5	6
Case 3	Yes	Class 4-2 (100)	Nil	>1 to <3	>4	6
Case 4	Yes	Class 4-3 (21)	Nil	>1 to <3	>4	5
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 138 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1
- For ACR 7.5, all Cases provided a MI of <3, and Cases 3 to 6 provided a MI of <1
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 138: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	Nil		5
Case 1	Yes	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 2	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 3	Yes	Class 4-2 (100)	Nil	<1	<1	>5
Case 4	Yes	Class 4-3 (21)	Nil	<1	<1	>4
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 139 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 4 to 6 provided a MI of <3, and Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 139: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>1 to <3		5
Case 1	Yes	Class 3 (1398)	Nil	<1	4	6
Case 2	Yes	Class 4-1 (175.4)	Nil	<1	4	6
Case 3	Yes	Class 4-2 (100)	Nil	<1	4	>5
Case 4	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	5
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 140 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 4 to 6 provided a MI of <3, and a Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 140: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>3		5
Case 1	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	>3	>5	6
Case 3	Yes	Class 4-2 (100)	Nil	>3	5	>5
Case 4	Yes	Class 4-3 (21)	Nil	>1 to <3	>4	5
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 141 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 141: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	>2.5		5
Case 1	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 3	Yes	Class 4-2 (100)	Nil	>3	>5	5
Case 4	Yes	Class 4-3 (21)	Nil	>3	>4	4
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 142 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and Cases 3 to 6 provided a MI of <1.
- For ACR 7.5, Cases 4 to 6 provided a MI of <3, and only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 142: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	Nil		5
Case 1	Yes	Class 3 (1398)	Nil	>1 to <3	>3	>5
Case 2	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 3	Yes	Class 4-2 (100)	Nil	<1	>3	>5
Case 4	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 143 shows the results for enhancements to the 6 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from report 1, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 143: bio-hygrothermal simulation results from southern oriented 6 Star AAC clad wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	Yes	Class 3 (1398)	Nil	Nil		5
Case 1	Yes	Class 3 (1398)	Nil	4	>5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	4	>5	6
Case 3	Yes	Class 4-2 (100)	Nil	4	>5	6
Case 4	Yes	Class 4-3 (21)	Nil	>3	>4	>5
Case 5	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 144 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, except for Case 1, all Cases provided a MI of <3 and <1.
- For ACR 7.5, except for Cases 1 and 2 all Cases provided a MI of <3, and Cases 4, 5, 7 and 8 provided a MI of <1.
- For ACR 5, only Case 5, a Class 7 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 8 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 144: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		5
Case 1	Yes	Class 1 (200000)	Nil	>3	>5	6
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	>1.25	>5
Case 2	Yes	Class 3 (1398)	Nil	<1	>4	6
Case 3	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 4	Yes	Class 4-2 (100)	Nil	<1	<1	>5
Case 5	Yes	Class 4-3 (21)	Nil	<1	<1	>4
Case 6	Yes	Class 1 (2000000)	Yes	<1	>1 to <3	>5
Case 7	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 145 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 4, 5, 7 and 8 provided a MI of <3. Only Case 7, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 8, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 7, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 8, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 145: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
Case 1	Yes	Class 1 (200000)	Nil	>5	6	6
RR2 7 Star	Yes	Class 3 (1398)	Nil	>1.5	>4	>5
Case 2	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 3	Yes	Class 4-1 (175.4)	Nil	>3	>4	6
Case 4	Yes	Class 4-2 (100)	Nil	>1 to <3	>4	>5
Case 5	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>4
Case 6	Yes	Class 1 (2000000)	Yes	>4	>5	6
Case 7	Yes	Class 3(1398)	Yes	<1	<1	>3
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 146 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, Only Case 7, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 8, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Case 7, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 8, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 8, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 146: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
Case 1	Yes	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	Yes	Class 3 (1398)	Nil	>2	>4	>5
Case 2	Yes	Class 3 (1398)	Nil	>5	6	6
Case 3	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 4	Yes	Class 4-2 (100)	Nil	>3	>5	6
Case 5	Yes	Class 4-3 (21)	Nil	>3	>4	5
Case 6	Yes	Class 1 (2000000)	Yes	>5	6	6
Case 7	Yes	Class 3(1398)	Yes	<1	<1	5
Case 8	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 147 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and Cases 4, 5 and 6 provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 147: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	<1	>3
Case 1	Yes	Class 3 (1398)	Nil	<1	>1 to <3	5
Case 2	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	5
Case 3	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>4
Case 4	Yes	Class 4-3 (21)	Nil	<1	<1	4
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 148 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, Cases 3 to 6 provided a MI of <3, and only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI or <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 148: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>2		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	>2	<5
Case 1	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	>3	>5	6
Case 3	Yes	Class 4-2 (100)	Nil	>1 to <3	5	6
Case 4	Yes	Class 4-3 (21)	Nil	>1 to <3	4	5
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 149 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, all Cases provided a MI of <3, and Cases 3 to 6 provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 149: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	<1	>3
Case 1	Yes	Class 3 (1398)	Nil	<1	>1 to <3	>5
Case 2	Yes	Class 4-1 (175.4)	Nil	<1	>1 to <3	>5
Case 3	Yes	Class 4-2 (100)	Nil	<1	<1	>5
Case 4	Yes	Class 4-3 (21)	Nil	<1	<1	>4
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 150 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, all Cases provided a MI of <3 and <1.
- For ACR 7.5, Cases 3 to 6 provided a MI of <3, and only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 150: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>1.2		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	<1	>4
Case 1	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 2	Yes	Class 4-1 (175.4)	Nil	<1	>3	>5
Case 3	Yes	Class 4-2 (100)	Nil	<1	>1 to <3	>5
Case 4	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 151 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, Cases 3 to 6 provided a MI of <3, and only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 151: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	<2.5	<5
Case 1	Yes	Class 3 (1398)	Nil	>3	>4	>5
Case 2	Yes	Class 4-1 (175.4)	Nil	>3	>4	>5
Case 3	Yes	Class 4-2 (100)	Nil	>1 to <3	>4	>5
Case 4	Yes	Class 4-3 (21)	Nil	>1 to <3	>3	>4
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 152 shows the results for enhancements to the 7 Star autoclaved aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 152: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>2.5		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	>1	>2.5	<5
Case 1	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 3	Yes	Class 4-2 (100)	Nil	>4	>5	6
Case 4	Yes	Class 4-3 (21)	Nil	>3	>4	5
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved Aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 153 shows the results for enhancements to the 7 Star autoclaved Aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, all Cases provided a MI of <3, and Cases 3 to 6 provided a MI of <1.
- For ACR 7.5, Cases 4 to 6 provided an MI of <3, and Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- .
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 153: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	Nil		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	<1	>3
Case 1	Yes	Class 3 (1398)	Nil	>1 to <3	>3	>5
Case 2	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>3	>5
Case 3	Yes	Class 4-2 (100)	Nil	<1	>3	>5
Case 4	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>4
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

7 Star autoclaved aerated concrete external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 154 shows the results for enhancements to the 7 Star autoclaved Aerated concrete external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 5, only Case 5, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane, and Case 6, a Class 4 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 154: bio-hygrothermal simulation results from southern oriented 7 Star AAC clad wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
RR2 7 Star	Yes	Class 3 (1398)	Nil	<1	>3	>5
Case 1	Yes	Class 3 (1398)	Nil	>4	>5	6
Case 2	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 3	Yes	Class 4-2 (100)	Nil	>3	>5	6
Case 4	Yes	Class 4-3 (21)	Nil	>3	>4	>5
Case 5	Yes	Class 3(1398)	Yes	<1	<1	<1
Case 6	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star autoclaved aerated concrete (AAC) clad external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star autoclaved aerated concrete (AAC) clad external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 155 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star autoclaved aerated concrete (AAC) clad external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 155 shows that:

- For ACR 10, nine external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, five external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, three external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 155 shows that:

- For ACR 10, five external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, four external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, one external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 155: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 autoclaved aerated concrete (AAC) clad external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	Yes	Nil	17%	0%	0%		17%	0%	0%
Class 4-1 (175.4)	Yes	Nil	33%	17%	0%		33%	0%	0%
Class 4-2 (100)	Yes	Nil	50%	33%	0%		33%	17%	0%
Class 4-3 (21)	Yes	Nil	50%	33%	0%		33%	33%	0%
Class 1 (200000)	Yes	Yes	33%	33%	0%		33%	17%	0%
Class 3 (1398)	Yes	Yes	83%	100%	33%		83%	100%	33%
Class 4 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of building airtightness and its link to risks of interstitial mould. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and autoclaved aerated concrete (AAC) clad external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria.

NCC climate zone 6 & 7

Table 156 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 autoclaved aerated concrete (AAC) clad external wall system located within NCC climate zone 6 & 7. Table 156 shows that:

- For ACR 10, eight external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, six external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, four external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 156 shows that:

- For ACR 10, seven external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, five external wall system scenarios in the eight simulated climates had a MI of <1.0, and
- For ACR 5, three external wall system scenarios in the eight simulated climates had a MI of <1.0.

Table 156: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star autoclaved aerated concrete (AAC) clad external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 3 (1398)	Yes	Nil	50%	25%	0%		38%	0%	0%
Class 4-1 (175.4)	Yes	Nil	50%	25%	0%		38%	0%	0%
Class 4-2 (100)	Yes	Nil	69%	31%	0%		50%	13%	0%
Class 4-3 (21)	Yes	Nil	75%	50%	0%		50%	25%	0%
Class 3 (1398)	Yes	Yes	100%	100%	100%		100%	100%	100%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

These results clearly show the impact of different water vapour diffusion resistivity properties of the external pliable membrane, the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and autoclaved aerated concrete (AAC) clad external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria.

4.9 Flat sheet-metal cladding with insulated timber frame

This section presents the hygrothermal and bio-hygrothermal results for the enhancements to the southern oriented 6 Star and 7 Star flat sheet-metal clad external wall systems. The complete set of MI graphs for this wall system are in Appendix 9. The results from NCC Climate Zone 4 are presented first, followed by NCC climate zone 6 & 7.

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 4, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 157 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 4, NatHERS climate zone 27. The simulation results show:

- For ACR 10, Cases 8 to 14 provided a MI of <3 and <1.
- For ACR 7.5, Cases 8, 9 and 14 provided a MI of <3 and <1.
- For ACR 5, only Case 14, a Class 3 (1398) membrane, with a vented and drained cavity, with an interior vapour control membrane provided and MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 157: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 27, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	>3		5
Case 1	No	Class 1 (200000)	Nil	>5	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	>3	>5	>5
Case 2	No	Class 3 (1398)	Nil	>5	6	6
Case 3	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 4	No	Class 4-2 (100)	Nil	>5	6	6
Case 5	No	Class 4-3 (21)	Nil	>5	6	6
Case 6	Yes	Class 1 (200000)	Nil	>4	>5	6
Case 7	Yes	Class 3 (1398)	Nil	>3	>5	6
Case 8	Yes	Class 4-1 (175.4)	Nil	<1	<1	6
Case 9	Yes	Class 4-2 (100)	Nil	<1	<1	6
Case 10	Yes	Class 4-3 (21)	Nil	<1	>3	>5
Case 11	No	Class 1 (200000)	Yes	<1	>4	6
Case 12	No	Class 3 (1398)	Yes	<1	>4	6
Case 13	Yes	Class 1 (200000)	Yes	<1	>4	6
Case 14	Yes	Class 3 (1398)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 4, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 158 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 4, NatHERS climate zone 61. The simulation results show:

- For ACR 10, only Case 14, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, no Cases provided an MI of <3 or <1.
- For ACR 5, no Cases provided an MI of <3 or <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.
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Table 158: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 61, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	5		5
Case 1	No	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	<5	>5	>5
Case 2	No	Class 3 (1398)	Nil	6	6	6
Case 3	No	Class 4-1 (175.4)	Nil	6	6	6
Case 4	No	Class 4-2 (100)	Nil	6	6	6
Case 5	No	Class 4-3 (21)	Nil	6	6	6
Case 6	Yes	Class 1 (200000)	Nil	6	6	6
Case 7	Yes	Class 3 (1398)	Nil	>5	6	6
Case 8	Yes	Class 4-1 (175.4)	Nil	>4	>5	6
Case 9	Yes	Class 4-2 (100)	Nil	5	>5	6
Case 10	Yes	Class 4-3 (21)	Nil	>5	>5	>5
Case 11	No	Class 1 (200000)	Yes	6	6	6
Case 12	No	Class 3 (1398)	Yes	6	6	6
Case 13	Yes	Class 1 (200000)	Yes	>5	6	6
Case 14	Yes	Class 3 (1398)	Yes	<1	>3	>5

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 4, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 159 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 4, NatHERS climate zone 66. The simulation results show:

- For ACR 10, only Case 14, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane provided a MI of <3 and <1.
- For ACR 7.5, no Cases provided an MI of <3 or <1.
- For ACR 5, no Cases provided an MI of <3 or <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.

Table 159: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 66, NCC CZ 4 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 1 (200000)	Nil	5		5
Case 1	No	Class 1 (200000)	Nil	6	6	6
RR2 7 Star	No	Class 3 (1398)	Nil	>5	>5	>5
Case 2	No	Class 3 (1398)	Nil	6	6	6
Case 3	No	Class 4-1 (175.4)	Nil	6	6	6
Case 4	No	Class 4-2 (100)	Nil	6	6	6
Case 5	No	Class 4-3 (21)	Nil	6	6	6
Case 6	Yes	Class 1 (200000)	Nil	6	6	6
Case 7	Yes	Class 3 (1398)	Nil	6	6	6
Case 8	Yes	Class 4-1 (175.4)	Nil	>5	6	6
Case 9	Yes	Class 4-2 (100)	Nil	>5	6	6
Case 10	Yes	Class 4-3 (21)	Nil	>5	>5	>5
Case 11	No	Class 1 (200000)	Yes	6	>5	6
Case 12	No	Class 3 (1398)	Yes	6	6	6
Case 13	Yes	Class 1 (200000)	Yes	6	6	6
Case 14	Yes	Class 3 (1398)	Yes	<1	4	>5

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 21

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 160 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 21. The simulation results show:

- For ACR 10, Cases 6 to 8, 11 and 12 provided a MI of <3 and <1.
- For ACR 7.5, Cases 6 to 8, 11 and 12 provided a MI of <3 and <1.
- For ACR 5, Cases 8, 11 and 12 provided a MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.

Table 160: Bio-hygrothermal results from southern oriented 6 Star sheet-metal cladding wall systems NatHERS CZ 21, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3		5
Case 1	No	Class 3 (1398)	Nil	5	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<3.5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	5	6	6
Case 3	No	Class 4-2 (100)	Nil	5	6	6
Case 4	No	Class 4-3 (21)	Nil	5	6	6
Case 5	Yes	Class 3 (1398)	Nil	3	5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	<1	<1	>4
Case 7	Yes	Class 4-2 (100)	Nil	<1	<1	>3
Case 8	Yes	Class 4-3 (21)	Nil	<1	<1	<1
Case 9	No	Class 3 (1398)	Yes	>3	5	6
Case 10	No	Class 4-1 (175.4)	Yes	>3	5	6
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 22

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 161 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 22. The simulation results show:

- For ACR 10, only Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) pliable membrane, with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1
- For ACR 7.5, Cases 11 and 12 provided a MI of <3, and only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <1
- For ACR 5, Only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 161: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 22, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		5
Case 1	No	Class 3 (1398)	Nil	6	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	6	6	6
Case 3	No	Class 4-2 (100)	Nil	6	6	6
Case 4	No	Class 4-3 (21)	Nil	6	6	6
Case 5	Yes	Class 3 (1398)	Nil	>5	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	5	6	6
Case 7	Yes	Class 4-2 (100)	Nil	>5	6	6
Case 8	Yes	Class 4-3 (21)	Nil	>5	>5	6
Case 9	No	Class 3 (1398)	Yes	>5	6	6
Case 10	No	Class 4-1 (175.4)	Yes	6	6	6
Case 11	Yes	Class 3 (1398)	Yes	<1	>1 to <3	>5
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 27

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 162 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 27. The simulation results show:

- For ACR 10, Only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 7.5, Case 6, 7, 11 and 12 provided a MI of <3, and only Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <1.
- For ACR 5, only Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.

Table 162: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 27, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3		5
Case 1	No	Class 3 (1398)	Nil	6	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>3	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	6	6	6
Case 3	No	Class 4-2 (100)	Nil	6	6	6
Case 4	No	Class 4-3 (21)	Nil	6	6	6
Case 5	Yes	Class 3 (1398)	Nil	6	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	6	>1 to <3	6
Case 7	Yes	Class 4-2 (100)	Nil	6	>1 to <3	6
Case 8	Yes	Class 4-3 (21)	Nil	6	>5	>5
Case 9	No	Class 3 (1398)	Yes	6	>4	6
Case 10	No	Class 4-1 (175.4)	Yes	6	>4	6
Case 11	Yes	Class 3 (1398)	Yes	>5	<1	<1
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 60

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 163 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 60. The simulation results show:

- For ACR 10, Cases 6, 7, 8, 11 and 12 provided an MI of <3, and Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <1.
- For ACR 7.5, only Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.

Table 163: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 60, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		5
Case 1	No	Class 3 (1398)	Nil	>5	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 3	No	Class 4-2 (100)	Nil	>5	6	6
Case 4	No	Class 4-3 (21)	Nil	>5	6	6
Case 5	Yes	Class 3 (1398)	Nil	5	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>1 to <3	>4	6
Case 7	Yes	Class 4-2 (100)	Nil	<1	>3	6
Case 8	Yes	Class 4-3 (21)	Nil	<1	>5	>5
Case 9	No	Class 3 (1398)	Yes	5	6	6
Case 10	No	Class 4-1 (175.4)	Yes	5	6	6
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 61

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 164 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 61. The simulation results show:

- For ACR 10, only Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 7.5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.

Table 164: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 61, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		5
Case 1	No	Class 3 (1398)	Nil	6	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	>5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	6	6	6
Case 3	No	Class 4-2 (100)	Nil	6	6	6
Case 4	No	Class 4-3 (21)	Nil	6	6	6
Case 5	Yes	Class 3 (1398)	Nil	>5	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>5	>5	6
Case 7	Yes	Class 4-2 (100)	Nil	>5	>5	6
Case 8	Yes	Class 4-3 (21)	Nil	>5	>5	>5
Case 9	No	Class 3 (1398)	Yes	6	6	6
Case 10	No	Class 4-1 (175.4)	Yes	6	6	6
Case 11	Yes	Class 3 (1398)	Yes	<1	>3	5
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 63

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 165 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 63. The simulation results show:

- For ACR 10, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 7.5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.

Table 165: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 63, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		5
Case 1	No	Class 3 (1398)	Nil	6	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	6	6	6
Case 3	No	Class 4-2 (100)	Nil	6	6	6
Case 4	No	Class 4-3 (21)	Nil	6	6	6
Case 5	Yes	Class 3 (1398)	Nil	6	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>5	6	6
Case 7	Yes	Class 4-2 (100)	Nil	>5	6	6
Case 8	Yes	Class 4-3 (21)	Nil	>5	>5	6
Case 9	No	Class 3 (1398)	Yes	6	6	6
Case 10	No	Class 4-1 (175.4)	Yes	6	6	6
Case 11	Yes	Class 3 (1398)	Yes	>3	>4	>5
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 64

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 166 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 64. The simulation results show:

- For ACR 10, Cases 6, 7, 8, 11 and 12 provided a MI of <3, and Cases 8, 11 and 12 provided an MI of <1.
- For ACR 7.5, Cases 8, 11 and 12 provided a MI of <3, and only Case 11 a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane or Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <1.
- For ACR 5, Cases 11 and provided a MI of <3, and only Case 11 a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane or Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 166: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 64, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	>3.5		5
Case 1	No	Class 3 (1398)	Nil	>5	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<3.5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	>5	6	6
Case 3	No	Class 4-2 (100)	Nil	>5	6	6
Case 4	No	Class 4-3 (21)	Nil	>5	6	6
Case 5	Yes	Class 3 (1398)	Nil	5	>5	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>1 to <3	4	5
Case 7	Yes	Class 4-2 (100)	Nil	>1 to <3	>3	>4
Case 8	Yes	Class 4-3 (21)	Nil	<1	>1 to <3	>3
Case 9	No	Class 3 (1398)	Yes	>5	>5	6
Case 10	No	Class 4-1 (175.4)	Yes	>5	>5	6
Case 11	Yes	Class 3 (1398)	Yes	<1	<1	>1 to <3
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

6 Star and 7 Star flat sheet-metal external wall: NCC climate zone 6 & 7, NatHERS climate zone 66

Hygrothermal simulation (moisture accumulation)

There was nil moisture accumulation from the hygrothermal simulations.

Bio-hygrothermal simulation (mould growth)

Table 166 shows the results for enhancements to the 6 Star and 7 Star flat sheet-metal external wall located within NCC climate zone 6 & 7, NatHERS climate zone 66. The simulation results show:

- For ACR 10, only Case 11, a Class 3 (1398) membrane with a vented and drained cavity and an interior vapour control membrane and Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 7.5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- For ACR 5, only Case 12, a Class 4-1 (175.4) membrane with a vented and drained cavity and an interior vapour control membrane provided an MI of <3 and <1.
- Comparing the results from reports 1 and 2, which included the old NatHERS climate data, (with no precipitation) to the results from this stage of the research, which included the new NatHERS climate data (with precipitation data added), the corresponding results show a slightly higher MI.
- This wall system requires further exploration to establish external wall system configurations that may reduce the Mould Index for this wall system in this climate zone.

Table 167: Bio-hygrothermal simulation results from southern oriented 6 Star and 7 Star sheet-metal cladding wall systems NatHERS CZ 66, NCC CZ 6 with rain data.

	Cavity	Exterior membrane	Interior membrane	ACR 10	ACR 7.5	ACR 5
RR1 6 Star	No	Class 3 (1398)	Nil	5		5
Case 1	No	Class 3 (1398)	Nil	6	6	6
RR2 7 Star	No	Class 4-1 (175.4)	Nil	<5	>5	>5
Case 2	No	Class 4-1 (175.4)	Nil	6	6	6
Case 3	No	Class 4-2 (100)	Nil	6	6	6
Case 4	No	Class 4-3 (21)	Nil	6	6	6
Case 5	Yes	Class 3 (1398)	Nil	6	6	6
Case 6	Yes	Class 4-1 (175.4)	Nil	>5	6	6
Case 7	Yes	Class 4-2 (100)	Nil	>5	6	6
Case 8	Yes	Class 4-3 (21)	Nil	>5	>5	6
Case 9	No	Class 3 (1398)	Yes	6	6	6
Case 10	No	Class 4-1 (175.4)	Yes	6	6	6
Case 11	Yes	Class 3 (1398)	Yes	<1	4	>5
Case 12	Yes	Class 4-1 (175.4)	Yes	<1	<1	<1

Summary of results - 6 Star and 7 Star flat sheet-metal clad external wall

This section summarises the hygrothermal and bio-hygrothermal simulation results for the 6 Star and 7 Star flat sheet-metal clad external wall systems. The results from NCC Climate Zone 4 are discussed first, followed by the NCC climate zone 6 & 7 results.

NCC Climate Zone 4

Table 168 shows a summary of the bio-hygrothermal simulation results of <3.0 and <1.0 from the 6 Star and 7 Star flat sheet-metal clad external wall system located within NCC climate Zone 4. The NCC 2022 requires an external wall system to have an MI of <3.0. Table 168 shows that:

- For ACR 10, one external wall system scenarios in the three simulated climates had a MI of <3.0,
- For ACR 7.5, one external wall system scenarios in the three simulated climates had an MI of <3.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had an MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 168 shows that:

- For ACR 10, one external wall system scenarios in the three simulated climates had a MI of <1.0,
- For ACR 7.5, nil external wall system scenarios in the three simulated climates had a MI of <1.0, and
- For ACR 5, nil external wall system scenarios in the three simulated climates had a MI of <1.0.

Table 168: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 flat sheet-metal clad external wall systems NCC CZ 4

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	No	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-2 (100)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-3 (21)	No	Nil	0%	0%	0%		0%	0%	0%
Class 1 (200000)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	Yes	Nil	33%	33%	33%		33%	33%	0%
Class 4-2 (100)	Yes	Nil	33%	33%	33%		33%	33%	0%
Class 4-3 (21)	Yes	Nil	33%	33%	0%		33%	0%	0%
Class 1 (200000)	No	Yes	33%	33%	0%		33%	0%	0%
Class 3 (1398)	No	Yes	33%	33%	0%		33%	0%	0%
Class 1 (200000)	Yes	Yes	33%	33%	0%		33%	0%	0%
Class 3 (1398)	Yes	Yes	100%	100%	33%		100%	33%	33%

As per the wall system description, these simulations are for flat sheet-metal. Flat sheet-metal is often used as a fire management product on external walls. The sheet-metal has a high conductivity value and is vapour impermeable. These results clearly show the impact of the inclusion of a vented and drained cavity behind

the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of building airtightness and its link to risks of interstitial mould. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and flat sheet-metal clad external wall systems are designed in a climatically appropriate manner for NCC CZ4 in Victoria. Furthermore, there is an extensive range of profiled sheet-metal products with varying forms and opportunities for a vented and drained cavity. The simulation Cases which included a vented and drained cavity are a first attempt to assess how profiled sheet metal cladding may perform. The assessment of the water vapour diffusion and mould risk performance for each of these profile shapes is an extensive research task that needs to be undertaken, such that the design and construction professionals can be confident about the specification of these cladding systems.

NCC climate zone 6 & 7

Table 169 shows a summary of the bio-hygrothermal simulation results for a MI of <3.0 and <1.0 from the 6 Star and 7 flat sheet-metal clad external wall system located within NCC climate zone 6 & 7.

Table 169: Summary of Bio-hygrothermal simulation mould index results from southern oriented 6 Star and 7 Star flat sheet-metal clad external wall systems NCC CZ 6

Exterior membrane	Cavity	Interior membrane	Mould Index <3.0				Mould Index <1.0		
			ACR10	ACR7.5	ACR10		ACR10	ACR7.5	ACR10
Class 3 (1398)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-2 (100)	No	Nil	0%	0%	0%		0%	0%	0%
Class 4-3 (21)	No	Nil	0%	0%	0%		0%	0%	0%
Class 3 (1398)	Yes	Nil	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	Yes	Nil	38%	25%	0%		13%	13%	0%
Class 4-2 (100)	Yes	Nil	38%	25%	0%		25%	13%	0%
Class 4-3 (21)	Yes	Nil	38%	25%	13%		38%	13%	13%
Class 3 (1398)	No	Yes	0%	0%	0%		0%	0%	0%
Class 4-1 (175.4)	No	Yes	0%	0%	0%		0%	0%	0%
Class 3 (1398)	Yes	Yes	75%	63%	38%		75%	50%	25%
Class 4-1 (175.4)	Yes	Yes	100%	100%	100%		100%	100%	100%

Table 169 shows that:

- For ACR 10, one external wall system scenarios in the eight simulated climates had a MI of <3.0,
- For ACR 7.5, one external wall system scenarios in the eight simulated climates had a MI of <3.0, and
- For ACR 5, one external wall system scenarios in the eight simulated climates had a MI of <3.0.

Even though the NCC 2022 requires an external wall system to have an MI of <3.0, the simulation software and its linked national and international standards clearly state that when a simulated wall system has a MI of >1.0 but <3.0 further investigation should occur. Table 169 shows that:

- For ACR 10, one external wall system scenarios in the eight simulated climates had a MI of <1.0,
- For ACR 7.5, one external wall system scenarios in the eight simulated climates had a MI of <1.0, and

- For ACR 5, one external wall system scenarios in the eight simulated climates had a MI of <1.0.

As per the wall system description, these simulations are for flat sheet-metal. Flat sheet-metal is often used as a fire management product on external walls. The sheet-metal has a high conductivity value and is vapour impermeable. These results clearly show the impact of the inclusion of a vented and drained cavity behind the cladding system and the inclusion of an interior vapour control layer. The results also clearly show the impact of building airtightness and its link to risks of interstitial mould. The results clearly indicate that further research needs to occur which explores exterior pliable membranes and wall system configurations to ensure durable and mould free timber framed, and flat sheet-metal clad external wall systems are designed in a climatically appropriate manner for NCC CZ6 in Victoria. Furthermore, there is an extensive range of profiled sheet-metal products with varying forms and opportunities for a vented and drained cavity. The simulation Cases which included a vented and drained cavity are a first attempt to assess how profiled sheet metal cladding may perform. The assessment of the water vapour diffusion and mould risk performance for each of these profile shapes is an extensive research task that needs to be undertaken, such that the design and construction professionals can be confident about the specification of these cladding systems.

Results Summary

The results section summarises the 4310 hygrothermal and 4310 bio-hygrothermal simulations of the nine external wall systems within eight of the NatHERS climates of Victoria. All external wall systems were simulated in the non-equatorial south facing orientation. Research Report 1 and Research Report 2 identified that the non-equatorial oriented wall system demonstrated the highest moisture and mould growth risks. The base cases for each of the nine external wall systems applied the built fabric as described in Research Report 1 for the 6 Star systems and Research Report 2 for the 7 Star systems. Each wall system was then subject to the addition of an increasingly water vapour permeable external membrane, a vented and drained cavity behind the cladding system and an interior vapour control membrane. Whereas Research Report 1 and Research Report 2 applied the 2002 to 2022 NatHERS RMY climate data that did not include hourly precipitation data, this report included the 2022 NatHERS RMY climate data with precipitation data added.

The NatHERS climate type that each wall system was located within also played a significant role. Subject to NatHERS climate each external wall system's simulated mould growth index varied significantly. A warm and dry climate like NatHERS CZ 27 generally showed the lowest calculated Mould Index values. A cooler climate like NatHERS CZ 66 showed the highest calculated Mould Index values. These differences are quite evident when comparing results from warm and low humidity climates to results from cooler and more humid climates. This highlights that the current NCC climate zone classifications for Victoria may be inadequate for specifying requirements to mitigate moisture and mould risks in external wall systems. In this research it was identified that NCC climates crossed boundaries with NatHERS climates such that NCC CZ4, a temperate and dry climate included NatHERS CZ 66, one of the coolest climate types.

In all scenarios, as the external wall system was made more airtight; from ACR10@n50 to ACR7.5@n50 to ACR5@n50, they generally required a vented and drained cavity, and a more water vapour permeable external weather resistive membrane. In the cooler NCC CZ6 type climates and more humid climates, an interior vapour control membrane was also needed to ensure that the calculated Mould Index could remain below 3. When the ACR@n50 was set to 5.0, the most suitable wall systems often included a vented and drained cavity, a vapour permeable external membrane and an interior vapour control membrane.

The other significant differences in simulated mould growth, related to external wall systems ability to retain moisture. This was most evident in the clay masonry veneer and autoclaved aerated concrete results. The moisture retained in the unpainted clay masonry bricks was continuously increased. This was not condensation but moisture retention within the clay brick. The moisture was provided by the site conditions (rain and exterior relative humidity) and the interior conditions (relative humidity diffusing through the external wall system. A similar pattern was observable in the concrete block masonry but as this had an external surface was painted, the impact of exterior moisture was reduced. Recent and soon to be published research from Canada, Belgium and New Zealand has also identified issues regarding moisture retention in clay masonry external wall systems.

NCC Climate Zone 4

Table 170 shows a summary of the simulation results for the nine external wall systems located within NatHERS climate zones 27, 61 and 66 and applying the principles of NCC climate zone 4. The light blue filled row represents requirements for the non-clay masonry construction systems within NCC 2019. The light purple filled row represents requirements for the non-masonry construction systems within NCC 2022. This shows that only 43% of the non-masonry external wall systems, when constructed to NCC2022, achieved a Mould Index of <3 when the ACR@n50 was 10. When the ACR@n50 was reduced to 7.5 and 5, the number of wall systems with a MI of <3 reduced to 17% and 0% respectively.

Exploring this in a vertical fashion, if the water vapour diffusion properties are increased from the light purple NCC 2022 requirement to a Class 4-1 membrane, as shown in the green cell, the number of wall systems that have a MI of <3 increases to 57%, and if a cavity is added, (as shown in the red cell), this

increases to 67%. To exceed 85%, as shown in the brown cell (Class 4-3 21 exterior membrane with a cavity), an interior vapour control membrane needs to be included (as shown in the orange cell).

Table 170: Summary of external wall system results for NCC Climate Zone 4

Exterior membrane	Vented and drained cavity	Interior vapour control membrane	Percentage of simulations with a MI ⩽3				Percentage of simulations with a MI ⩽1		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 1 (200000)	No	Nil	42% (10/24)	8% (2/24)	0% (0/24		42% (10/24)	8% (2/24)	0% (0/24)
Class 3 (1398)	No	Nil	43% (13/30)	17% (5/30)	0% (0/30)		40% (12/30)	13% (4/30)	0% (0/30)
Class 4-1 (175.4)	No	Nil	57% (17/30)	20% (6/30)	3% (1/30)		47% (14/30)	10% (3/30)	0% (0/30)
Class 4-2 (100)	No	Nil	60% (18/30)	20% (6/30)	3% (1/30)		47% (14/30)	13% (4/30)	0% (0/30)
Class 4-3 (21)	No	Nil	60% (18/30)	23% (7/30)	3% (1/30)		47% (14/30)	17% (5/30)	3% (1/30)
Class 1 (200000)	Yes	Nil	24% (8/30)	6% (2/30)	0% (0/30)		15% (5/30)	3% (1/30)	0% (0/30)
Class 3 (1398)	Yes	Nil	33% (13/39)	8% (3/39)	0% (0/39)		23% (9/39)	8% (3/39)	0% (0/39)
Class 4-1 (175.4)	Yes	Nil	67% (26/39)	54% (21/39)	21% (8/39)		62% (24/39)	44% (17/39)	15% (6/39)
Class 4-2 (100)	Yes	Nil	74% (29/39)	62% (24/39)	38% (15/39)		67% (26/39)	56% (22/39)	23% (9/39)
Class 4-3 (21)	Yes	Nil	85% (33/39)	69% (27/39)	51% (20/39)		74% (29/39)	64% (25/39)	51% (20/39)
Class 1 (200000)	No	Yes	63% (15/24)	25% (6/24)	0% (0/24)		50% (12/24)	25% (6/24)	0% (0/24)
Class 3 (1398)	No	Yes	87% (26/30)	60% (18/30)	40% (12/30)		67% (20/30)	50% (15/30)	27% (8/30)
Class 1 (200000)	Yes	Yes	57% (17/30)	33% (10/30)	3% (1/30)		43% (13/30)	23% (7/30)	0% (0/30)
Class 3 (1398)	Yes	Yes	94% (34/36)	89% (32/36)	61% (22/36)		94% (34/36)	78% (28/36)	50% (18/36)

As the NCC 2022 deemed to satisfy provisions only require a Class 3 pliable weather resistive membrane, this stage of the research only explored if a good result could be achieved using a Class 3 weather resistive pliable membrane combined with a cavity and an interior vapour control membrane. This configuration is what was described above and is in the orange coloured cell. Further research for the NCC CZ4 external wall systems needs to explore what benefits may occur if a Class 4 weather resistive pliable membrane is applied, instead of the Class 3 membrane, and is combined with an interior vapour control layer. Additionally, a Class 3 membrane has a water vapour diffusion resistivity range from 176 to 1398. A very water vapour open Class 3 pliable membrane may have a very similar result to the Class 4-1 (175.4) pliable

weather resistive membrane. This aspect needs to be explored in more detail for warmer and dryer climates of Victoria.

The green and red cells allow us to explore the impact of the vented and drained cavity behind the cladding system. The green cell does not include a cavity and 57% of simulated wall systems with a MI of <3. The red cell, which is the same built fabric as the green cell but also includes a vented and drained cavity, shows an increase in the number of simulated wall systems with an MI of <3 increase to 67%. The cavity allows outward bound water vapour and inward bound moisture to leave the built fabric in a structured manner. This method of construction also separates the cold cladding system from the insulation layer. This allows the insulation layer to stay warmer, further mitigating moisture and mould. Interestingly, the scenario just above the red cell is a Class 3 (1398) membrane which shows only 33% of simulated wall systems with an MI of <3. This result is worse than the same system without a vented and drained cavity (light purple). This may be caused due to the restricted flow of water vapour diffusion promoting a moister condition within the external wall system. This aspect requires further investigation.

However, a key concern for energy efficient homes is the need to move from 10 ACR@n50 down to 5ACR@n50. The two grey cells show that the optimal wall system with a Class 3 pliable membrane only achieves 61% of Cases with an MI of >3 and 50% when the MI is <1. The reason for including the MI <1 data, even though the NCC describes the verification method with a MI of <3, is that the software and its associated international guidelines clearly state if a wall system has a simulated MI >1 but <3, further analysis needs to be completed. This is due to the software simulating a perfect wall, and rarely is a perfect wall constructed. This further indicates the need for a broad range of external wall system configurations for NCC CZ4.

NCC climate zone 6 & 7

Table 171 shows a summary of the simulation results for the nine external wall systems located within NatHERS climate zones 21, 22, 27, 60, 61, 63, 64 and 66 and applying the principles of NCC climate zone 6. The light blue filled row represents requirements for the non-clay masonry construction systems within NCC 2019. The light purple filled row represents requirements for the non-clay masonry construction systems within NCC 2022. The purple highlight shows that only 53% of external wall systems, with an ACR10@n50, that do not require a vented and drained cavity, but do require a class 4 pliable membrane achieved a MI of <3. In the walls without a vented and drained cavity, increasing the water vapour diffusion properties of the exterior membrane has, for ACR10, 7.5 and 5, only increases the number of scenarios with a MI of <3 by 7%, 5% and 1% respectively.

Exploring this in a vertical fashion, if a vented and drained cavity behind the cladding system is added, (as shown in the red cell), this increases to 67%. To exceed 85%, as shown in the brown cell (Class 4-3 21 exterior membrane with a cavity), an interior vapour control membrane needs to be included (as shown in the orange cell).

If we presume that homes in Victoria are being constructed to an ACR of 7.5, and for more than 90% of wall systems to have an MI of <3, the external wall system needs to comprise a Class 3 or a Class 4 exterior weather resistive pliable membrane, a vented and drained cavity and interior vapour control membrane.

The light purple and red cells allow us to explore the impact of the vented and drained cavity behind the cladding system. The purple cell does not include a cavity and 53% of simulated wall systems with a MI of <3. The red cell, which is the same built fabric as the green cell but also includes a vented and drained cavity, shows an increase in the number of simulated wall systems with an MI of <3 increase to 69%. The cavity allows outward bound water vapour and inward bound moisture to leave the built fabric in a structured manner. This method of construction also separates the cold cladding system from the insulation layer. This allows the insulation layer to stay warmer, further mitigating moisture and mould. Interestingly, the scenario just above the red cell is a Class 3 (1398) membrane which shows only 53% of simulated wall systems with an MI of <3. This result is the same as the system without a vented and drained cavity (light

purple). This may be caused due to the restricted flow of water vapour diffusion promoting a moister condition within the external wall system. This aspect requires further investigation.

Table 171: Summary of external wall system results for NCC climate zone 6 & 7

Exterior membrane	Vented and drained cavity	Interior vapour control membrane	Percentage of simulations with a MI ⩽3				Percentage of simulations with a MI ⩽1		
			ACR10	ACR7.5	ACR5		ACR10	ACR7.5	ACR5
Class 3 (1398)	No	Nil	63% (30/48)	42% (20/48)	0% (0/48)		46% (22/48)	21% (10/48)	0% (0/48)
Class 4-1 (175.4)	No	Nil	53% (42/80)	30% (24/80)	1% (1/80)		41% (33/80)	18% (14/80)	0% (0/80)
Class 4-2 (100)	No	Nil	58% (46/80)	30% (24/80)	3% (2/80)		45% (36/80)	18% (14/80)	3% (2/80)
Class 4-3 (21)	No	Nil	59% (47/80)	33% (26/80)	4% (3/80)		46% (37/80)	20% (16/80)	3% (2/80)
Class 3 (1398)	Yes	Nil	53% (34/64)	25% (16/64)	0% (0/64)		44% (28/64)	9% (6/64)	0% (0/64)
Class 4-1 (175.4)	Yes	Nil	69% (72/104)	52% (54/104)	24% (25/104)		61% (63/104)	39% (41/104)	19% (20/104)
Class 4-2 (100)	Yes	Nil	78% (81/104)	63% (65/104)	39% (41/104)		69% (72/104)	55% (57/104)	29% (30/104)
Class 4-3 (21)	Yes	Nil	87% (90/104)	75% (78/104)	57% (59/104)		77% (80/104)	66% (69/104)	55% (57/104)
Class 3 (1398)	No	Yes	83% (40/48)	75% (36/48)	48% (23/48)		73% (35/48)	63% (30/48)	29% (30/48)
Class 4-1 (175.4)	No	Yes	89% (71/80)	81% (65/80)	60% (48/80)		75% (60/80)	68% (54/80)	41% (33/80)
Class 3 (1398)	Yes	Yes	97% (62/64)	94% (60/64)	84% (54/64)		95% (61/64)	91% (58/64)	77% (49/64)
Class 4-1 (175.4)	Yes	Yes	96% (100/104)	96% (100/104)	96% (100/104)		96% (100/104)	96% (100/104)	96% (100/104)

However, a key concern for energy efficient homes is the need to move from 10 ACR@n50 down to 5ACR@n50. The two grey cells show that the optimal wall system with a Class 4 pliable membrane achieves 96% of Cases with an MI of >3 and 96% when the MI is <1. This is a good result, however the 4% of wall systems That are still failing the test need further investigation. The reason for including the data from MI <1, even though the NCC describes the verification method with a MI of <3, the software and its associated international guidelines clearly state if a wall system has a simulated MI >1 but <3, further analysis is needed. This is due to the software simulating a perfect wall, and rarely is a perfect wall constructed. This further indicates the need for a broad range of external wall system configurations for NCC CZ6.

Climate Data

The other key difference between Research Reports 1 and 2 and this report is the adoption of the NCC NatHERS 2022 RMY climate data, with hourly precipitation data added. Research Reports 1 and 2, noted

that the simulated Mould Index results may be conservative due to the non-inclusion of hourly rain data. Within this report:

- Research Report 1 and Research Report 2, (which used the pre 2022 NatHERS climate data, with no rain) often had similar results,
- In this report, some base case simulations, (which used the 2022 Nathers data, with hourly rain data added), had slightly higher MI results than Research Report 1 and Research Report 2, and
- In this report, most base case simulations, (which used the 2022 Nathers data, with hourly rain data added), had a significantly higher MI result than Research Report 1 and Research Report 2.

In some climate types, some wall systems struggled to achieve a suitable MI of <3. This led to a preliminary analysis of the NatHERS RMY climate data. The method of selecting RMY average months applies a weighted statistical method that prioritises air temperature and solar radiation. Table 172 shows a summary of the NatHERS climate zone 61 2002-2022 RMY climate data and the 2022 NatHERS RMY climate data with hourly precipitation data added. The mean, minimum and maximum temperatures are similar. The mean, minimum and maximum relative humidity conditions are similar. The mean wind speeds are reasonably similar. To be expected, the precipitation data is very different. Surprisingly, the radiation data is very different. The combination of hourly precipitation data and the much lower radiation data would significantly impact the wetting and drying processes of external wall systems and their capacity to diffuse water vapour.

Table 172: Mean climate data for NatHERS climate zone 61

Climatic value	NatHERS 2002 to 2022 RMY data	NatHERS 2022 RMY data with hourly precipitation data added
Mean Temperature (°C)	13	13.2
Max Temperature (°C)	42.3	40.2
Min Temperature (°C)	0.4	-1
Counter radiation sum (kWh/m2a)	2864.3	1751.8
Mean cloud index	0.5	-1
Mean relative humidity (%)	75.7	76.2
Max relative humidity (%)	100	100
Min relative humidity (%)	8	6
Mean wind speed (m/s)	4	4.4
Normal rain (mm/a)	0	743.4

The bio-hygrothermal simulations for the clay masonry veneer external wall systems provided quite high MI values. This could relate the combination of the rain data, as unpainted clay masonry will absorb significant amounts of moisture. This could be further posited based on the simulation results for the concrete masonry and autoclaved aerated concrete external wall systems, which were simulated with an acrylic façade paint, which would significantly lessen opportunities for moisture inward adsorption.

These differences in precipitation and solar radiation data would also explain the general increase of MI values across most of the bio-hygrothermal simulations.

Software limitations

It should be noted that there are several limitations to the results from this research, including:

- the physical properties of the materials simulated. If water vapour diffusion resistivity value of a material is higher than what has been simulated, the element may then trap more water vapour within the wall system leading to mould growth and/or moisture accumulation. Conversely, if water vapour diffusion resistivity value of a material is lower than what has been simulated, the element may then allow more water vapour to leave the wall system leading to lower mould growth and/or moisture accumulation.
- as per international requirements, the software has a cap on the interior relative humidity of 70%. However, as there is no numerical requirement for interior relative humidity control in Australian homes. Academic and business based researchers have measured interior relative humidity conditions well over 70% and 80% in many homes. This elevated relative humidity condition would create a greater mould growth risk than what the software currently simulates.
- the climate data used in the research has applied average climate data. Simulations that include extreme weather events would create different moisture accumulation and mould growth results.
- if a home was heated to more than 20^0C, the vapour load within the home would increase, leading to a greater risk of mould growth.
- the software is simulating a 'perfect wall'. However, walls are rarely made perfectly. Subject to construction practices, a wall may be less, or more insulated, may be less or more leaky, or may allow for a greater ingress of moisture.

Each of these scenarios would increase risks associated with moisture and mould. Within this context, the results presented here may be conservative.

6. Conclusion and recommendations

This first stage of the research, as documented in Research Report 1, examined if a 'code-compliant' external wall system for a Class 1 and 2 buildings constructed in accordance with NCC 2019 6 Star requirements, located within Victoria may or may not promote moisture accumulation and/or mould growth. That report identified significant mould growth risk for the common external wall systems used for Class 1 and Class 2 buildings in Victoria.

The focus of this second stage of the research, examined if a 'code-compliant' external wall system for a Class 1 and 2 buildings constructed in accordance with draft NCC 2022 for a 7 Star home, located within Victoria may or may not promote moisture accumulation and/or mould growth. That report identified that the requirement for a Class 3 exterior membrane for NCC climate zone 4, and a Class 4 exterior membrane for NCC climate zones 6 to 8, provided improved results when compared the Research report 1.

The focus of Research Report 3, was to further explore options regarding exterior membrane water vapour permeability, vented and drained cavities and interior vapour control layers, to reduce the simulated occurrences of interstitial mould growth identified in Research Report 1 and Research Report 2. The other significant difference planned for Research Report 3 (this report) was the inclusion of hourly precipitation data within the RMY climate data-sets. Due to a NCC update, this process also included the use of the new 2022 NatHERS RMY climate data.

This report has shown that increasing the water vapour permeability of the exterior membrane significantly increases the number of external wall simulations with a Mould Index of <3 and <1.

The results regarding the inclusion of a vented and drained cavity further increased the number of external wall simulations with a Mould Index of <3 and <1. It should be noted that many developed nations treat the external cladding system as a rain control layer and not a water barrier. This is due to the common expectation that moisture forms on the interior surface of cladding systems, and moisture migrates through cladding systems due to a combination of rain and wind pressure. The ability for a cladding system to freely drain this unwanted moisture, without it contacting the next layer of the envelope system provides significant durability benefits.

The results regarding the inclusion of an interior vapour control layer further increased the number of external wall system simulations at achieved a Mould Index of <3 and <1. The results also identified that an external wall system comprising a Class 4-1 (175.4) exterior membrane combined with a vented and drained cavity, and an interior vapour control membrane provided the most examples of a Mould Index of <3 and <1. This combination provided the lowest calculated MI values for Air Change Rates 10, 7.5 and 5 (@n50). The maximum ACR@n50 expected within a new 6 Star or 7 Star house in ACR 10. Anecdotally, it is thought that many new homes in Victoria may have an ACR between 5.0 and 7.5. A new home can have a acr@n50 of <5, but it is then required to have a mechanical ventilation system (such that the interior ventilation is never <5ACR@n50).

Research

The primary focus of this research was to enhance existing external wall construction systems to achieve a Mould Index of <3, or better, for all nine wall systems with the eleven NatHERS and three NCC climate zones. Many wall systems did not achieve this goal. This leads to several aspects that need further research, namely:

- The NCC CZ4 simulations did not include a Class 4 membrane. Many of these wall systems did not achieve an appropriate Mould Index value. A further exploration of Class 4 membranes for external wall systems located within NCC Climate Zone 4 should be undertaken.
- International research has shown that applying a layer of insulation to the exterior of the building

frame further reduces risks associated with interstitial moisture and mould growth risk. This improvement should be applied to wall systems that did not provide an appropriate Mould Index.

- The research identified that the NatHERS RMY climate data for some locations showed a very high relative humidity. This would significantly impact an external wall's ability to remove unwanted water vapour. It needs to be established if the relative humidity data within the selected RMY months best represents the average conditions within these climate zones.
- The poor results for the clay masonry veneer external walls was unexpected. However, a review of recent experiences in Canada and research from Europe has identified significant moisture and mould concerns relating the clay masonry veneer external walls. As this external wall type comprises a large percentage of new buildings, it is a matter of urgency that this external wall system is further analysed and enhanced such that acceptable Mould Index values are achieved. This moisture storage effect is also observable in the results for the aerated autoclaved concreate external wall system.
- The international software tools that provide hygrothermal design guidance have generally been developed in climates much cooler than Australia, where constant conditioning is needed to ensure building interiors are warm. Australia's more temperate climates have led to a 'intermittent' conditioning regime. In hot and humid climates day-time conditioning provides the greatest hygrothermal risk. Whilst in cooler climates, night-time conditioning may provide the greatest hygrothermal risk. Within this context, more complex simulations should be completed that assess the effects of intermittent conditioning on hygrothermal simulation results for climates in southern Australia.
- This research has applied the international requirement that the relative humidity within building interiors does not exceed 70%. Data from previous research has identified that the relative humidity within many Class 1 and Class 2 buildings exceeds this condition. Further hygrothermal simulations need to be completed that include interior relative humidity conditions above 70%RH.
- This research is based on simulations completed by software that has been empirically validated in Europe, England, Canada and the United States of America. Similar forms of empirical validation need to occur within Australia, that explores typical Australian external wall systems.

Regulatory Intervention

This research highlights a few key aspects requiring regulatory intervention, namely;

- Current code compliant construction methods for the nine external wall systems simulated in this research did not provide suitable simulated Mould Index values for south facing wall systems, (and wall systems facing other orientations that are shaded). This indicates that they do not meet the verification method requirements of H4V5 of NCC as prescribed in NCC 2022. This aspect of the national building regulations requires urgent action, prior to Australia experiencing its own 'Leaking building syndrome' or 'condo crisis'.
- Research Report 1 and Research Report 2 applied the NatHERS 2002-2022 RMY climate data (without precipitation data) to the hygrothermal simulations. Research Report 3 applied the 2022 NatHERS RMY climate data (with precipitation data added) to the hygrothermal simulations. The differences highlight the impacts of climate data selection on hygrothermal simulation results. As regulators have identified the need to regulate climate data selection for building energy rating, a similar approach needs to be taken regarding climate data that is used for hygrothermal simulation purposes.
- This research has highlighted the inter-relationship of Health and Amenity and Energy Efficiency

regulations. A key aspect to this research is the rate of air changes per hour within a new Class 1 or Class 2 building. As mentioned above, the hygrothermal simulation software expects that interior relative humidity is kept below 70%. Law and Dewsbury have both identified that when applying the NatHERS method, many locations within Australia have limited times when a window or door should be opened. The Condensation section within Health and Amenity applies the AIRAH DA07 (ASHRAE160) simulation method that expects interior RH to be managed and kept below 70%. The Ventilation section within Health and Amenity includes relative humidity as one of the listed pollutants that must be controlled. The DTS ventilation method within the NCC prescribes the 5% of operable windows/doors for ventilation. However, operating these is likely to conflict with the conditions expected within the Energy Efficiency section. This is before aspects of better air sealing are considered. The hygrothermal simulation software uses the input term Air Exchange per Hour (AER). This represents a combination of building air-sealing (air-tightness) and ventilation. That is, a building may have a measured air tightness of 2 ACR but is required to have a minimum ACR of 5, thus requiring a mechanical ventilation system of 3 ACR. This aspect of the code needs to be improved, such that it recognises contemporary construction and building air-sealing methods.

List of Appendices

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