1 Assembly Modelled

The EcoCocon wall system comprises structural timber-straw wall panels (Figure 1.1) that are available in a variety of shapes (i.e., standard, column, lintel, sill, etc) to facilitate the design and construction of custom home plans. The EcoCocon system is a certified Passivhaus component and has achieved Cradle to Cradle Silver licensing.

Figure 1.1 – 3D representation of an EcoCocon wall panel (left) and photograph of an assembled EcoCocon wall system to form a gable with window.
[both images from EcoCocon]

The building assembly as modelled is summarized in Table 1.1, from exterior to interior. A visual representation of the assembly, taken from WUFI 6.5, is presented in Figure 1.2. Further material data are provided in Appendix A. Additional details about the modelled assembly are provided in Table 2.1 in Section 2 below.

TABLE 1.1 – ASSEMBLY MATERIALS AND DETAILS			
Material Layer (thickness)	Data Source	Summary of Modifications	Additional Details
Scottish Larch cladding (25 mm)	Adapted from *Southern Yellow Pine* from the *North America Database* in WUFI 6.5.3	Density: 550 kg/m^3[1] Thermal conductivity: 0.14 W/m·K[2]	Charred finish
Ventilated gap (50 mm)	*Air Layer 50 mm* from the *Generic Materials Database* in WUFI 6.5.3	None	Air changes/hr: 10
Wood-fiber insulation board (60 mm)	*Wood-fibre Insulation* from the *Fraunhofer-IBP Database* in WUFI 6.5.3	None	-
Weather resistive barrier with max sd=0.2m (0.001 mm)	*Weather resistive barrier (sd=0.2 m*) from the *Fraunhofer-IBP Database* in WUFI 6.5.3	None	-
EcoCocon panel (400 mm)	Adapted from *Straw Bales* from the *Fraunhofer-IBP Database* in WUFI 6.5.3	Density: 100 kg/m^3 Porosity: 0.9 m^3/m^3 Spec. heat capacity: 2000 J/kg·K Thermal conductivity: 0.045 W/m·K VDRF: 1.3	Material data provided by EcoCocon.
Interior plaster (25 mm)	*Interior plaster (gypsum plaster)* from the *Fraunhofer-IBP Database* in WUFI 6.5.3	None	-

[1] Russwood Ltd (2022). *Scottish Larch Cladding: Scotlarch*. Retrieved from: https://www.russwood.co.uk/cladding/products/scotlarch/
[2] Architecture-Design Scotland (nd). *Larch Cladding*. Retrieved from: https://materials.ads.org.uk/larch-cladding/

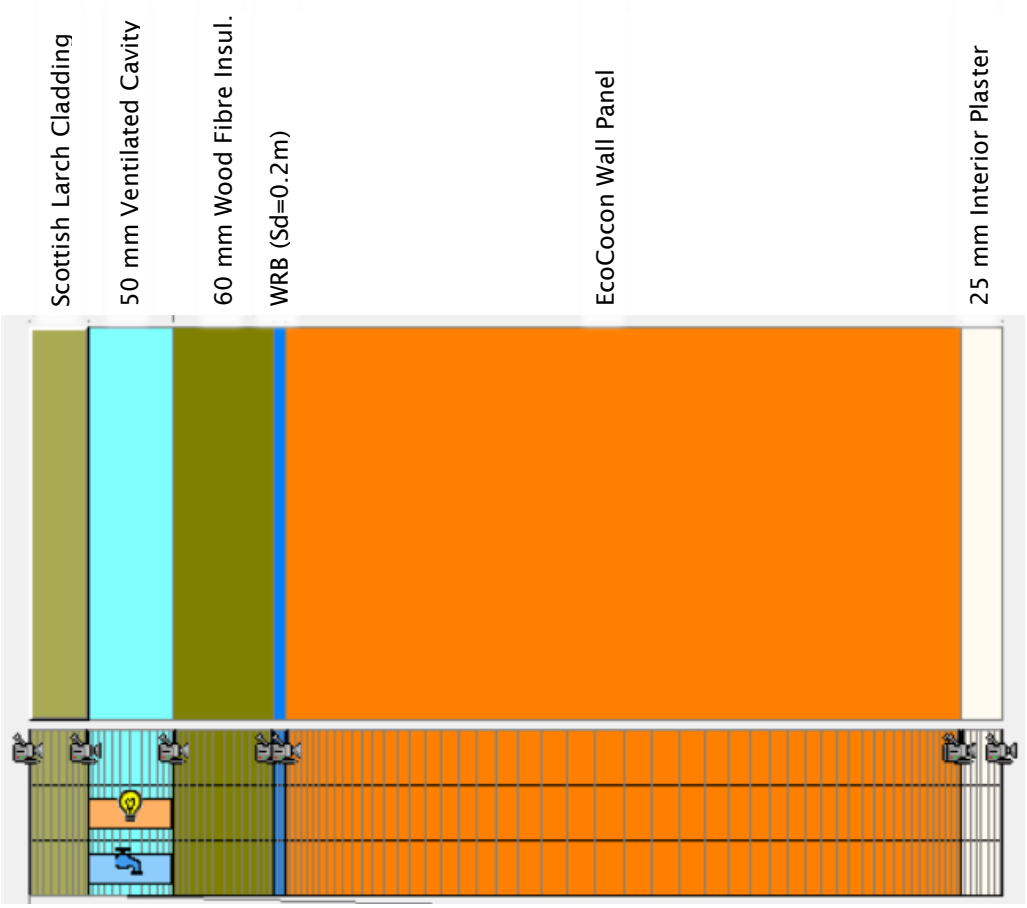

Figure 1.2 – Image of assembly from WUFI.

2 Model Parameters and Building Information

Table 2.1 provides details of the building and modeling parameters. Briefly, the building is a 2-story residential design located in Perth, Scotland. It is new construction. The design is 1056 m^3, containing 5 bedrooms, 4 bathrooms, a kitchen, and additional gathering spaces (i.e., family room and cinema room). The building has an attached garage.

Other important considerations for moisture management include:

- → Indoor Humidity Levels - The warrant drawings indicate mechanical ventilation with a heat recovery unit and exhaust fans in all bathrooms and the kitchen. This analysis assumes these systems are installed and operated to maintain safe indoor humidity conditions (i.e., below 40% RH in winter months; below 70% RH in summer).
- → Door and Window Installation – This analysis assumes the windows are water -penetration resistant and that the installation prevents water leakage into the wall assembly.
- → Construction Moisture Management - The warrant drawings specify that all materials shall be stored in a weather proofed manner. This analysis assumes built-in moisture is at equilibrium with 80% RH (i.e., consistent with requirements of ASHRAE 160).

TABLE 2.1 – MODEL PARAMETERS AND BUILDING INFORMATION		
Criteria	ASHRAE 160 Requirements	Model Parameters
Analytic program	Requirements listed in ASHRAE 160-2021 Section 5	WUFI Pro 6.5.3 – standard program for evaluating moisture conditions in building envelopes. Performs one-dimensional hygrothermal calculations on building component cross-sections. Incorporates all requirements listed in Section 5
Total Model Count	Not specified	4 models
Orientation	Described in ASHRAE 160-2021 Section 4.5.1	Not required based on method selected (chose Weather Data method, Section 4.5.2). However, modelled two orientations to assess performance. - North (least solar radiation) - Southeast (most wind-driven rain)
Interior Design Temperature	Requirements listed in ASHRAE 160-2021 Section 4.2	21˚C ± 2.8˚C Based on design setpoint provided and Table 4.1, Heating Only, where 18.3˚C < $T_{0,24h}$ ≤ 21.1˚C
HVAC Equipment and Controls	Requirements listed in ASHRAE 160-2021 Section 4.3	Mechanical system with heat-recover ventilation. Local exhausts in kitchen and bathrooms. Controls not provided.
Indoor Design Humidity	Requirements listed in ASHRAE 160-2021 Section 4.3.2 and Section 7.4	ASHRAE 160 option in WUFI Pro 6.5, based on Intermediate Method: - Residential occupancy - Number of bedrooms (n = 5) - Air exchange rate (0.3/h) - Building volume (1056 m^3) - No air conditioning
Airflow Effects	Requirements listed in ASHRAE 160-2021 Section 4.4	Not considered (assumes airtight assembly)

Table 2.1 continued

Criteria	ASHRAE 160 Requirements	Model Parameters
Moisture Design Weather Data	Requirements listed in Section 4.5.2 ASHRAE 160-2021	10-year data for Perth, Scotland (Jan 1/2012 to Dec 31/2021; sourced from meteoblue[3] with hourly data comprising air temperature, relative humidity, direct and diffuse solar radiation, average wind speed and direction, air pressure, precipitation, and cloud index) Models run for 10 years (Jan 1/2012 to Dec 31/2021)
Rain Exposure Factor	Requirements listed in Section 4.6 ASHRAE 160-2021	1.0, based on a building height of <10 m and medium exposure category.
Rain Deposition Factor	Requirements listed in Section 4.6 ASHRAE 160-2021	0.35, based on “walls below a steep sloped roof” factor
Rain Penetration	Requirements listed in Section 4.6.1 ASHRAE 160-2021	1% of incident rainwater to be applied to the exterior surface of the water-resistive barrier (as system sensitivity test)

The historical outdoor climate (Jan 1, 2012 to Dec 31, 2021) and modelled indoor climate are presented in Figure 2.1 through Figure 2.3.

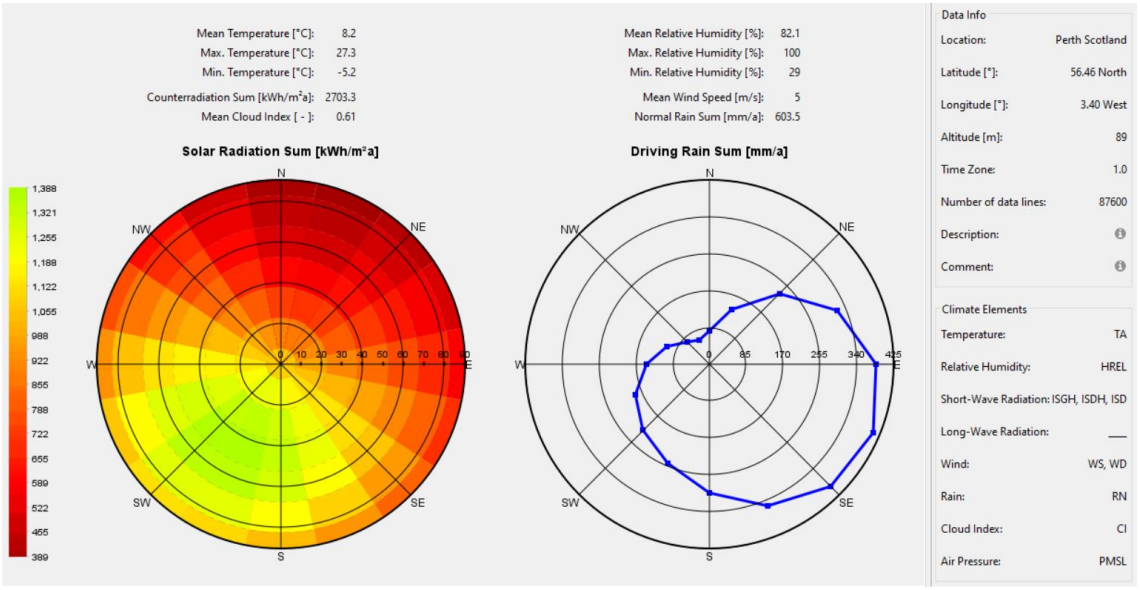

Figure 2.1 – Solar radiation and driving rain data for Perth, Scotland.

[3] https://content.meteoblue.com/en/about-us

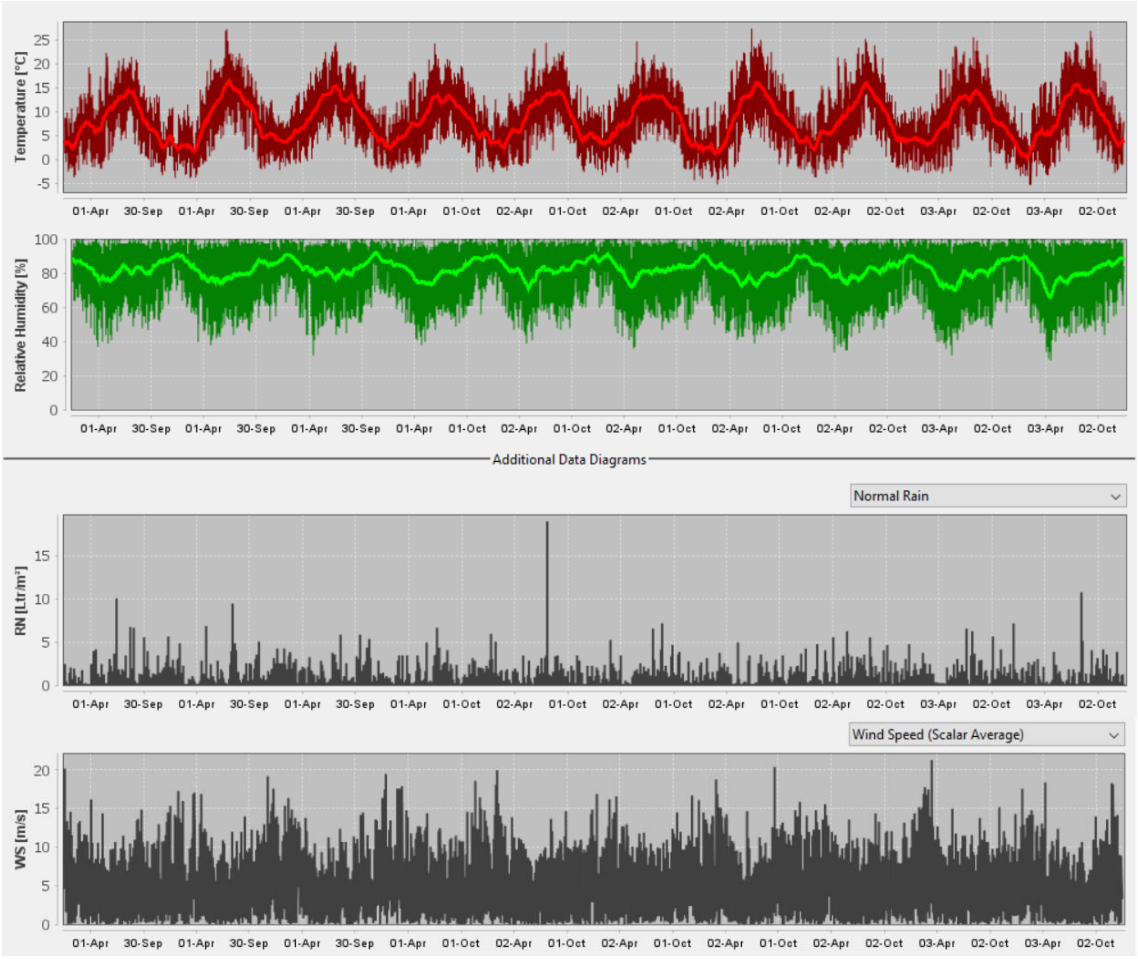

Figure 2.2 – Time series graphs of outdoor temperature, relative humidity, rain, and wind speed for Perth, Scotland.

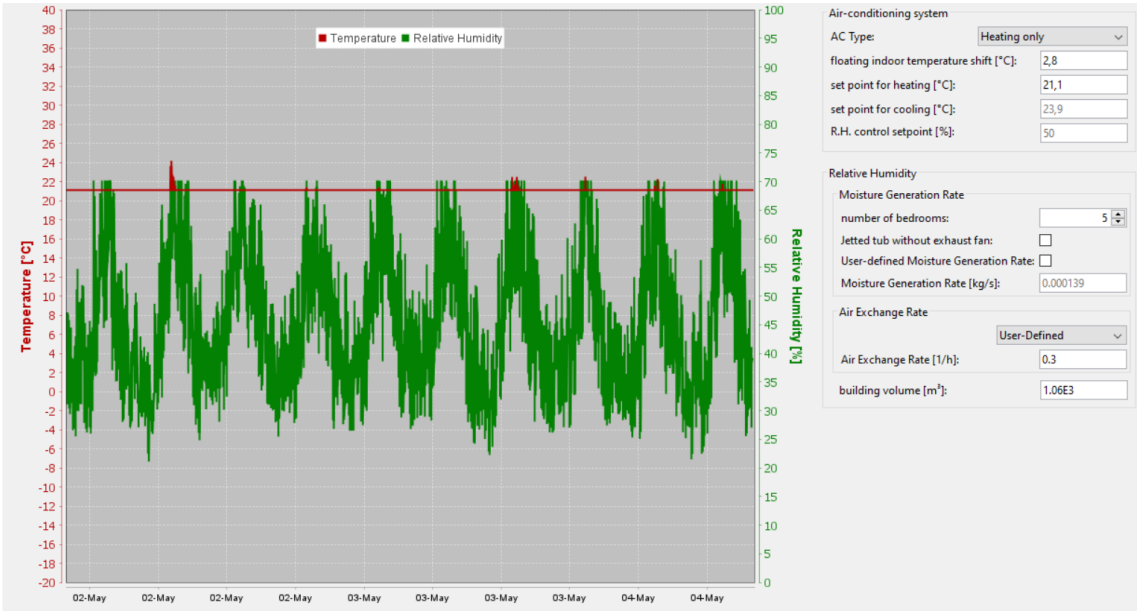

Figure 2.3 – Time series graphs of indoor temperature and relative humditiy conditions.

3 Moisture Performance and Evaluation

ASHRAE 160-2021, Section 6 requires the modelled assembly be evaluated through consideration of several key moisture performance criteria. In this assessment the performance of the EcoCocon assembly was evaluated for undue risk related to moisture accumulation, decay, and mold growth.

3.1 Total water content

In this assessment moisture accumulation was evaluated through consideration of the predicted total water content (TWC) in the assembly. Figure 3.1 presents the predicted TWC for a southeast-facing assembly with no rain leaks and with the ASHRAE 160-2021 prescribed rain leak test of 1% (applied to the outside face of the WRB). In these simulations the built-in moisture is predicted to dry over the first 6 months of operation then the assembly achieves a pseudo-steady state pattern with TWC peaking in the wet season (winter) and drying back out the following summer. Wetter years are predicted to have only slightly larger impact. The 1% rain leak is safely accommodated by the assembly. ***No long-term moisture accumulation is predicted.***

Consideration of North-facing assemblies are presented in Appendix B.

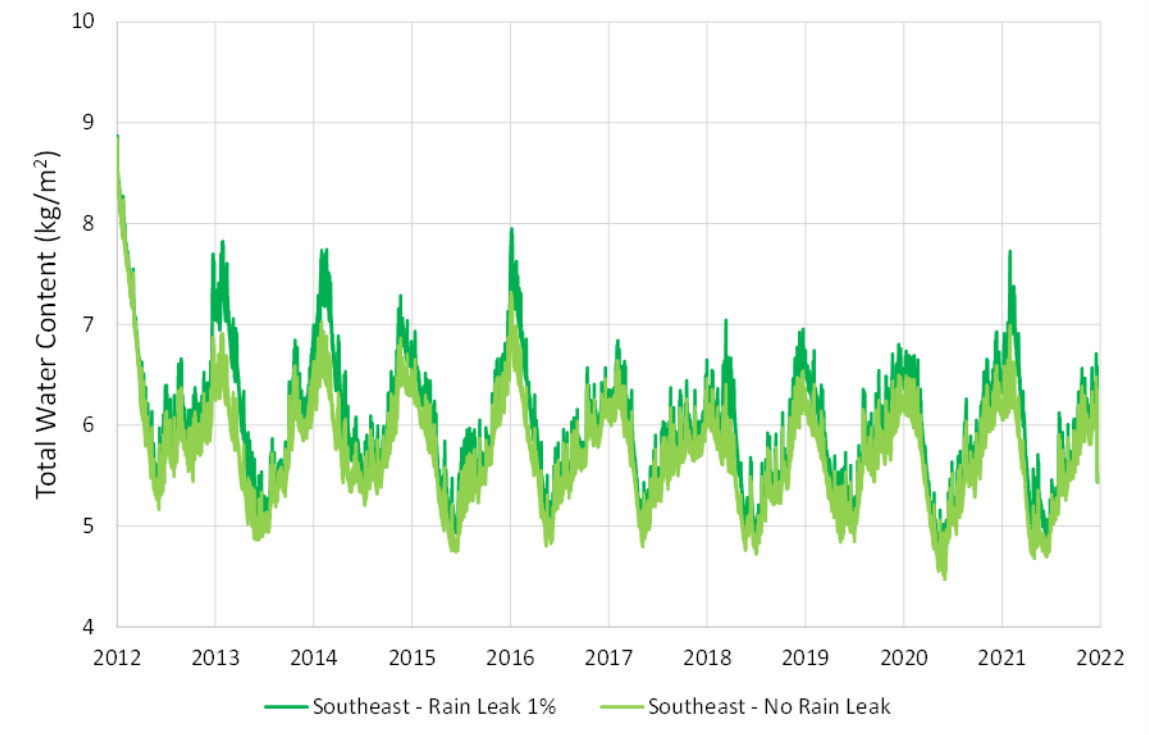

Figure 3.1 – Total water content graph: southeast orientation.

3.2 Moisture Content

ASHRAE 160-2021 requires consideration of the critical moisture content within sensitive material layers. In this assessment moisture content of the wood-fiber-insulation board and EcoCocon straw core were considered. These cellulose-based materials can be susceptible to decay if high moisture levels persist. The time series data are presented in Figure 3.2 and Figure 3.3 and Appendix B. ***Moisture content levels in the wood-fiber and straw layers are predicted to remain below accepted thresholds for decay.***

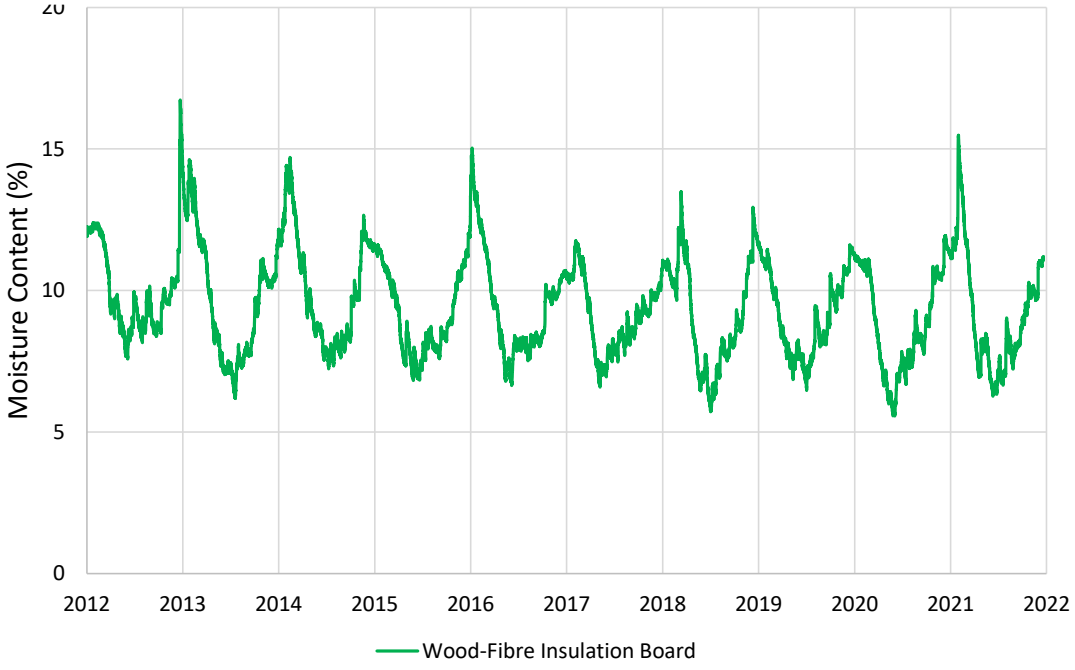

Figure 3.2 – Moisture content graph for wood-fibre insulation board: southeast oriented, 1% rain leak.

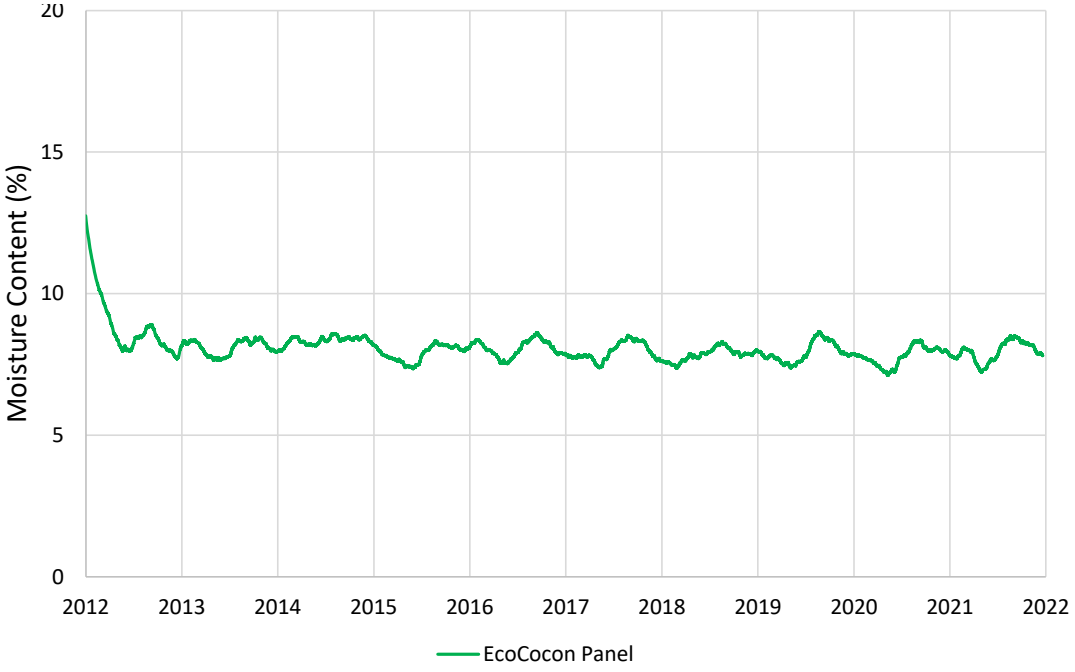

Figure 3.3 – Moisture content graph for EcoCocon panel: southeast oriented, 1% rain leak.

3.3 WUFI Model Videos

The temperature, relative humidity, and moisture content values across the entire modelled assembly were captured in the WUFI 6.5 model videos. Snapshots in time from the videos are presented in Figure 3.4 and Appendix B. These images provide the viewer a sense of the range and spatial distribution of moisture contents over the course of the 10 years simulated.

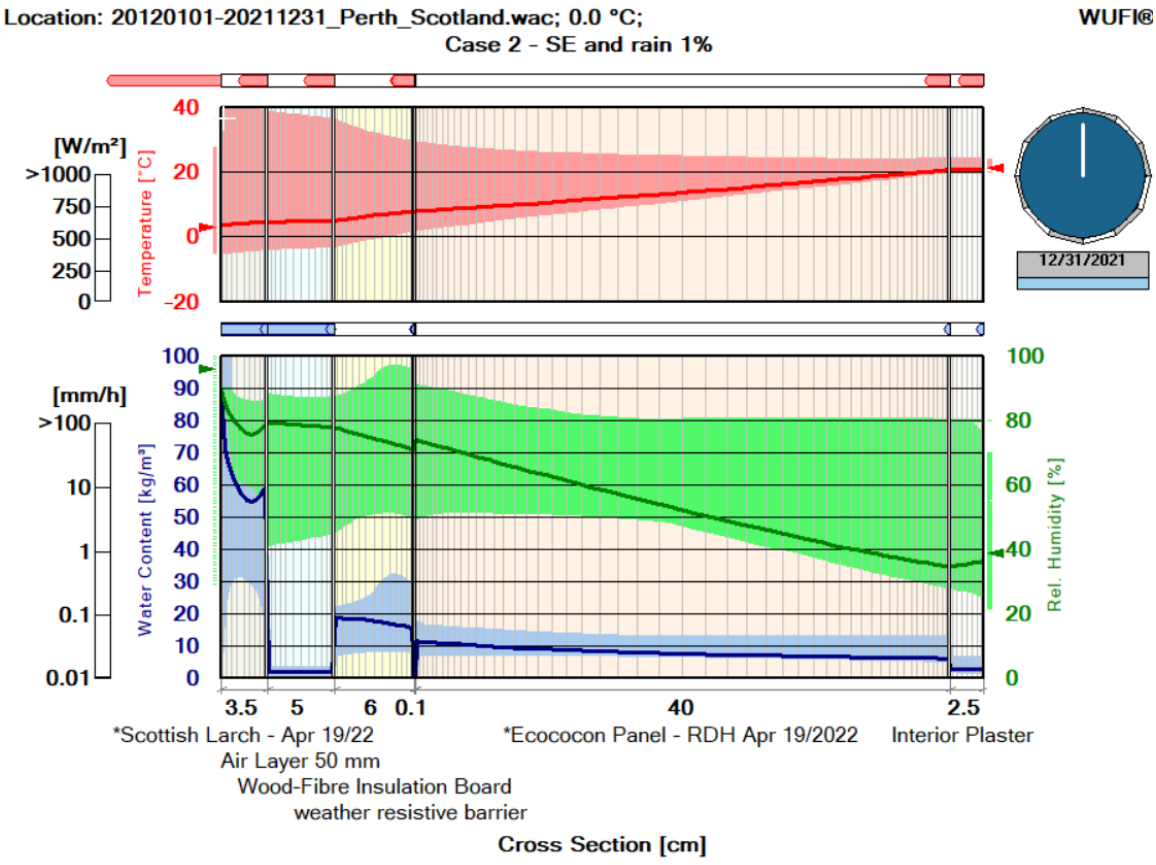

Figure 3.4 – WUFI model video: southeast oriented, 1% rain leak.

3.4 Mold risk:

ASHRAE 160-2021, Section 7, provides a model for assessing mold growth risk. In this assessment the mold growth risk was evaluated at the inside and outside faces of the wood-fiber insulation board and EcoCocon panels. Details of this assessment are outlined in Table 3.1 and the time series data are presented in Figure 3.5 and Appendix C. None of the layers considered were predicted to exceed the ASRHAE 160-accepted mold index of 3, hence ***all assemblies passed the mold risk assessment.***

TABLE 3.1 – MOLD GROWTH EVALUATION CRITERIA		
Criteria	ASHRAE 160 Requirements	Final Model
Sensitivity Class	Requirements listed in Table 6-1 ASHRAE 160-2021	Very sensitive
Mold Index Decline Coefficient	Requirements listed in Section 6.2 ASHRAE 160-2021	No mold index decline values were provided, therefore $k_3 = 0.1$ was applied in this analysis.
Time Series T & RH Data	Not specified.	Time series data for 2 locations in each material were selected for analysis: 1) Surface closest to exterior 2) Surface closest to interior
Pass/Fail Criteria	Requirements listed in Section 6.2	Mold index must not exceed 3.0 (Scale covers range of 0-6)

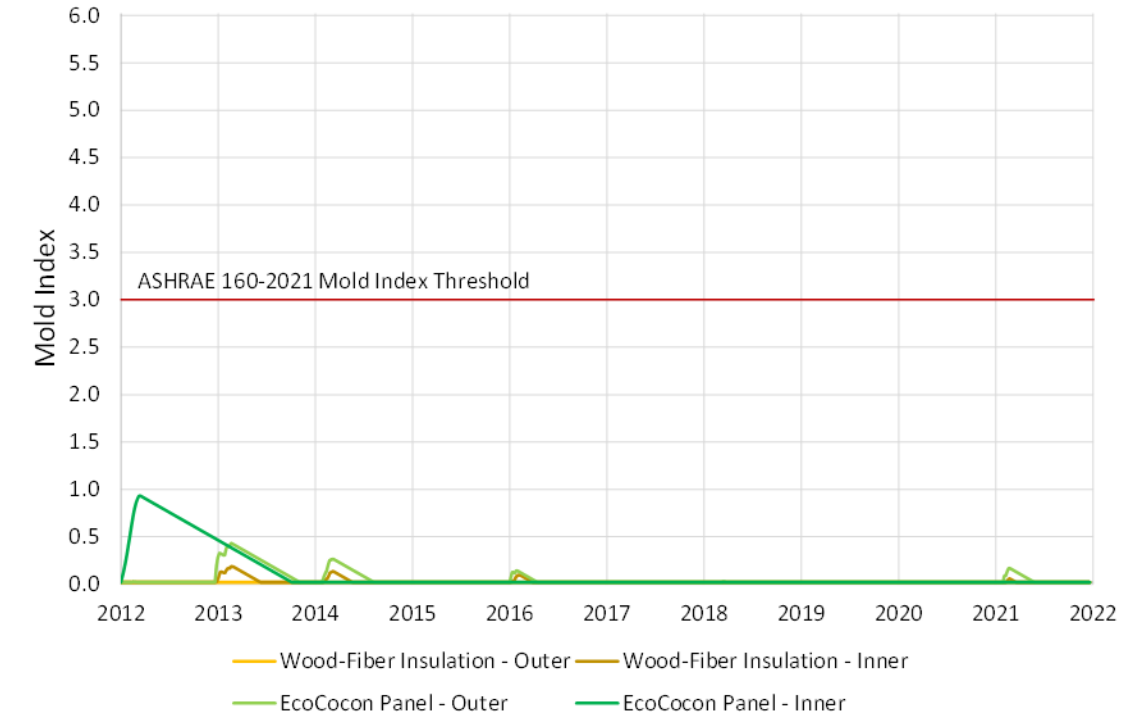

Figure 3.5 – Mold index graph: southeast oriented, 1% rain leak.

4 Conclusion

This hygrothermal modelling assessment was undertaken to evaluate the predicted thermal and moisture performance of an EcoCocon wall system for a house in Perth, Scotland. The modelling and assessment were undertaken following ASHRAE Standard 160-2021. The assembly was evaluated for moisture accumulation, critical moisture content (e.g., for decay), and mold risk. The assessed EcoCocon wall system is predicted to provide acceptable performance in this building application, in Perth, Scotland.

It is important to note that the modeling activities undertaken herein reflect best practice construction for this specific assembly design and in this specific climate. Best practice includes the implementation of appropriate and effective air, water, and thermal control layers and features in both design and construction. It is also important that these elements be routinely inspected, maintained, and repaired through the operational life of the building.

Should you have any questions about the contents of this report, please do not hesitate to contact us directly.

Yours truly,

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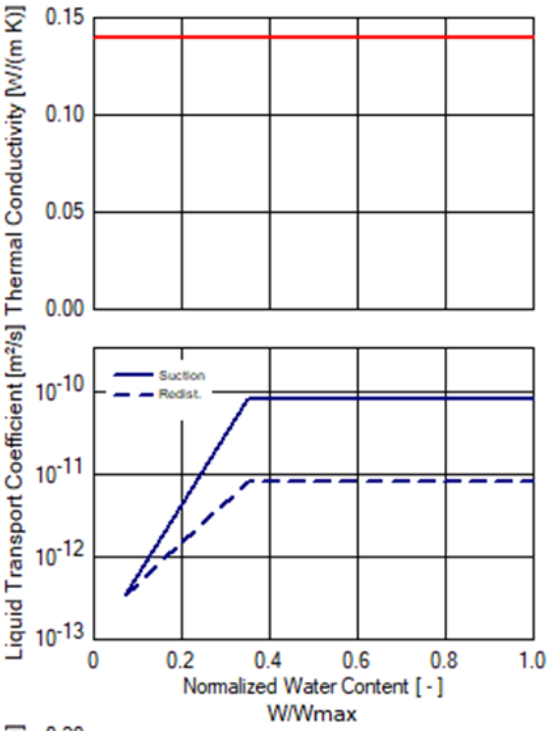
Appendix A

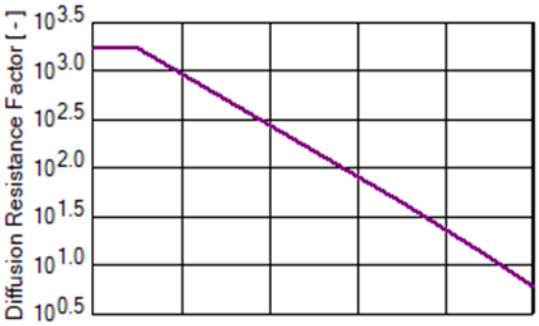
Assembly Material Data

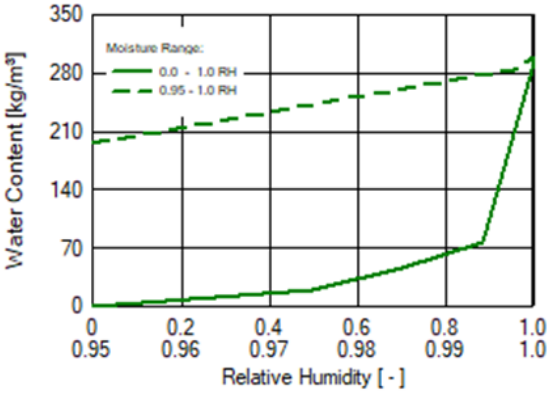
WUFI Pro 6.5

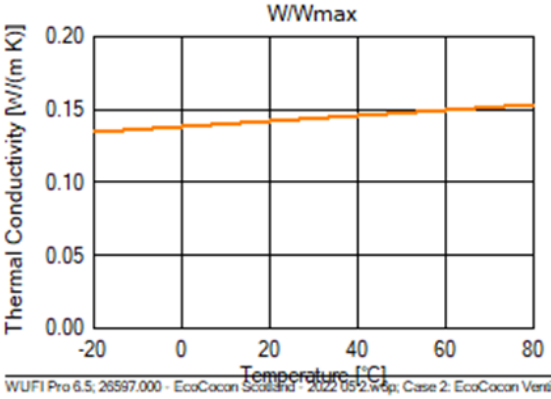
Material: *Scottish Larch - Apr 19/22

Property	Unit	Value
Bulk density	[kg/m³]	550
Porosity	[m³/m³]	0.858
Specific Heat Capacity, Dry	[J/(kg K)]	1880
Thermal Conductivity, Dry, 10°C	[W/(m K)]	0.14
Water Vapour Diffusion Resistance Factor	[-]	1734.1
Reference Water Content	[kg/m³]	62.2
Free Water Saturation	[kg/m³]	300
Water Absorption Coefficient	[kg/(m² s^0.5)]	0.0014
Temp-dep. Thermal Cond. Supplement	[W/(m K²)]	0.0002





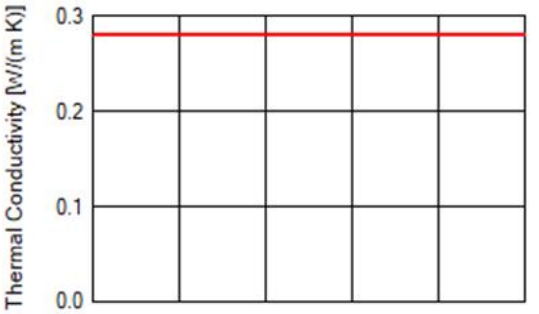


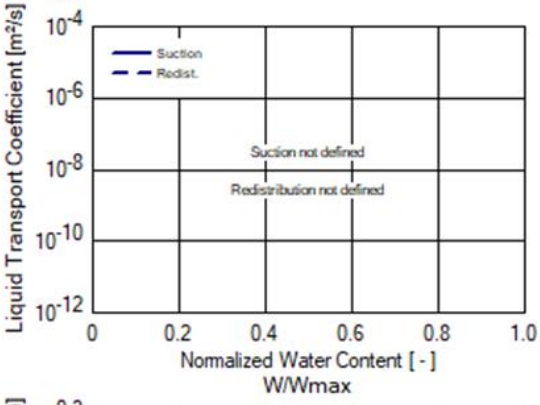


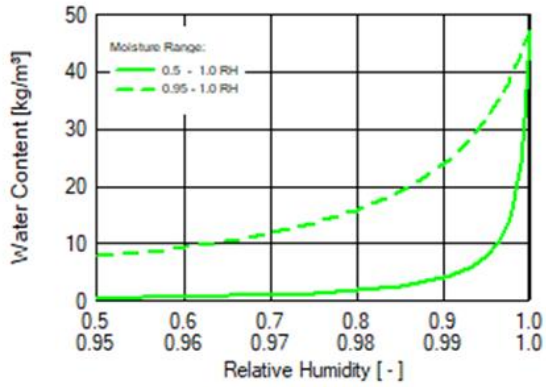
WUFI Pro 6.5

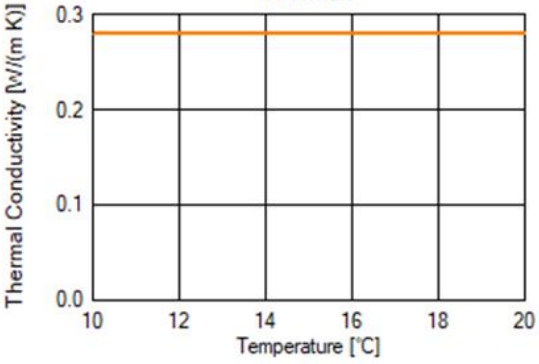
Material: Air Layer 50 mm

Property	Unit	Value
Bulk density	[kg/m³]	1.3
Porosity	[m³/m³]	0.999
Specific Heat Capacity, Dry	[J/(kg K)]	1000
Thermal Conductivity, Dry, 10°C	[W/(m K)]	0.28
Water Vapour Diffusion Resistance Factor	[-]	0.32





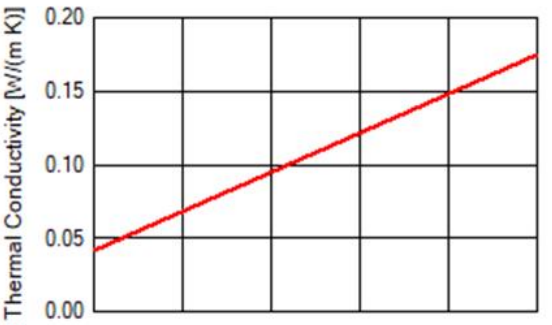


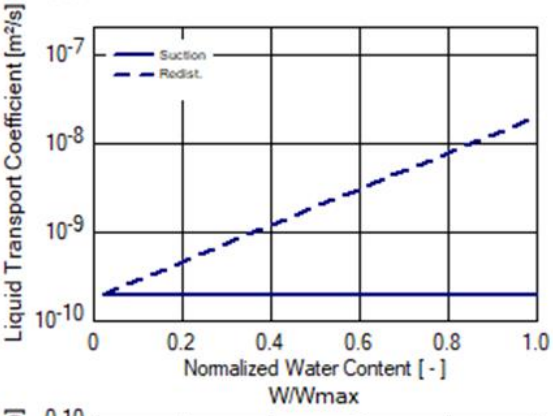


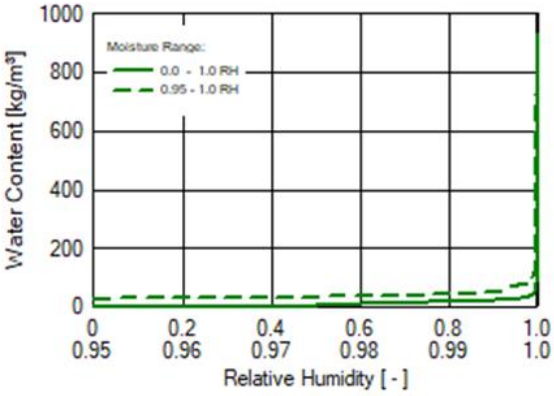
WUFI Pro 6.5

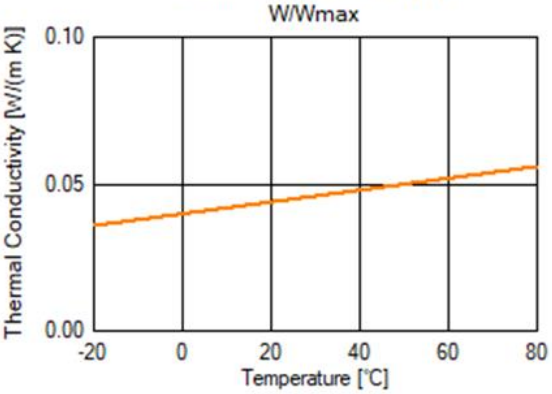
Material: Wood-Fibre Insulation Board

Property	Unit	Value
Bulk density	[kg/m³]	155
Porosity	[m³/m³]	0.981
Specific Heat Capacity, Dry	[J/(kg K)]	1400
Thermal Conductivity, Dry, 10°C	[W/(m K)]	0.042
Water Vapour Diffusion Resistance Factor	[-]	3
Moisture-dep. Thermal Cond. Supplement	[%/M.-%]	0.5
Temp-dep. Thermal Cond. Supplement	[W/(m K²)]	2.00000E-4





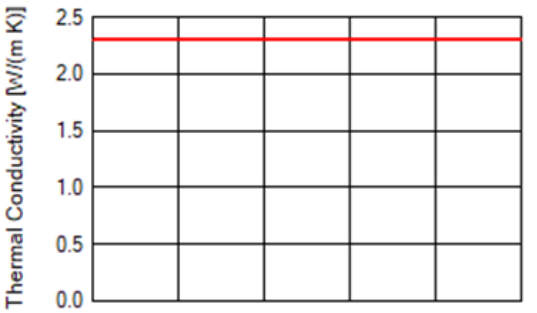


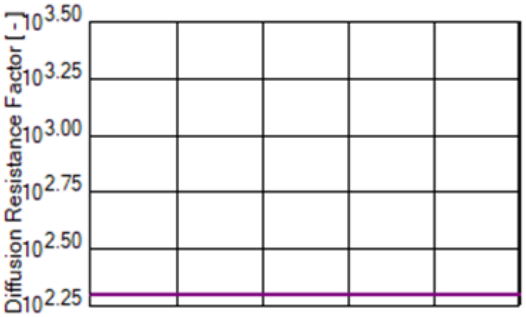


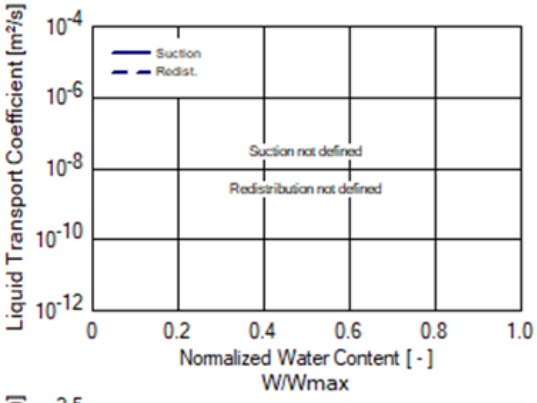
WUFI Pro 6.5

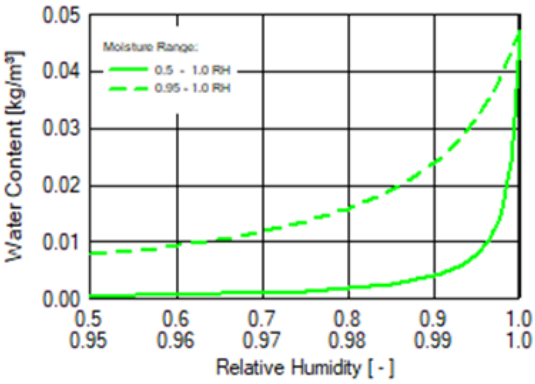
Material: weather resistive barrier (sd=0,2m)

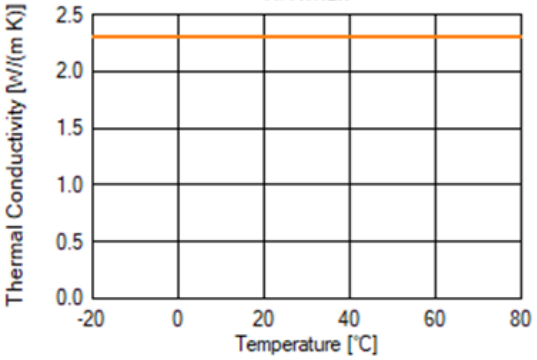
Property	Unit	Value
Bulk density	[kg/m³]	130
Porosity	[m³/m³]	0.001
Specific Heat Capacity, Dry	[J/(kg K)]	2300
Thermal Conductivity, Dry, 10°C	[W/(m K)]	2.3
Water Vapour Diffusion Resistance Factor	[-]	200
Temp-dep. Thermal Cond. Supplement	[W/(m K²)]	2.00000E-4







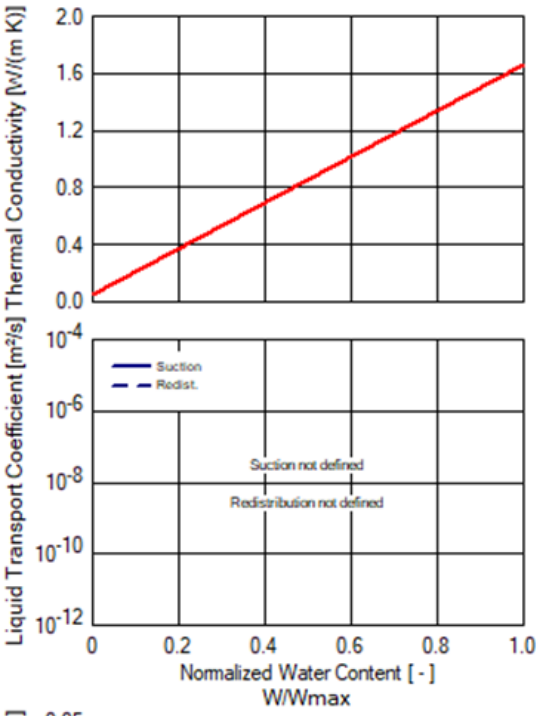


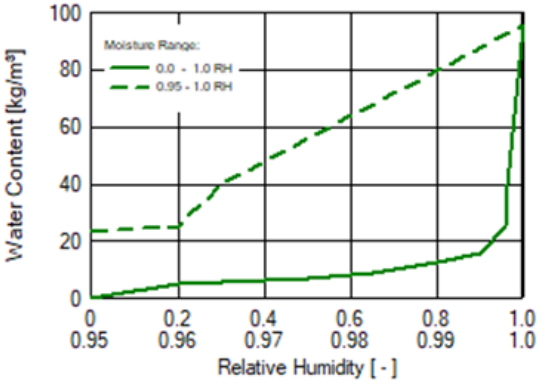


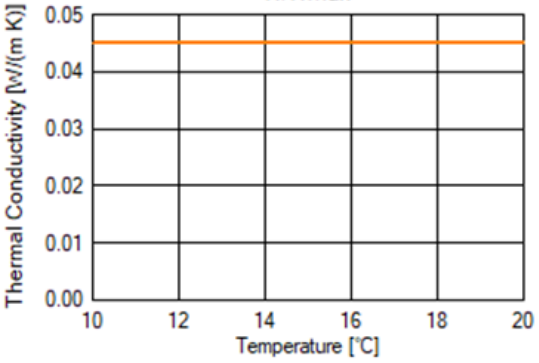
WUFI Pro 6.5

Material: *Ecococon Panel - RDH Apr 19/2022

Property	Unit	Value
Bulk density	[kg/m³]	100
Porosity	[m³/m³]	0.9
Specific Heat Capacity, Dry	[J/(kg K)]	2000
Thermal Conductivity, Dry, 10°C	[W/(m K)]	0.045
Water Vapour Diffusion Resistance Factor	[-]	1.3
Moisture-dep. Thermal Cond. Supplement	[%/M.-%]	4



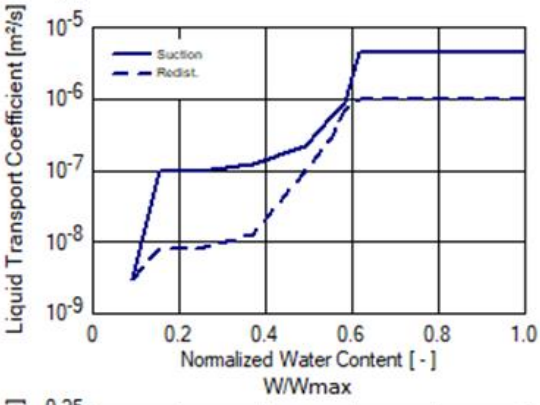


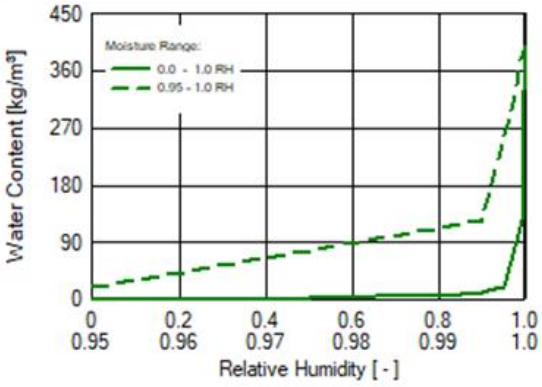


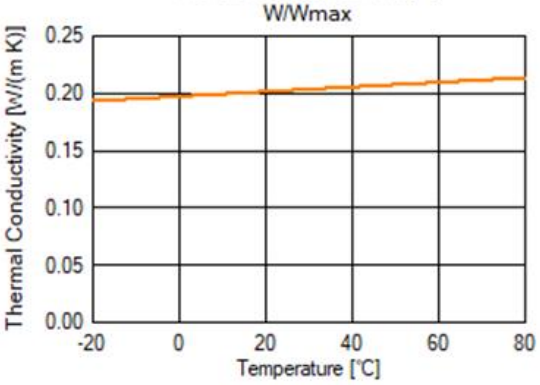
WUFI Pro 6.5

Material: Interior Plaster (Gypsum Plaster)

Property	Unit	Value
Bulk density	[kg/m³]	850
Porosity	[m³/m³]	0.65
Specific Heat Capacity, Dry	[J/(kg K)]	850
Thermal Conductivity, Dry, 10°C	[W/(m K)]	0.2
Water Vapour Diffusion Resistance Factor	[-]	8.3
Moisture-dep. Thermal Cond. Supplement	[%/M.-%]	8
Temp-dep. Thermal Cond. Supplement	[W/(m K²)]	2.00000E-4







Appendix B

Moisture Performance Analysis:

Total Water Content Graphs

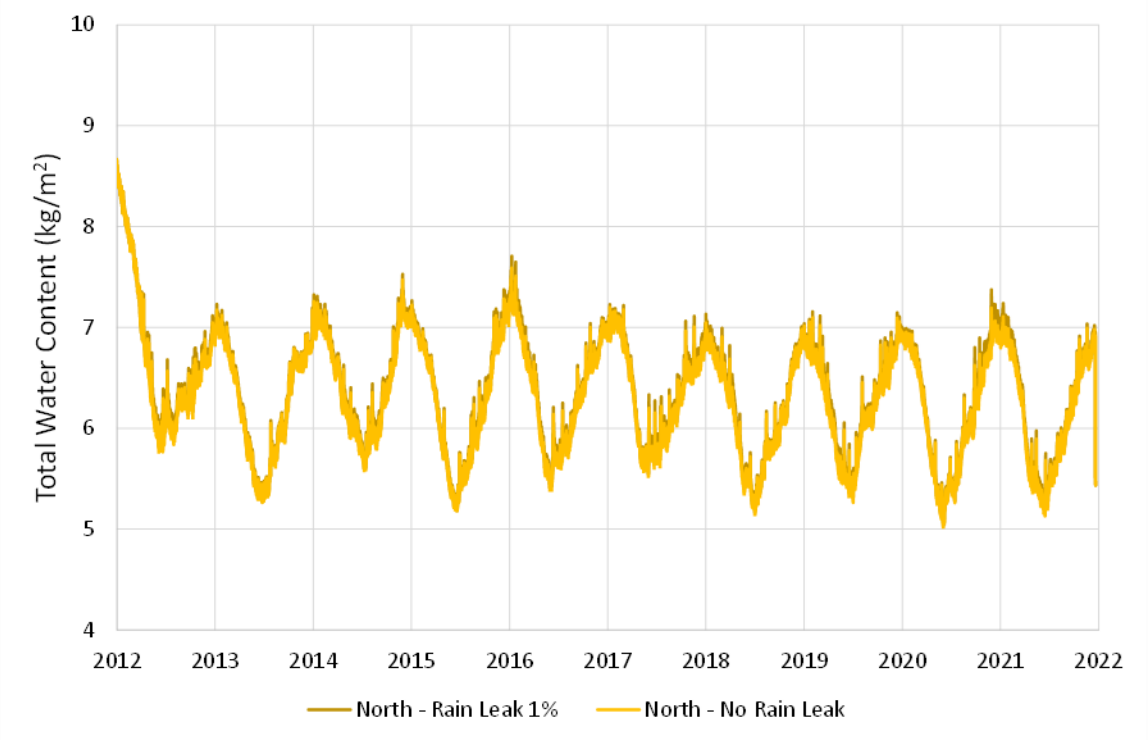


Figure 4.1 - Total water content: north orientation.

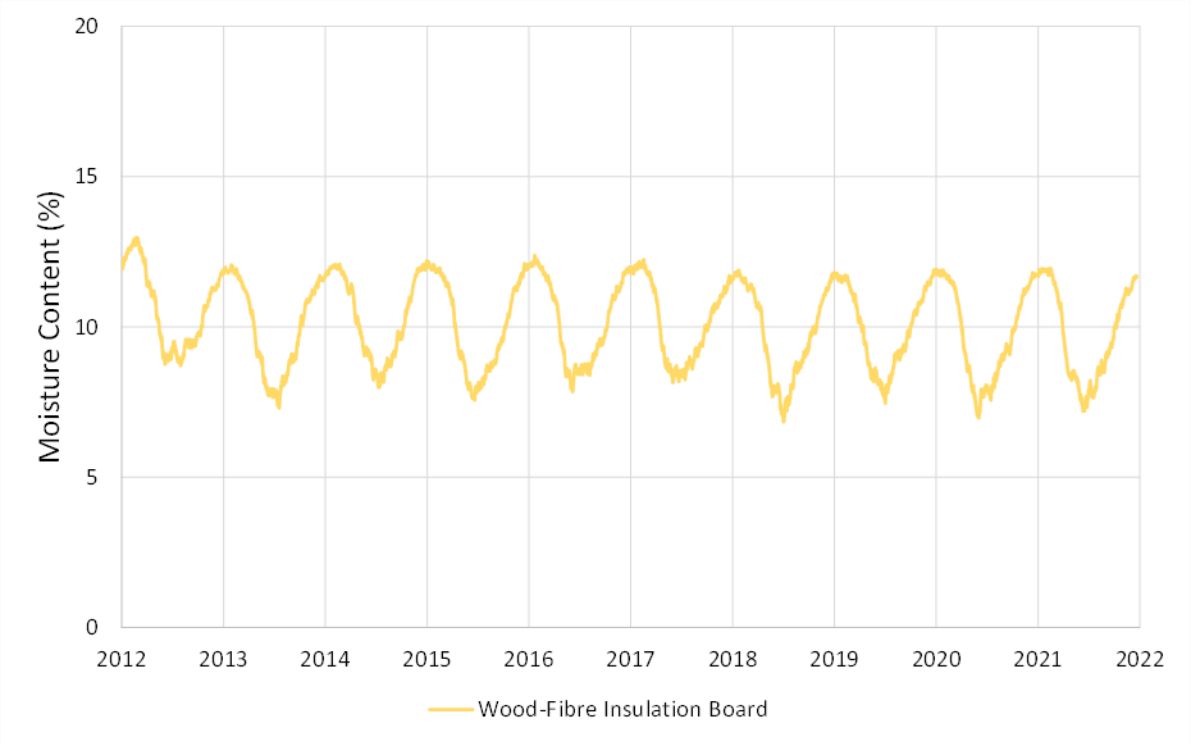


Figure 4.2 – Moisture content graph for wood-fibre insulation board: north oriented, no rain leak.

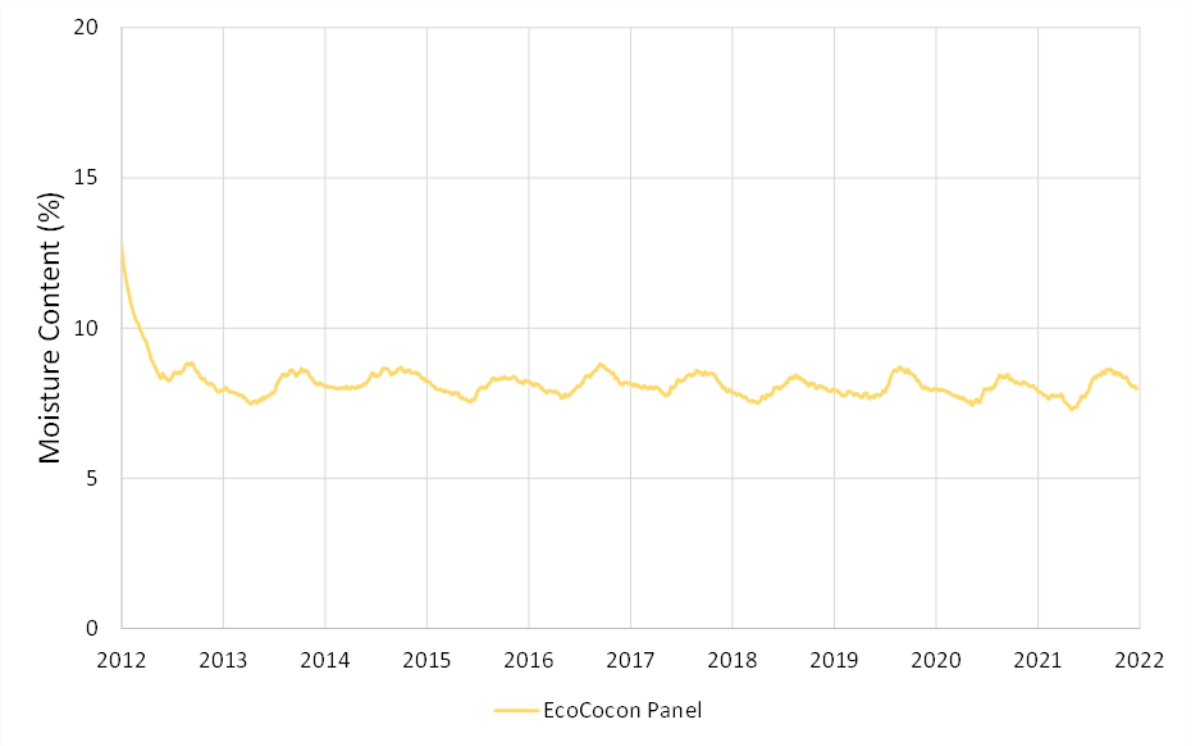


Figure 4.3 – Moisture content graph for EcoCocon panel: north oriented, no rain leak.

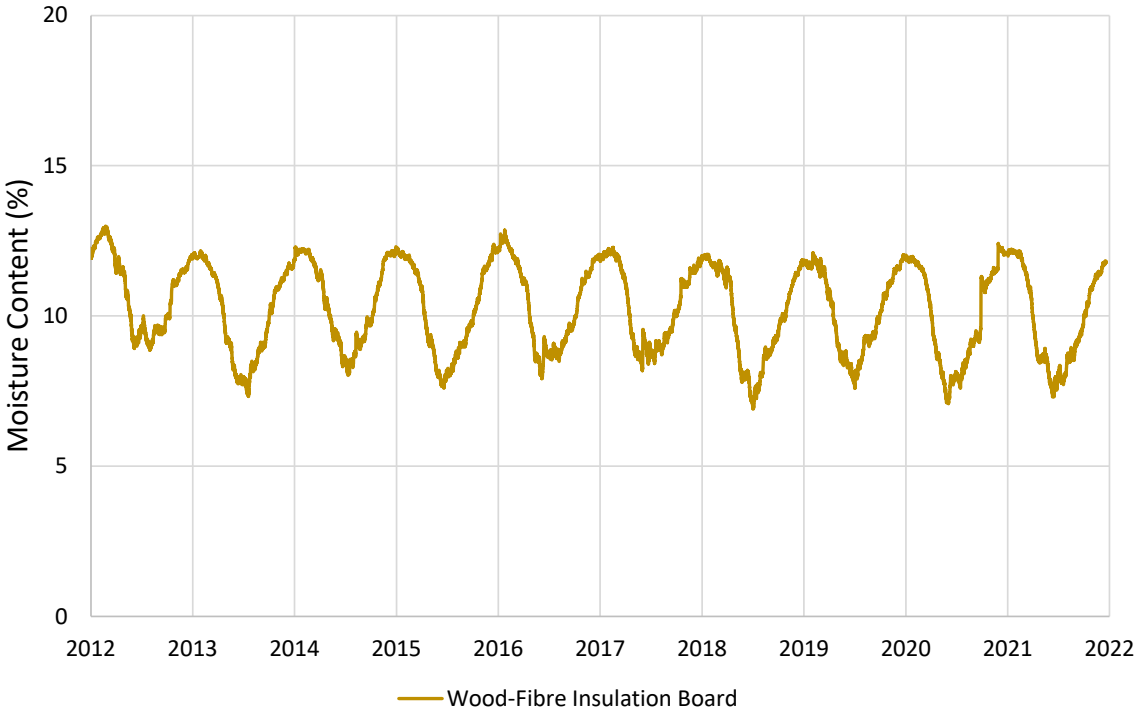


Figure 4.4 – Moisture content graph for wood-fibre insulation board: north oriented, 1% rain leak.

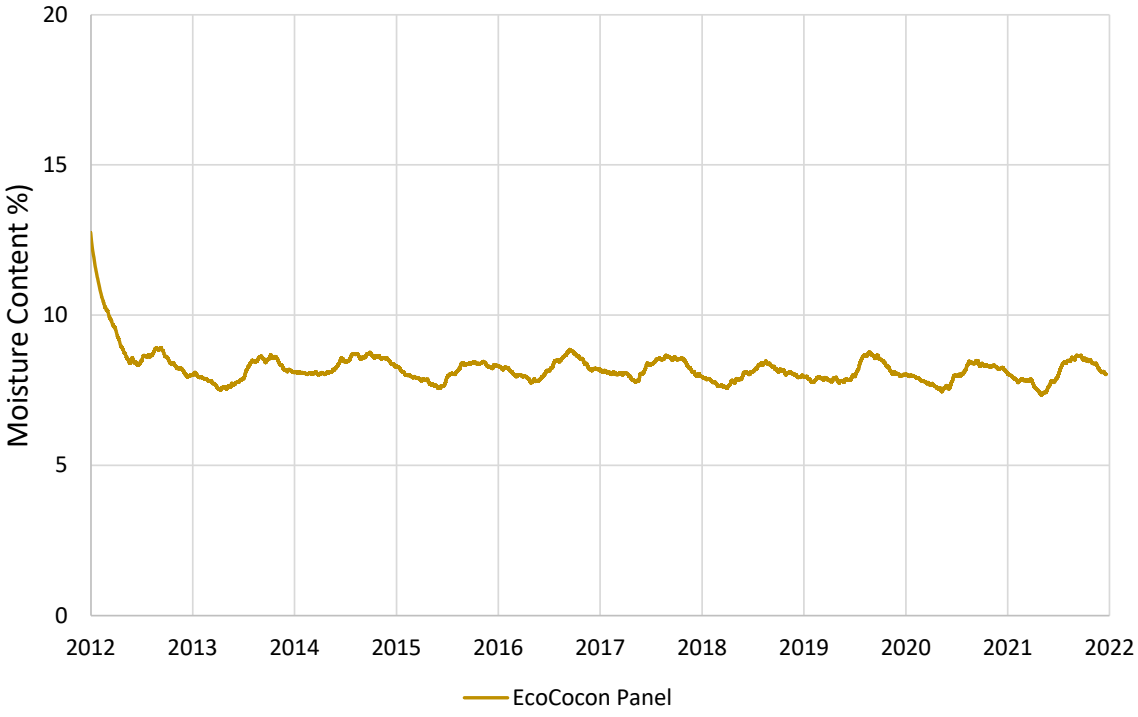


Figure 4.5 – Moisture content graph for EcoCocon panel: north oriented, 1% rain leak.

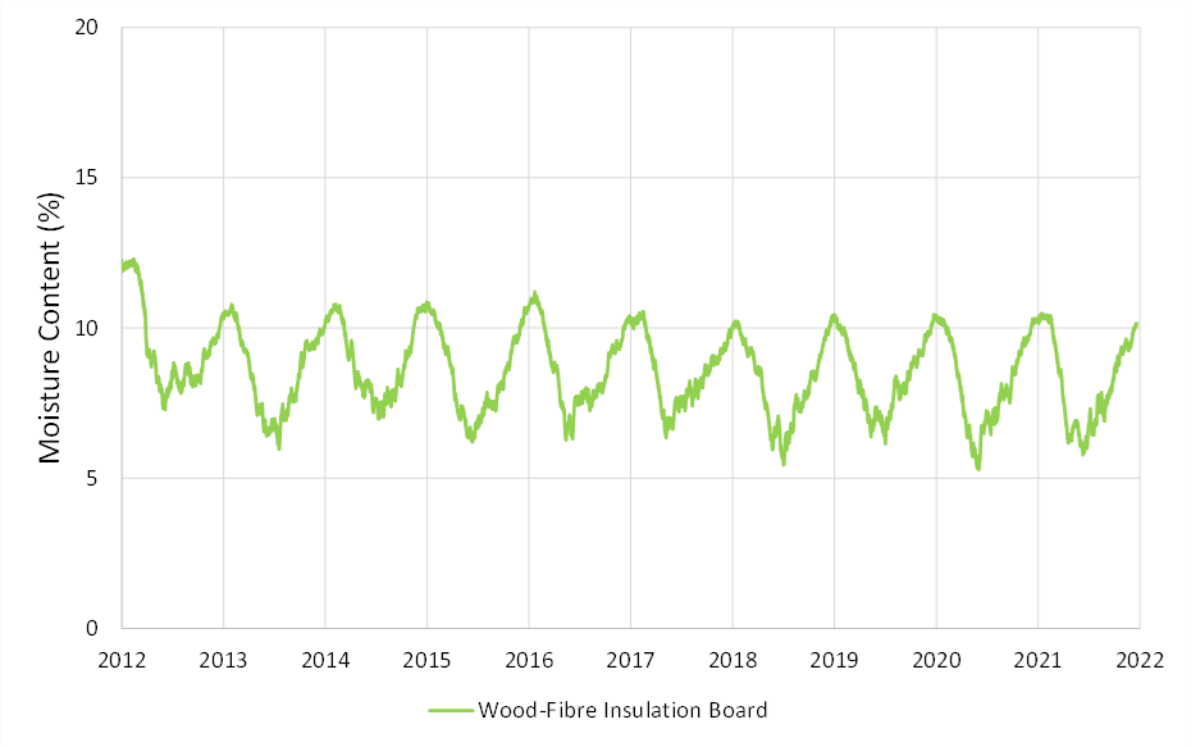


Figure 4.6 – Moisture content graph for wood-fibre insulation board: southeast oriented, no rain leak.

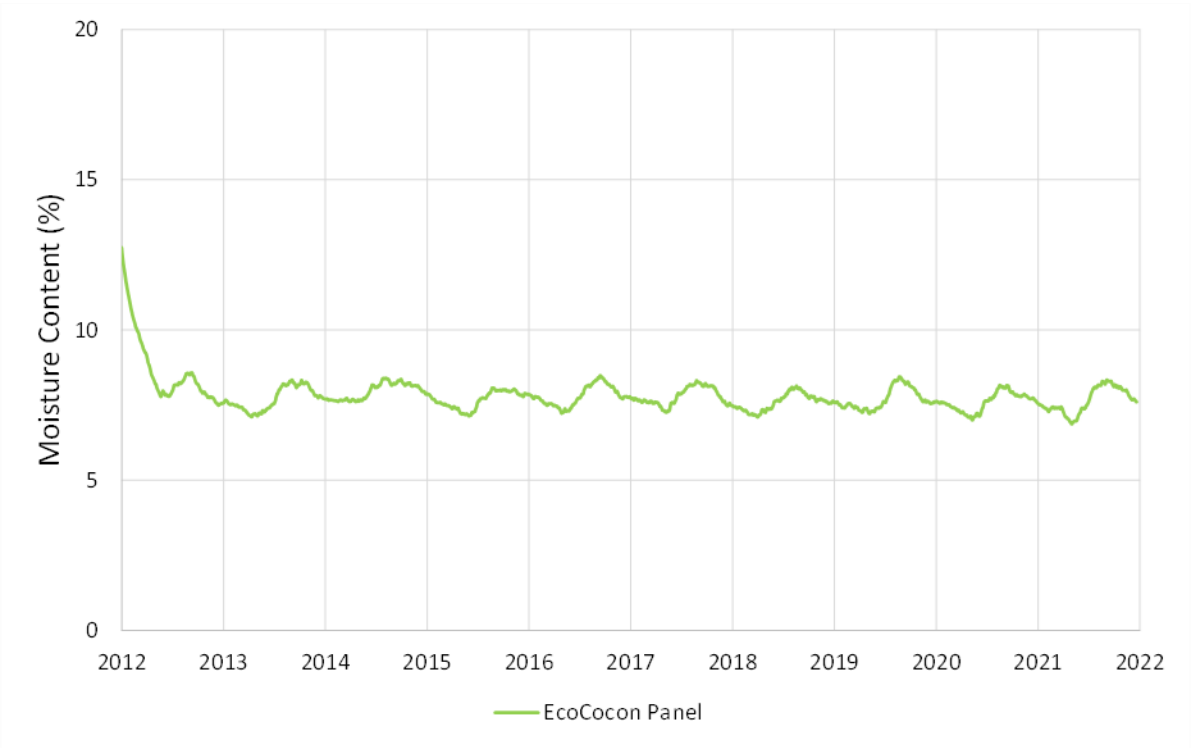


Figure 4.7 – Moisture content graph for EcoCocon panel: southeast oriented, no rain leak.

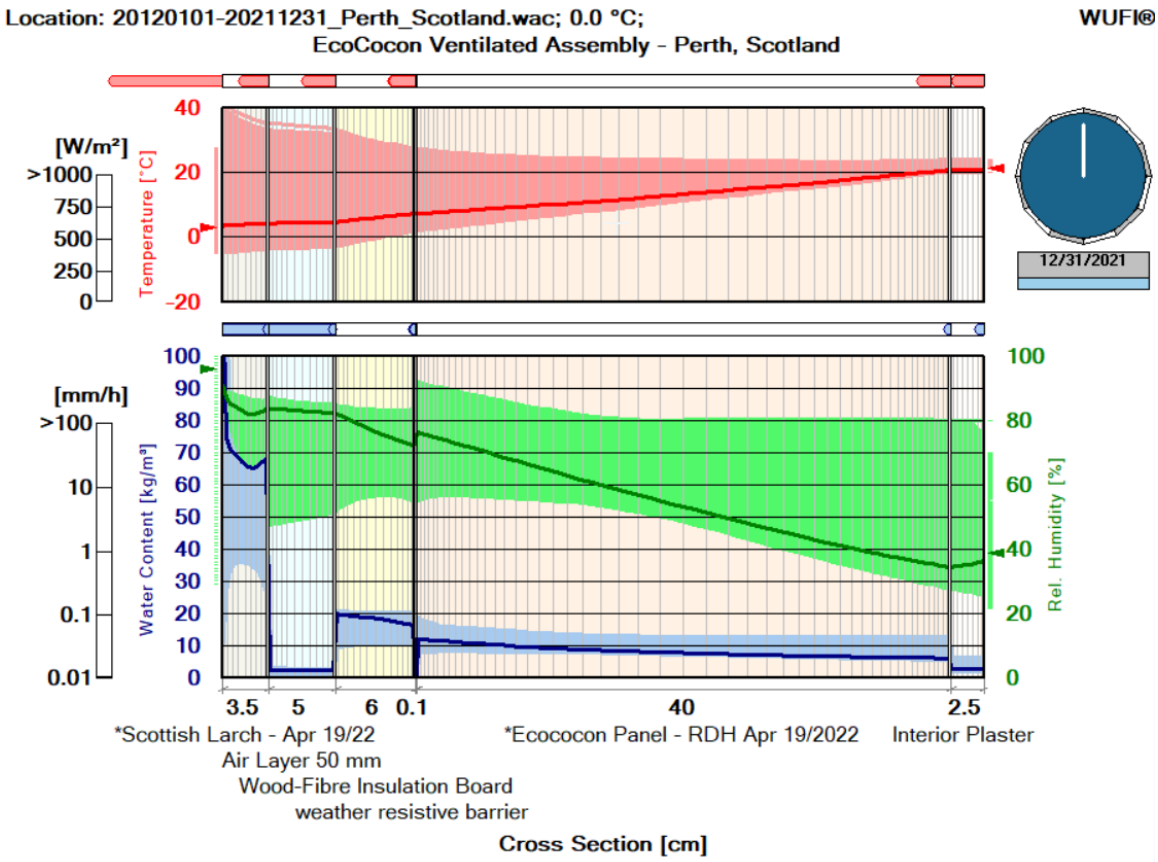


Figure 4.8 – WUFI model video: north oriented, no rain leak.

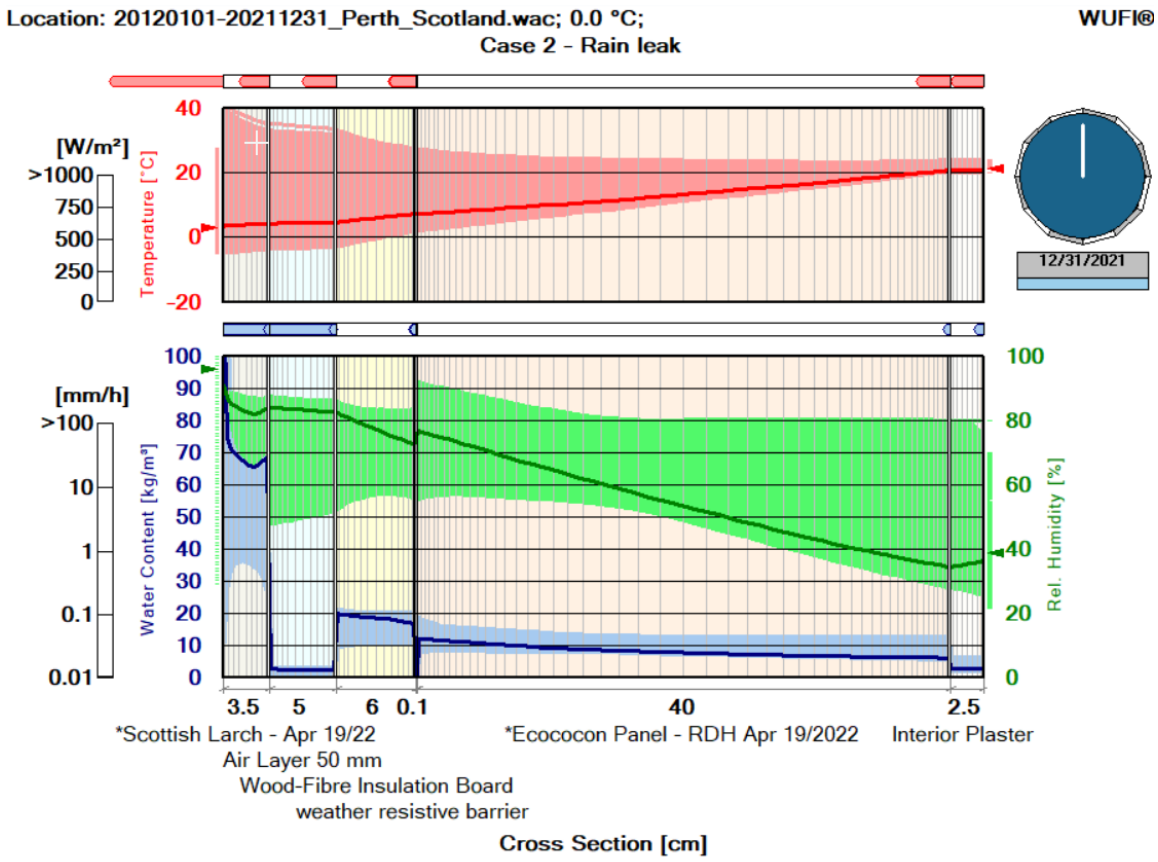


Figure 4.9 – WUFI model video: north oriented, 1% rain leak.

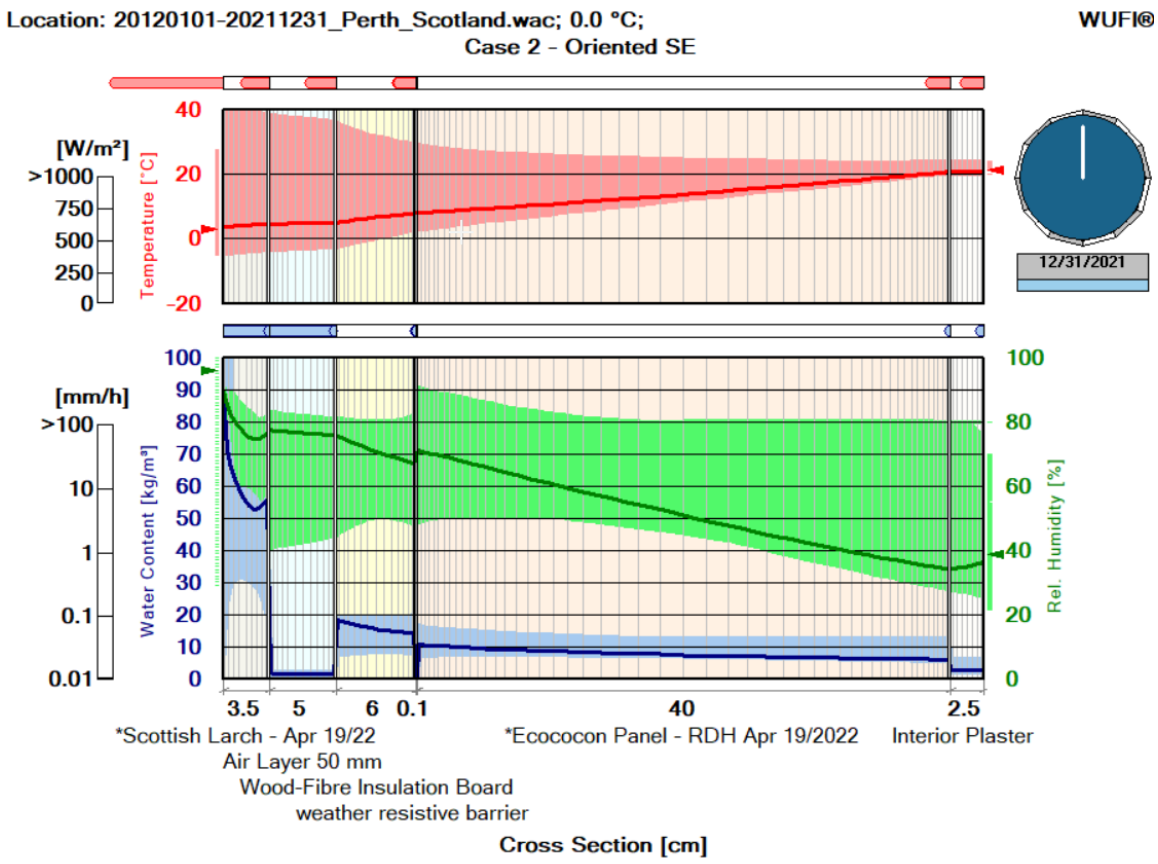


Figure 4.10 – WUFI model video: southeast oriented, no rain leak.

Appendix C

Mold Risk Analysis:

Mold Index Graphs

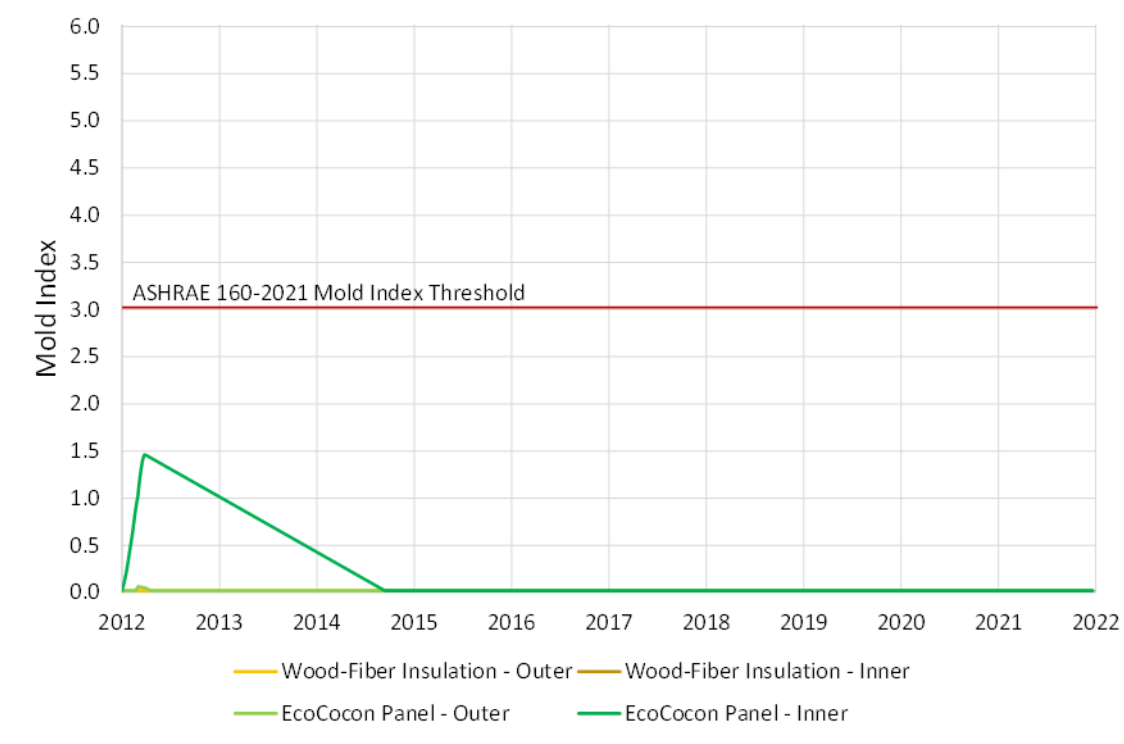


Figure 4.11 - Mold index graph: north oriented, no rain leak.

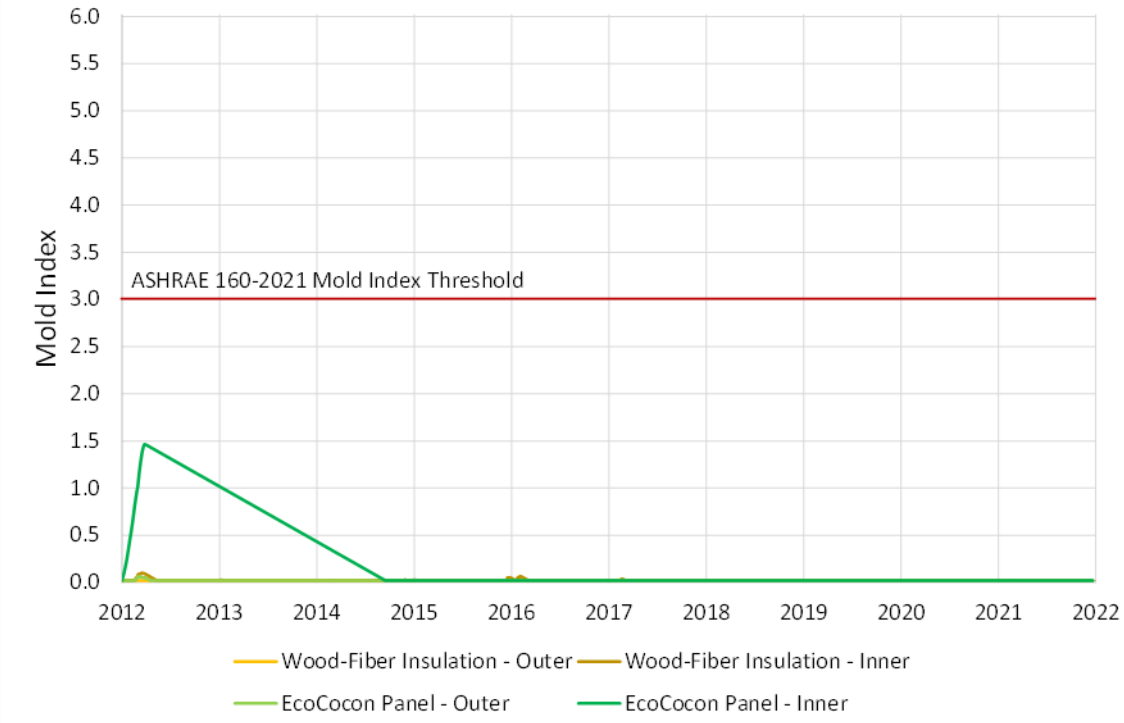


Figure 4.12 - Mold index graph: north oriented, 1% rain leak.

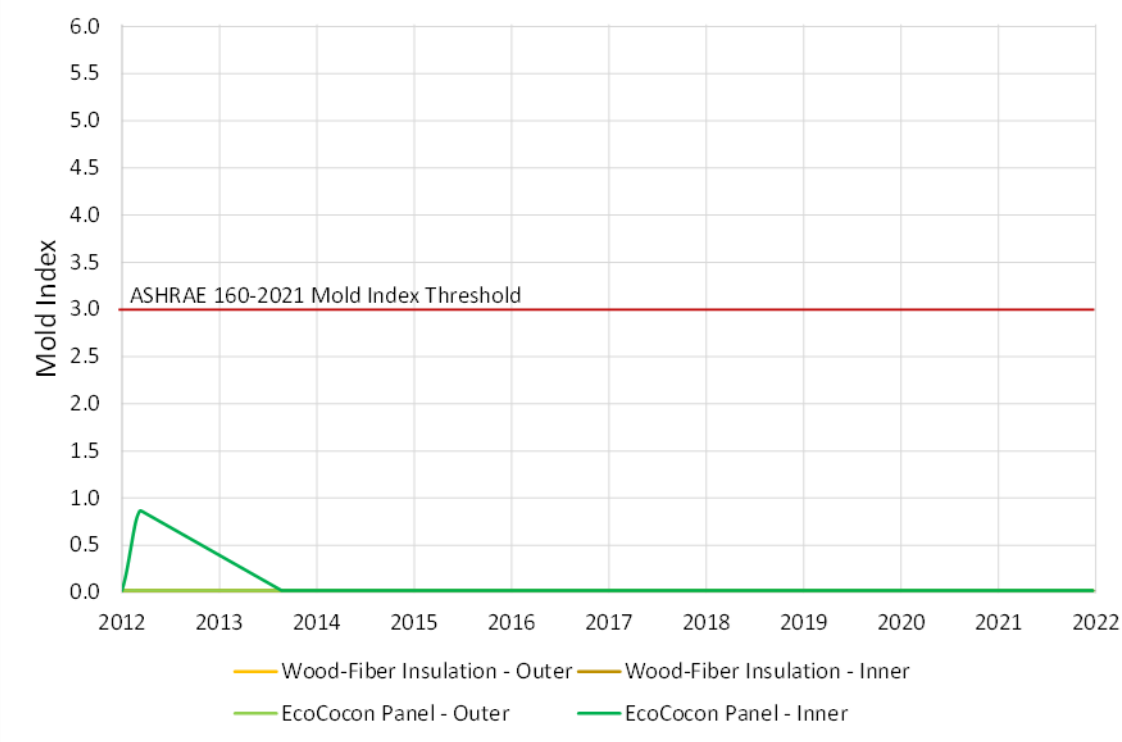


Figure 4.13 - Mold index graph: southeast oriented, no rain leak.