Hygrothermal analysis of the EcoCocon building system for Belmullet and Valentia, Ireland

(as per 2nd February 2023)

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Background and assignment

Passivhusbyrån has been commissioned to produce a hygrothermal analysis of *EcoCocon's* building system for two locations on the west coast of Ireland, namely Belmullet and Valentia, with four different wall types (from outside to inside):

1. Façade panels (wood), airgap, 60 mm woodfibre board, EC panel, plasterboard
2. Façade panels (wood), airgap, 60 mm woodfibre board, EC panel, interior plaster
3. Exterior render, 60 mm woodfibre board, EC panel, plasterboard
4. Exterior render, 60 mm woodfibre board, EC panel, interior plaster

The aim of the analysis is to obtain results with the following input data and to examine the long-term performance as regards to moisture safety.

Reservations

The calculations and simulations for this project are based on the submitted input data received between 17th and 31st January 2023. For the simulation, climate data sets containing all necessary parameters have been used, in this case from the *Belmullet* and *Valentia* weather stations, both located on the west coast of Ireland. For additional stress testing, according to ANSI/ASHRAE standard 160, a 1 % fraction of the rain load has been included as seeping into the construction, namely into the straw panel directly behind the weather resistive barrier, which EcoCocon is delivering with their straw panels.

Hygrothermal analysis

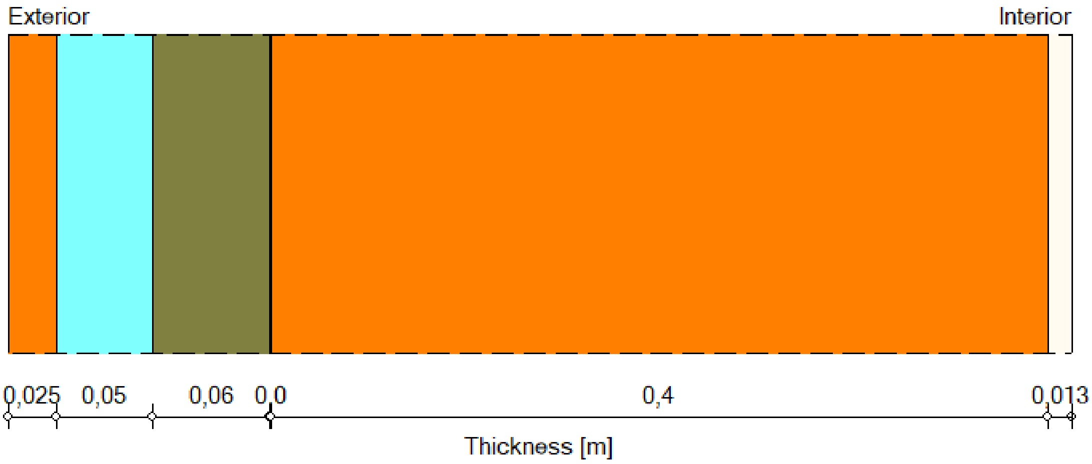
The simulation was done with WUFI 6.5 Pro, which allows for an hourly dynamic simulation for an unlimited number of years to come. During the process, the following parameters are considered, among others:

Material properties: these quantities describe the hygrothermal behaviour of the materials to be examined: bulk density [kg/m³], porosity [m³/m³], specific heat capacity [J/(kg·K)], dry thermal conductivity [W/(m·K)], dry water vapour diffusion resistance, moisture storage function [kg/m³], and liquid transport coefficient suction and redistribution [m²/s] (w-value). If applicable, moisture-dependent thermal conductivity [W/(m·K)] and water vapour diffusion resistance number are also included.

Climate data: these quantities describe the boundary conditions acting on the internal or external surface of the building component: rainfall load on the surface [l/(m²·h)], depending on the slope and orientation of the component, shortwave radiant flux density (solar) [W/m²], depending on the slope and orientation of the component, outdoor air temperature [°C], outdoor air relative humidity [0...100%], indoor air temperature [°C], indoor air relative humidity [0...100%] and average air pressure [hPa] during the calculation period.

Input data

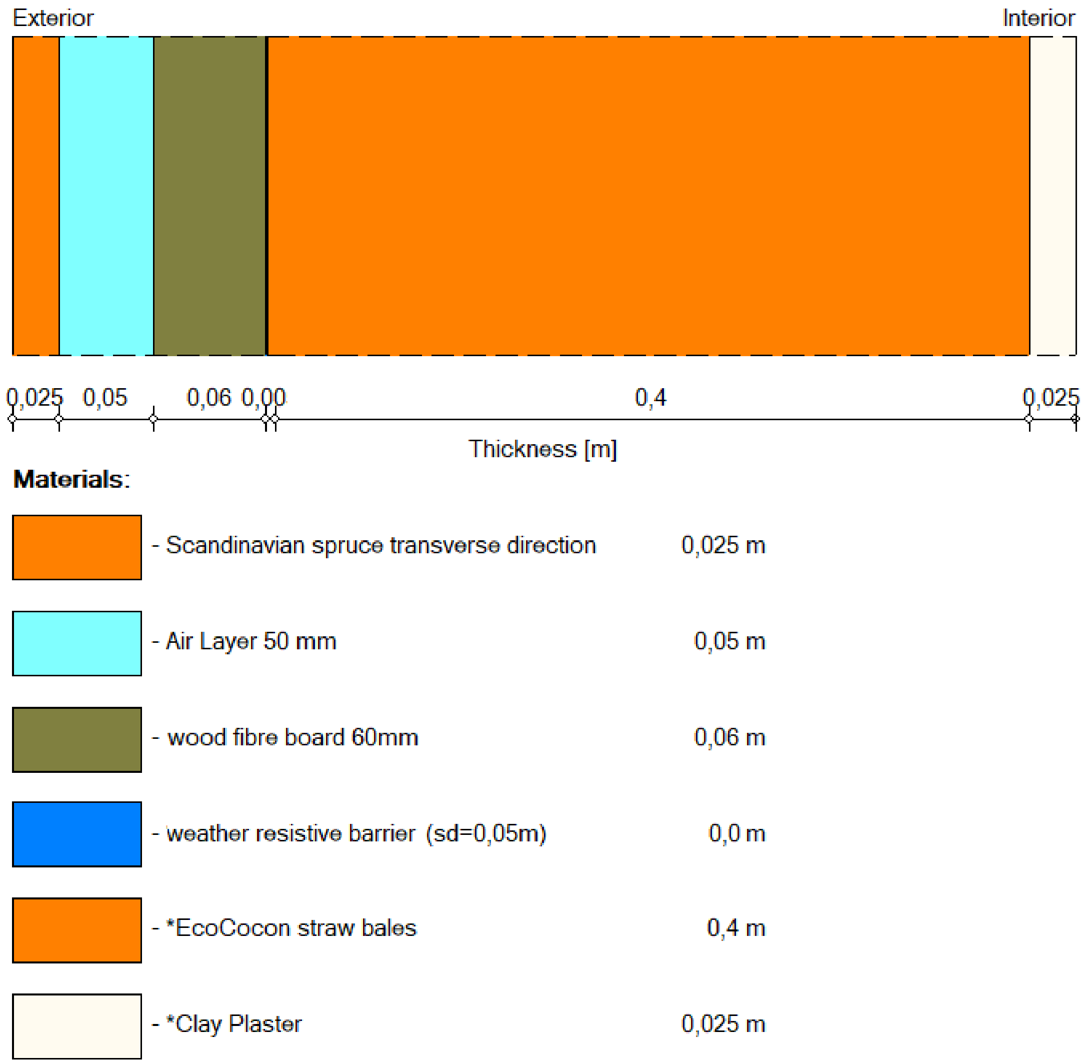
Construction - wall type A:



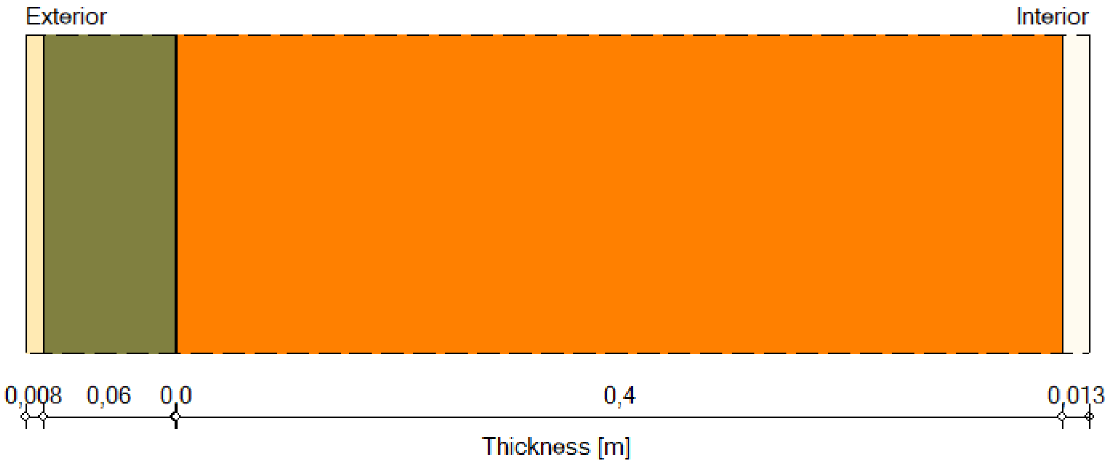
Materials:

- Scandinavian spruce transverse direction	0,025 m
- Air Layer 50 mm	0,05 m
- wood fibre board 60mm	0,06 m
- weather resistive barrier (sd=0,05m)	0,0 m
- *EcoCocon straw bales	0,4 m
- plasterboard	0,013 m

Construction - wall type B:



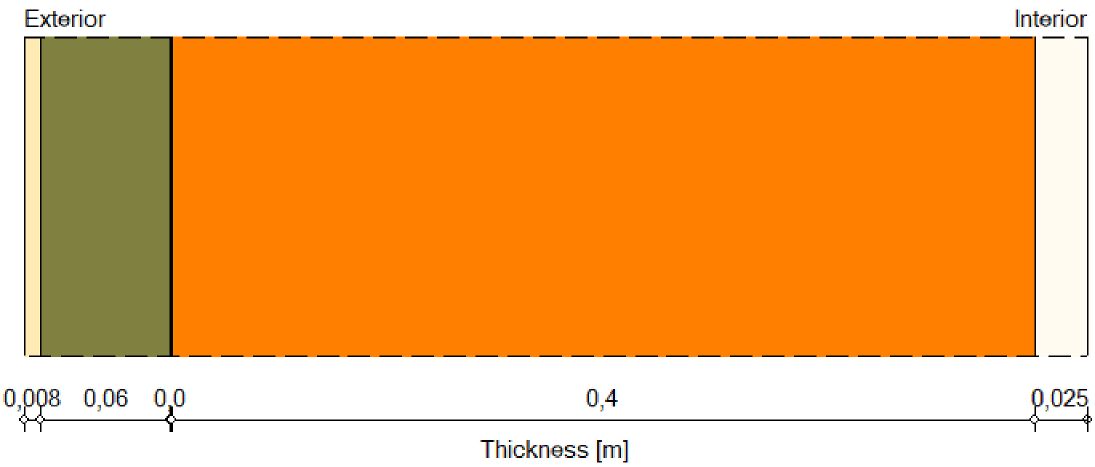
Construction - wall type C:



Materials:

	- Mineral Plaster (stucco, A-value: 0.1 kg/m2h0.5)	0,008 m
	- wood fibre board 60mm	0,06 m
	- weather resistive barrier (sd=0,05m)	0,0 m
	- *EcoCocon straw bales	0,4 m
	- plasterboard	0,013 m

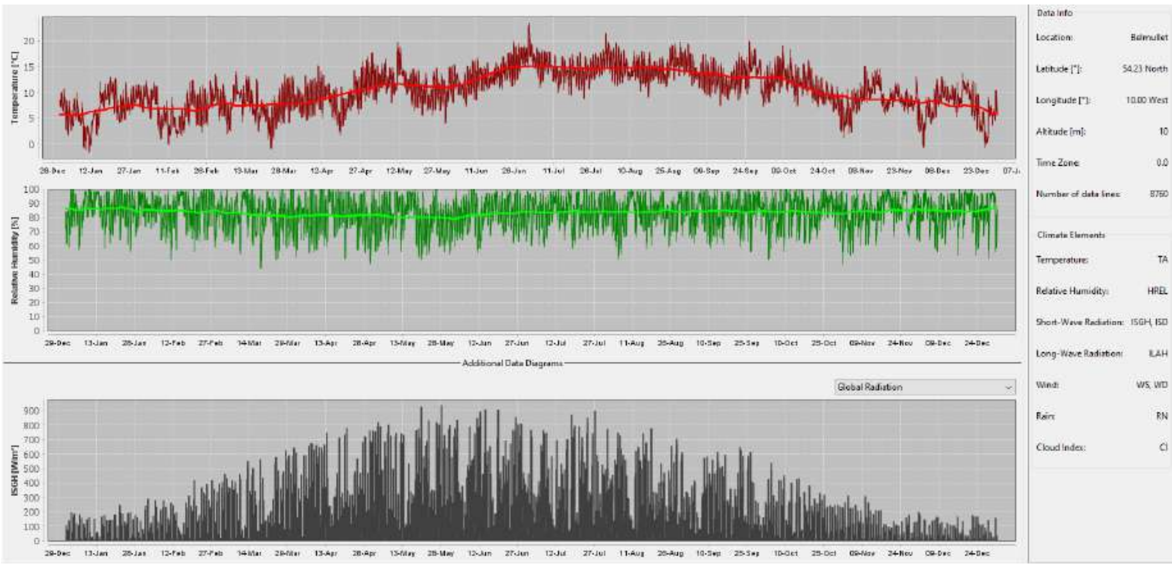
Construction - wall type D:

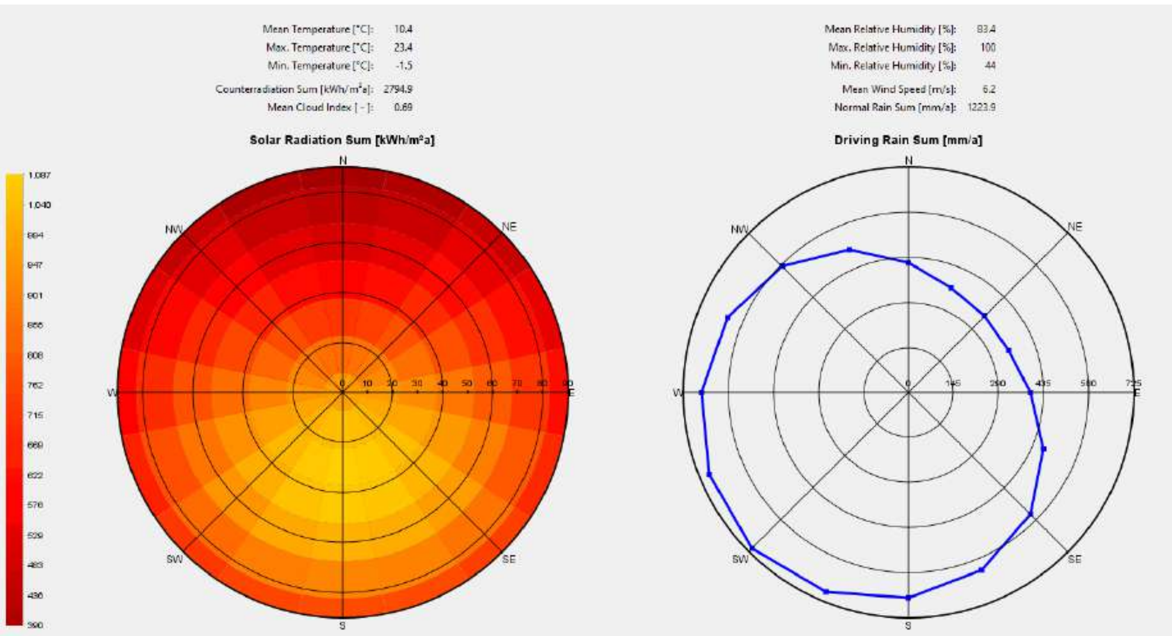


Materials:

- Mineral Plaster (stucco, A-value: 0.1 kg/m2h0.5)	0,008 m
- wood fibre board 60mm	0,06 m
- weather resistive barrier (sd=0,05m)	0,0 m
- *EcoCocon straw bales	0,4 m
- *Clay Plaster	0,025 m

Outdoor climate Belmullet (Ireland)





The direction of the strongest driving rain is Southwest, but for ventilated facades, the northward orientation is decisive for these simulations and therefore has been applied. For stress-testing, 1% of the driving rain for an additional moisture source *behind* the weather membrane has been added in order to simulate water possibly seeping into the structure via small leaks, e.g., around the window installations. For rendered façades, the Southwest orientation has been applied.

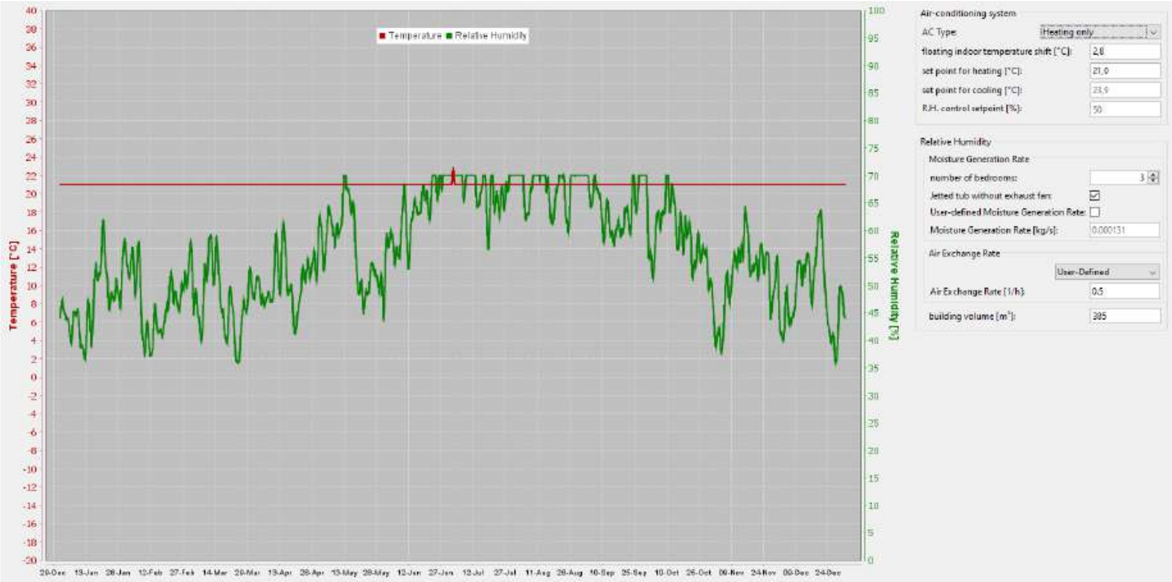
Indoor climate Belmullet (Ireland)

The same model building was used for all simulations: a three-bedroom villa with 385 m³ interior volume.

A whirlpool bath without exhaust fan was added for possible additional moisture production - just to be on the safe side. An MVHR unit delivers 0.5 air changes per hour.

Airconditioning is only available as heating, no active cooling. The set point for heating is 21°C (typical value for SFH).

The indoor climate model was based on ASHRAE 160-2021 as this provided the possibilities to represent the above conditions. For Belmullet, it looks like this:

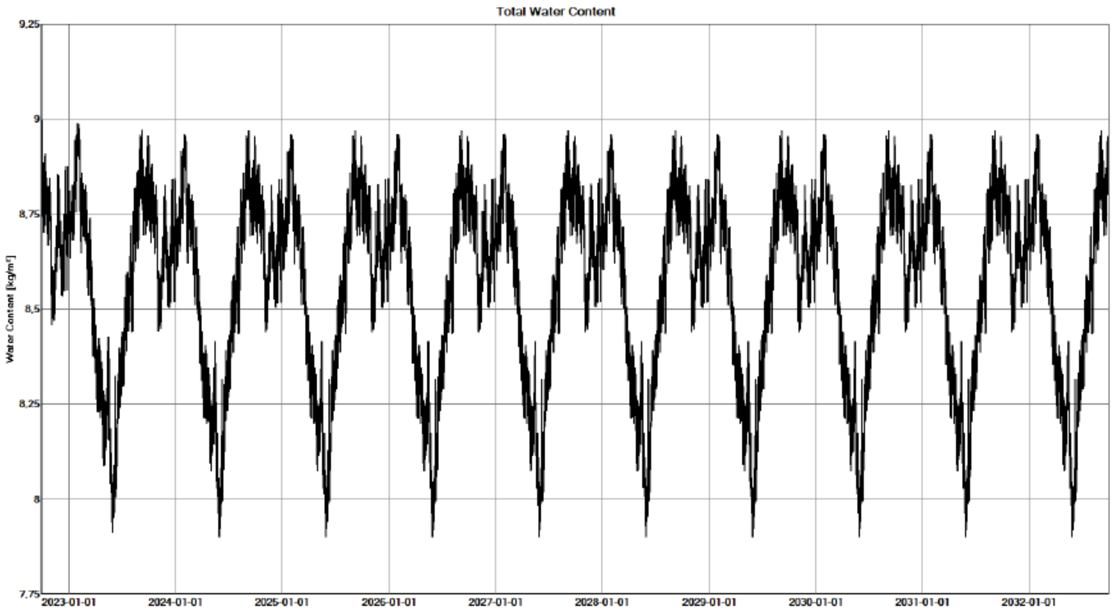


Results

The following diagrams show the water contents of the individual layers.

Wall type A

Entire wall

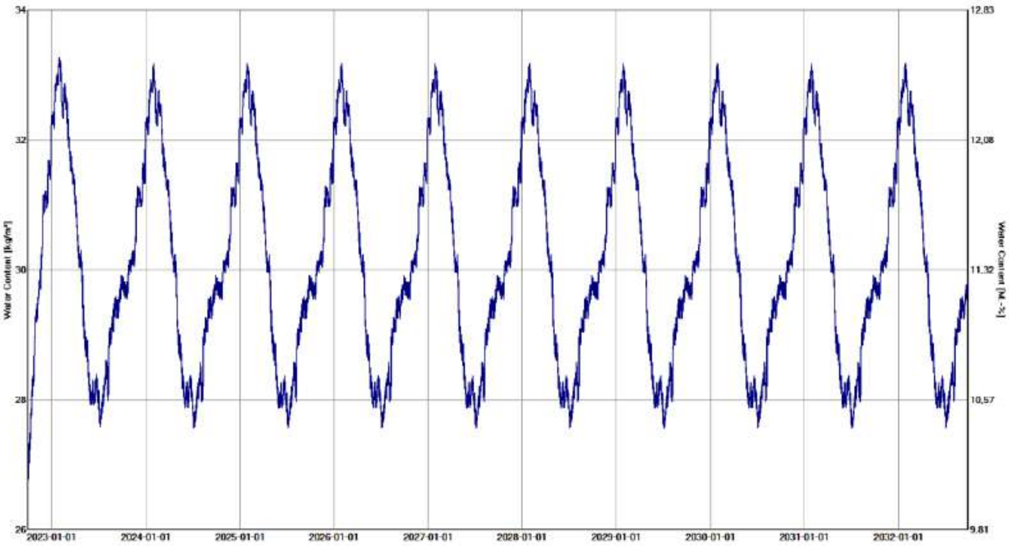


The simulation over 10 years shows that there is no accumulation of moisture over the long term (apart from the usual seasonal fluctuation). No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly.

For the simulation, 80 % relative humidity has been assumed for the materials built into the construction. As the house consists of prefabricated modules, there is even less risk of built-in moisture or leakage. For additional stress testing, the air exchange rate in the ventilation gap has been set to be very low, i.e., 10/h. This goes for all other ventilated façade simulations in this report as well.

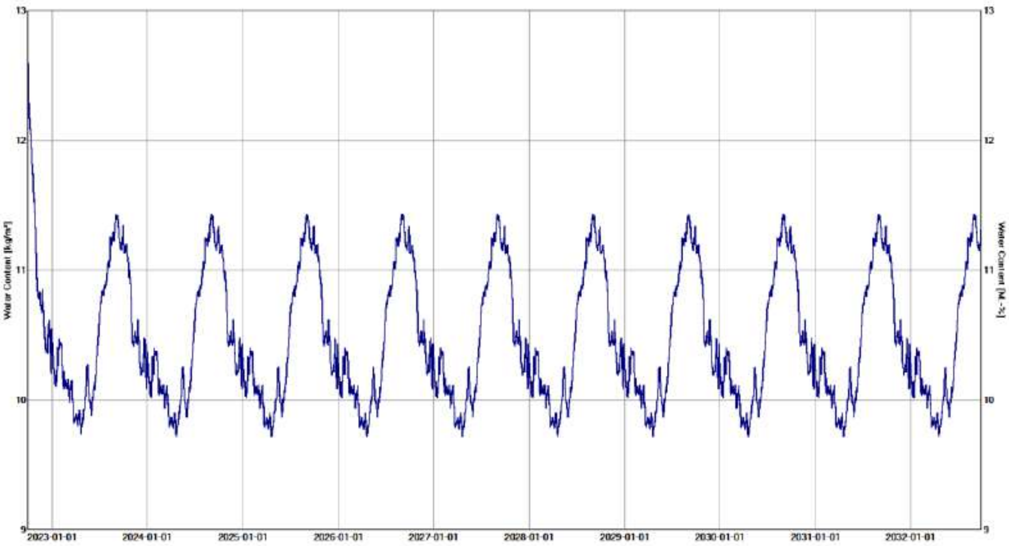
Individual layers

Woodfibre board behind the air gap:



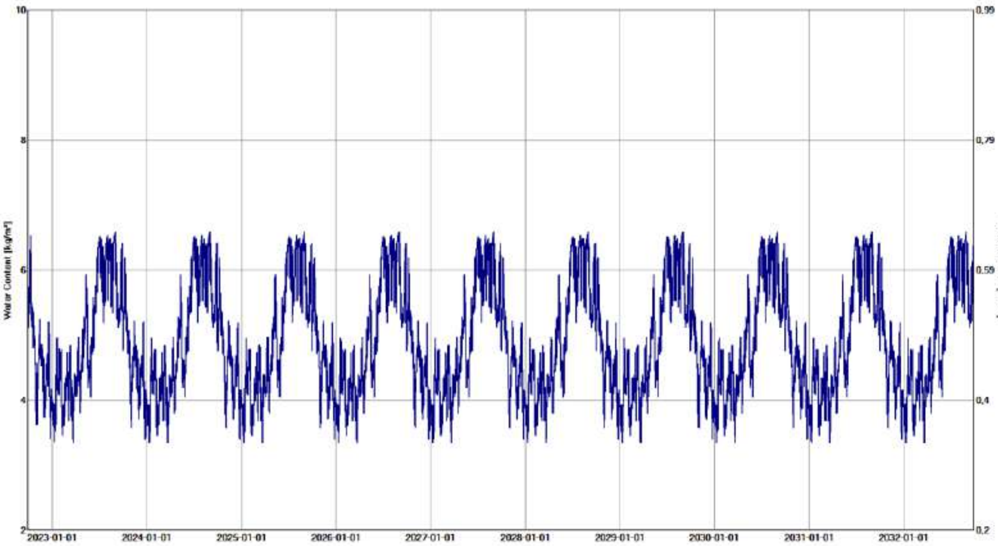
The woodfibre board has the ability to dry out and the relative humidity remains below 13 %, which is significantly below the critical limit.

EcoCocon straw panel:



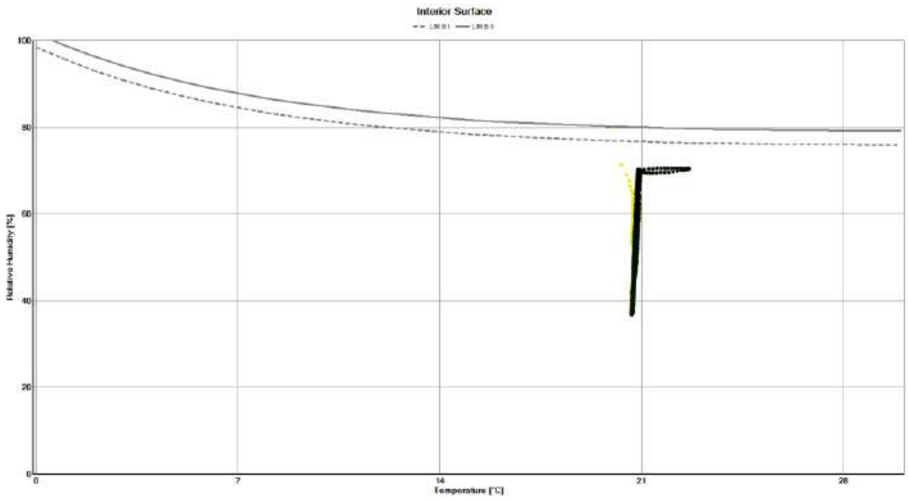
After the deliberately high setting at the beginning, the relative humidity drops immediately and continuously stays below 11.5 M.-%.

Plasterboard layer:



The moisture content does not take harmful forms.

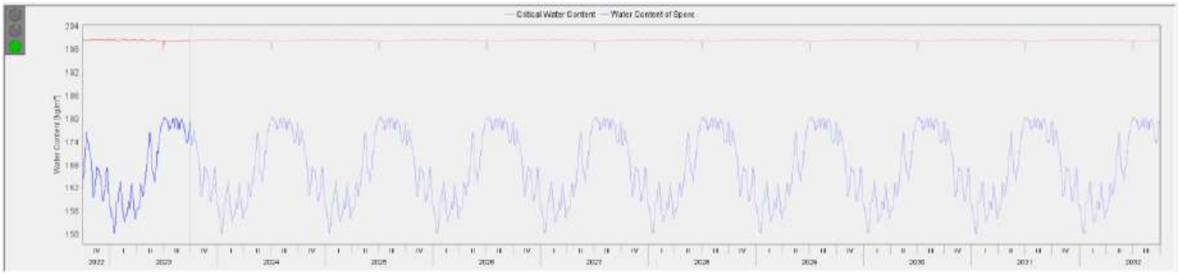
Isoplet on inner surface:



*) "LIM" stands for lowest isoplet for mould, "B" for construction.
The two scenarios I & II mean:
I = substrates that are readily biodegradable (e.g. wallpaper, dirt).
II = Substrates that are hardly biodegradable (e.g. mineral building materials).
Here, the interior surface examined is made of mineral plaster, i.e. No. II is relevant.

Each point represents one of the 87,600 calculations performed with respect to the combination of humidity and temperature and its potential to promote mould growth on the inside of the investigated exterior wall over a 10-year period. All are well below the two LIM threshold lines that represent two different scenarios for mould growth.

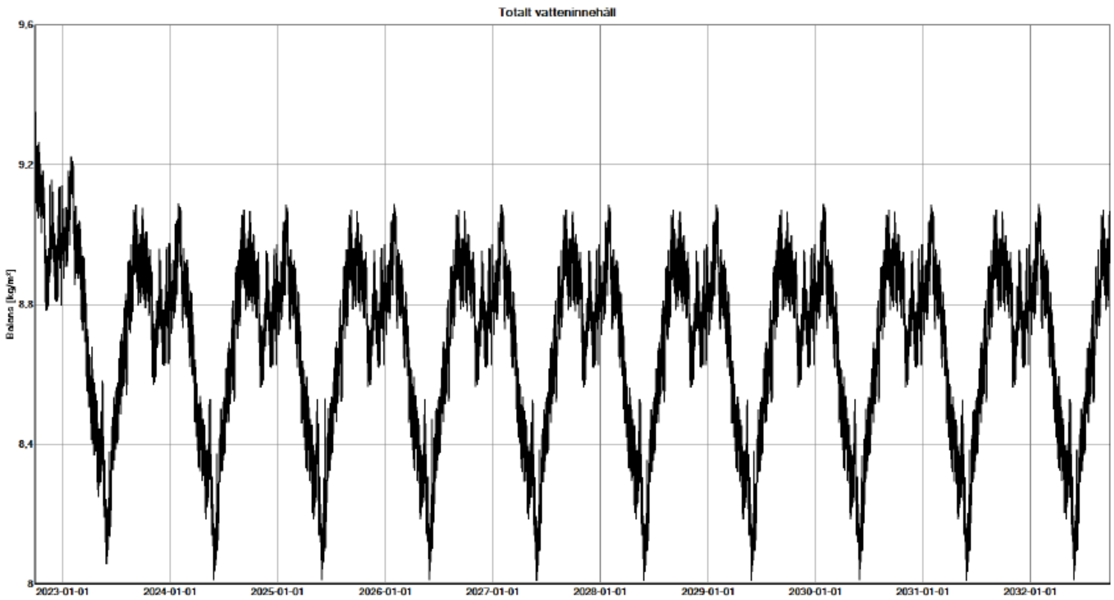
In addition to that, a study was carried out using *WUFI Bio 4.0*, a tool that examines spore formation by calculating their water content required for growth. The results show that the spores never reach a critical level - the traffic light shows *green*, i.e. approved, no problem:



Since the results regarding mould growth on the interior surface are basically identical for all four wall types, the above graphs and comments are not included again for the remaining three wall types.

Wall type B

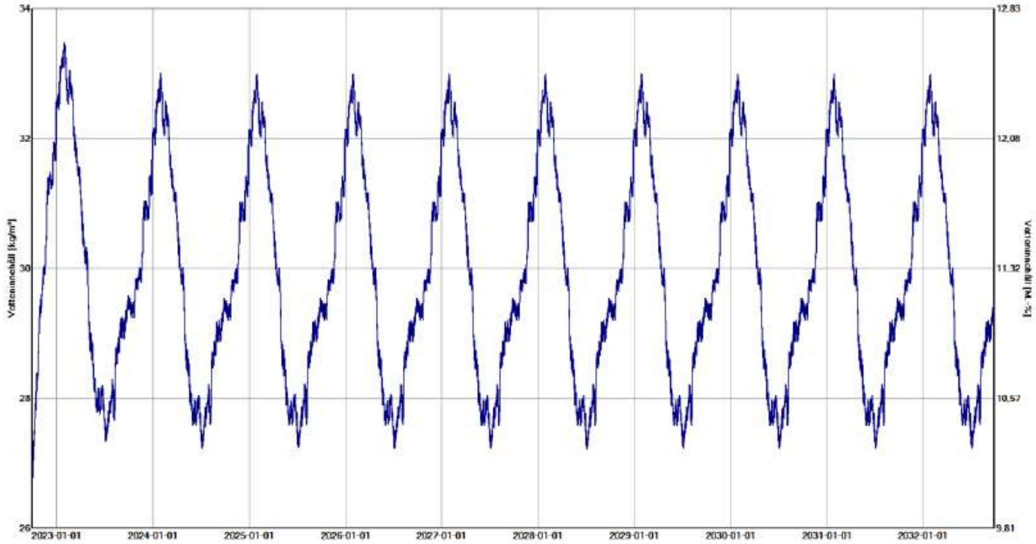
<u>Entire wall</u>



Even with built-in moisture content (80%), the entire wall structure dries out quite quickly. The simulation over 10 years shows that there is no accumulation of moisture over the long term. No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly. As the building consists of prefabricated modules, the risk of internal moisture or leakage is even lower.

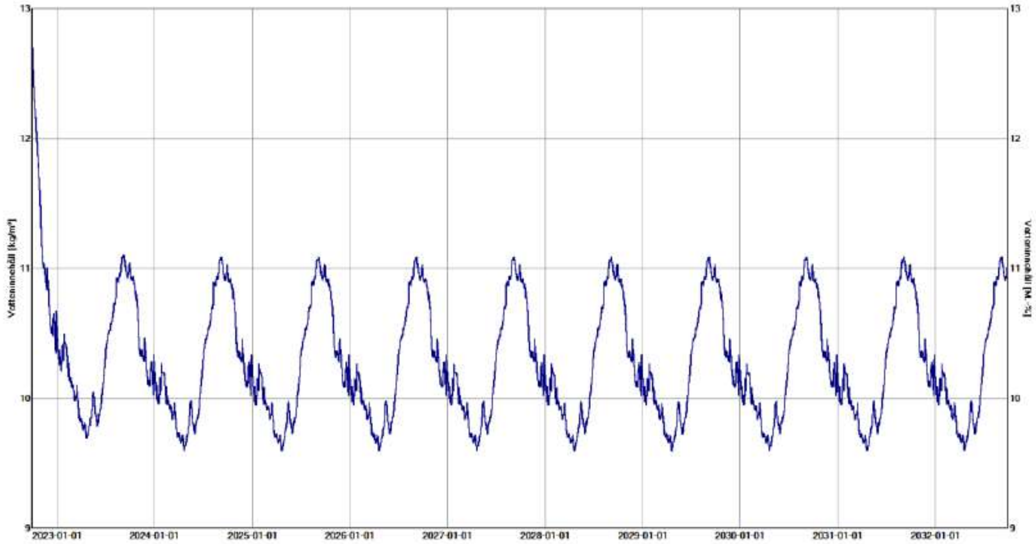
Individual layers

Woodfibre board behind the air gap:



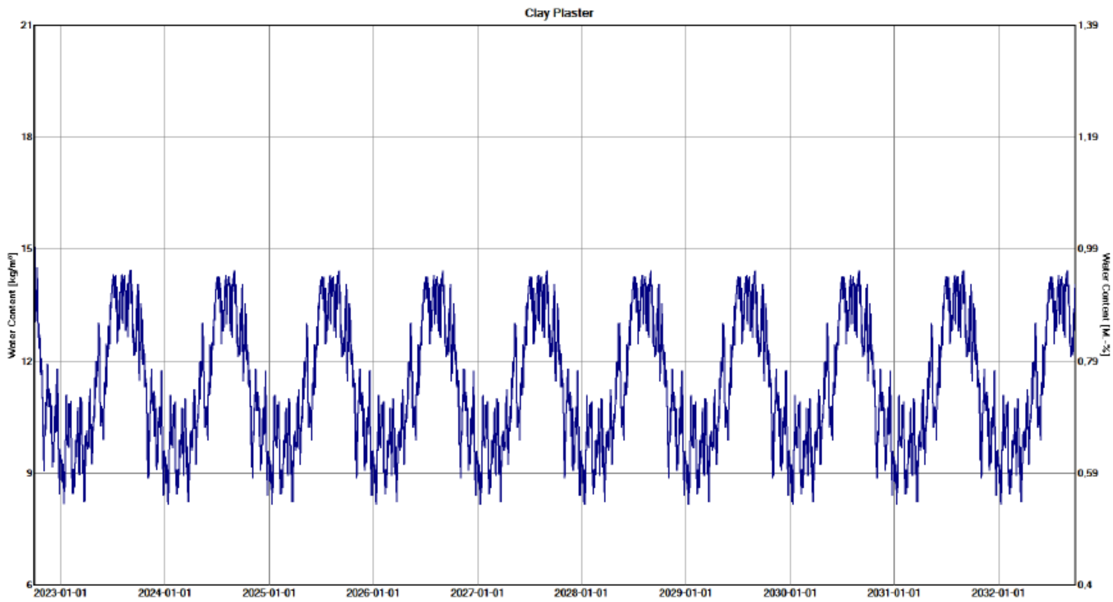
The woodfibre board has the ability to dry out and the relative humidity remains below 13 %, which is significantly below the critical limit.

EcoCocon straw panel



Even if an 80 % moisture content is assuemed for the construction phase, the straw panel dries out quickly and the water content remains below 12 M.-% all year round. It does not exceed this value over the course of the examined years either. After the initial steadying, the periodic variation remains the same.

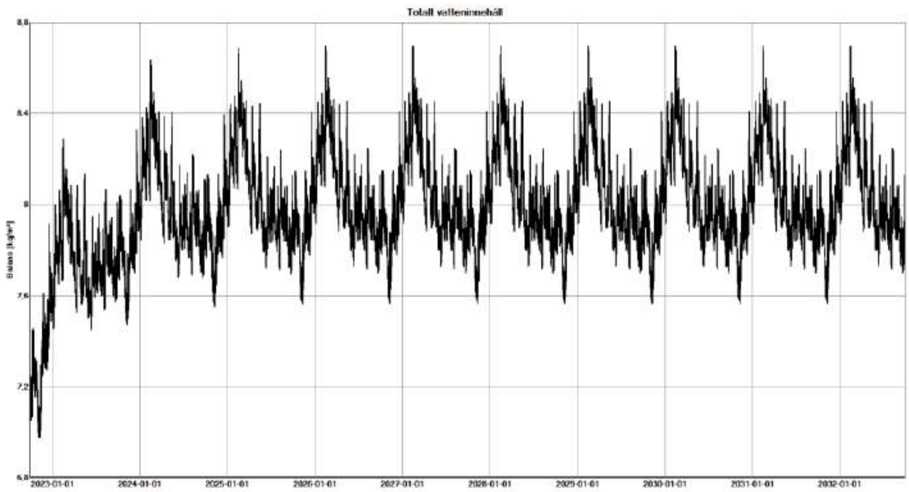
Interior clay paster:



The moisture content here does not take on any harmful forms. Rather does the clay render layer help to improve the indoor climate by buffering the humidity.

Wall type C

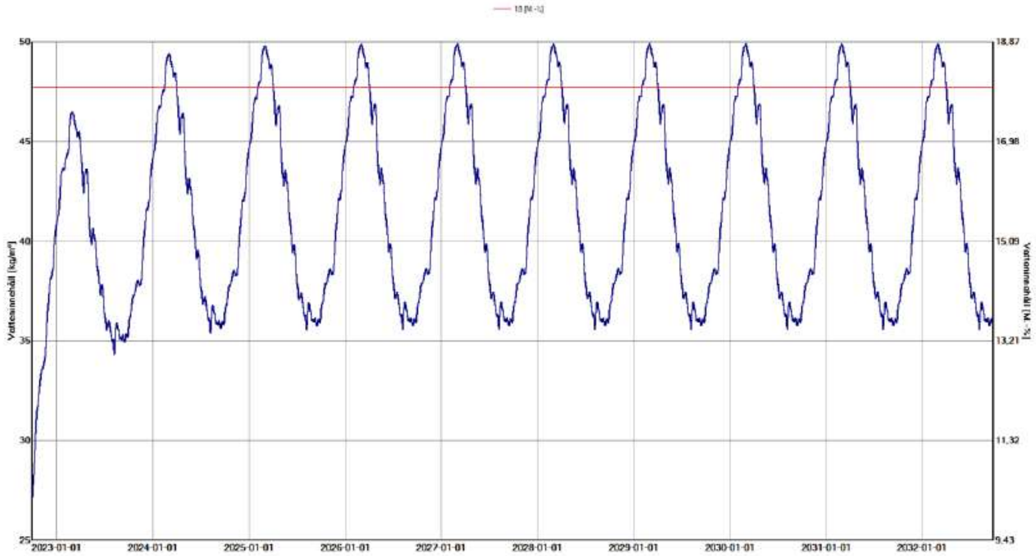
<u>Entire wall</u>



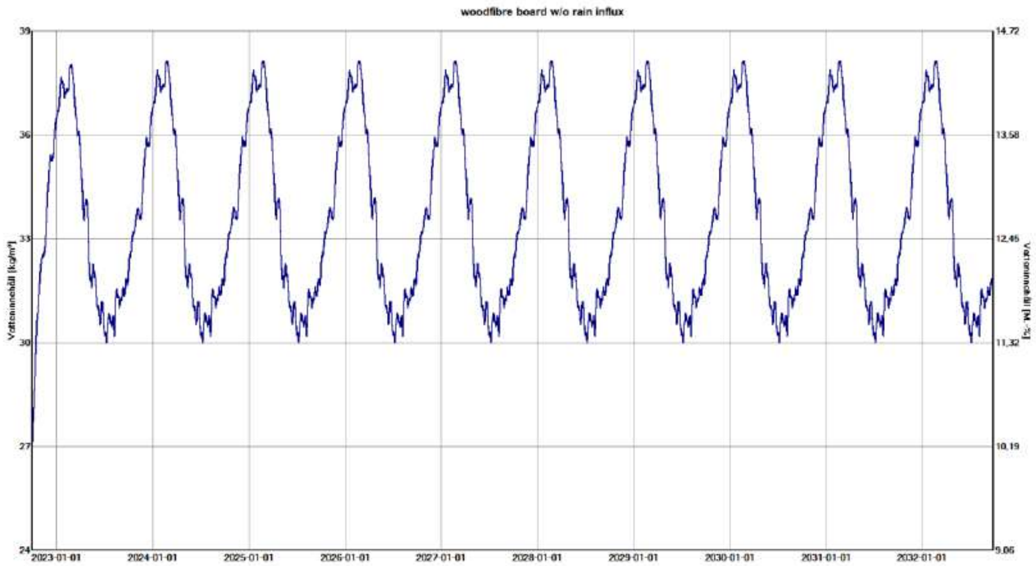
The simulation over 10 years shows that there is no further accumulation of moisture over the long term after the initial stabilisation period. No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly.As the building consists of prefabricated modules, the risk of internal moisture or leakage is even lower.

Individual layers

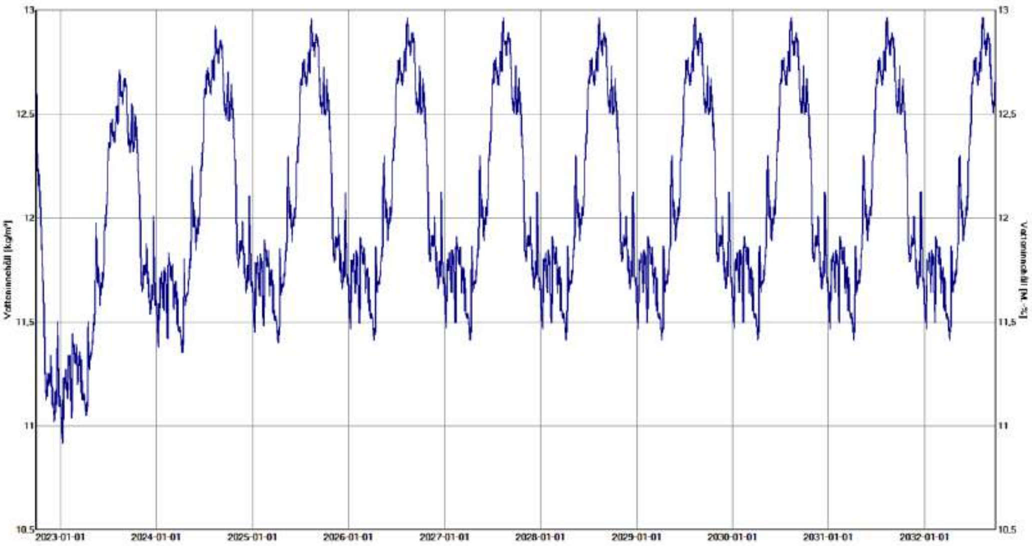
Woodfibre board behind the external render layer:



The woodfibre board including the 1% influx of rain partially reaches over the critical limit of 18 M.-%. Particular focus on watertightness during construction would therefore be required. Below, the results for woodfibre board *without* the additional "stress" of rainwater influx is shown – the water content there remains well below the critical limit:

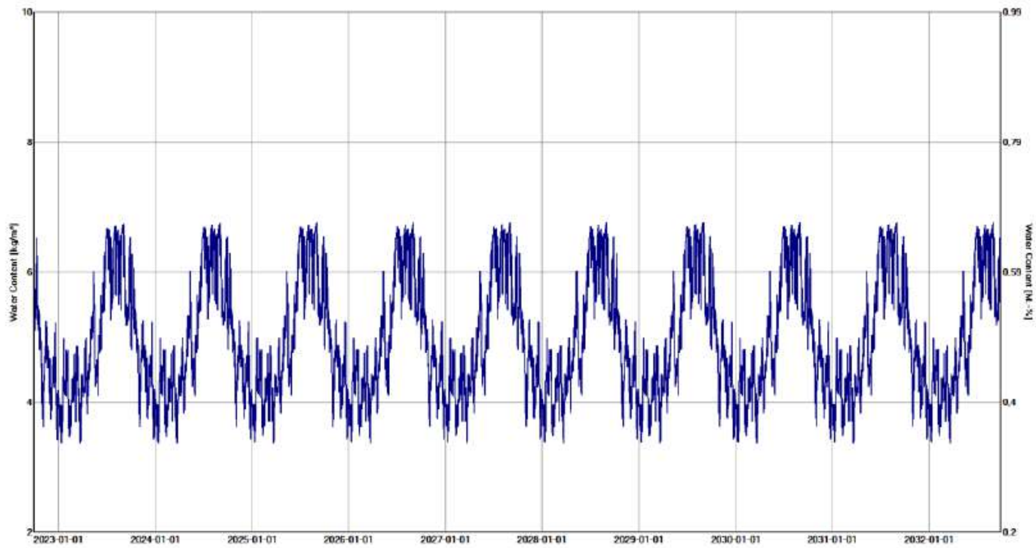


EcoCocon straw panel:



Even with a high moisture content assuemed for the construction phase, the straw panel dries out quickly and the water content remains below 13 M.-% all year round. It does not exceed this value over the course of the examined years either.

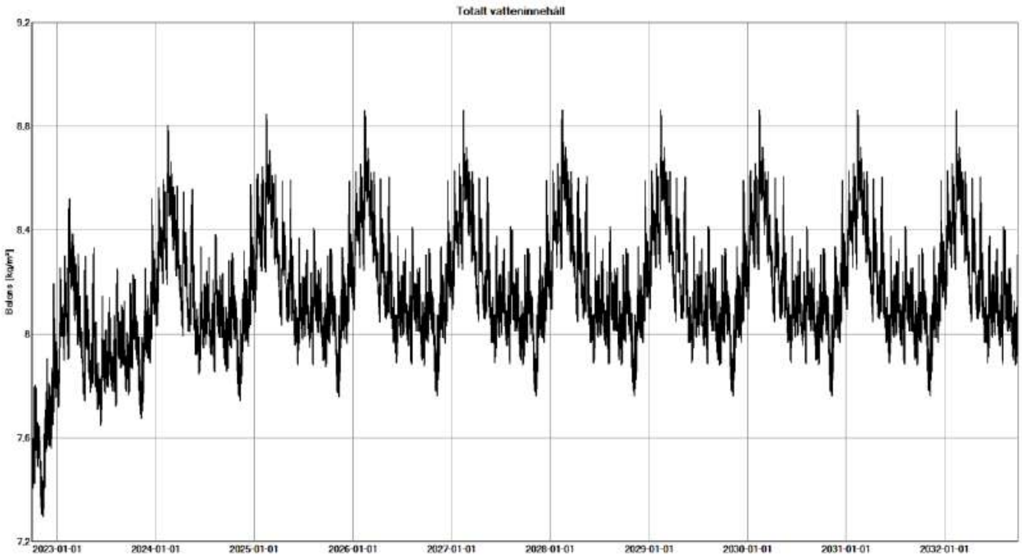
Plasterboard layer:



The moisture content here does not take on any harmful forms.

Wall type D

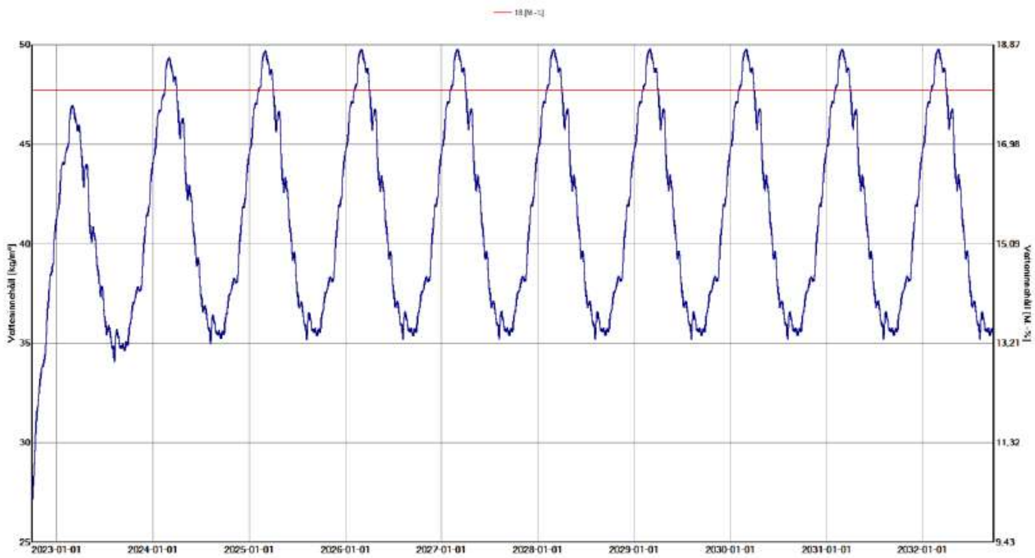
Entire wall



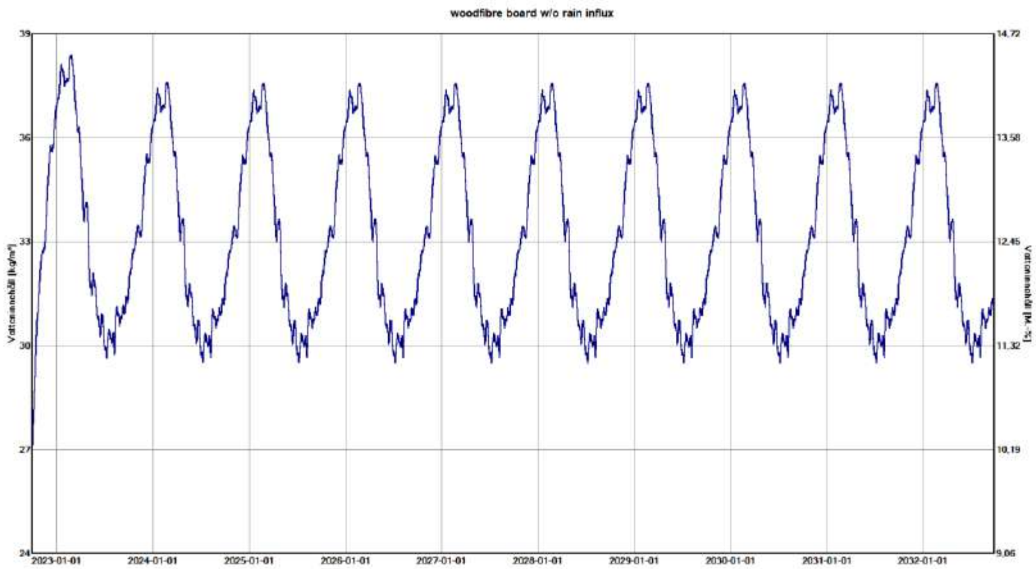
The simulation over 10 years shows that there is no further accumulation of moisture over the long term after the initial stabilisation period. No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly.As the building consists of prefabricated modules, the risk of internal moisture or leakage is even lower.

Individual layers

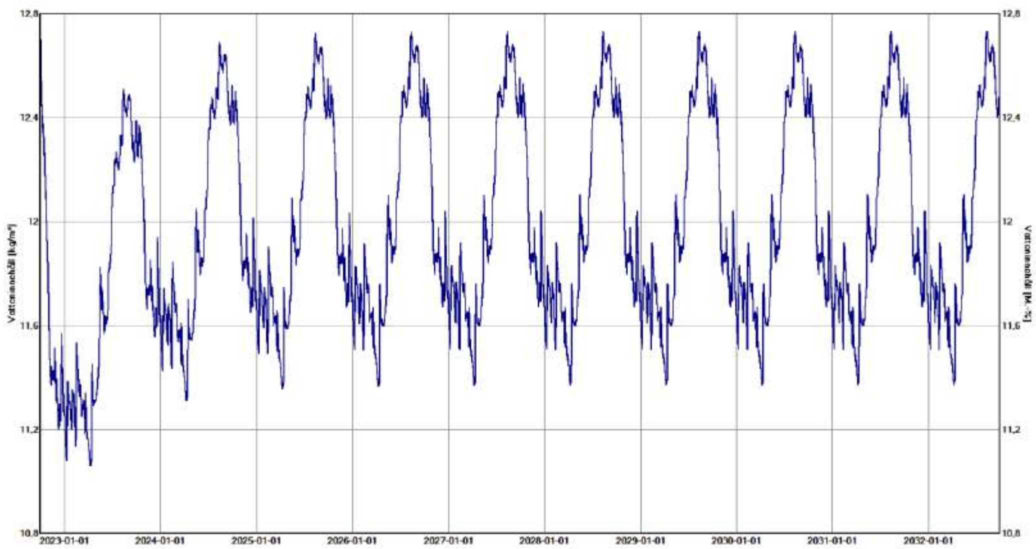
Wood fibre board behind the external render layer:



The woodfibre board including the 1% influx of rain partially reaches over the critical limit of 18 M.-%. Particular focus on watertightness would be required. Below, the results for woodfibre board *without* the additional "stress" of rainwater influx is shown – the water contents there remains well below the critical limit:

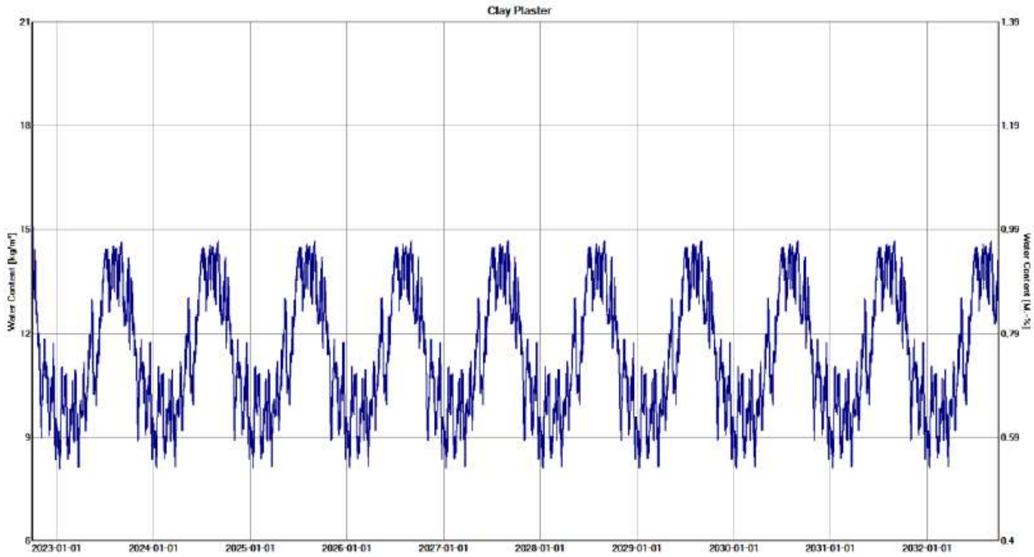


EcoCocon straw panel:



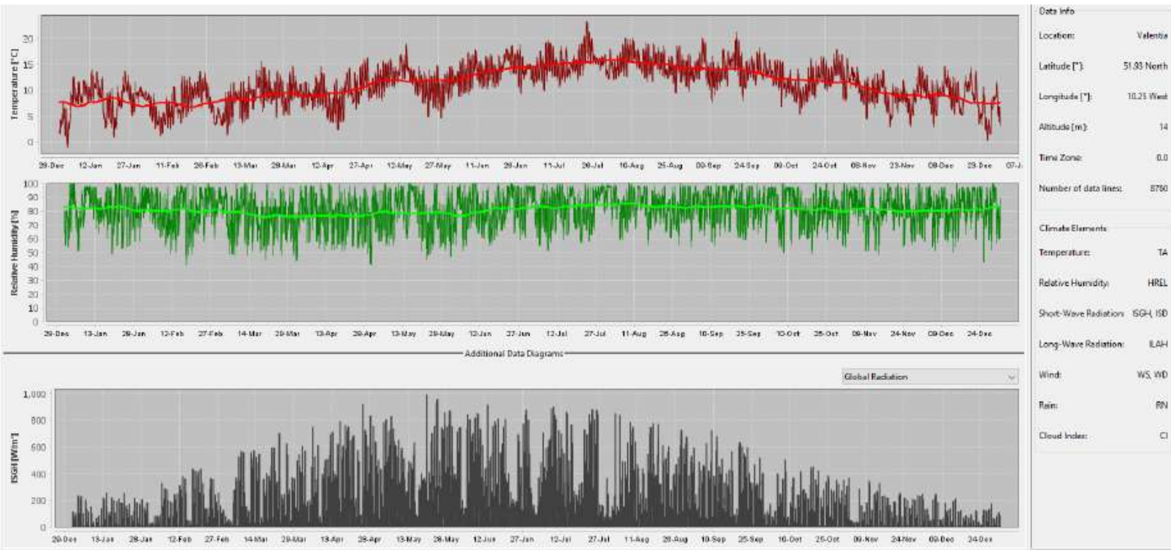
Even with a high moisture content assuemed for the construction phase, the straw panel dries out quickly and the water content remains below 13 M.-% all year round. It does not exceed this value over the course of the examined years either.

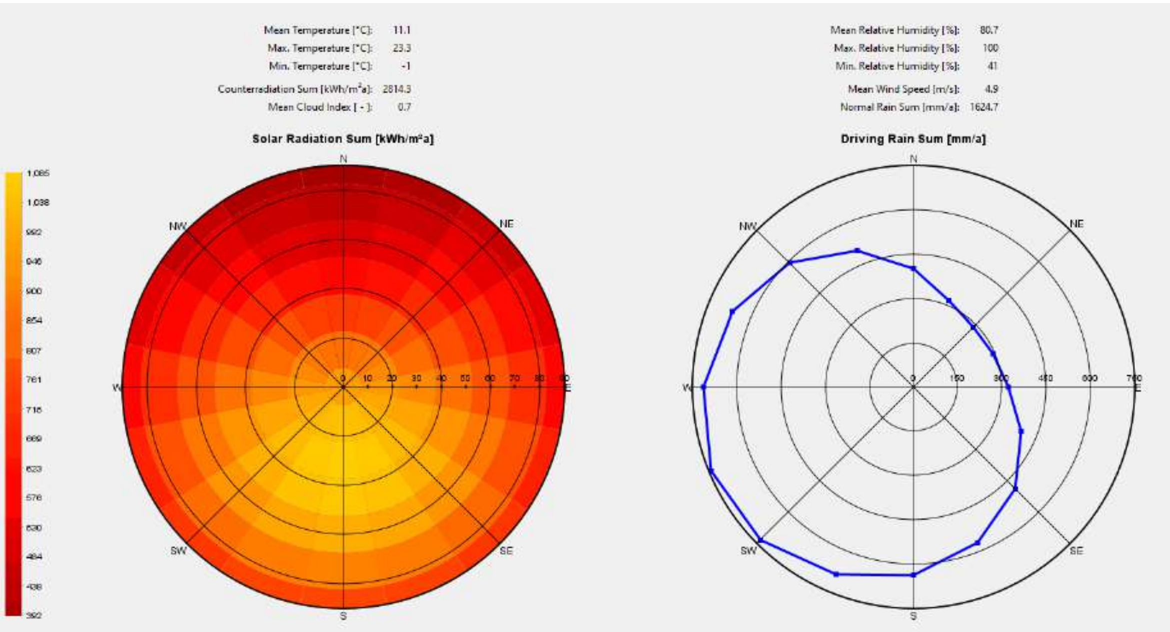
Interior clay plaster:



The moisture content here does not take on any harmful forms. As for wall types 1 and 2, the clay render layer rather helps to improve the indoor climate by buffering the humidity.

Outdoor climate Valentia (Ireland)





The direction of the strongest driving rain is West-southwest, but for ventilated facades, the northward orientation is decisive for these simulations and therefore has been applied. For stress-testing, 1% of the driving rain for an additional moisture source *behind* the weather membrane has been added in order to simulate water possibly seeping into the structure via small leaks, e.g., around the window installations. For rendered façades, West orientation has been applied. The driving rain is almost the same as for West-southwest, but there is less solar radiation – and therefore less drying potential. This will make the results even more on the safe side.

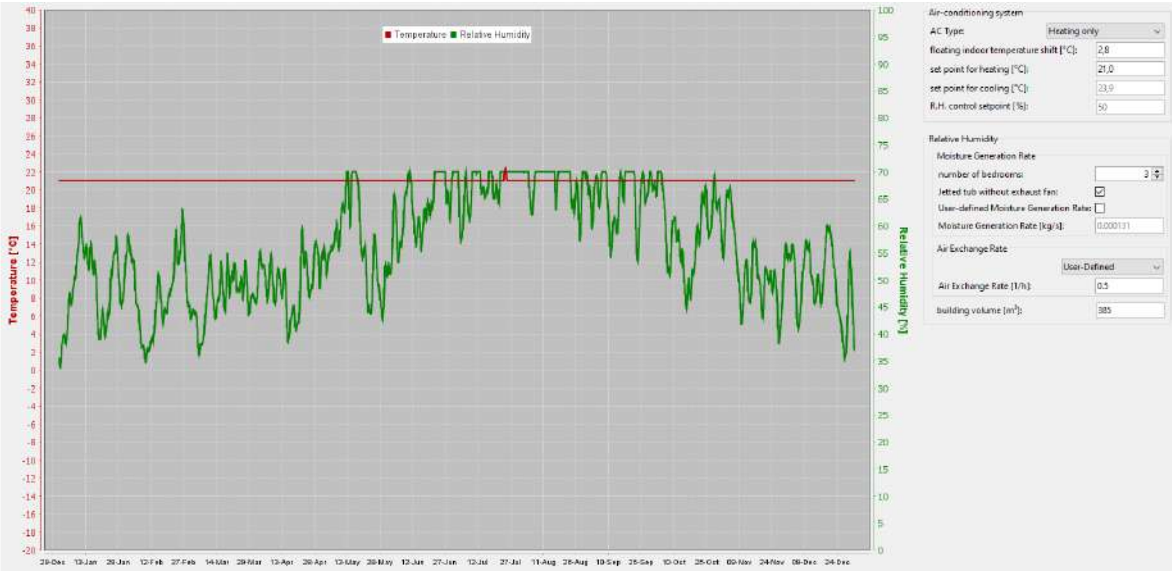
Indoor climate Valentia (Ireland)

The same model building was used for all simulations: a three-bedroom villa with 385 m³ interior volume.

A whirlpool bath without exhaust fan was added for possible additional moisture production - just to be on the safe side. An MVHR unit delivers 0.5 air changes per hour.

Airconditioning is only available as heating, no active cooling. The set point for heating is 21°C (typical value for SFH).

The indoor climate model was based on ASHRAE 160-2021 as this provided the possibilities to represent the above conditions. For Belmullet, it looks like this:

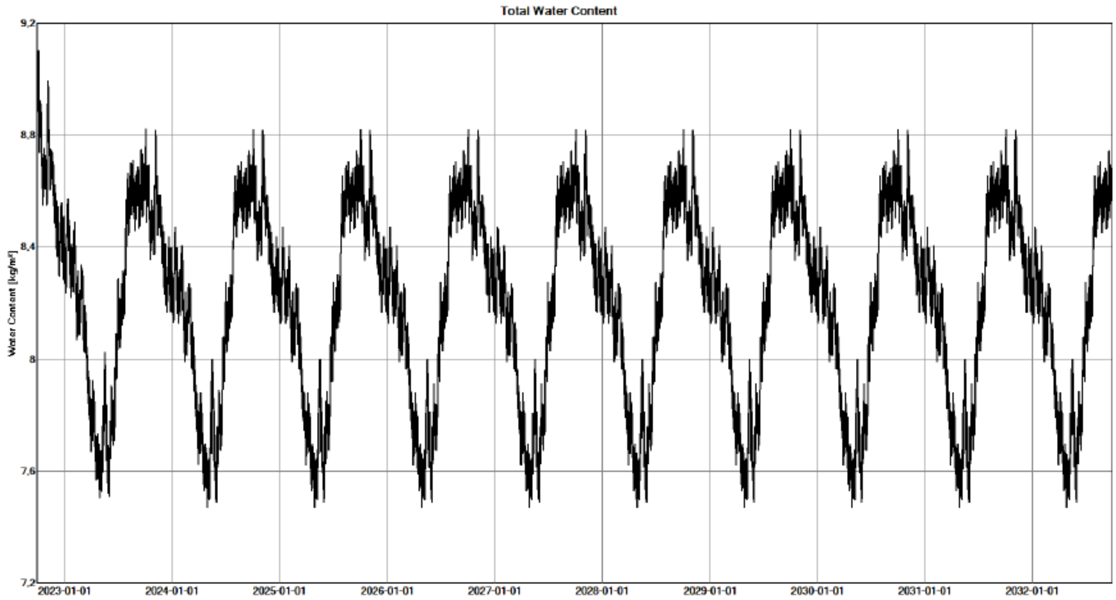


Results

The following diagrams show the water contents of the individual layers.

Wall type A

Entire wall

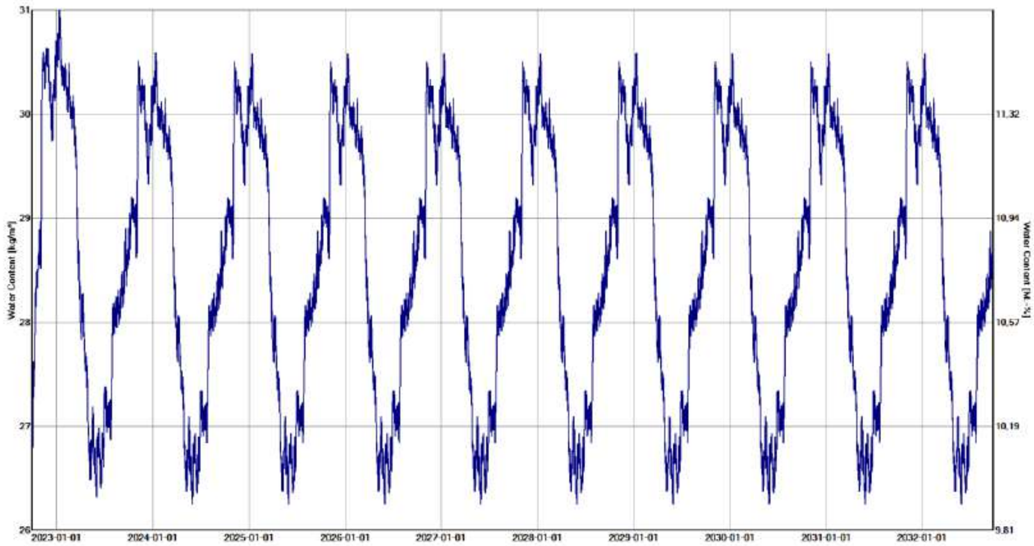


The simulation over 10 years shows that there is no accumulation of moisture over the long term (apart from the usual seasonal fluctuation). No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly.

For the simulation, 80 % relative humidity has been assumed for the materials built into the construction. As the house consists of prefabricated modules, there is even less risk of built-in moisture or leakage.

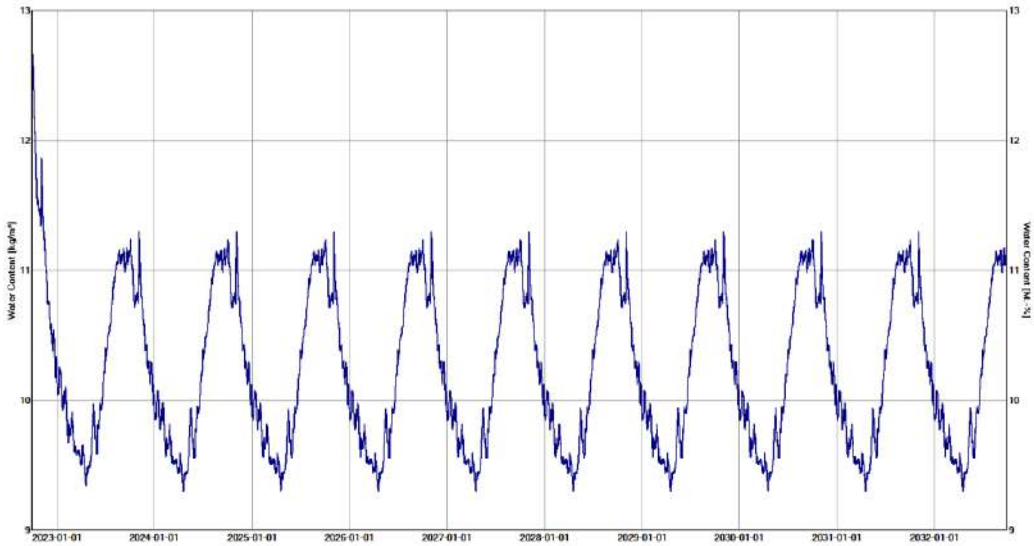
Individual layers

Woodfibre board behind the air gap:



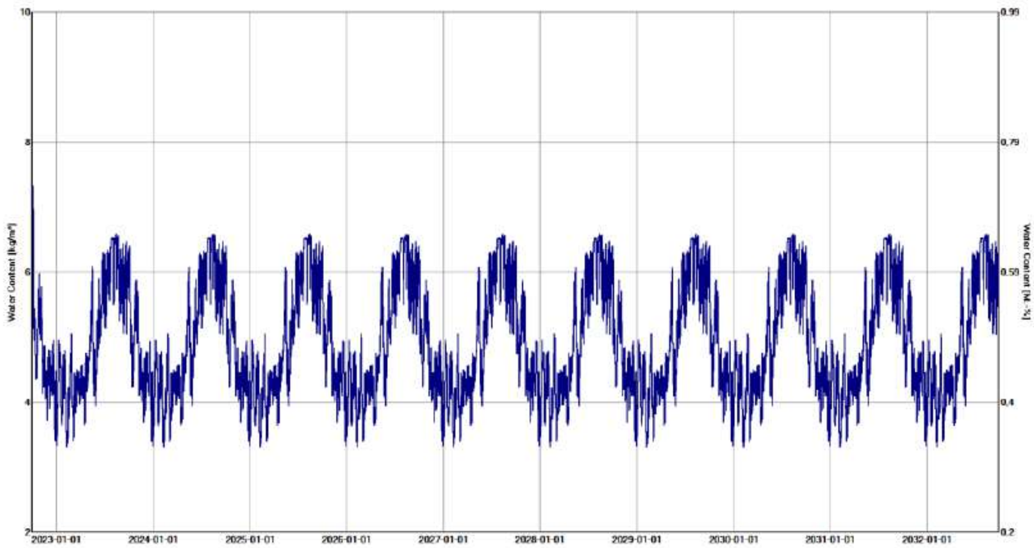
The woodfibre board has the ability to dry out and the relative humidity remains below 12 %, which is significantly below the critical limit.

EcoCocon straw panel:



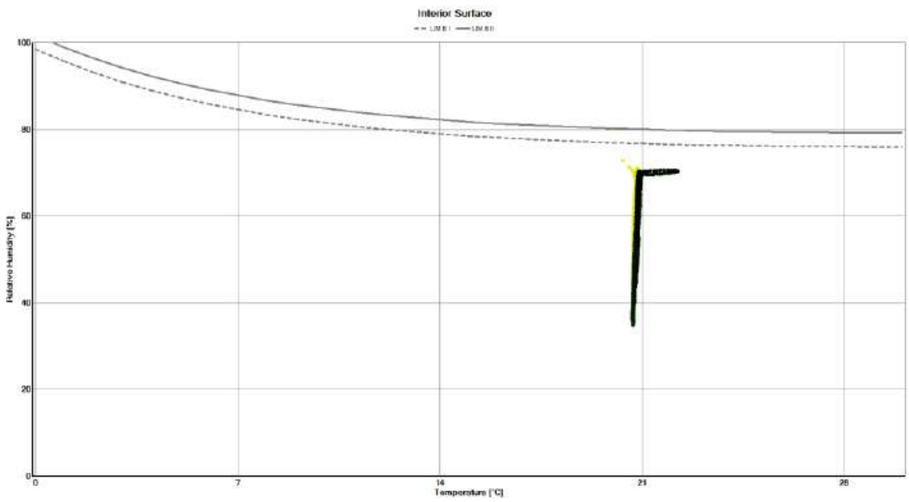
After the deliberately high setting at the beginning, the relative humidity drops immediately and continuously stays below 12 M.-%.

Plasterboard layer:



The moisture content does not take harmful forms here.

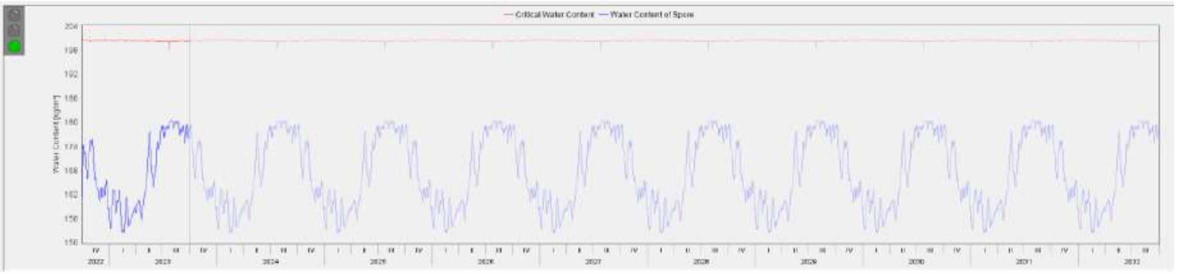
Isoplet on inner surface:



*) "LIM" stands for lowest isoplet for mould, "B" for construction.
The two scenarios I & II mean:
I = substrates that are readily biodegradable (e.g. wallpaper, dirt).
II = Substrates that are hardly biodegradable (e.g. mineral building materials).
Here, the interior surface examined is made of mineral plaster, i.e. No. II is relevant.

Each point represents one of the 87,600 calculations performed with respect to the combination of humidity and temperature and its potential to promote mould growth on the inside of the investigated exterior wall over a 10-year period. All are well below the two LIM threshold lines that represent two different scenarios for mould growth.

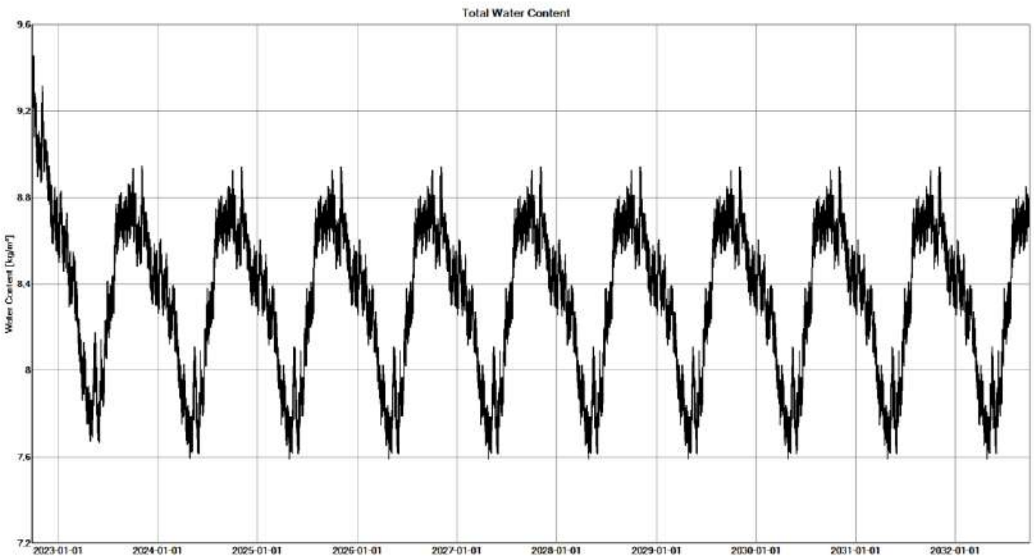
In addition to that, a study was carried out using *WUFI Bio 4.0*, a tool that examines spore formation by calculating their water content required for growth. The results show that the spores never reach a critical level - the traffic light shows *green*, i.e. approved, no problem:



Since the results regarding mould growth on the interior clay render surface are basically identical for all four wall types, the above graphs and comments are not included again for the remaining three wall types.

Wall type B

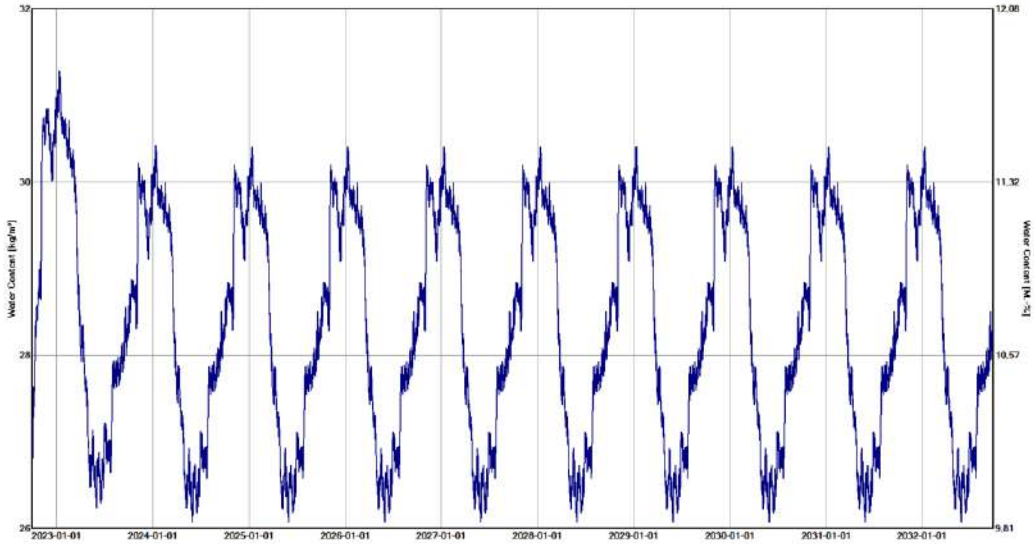
<u>Entire wall</u>



Even with built-in moisture content (80%), the entire wall structure dries out quite quickly. The simulation over 10 years shows that there is no accumulation of moisture over the long term. No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly. As the building consists of prefabricated modules, the risk of internal moisture or leakage is even lower.

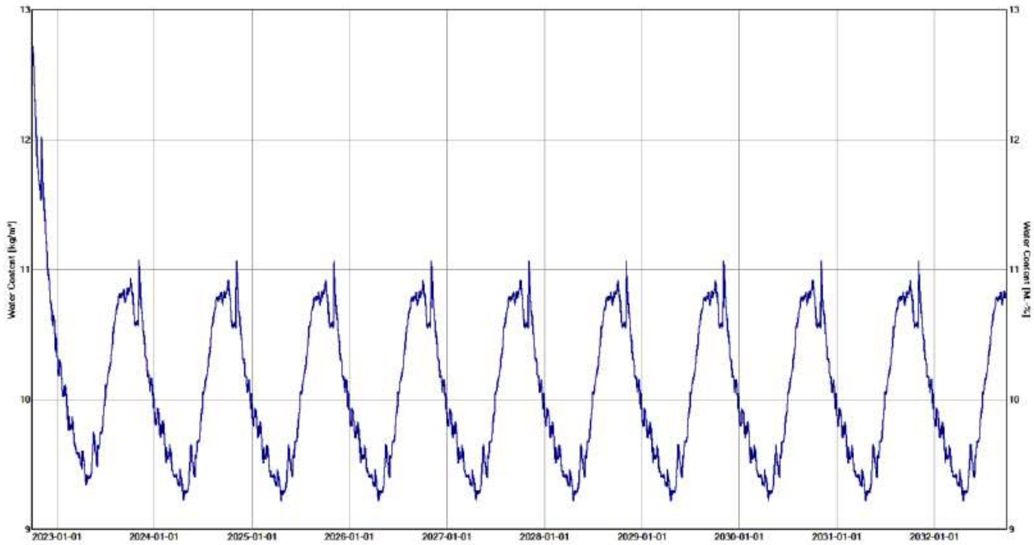
Individual layers

Woodfibre board behind the air gap:



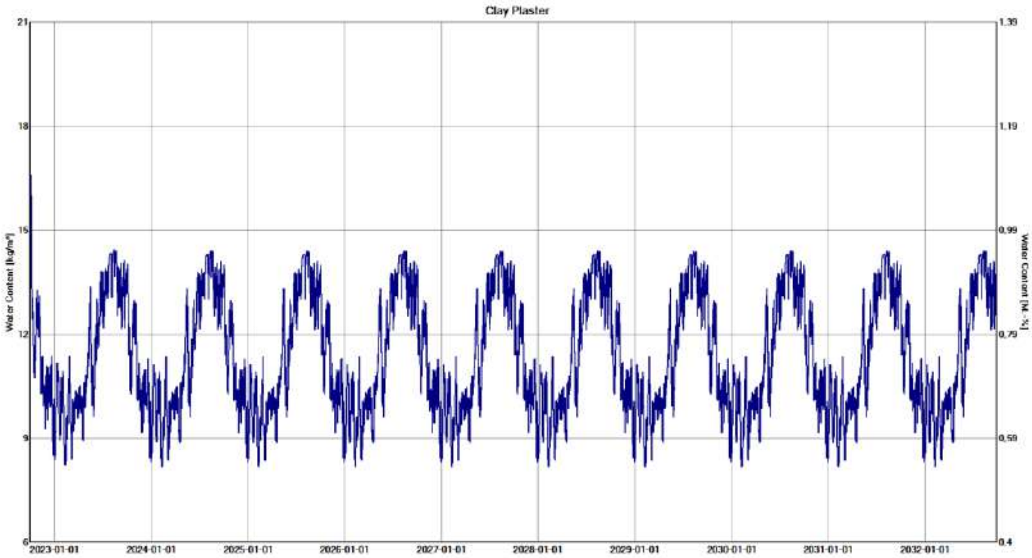
The woodfibre board has the ability to dry out and the relative humidity remains below 11 %, which is significantly below the critical limit.

EcoCocon straw panel



Even if an 80 % moisture content is assuemed for the construction phase, the straw panel dries out quickly and the water content remains below 12 M.-% all year round. It does not exceed this value over the course of the examined years either. After the initial steadying, the periodic variation remains the same.

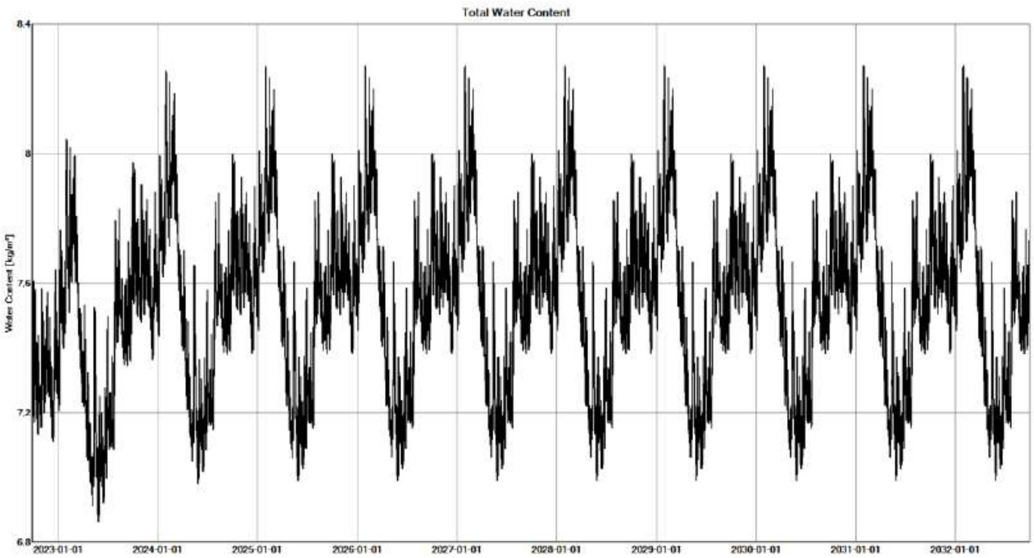
Interior clay paster:



The moisture content here does not take on any harmful forms. On the contrary: the clay render layer rather helps to improve the indoor climate by buffering the humidity.

Wall type C

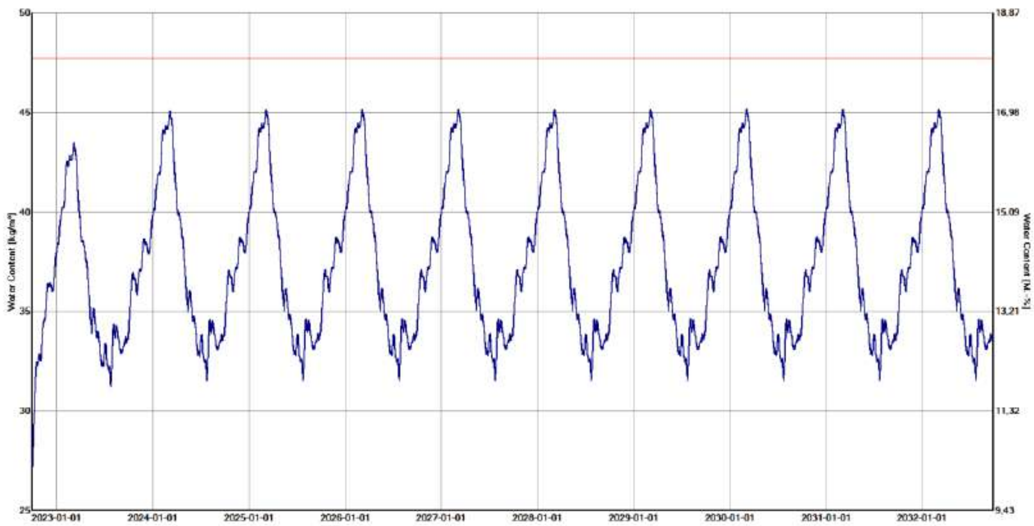
<u>Entire wall</u>



The simulation over 10 years shows that – after the initial stabilisation period - there is no accumulation of moisture over the long term. No risk of damage to the building fabric, or mould, would be expected if the work is carried out correctly. As the building consists of prefabricated modules, the risk of internal moisture or leakage is even lower.

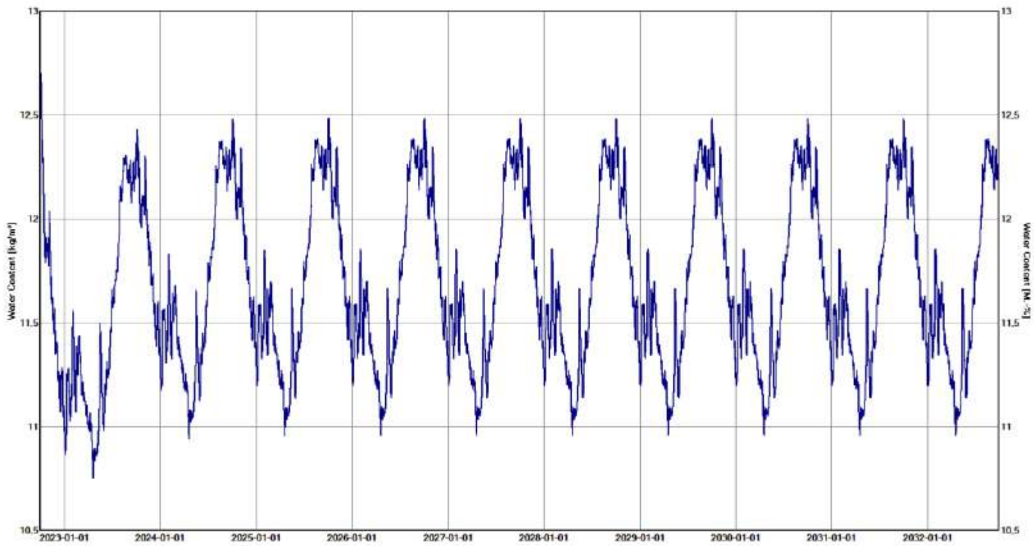
Individual layers

Wood fibre board behind the external render layer:



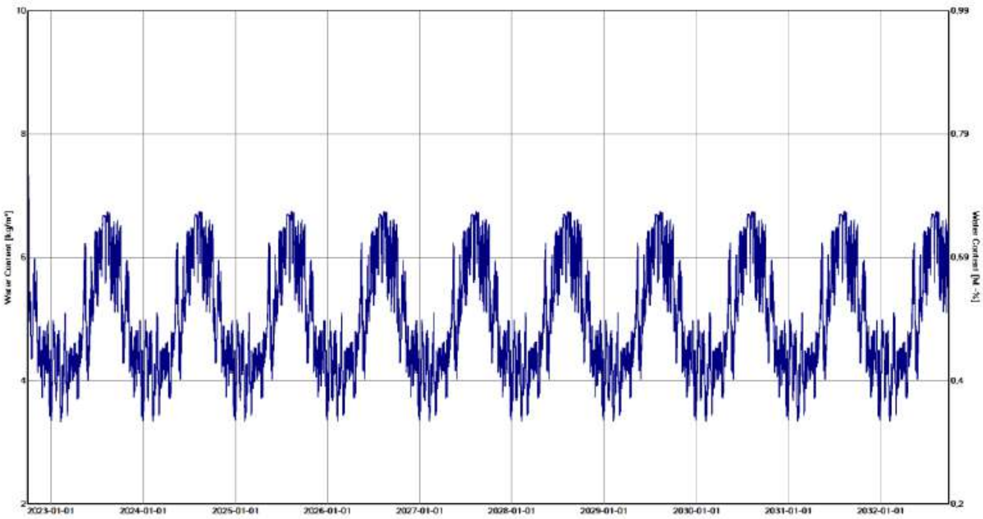
The relative humidity in the woodfibre board remains below 17 % - even with the additional stress through driving rain.

EcoCocon straw panel:



Even with a high moisture content assuemed for the construction phase, the straw panel dries out quickly and the water content remains below 12.5 M.-% all year round. It does not exceed this value over the course of the examined years either.

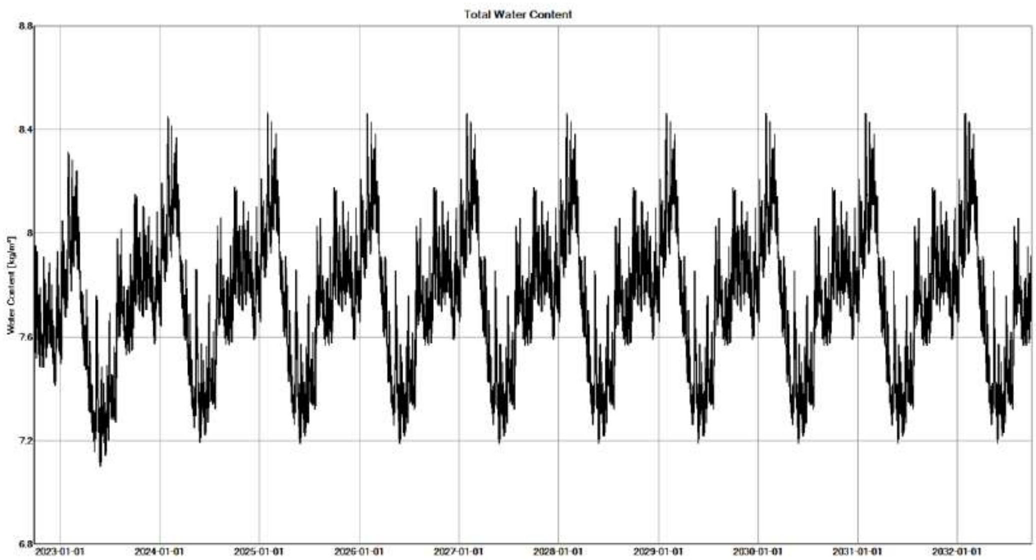
Plasterboard layer:



The moisture content here does not take on any harmful forms. As for wall types 1 and 2, the clay render layer rather helps to improve the indoor climate by buffering the humidity.

Wall type D

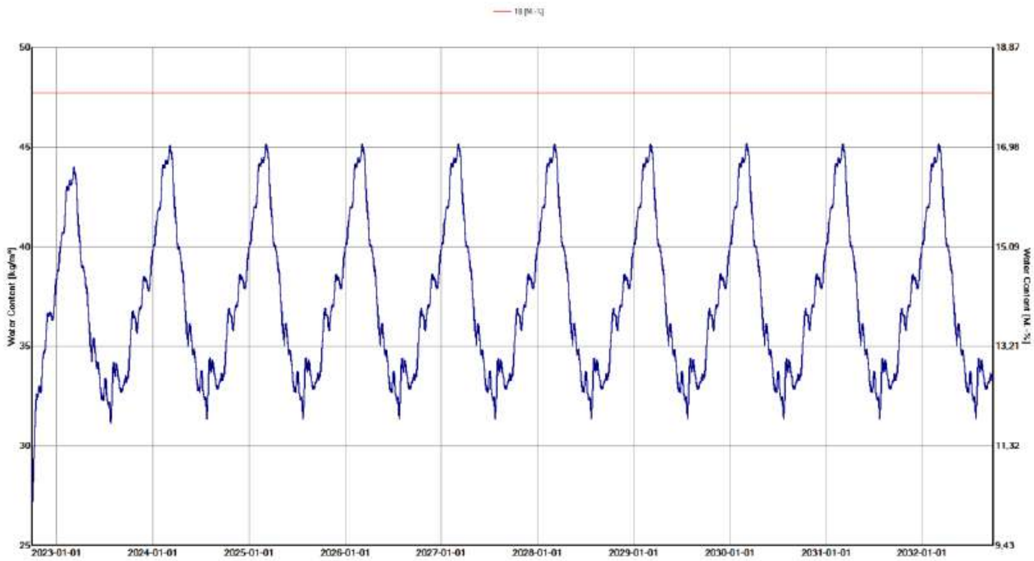
<u>Entire wall</u>



The simulation over 10 years shows that there is no accumulation of moisture over the long term – after the initial stabilisation period. No risk of damage to the building fabric, or mould, can be expected if the work is carried out correctly.As the building consists of prefabricated modules, the risk of internal moisture or leakage is even lower.

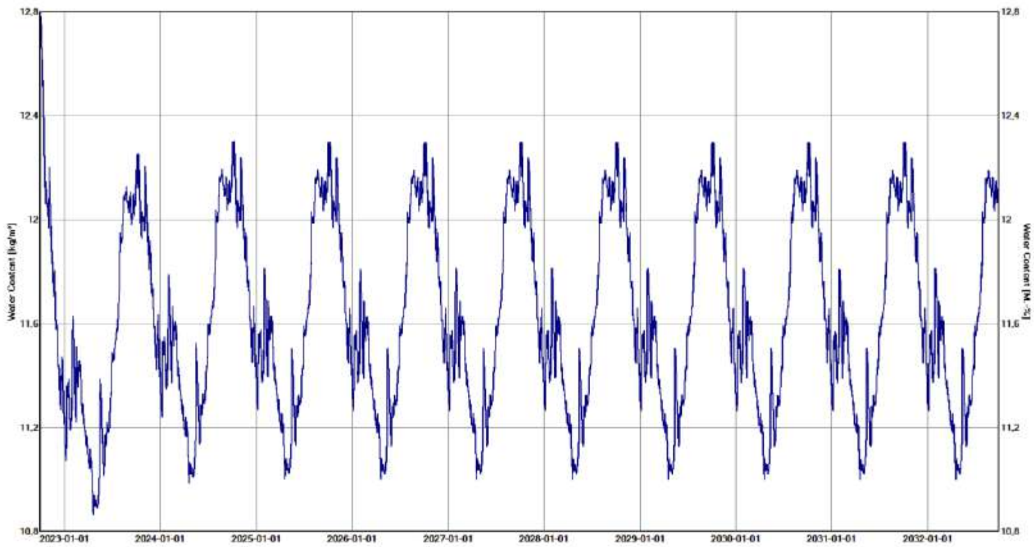
Individual layers

Woodfibre board behind the external render layer:



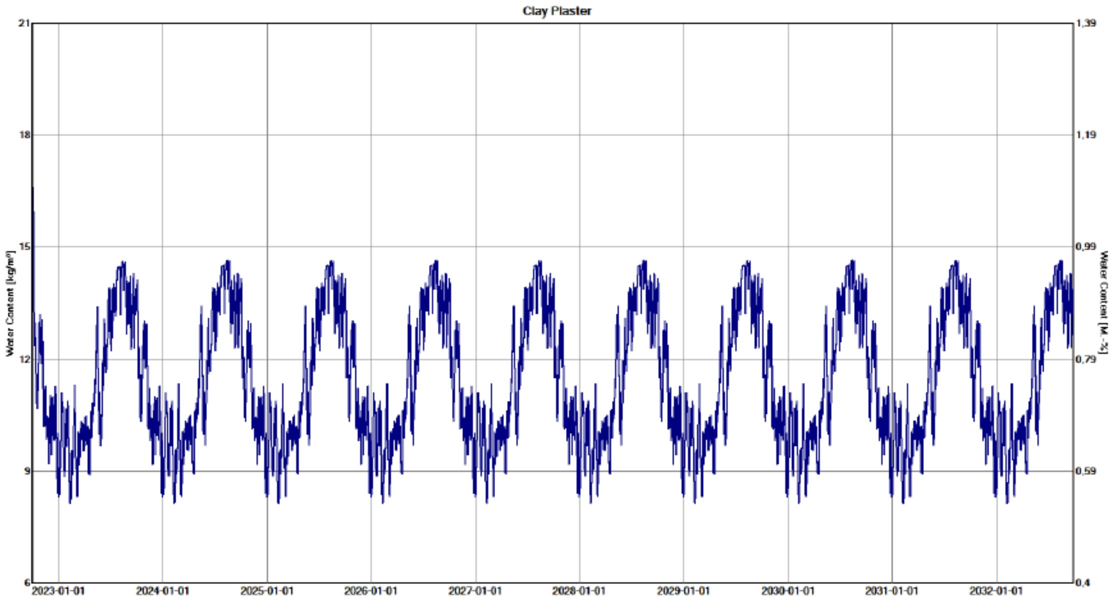
The woodfibre board - including the 1% influx of rain – never exceeds the critical limit of 18 M.-%.

EcoCocon straw panel:



Even with a high moisture content assuemed for the construction phase, the straw panel dries out quickly and the water content remains below 12.5 M.-% all year round. It does not exceed this value over the course of the examined years either.

Interior clay plaster:



The moisture content here does not take on any harmful forms. As for wall types B, the clay render layer rather helps to improve the indoor climate by buffering the humidity.

Summary

A simulation is only as good as its input data, including boundary conditions. The calculations were made with additional safety margins, namely an additional source of moisture indoors, 1% of driving rain was considered to leak into the structure - which can be prevented by proper construction – and a very low air exchange rate in the ventilation gap of the façade.

The simulation shows that the structure dries out quickly, even if it had 80 % humidity at the start of construction, or – depending on the wall type – at least remains stable in a safe state after an initial (slight) infiltration of moisture. There is a periodic accumulation and reduction of moisture in the individual layers, but this never reaches alarming proportions.

However, when applying these results, certain aspects must be taken into account:

1) The calculations are only related to the defined and specified boundary conditions and the named object and substructures and are not transferable, even if the structure is the same or similar.
2) In order for the calculation to be representative, accurate production is required and the contractor is responsible for consistently maintaining the specifications.
3) Airtightness and, ideally, airtightness testing, is a prerequisite.
4) The specified moisture contents for the materials, specifically for wood or wood-based products, must not be exceeded. Careful, clean and dry storage must be ensured.
5) The render on the rendered façades has been included with an A-value (coefficient of water absorption) of 0.1 $kg/(m^2 \cdot h^{0.5})$, which needed for the appropriate control of the water contents in the woodfibre board behind it. This A-value needs to be maintained.

Tvärred, 2nd February 2023

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