U-VALUE GUIDE

This document examines the method used to conduct a u-value calculation and condensation risk analysis using the u-value calculator available on the member's area of the A Proctor Group website.

Useful definitions:

Thermal Conductivity:

The thermal conductivity of a material is a measure of how well it conducts heat. Metals are excellent conductors of heat, while materials such as wool and woodfibres are more insulating. Consider the effects of holding onto a metal pot handle when cooking. The heat will quickly travel along the conductive handle, so in order to prevent burning oneself, you would use something like an oven mitt, which has a much lower thermal conductivity.

The units for thermal conductivity are Watts per metre Kelvin, or W/mK. In simple terms, this is a measure of how much heat energy passes through a solid metre of the material when there is a temperature difference between one side and the other, and is generally the best way to compare insulation products. The lower this value, the better any given material is as thermal insulation. Thermal conductivity is often written as the k-value or λ-value, or even just λ.

Thermal Resistance:

The thermal resistance or R-value of a material takes the thickness of the material and divides it by the thermal conductivity, therefore providing a value for the thermal performance of a specific depth of material. With insulations, it is difficult to compare the thermal resistance alone, as having only that information can be misleading. For example, it might be true that a particular layer of a mineral wool insulation has a thermal resistance of 1.25 m^2K/W while a specific layer of our own high performance Spacetherm A rated insulation only has a thermal resistance of 1.03; but what that fails to mention is that the mineral wool is 50mm thick while the Spacetherm is only 20mm. If the same depth of these materials is compared, the Spacetherm would have a thermal resistance of more than double that of the mineral wool. The units for this are metres squared Kelvin per Watt.

U-Value:

A u-value is a measure of how much heat is lost through an entire building element. It is measured in Watts per metre squared Kelvin (usually shortened to W/m^2K). This quantifies the amount of heat energy that will pass through a one metre squared section of wall, roof, or floor for every degree of temperature difference. U-values are considered to be homogenous, so each layer in the element is continuous. This means that it is not suitable for locations such as window reveals. Repeated thermal bridges can be accommodated in the calculation, however.

To calculate the u-value of any given thermal element, you take the sum of the thermal resistance of every layer in the construction, as well as that of the internal and external surface resistance. This total is then inverted to provide the u-value. If any elements contain repeating thermal bridges, this becomes slightly more complex, as the upper and lower limits of the bridged material need to be considered.

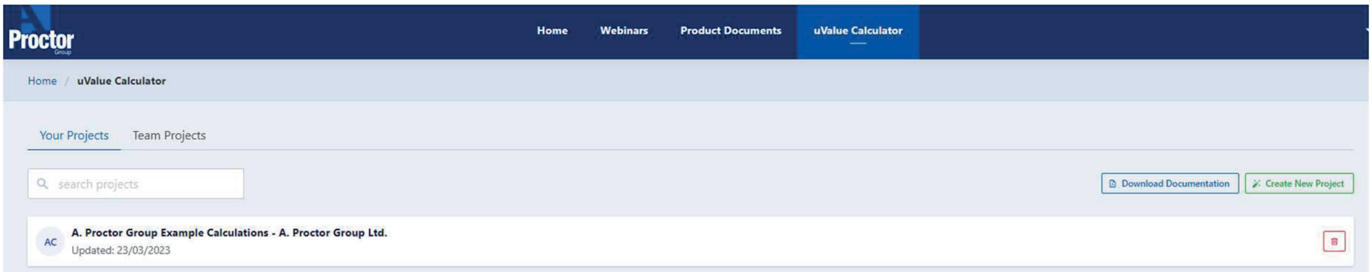
Proctor Group

The A Proctor Group's u-Value Calculator

Settng up a Project

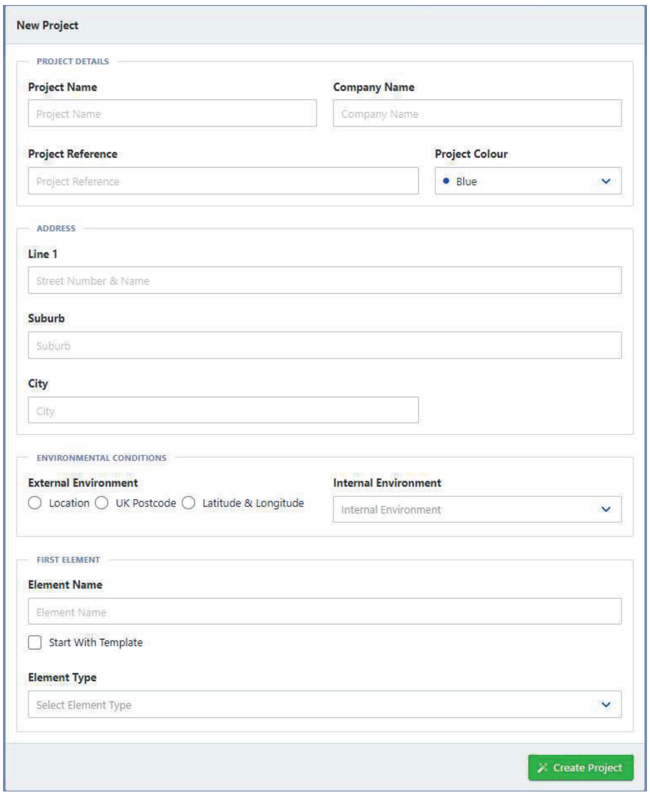
To conduct a u-value calculation using the A. Proctor Group's calculator, follow the below. This guide assumes that you have already logged onto the members' area of the website, and that you have requested access to the u-value calculator. On the u-value calculator home page, you will see that you have tabs for "Your Projects" and for "Team Projects". The latter allows for collaboration within your company, and is something that you can request access for. Under "Your Projects", you will only have one file to begin with: "A. Proctor Group Example Calculations – A Proctor Group Ltd." Opening this will give you access to a number of BRE worked examples for calculations, but this guide will look at creating a u-value from scratch, so click the green, "Create New Project" button on the top right.

This will bring up the "New Project" menu, which is shown below. Fill in the project details and address. The Project Name



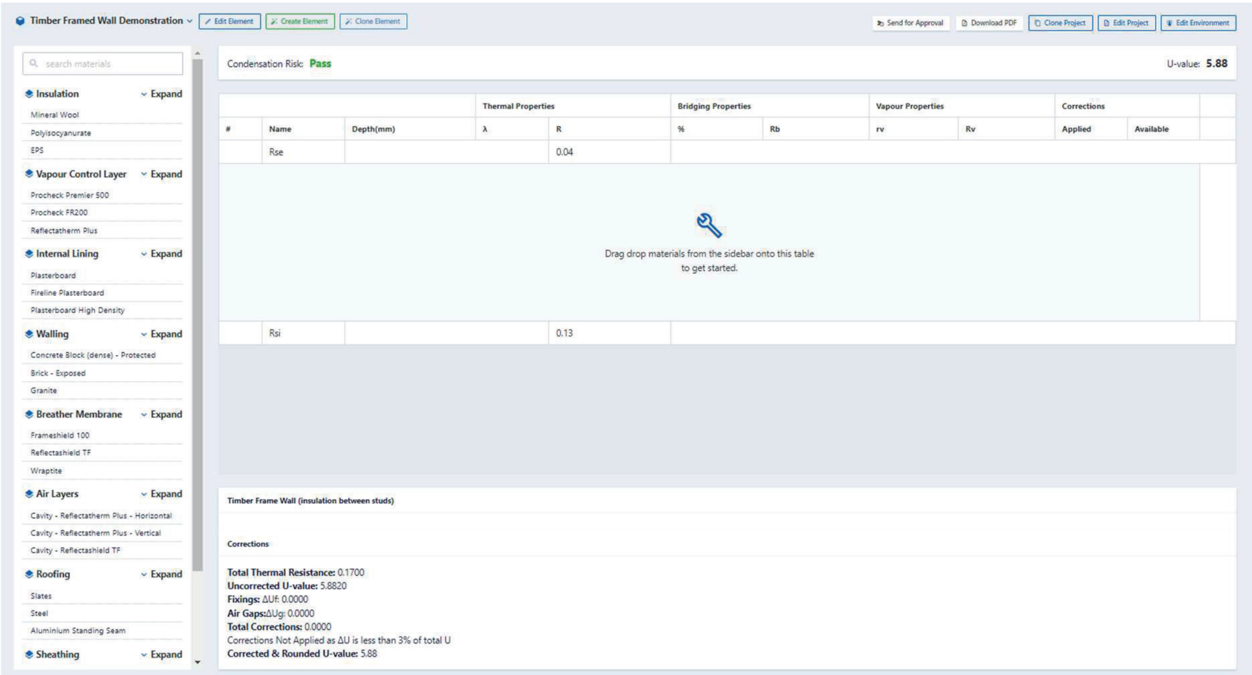
is what appears on the previously shown list of projects, so ensure that it is something easy to search for later. In the Environmental Conditions section, you can either select a preset location (which brings up a dropdown menu); or use a UK postcode. Outside of the UK, you can specify the lattitude and longitude. If using either the postcode or geographical data, the external climate information is taken from measured climate data for the location for the past 20 years.

In most cases, the internal environment should be "Average", though you may increase this to high occupancy where there is greater risk, such as in dense residential constructions.



The final box on the project creation menu is information about the first element. This is the wall, roof or floor that you wish to analyse. After giving it a name, such as Rear Wall or Extension Roof, you need to choose the element type and sub-type. These determine if it is calculated as a wall, roof, or floor, and the sub-type allows for further categorisation. You should choose the sub-type based on the primary structure of the element. For the purposes of this document, we will be looking at a Timber Frame Wall (insulation between studs). The "Start With Template" button has a number of prebuilt calculations for each element, which can expedite the process.

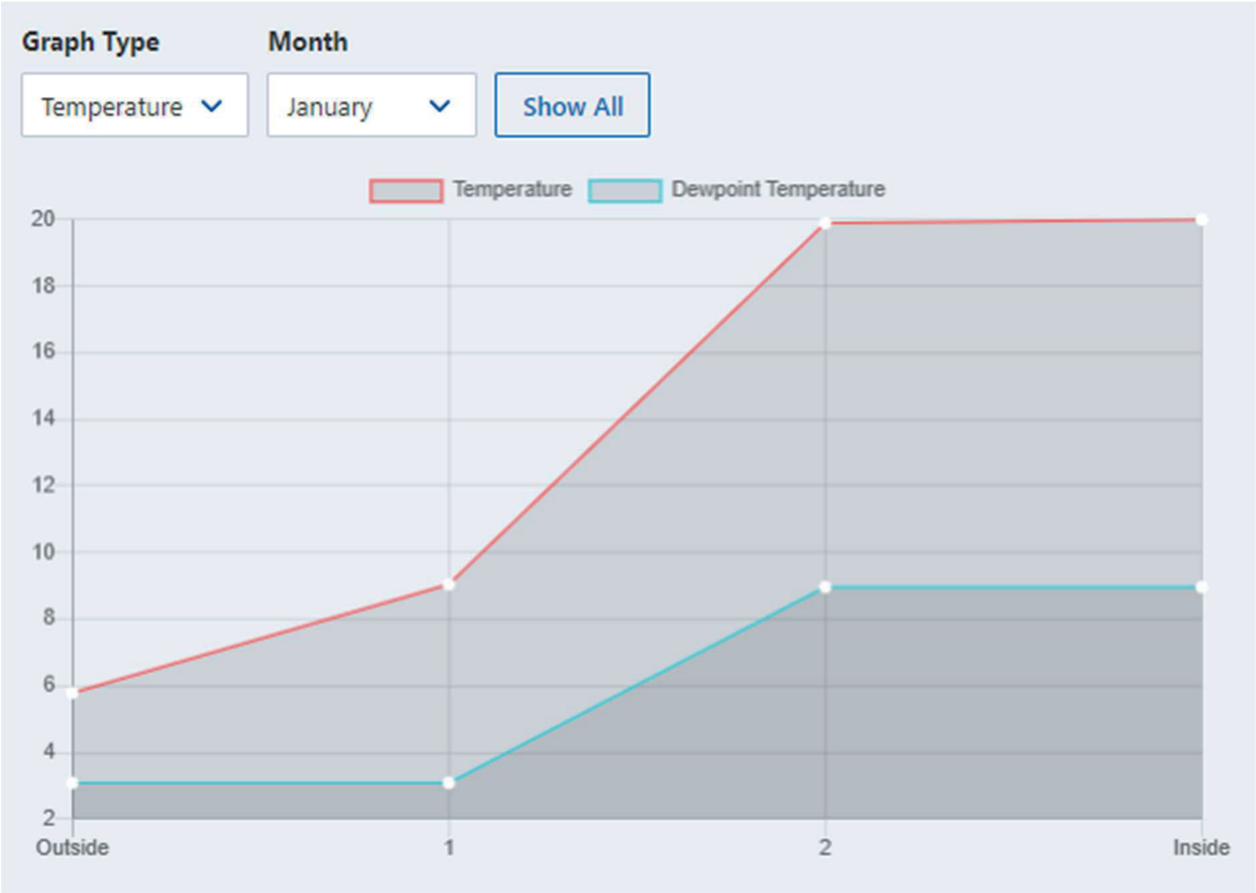
Pressing the green "Create Project" button will load the project screen, with the first element ready to be set up.



The material selection panel to the left of the screen contains all the materials available for use in the calculator, organised into categories for convenience. These categories show the top three most used materials by default, but can be expanded to show many more. Dragging these into the central table will add them to the u-value calculation. For example, dragging "Brick – Exposed" into the table will add a layer of brick to the construction. The depth of this can then be adjusted. With materials in the construction, the u-value Calculator will dynamically start calculating the u-value and risk of condensation. The results of these calculations will be displayed on the bar at the top, and will update every time a material is added or changed. Further corrections for the u-value calculation and graphs denoting the condensation risk will be displayed below the table.

Condensation Analysis

The default graph shown in this location is the temperature graph for the month of January. The red line shows the temperature of each interface, while the turquoise line shows the dewpoint temperature, which is the temperature that the interface would need to be in order for condensation to occur at that point. If these two lines coincide at any point, condensation would be expected. In the UK climate, January tends to be the worst month for interstitial condensation to occur, which is why the graph defaults to this. There will always be three more data points on the x axis of this graph than there are layers in the construction. This is because it also shows the internal and external climates, and is showing the interfaces between the layers rather than the layers themselves. In the below example, which is for our wall that we have only added the single layer of brick to, the first data point is the interface between the external conditions and the brick,



while point 2 is the interface between the brick and the internal conditions.
You can also set this graph to show the pressure, which reads in a similar manner to the temperature graphs, or (if condensation is present), the rate and accumulation of condensation upon any given interface. Clicking the "Edit Environment" button in the top right will allow you to see the performance of all months at once, as well as change the conditions.

The results of the condensation risk analysis are either "Pass", in which no condensation occurs; "Seasonal", stating that interstitial condensation forms in the construction but dries within the year; and "Fail", which is the result when condensation occurs but does not dry. Some condensation does not necessarily mean that the construction has failed. It depends on where the condensation occurs and how much of it there is. For example, if a small amount of condensation occurs on the inside face of the brick facing in a timber framed wall, then that would likely drain through the weep vents, which the calculation method does not allow for. In warm flat roofs, BS 5250 allows for up to 350g/m² of seasonal condensation.

Repeated Thermal Bridges

In many constructions, there will be some form of repeating thermal bridge that occurs through a material, usually the insulation. If we add a Mineral Wool inside of the brickwork from the insulation list to our calculation, a number of things happen. Firstly, the condensation risk will display a failure, demonstrating the coincident lines on the graph described above. This is partially because this demonstration is being done in an order that allows certain things to be highlighted, and will be fixed later. Typically, the element would be added either inside to out, or outside to in as the designer works through the construction This condensation risk will be resolved at a later stage. The other significant thing that happens is that the u-value of the wall drops significantly. While the wall with just the brick was achieving 3.3 W/m²K before the insulation was added, with the mineral wool, this drops to as low as 0.36. In the timber framed wall, the mineral wool insulation would be installed between the timber studs, whereas at the moment the calculation assumes it to be a continuous layer. Using the bridge button on the right of the element in the table, it is possible to include one of a number of materials as the thermal bridge. There are two main options for the bridging in timber framed walls. The first is "Softwood Timber – λ 0.13". This applies to timber elements that are installed on site rather than assembled as a module in factory conditions. For those, the bridge option for "Factory Fitted Timber Studs – λ 0.12" should be used. You can then define the bridging percentage or have the calculator work that out for you from the centres and bridge thickness. For typical timber frame walls, this would be 15%, which allows for 38mm timber studs at 600mm centres. We'll apply that to our worked example, which will worsen the u-value to 0.48. The difference between the 0.36W/m²K and this new value demonstrates the significant effect of cold bridging in buildings, and highlights the reason that these must be carefully accounted for. In steel frames, the bridging is much lower to represent the much narrower profile of the light gauge steel section. Typically, this would be 0.3 or 0.5%, and even that is enough to seriously offset the performance of a lot of the insulation due to the steel's high thermal conductivity. While it isn't an option in the u-value calculator, when specifying a wall with such bridging, it may be beneficial to consider a cold bridging strip, such as our Spacetherm CBS.

Fixings

Where insulation is not bridged, it usually needs to be held in place using mechanical fixings. These represent thermal bridges that should also be accounted for in the u-value calculations. Fixings can be added to any material in a u-value calculation using the icon resembling a nail on the right of the material in the u-value table. Typical fixings options are allowed for in the drop down menu, and you can also create custom fixings to allow for other configurations. Floor constructions do not require fixings, as per BS EN ISO 13370, which is the calculation standard for heat conduction via the ground.

Air Gap Corrections

The u-value calculator has a tolerance for air gaps passing through the insulation. In most cases, it should be assumed that the insulation has an air gap setting of "1", which allows for gaps exceeding 5mm between the boards. The setting of "0" should only be used where the insulation is double layered or in other situations where the method of installation ensures that gaps are avoided. The setting of "2" allows for extreme conditions in which the insulation layer may have air bypassing it. This setting can be changed for any insulation, using the button to the right of the u-value table which looks like blowing air. Unlike the bridging and fixing buttons, the air gap button always starts in the applied corrections column, even if set to "0". This is because the corrections are applied regardless, even if their effect is inconsequential.

Other Correction Factors

Below the table that provides the data on each layer of the construction in the u-value calculator, there is an additional box containing corrections. With our worked example (as with most walls) there is no additional data that can be entered there, but this box will sometimes allow a calculation to be modified and made more accurate, permitting factors that can have a significant effect on the u-value to be accounted for. For example, in floor constructions, the area and perimeter ratio can be set, as can any edge insulation. Rainscreen walls can have their fixings taken into consideration, while ceilings could include consideration for rooflights and other fixtures. It is important to check here to ensure that no details are missing from your calculation which could offset the results.

Membranes

Membranes are incredibly important to a building's hygrothermal performance. At the A. Proctor Group, we have a vast selection of both vapour permeable and impermeable membranes. If you would like particular help specifying these, please contact our technical department, who will be able to advise on the best options for your specific project. If you know what membranes you are using, you can drag these into the construction as you would with any other material. In the UK's temperate climate, the vapour control layer always goes inside of the insulation, while the breather membrane is used outside of the frame. The vapour permeable membrane is used to protect the structure; serving as a secondary layer of water resistance behind the cladding. It can also provide airtightness or other benefits to the building. The vapour control layer prevents water vapour from moving from the inside of the building into the wall, as well as serving as another airtight line. It is important to note that a u-value calculation does not take airtightness into account. This means that the calculation would show no difference between an air permeable membrane and a fully airtight one; but the difference these make to the energy efficiency of the construction is quite significant. This airtightness would be used in SAP or SBEM calculations.

In our demonstration wall, we will use Reflectatherm Plus as the vapour control layer and Reflectashield TF 0.81 as the vapour permeable membrane. Both of these membranes have low emissivity surfaces, which means that they are reflective. Any air layer which is adjacent to such a material will have an increased thermal performance, which will be accounted for later in this document. When a vapour control layer is added internally, the result of the condensation risk analysis changes to a pass. This is because the high resistance of the Reflectatherm Plus is preventing the calculated passage of water vapour through the wall. A condensation risk analysis does not show the entire picture, however, as mineral wool against brick in this way could be detrimental to the construction. Driving precipitation could permeate through the brick via capillary action, coming into contact with the insulation. Therefore, it is important to understand when air layers are required.

Condensation Risk: **Pass** U-value: **0.48**

			Thermal Properties		Bridging Properties		Vapour Properties		Corrections	
#	**Name**	**Depth(mm)**	**λ**	**R**	**%**	**Rb**	**rv**	**Rv**	**Applied**	**Available**
	Rse			0.04						
1	Brick - Exposed	102.5	0.77	0.13	-	-	50	5.13		
2	Reflectashield TF		-	-	-	-	-	0.44		
3	Mineral Wool	100	0.04	2.5	15.00%	0.77	7	0.7		
4	Reflectatherm Plus		-	-	-	-	-	750		
	Rsi			0.13						

Air Layers

Not every material in a construction is a solid layer. Most building elements have some form of cavity, with many having multiple; serving to separate materials as above, as the structural element, to provide space for services and allow for drainage. This could be ventilated or unventilated. If it is ventilated, for example between a framed wall and a rainscreen cladding, anything outside of the ventilated cavity is discounted from the construction in the results for both the u-value and condensation risk analysis, though they should still be included to ensure clarity of the construction for anyone reading it. The calculation method does not allow for partially ventilated cavities (often referred to as vented), so these should be treated as unventilated. In the u-value calculator, air layers can be bridged as any other material can, so if, for example, an air layer comprises timber battens that create a service zone and support the plasterboard, it should be bridged with timber, at 11.8%. This allows for 50mm battens at 600mm centres.

The most common air gap used is "Air Layer – Unventilated". This covers most applications, ranging from the cavity behind brickwork to service voids. "Air Layer – Ventilated (Wall)" or "Air Layer – Ventilated (Roof)" are options for ventilated cavities in their respective situations. At smaller depths than these allow, there are a number of air layers with resistances set to specific cavity depths. "Custom Air Layer" will calculate the air resistance, including using one or two low emissivity surfaces. As we are using reflective membranes, we could use this to calculate our air layers, but the preset ones are easier to use. "Cavity – Reflectashield TF" should be dragged outside of the Reflectashield, and "Cavity – Reflectatherm Plus – Vertical" positioned inside of the VCL. The Reflectatherm cavity should be bridged as described above. While the

Reflectashield cavity would have the brick ties through it, these would not be considered in the calculation, and so would not be included.

It is important to only use cavities that account for low emissivity when they are adjacent to a low emissivity surface, such as a reflective membrane or PIR. For our reflective membranes, this air gap uses a tested value, and so if you are using a cavity of at least 19mm, the full performance can be used. Otherwise, the thermal performance of the cavity will need to be calculated, which can be one in the "Custom Air Layer" option, and will have a reduced performance compared to the tested values.

We can then add any other materials to the construction, such as the internal lining of plasterboard and the sheathing board of OSB.

Unheated spaces are special air layers that are found in pitched roof constructions. These do not have a depth specified, as they generally represent the attic space, so their depth spans from nothing to the full height of the roofspace.

Condensation Risk: **Pass** U-value: **0.27**

			Thermal Properties		Bridging Properties		Vapour Properties		Corrections		
#	Name	Depth(mm)	λ	R	%	Rb	rv	Rv	Applied	Available	
	Rse			0.04							
1	Brick - Exposed	102.5	0.77	0.13	-	-	50	5.13			
2	Cavity - Reflectashield TF	50	-	0.81	-	-	-	0			
3	Reflectashield TF		-	-	-	-	-	0.44			
4	OSB	9	0.13	0.07	-	-	450	4.05			
5	Mineral Wool	100	0.04	2.5	15.00%	0.77	7	0.7			
6	Reflectatherm Plus		-	-	-	-	-	750			
7	Cavity - Reflectatherm Plus - Vertical	25	-	0.78	11.80%	0.19	-	0.05			
8	Plasterboard	12.5	0.21	0.06	-	-	60	0.75			

Other Features

The u-value calculation in our worked example is now complete, but there are other features of the software that are useful to know about. The element can be renamed or deleted (where there are multiple elements in the project) in the "Edit Element" button on the top left. In the adjacent buttons, new elements can be created in the project, or the current one can be cloned to allow variations on the same wall.

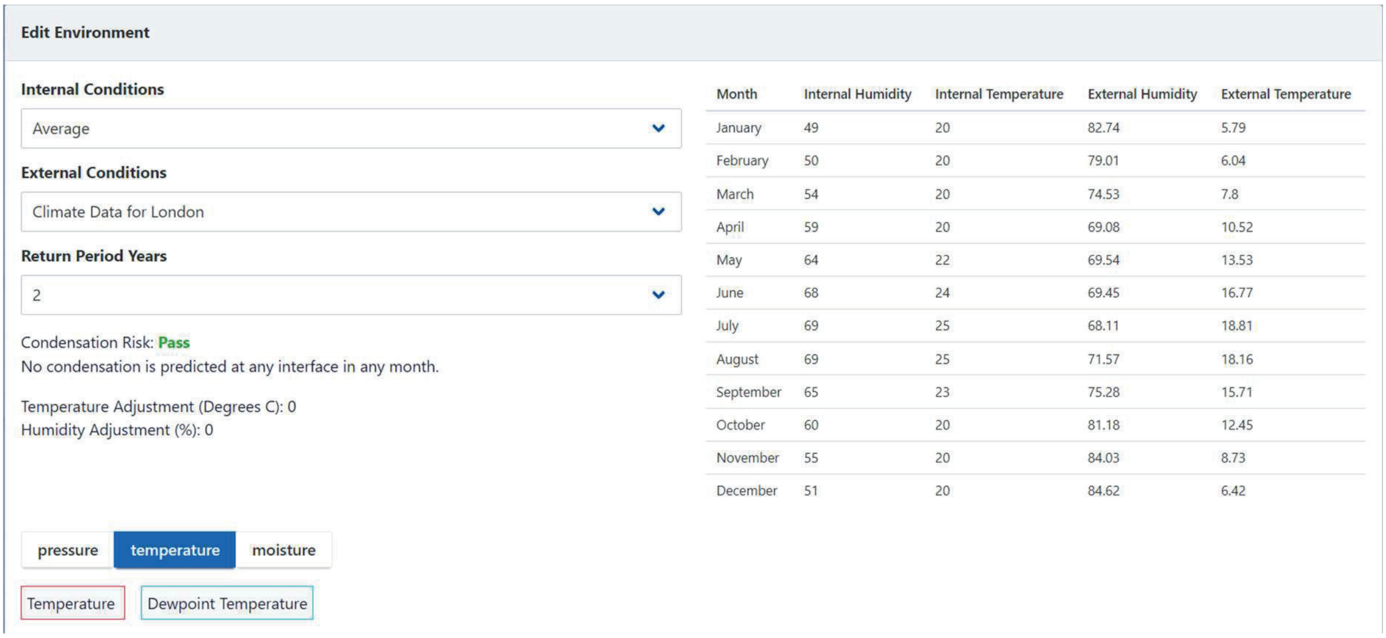
The "Send for Approval" and "Download PDF" buttons represent the methods by which you can get the calculation out of the software. The first sends it to our technical team, who will check it to ensure that it is technically correct before sending it back to you.

Cloning the project allows for variations to be made to a project without changing the existing buildups, which is useful for iterative design, where you want to create several options, or where you use a similar construction across a number of projects.

Layers can be added in any order as makes sense to you. The calculation is arranged from outside to in, which means that roofs are the right side up but that floors are inverted. Some people add layers starting at the outermost surface and working inwards, or vice versa. Others start with the structure, so would start with the insulation between the frame, and then work both outwards and inwards, building the calculation in the sequence the wall would be built. These layers can be rearranged or deleted at any time.

Edit Environment

The final button on the band that controls the project data is the "Edit Environment" button. This opens an interface in which you can see the climate conditions for every month, as well as change them to alter the conditions that define the calculation. The return period (which by default is at 2 years) offsets the external conditions to represent the "worst in a given number of years", so a 20 year return period would give conditions equating to the worst weather expected in 20 years.


Edit Environment

Internal Conditions: Average

External Conditions: Climate Data for London

Return Period Years: 2

Condensation Risk: Pass
No condensation is predicted at any interface in any month.

Temperature Adjustment (Degrees C): 0
Humidity Adjustment (%): 0

pressure | temperature | moisture

Temperature | Dewpoint Temperature

Month	Internal Humidity	Internal Temperature	External Humidity	External Temperature
January	49	20	82.74	5.79
February	50	20	79.01	6.04
March	54	20	74.53	7.8
April	59	20	69.08	10.52
May	64	22	69.54	13.53
June	68	24	69.45	16.77
July	69	25	68.11	18.81
August	69	25	71.57	18.16
September	65	23	75.28	15.71
October	60	20	81.18	12.45
November	55	20	84.03	8.73
December	51	20	84.62	6.42

Checklist

The below constitutes a checklist for calculations to ensure that they are as correct as possible, and include common issues that occur. Even using this, it is important to send the calculation for approval by our technical team, so they can ensure that you are using the correct products and that the calculation is technically accurate.

- Are the layers arranged from outside to in?
- Do all layers that have repeating thermal bridges have the required bridging?
- Does all insulation that isn't bridged have adequate fixings?
- Are air gaps set correctly? In most cases, this should be on option 1, i.e. insulation between rafters or joists etc.
- Are membranes located correctly, with any vapour control layers inside of the insulation?