

EDSL

Modeling Breathing Buildings Units in TAS

R-Series, S-Series

Draft
September 16th, 2016

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1 The Breathing Building e-stack Units

Breathing Buildings' roof units are designed to supplement low level windows in order to provide an enhanced natural ventilation strategy¹. These units have a fan boosted mode of operation that operates on hot days and during the night to provide effective night cooling.

The R and S-Series units have the following modes of operation, based on the **time of the day**:

- Day Mode (depending on occupancy schedule)
- Night mode (9pm to 6am)

The R and S-Series units also have **seasonal modes** of operation:

- Summer mode (ext. temp $\geq 16^{\circ}\text{C}$)
- Winter mode (ext. temp $< 16^{\circ}\text{C}$)

As the winter mode depends on external temperature, the winter mode of operation can come into operation at any time of year depending on the weather. It is therefore important to model the winter mode of operation for overheating analysis.

1.1 Description of the modes of operation

1.1.1 Day mode: Summer

When the external temperature is $\geq 16^{\circ}\text{C}$ and the time is between 9am and 6pm², the units are in the daytime summer mode of operation.

In this mode, the apertures on the e-stack units start to open at³ 19°C and are fully open at 24°C .

If the internal temperature exceeds 24°C , the fan boost provides **additional** ventilation at the rates given in Table 1.

e-stack Unit	Summer Day Flow rate (l/s)
R-Series	100
S-1200	100
S-1500	150

Table 1 - Boosted day time flow rates for the summer operation of the e-stack units

If the concentration of CO_2 in the zone exceeds 600ppmw at any time during this mode of operation, the apertures of the units also open and the fan boost will apply, starting at 600ppmw and being fully open at 1500ppmw.

1.1.2 Day mode: Winter

When the external temperature is $< 16^{\circ}\text{C}$ and the time is between 9am and 6pm², the units are in the daytime winter mode of operation.

In this mode, the apertures only open if the concentration of CO_2 in the zone exceeds 600ppmw. The apertures start to open at 600ppmw and are fully open at 1500ppmw. In this mode, the

¹ For more detailed and up to date information please see the relevant R-Series and S-Series pages at <http://www.breathingbuildings.com/products>

² This is a typical occupancy schedule. Exact schedule may vary.

³ These are the default unit settings, which can be altered upon request by the user.

system can provide a guaranteed fresh air flow rate, up to a maximum of the values listed in Table 2.

e-stack Unit	Winter Mixing Flow rate (l/s)
R-Series	160
S-1200	160
S-1500	500

Table 2- Guaranteed fresh air flow rate during CO₂ purge

1.1.3 Night mode (Summer & Winter)

Between the hours of 9pm and 6am, the unit is in the night mode of operation.

In this mode, if the internal temperature is above 18°C, (and external temperature is less than room temperature), the apertures on the units are fully open.

If the internal temperature is still above 18°C at 3am, the fan provides boosted ventilation until 6am. The boosted night flow rates are given in Table 3.

e-stack Unit	Night Boost Flow rate (l/s)
R-Series	240
S-1200	240
S-1500	150

Table 3- Boosted flow rates for the night time operation of the e-stack units

If the external temperature exceeds the internal temperature during any mode of operation apart from when ventilating CO₂, the units will close.

2 Modelling in Tas overview

The overall process of modelling the e-stack units in Tas is as follows:

3D Modeller:

- Create the units as roof lights

Building Simulator:

- Create and assign constructions for the units
- Create and assign apertures for the units
- Create and assign apertures for the openable windows⁴
- Create/modify the zones daytime internal condition (mech vent function)
- Create/modify the zones night time internal condition (mech vent function)

For the purposes of this guide, a simple building (Figure 1) has been created in TAS. The files may be available upon request. This simple one-story building has two rooms; the rooms will be identical wherever possible with the exception that one of the rooms will be modelled with an R-Series unit.

⁴ For more information about why the aperture functions of the windows may need altering, please see section 4.3.

3 3D Modeller

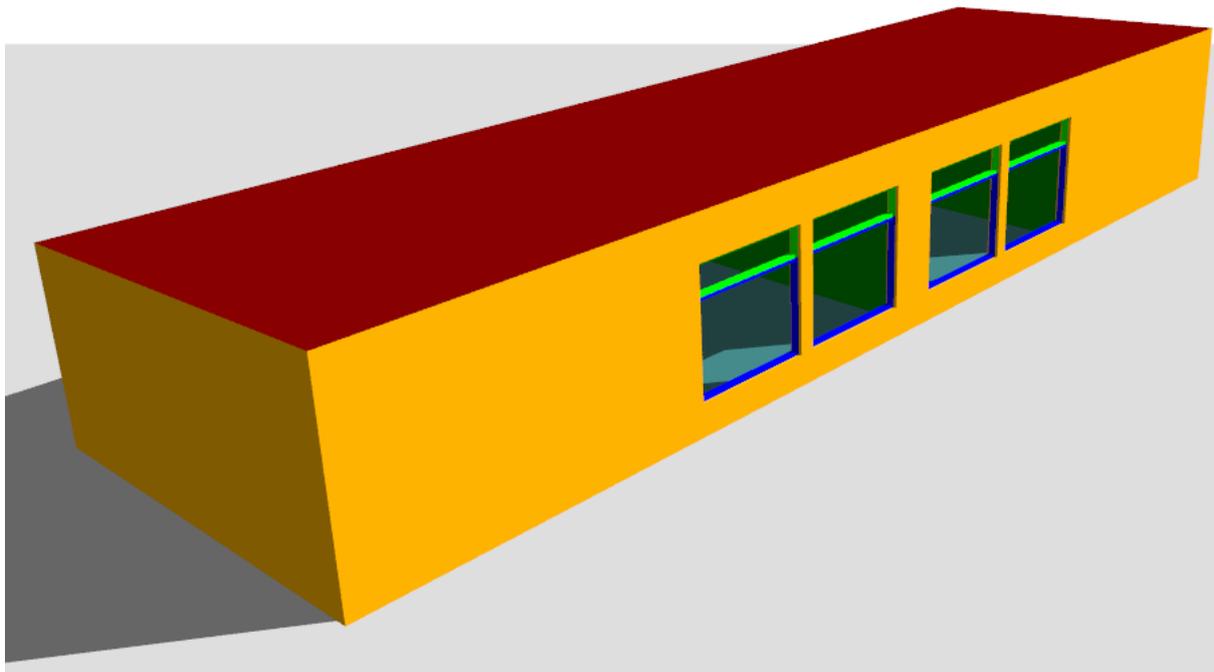


Figure 1 - The test building used throughout this guide, as seen in the 3D modeller

The test building (Figure 1) being used in this guide consists of two rooms with identical dimensions. These rooms are adjacent to one another and are situated in the middle of the building. Their surrounding spaces are un-zoned, so there is no heat transfer between them. The floor plan of the test building is shown in Figure 2.

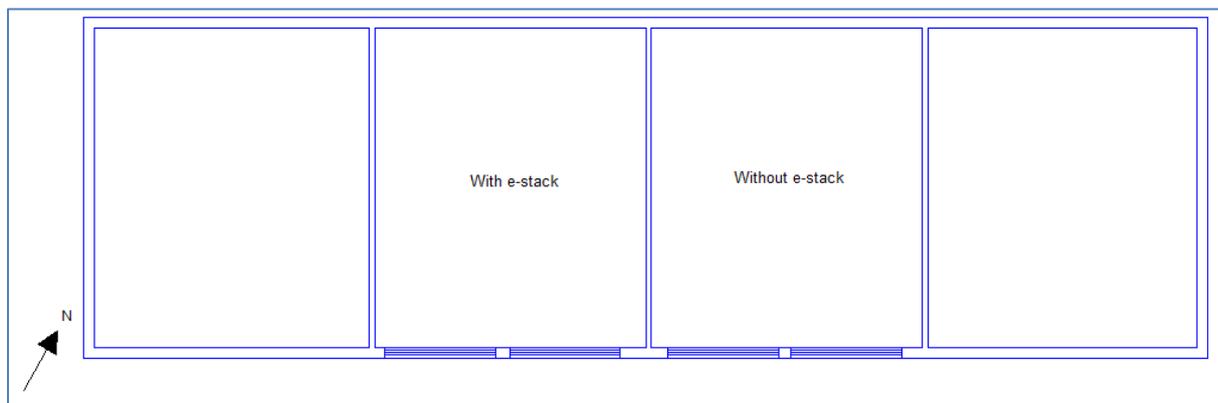


Figure 2- Floor plan of the test building before the e-stack units are added. Note that adjacent spaces are unzoned so are adiabatically linked with the zones of interest. The dimensions of each zone are (5.8x4.9) m.

3.1 Create the Units as roof lights

Create a new window in TAS as shown in Figure 3, entering the appropriate width and height of the unit being modelled (Table 4).

Unit	Roof light Dimensions (m)		Equivalent Orifice Area in Tas (m ²)
	Width	Height	
R-Series (Penthouse)	1.6	0.95	0.46 / Cd = 0.78
R-Series (Mushroom)	1.6	0.95	0.40 / Cd = 0.66
S-1500 (Penthouse)	1.5	1.5	0.80 / Cd = 1.32
S-1500 (Mushroom)	1.5	1.5	0.69 / Cd = 1.13
S-1200 (Penthouse)	1.2	1.2	0.56 / Cd = 0.91

Table 4 – Dimensions and equivalent orifice areas of various roof units. Note: the product of a unit's width and height gives the physical area of the unit, which is larger than the equivalent orifice area that should be achieved in the TBD. The Tas software has an inbuilt discharge coefficient (C_d of 0.62).

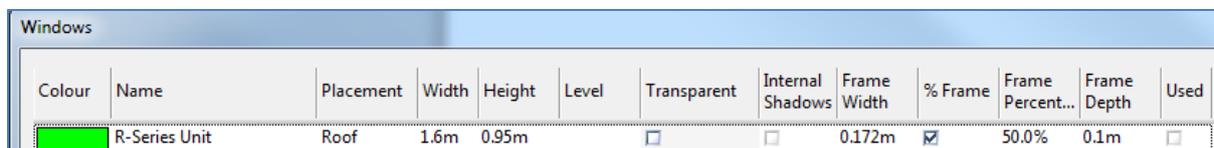


Figure 3 – R-Series Unit properties as shown in the window dialogue box of the 3D modeller

Set the frame percentage to be 50%; this is to allow two different apertures in the Tas Building Simulator to be applied to the same unit. One of the apertures is for the night mode of operation, and the other is for the day mode of operation.

If the zone the unit is serving has no roof void above in the 3D modeller, the unit can be placed in the appropriate zone directly. In the case of the test building, the R-Series unit is placed as in Figure 4.

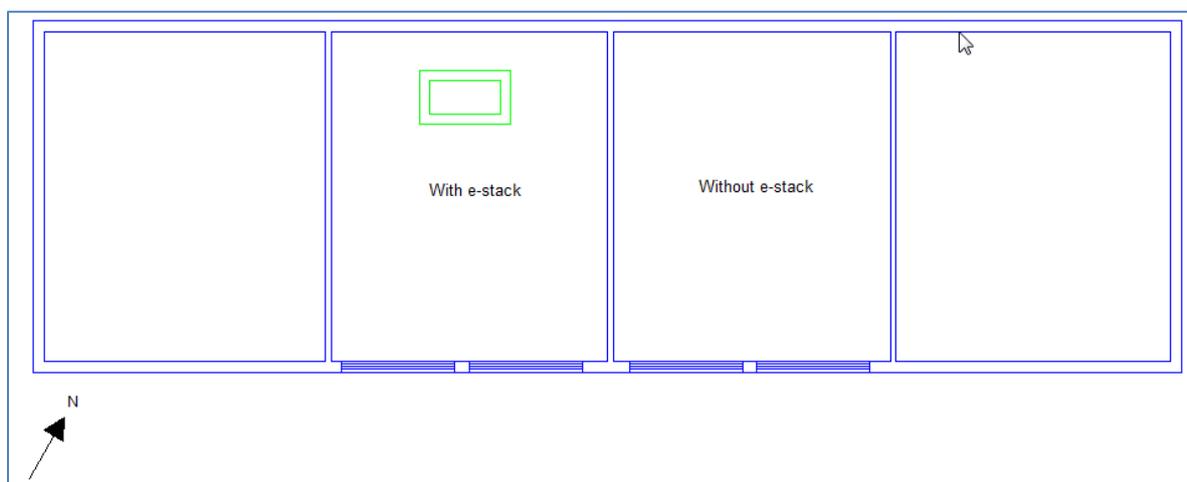


Figure 4 - Plan of test building with an R-series e-stack added to a zone

If there is a roof floor above, the unit should be placed over the zone it is serving and ducted to the zone it serves, as in Figure 5.

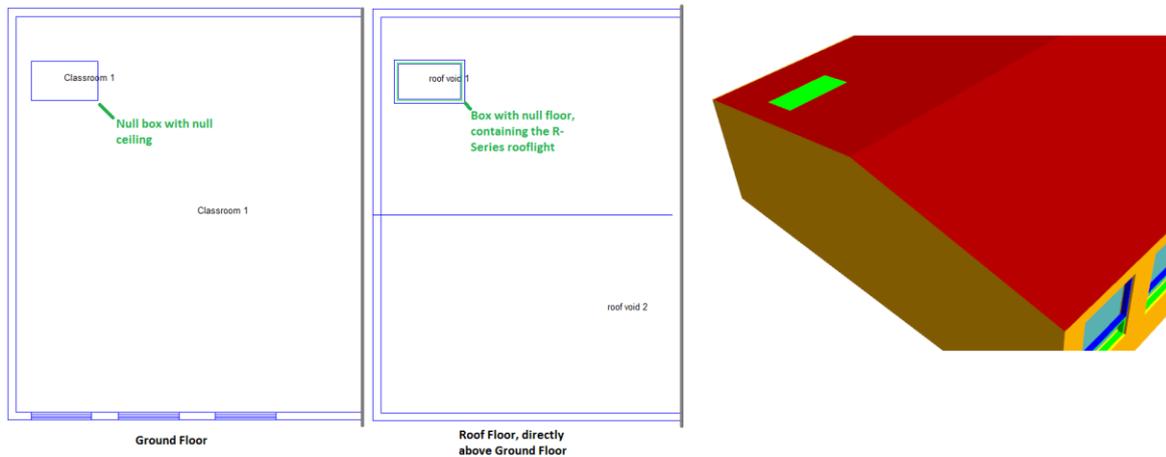


Figure 5 – A Unit placed in a room which has a roof void above the zone the unit serves.

The location the unit is placed can have a significant impact on the ventilation performance, so the location of the unit in the model should reflect the location of the unit in the real building.

3.2 Ensure sufficient openable windows are present

Breathing Buildings can advise on a minimum low level façade openable area, appropriate to your project, and if they do, it is important to that this requirement is met to ensure the e-stack units operate effectively.

To ensure sufficient minimum free area has been achieved, first determine the areas of each surface in Tas Building Simulator file that will have an aperture applied. This can be read directly from the surfaces information in the TBD file, or calculated from the 3D modeller file.

For the purposes of this test building, a minimum area of $1m^2$ is recommended; the test building has two sets of two windows in each zone. Each openable window in the test building has the following properties:

- Name (“Window 2 (openable)”)
- Width (2.0m)
- Height (0.5m)
- Frame Width (24%)

If the aperture is applied to the building element called “Window 2 (openable) - pane” in the TBD, the area of this surface will be $\text{Width} \times \text{height} \times \text{Pane percentage}/100 = 2 \times 0.5 \times 0.76 = 0.76m^2$.

Often, windows have restrictors that prevent them being fully opened. If the windows of the test building can be opened to 80% of their free area, this gives a total openable area of $0.608m^2$. As there are two windows, the total openable area of the windows in this zone would be $1.216m^2$. This area is greater than the minimum requirement.

The windows in a room with a unit may be controlled differently to a room without. If a window is present in a room with and without a unit, a copy of the window will need to be made in the 3D modeller. This is shown in Figure 6. When making a copy of the window, it is important to ensure that any windows that are already placed in the 3D modeller have their types changed accordingly.

Colour	Name	Placement	Width	Height	Level	Transparent	Internal Shadows	Frame Width	% Frame	Frame Percent...	Frame Depth	Used
Green	R-Series Unit	Roof	1.6m	0.95m		<input type="checkbox"/>	<input type="checkbox"/>	0.172m	<input checked="" type="checkbox"/>	50.0%	0.1m	<input checked="" type="checkbox"/>
Blue	Window 1	Wall	2.0m	1.5m	0.5m	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0.05m	<input type="checkbox"/>	11.33%	0.1m	<input type="checkbox"/>
Green	Window 2 (openable)	Wall	2.0m	0.5m	2.0m	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0.05m	<input type="checkbox"/>	24.0%	0.1m	<input type="checkbox"/>
Green	Window 2 (openable) (e-stack)	Wall	2.0m	0.5m	2.0m	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0.05m	<input type="checkbox"/>	24.0%	0.1m	<input type="checkbox"/>

Figure 6 - Each window in the window dialogue box can only have one aperture assigned to it in the building simulator.

4 The Building Simulator

For the purposes of this guide, the building simulator file associated with the test building model has been setup as follows:

- Notional constructions.
- The weather file used is the CIBSE Norwich DSY.
- Occupancy schedule of 9:00 – 16:00
- Internal conditions as in Figure 7
- Openable windows which are openable to 80% of their free area, start to open at 20°C and are fully open at 21°C
- Standard calendar

Gain	Value	Factor	Setback Value	Schedule
Infiltration	0.3 ach	1.0	0.0 ach	
Ventilation	0.0 ach	1.0	0.0 ach	
Lighting Gain	10.0 W/m ²	1.0	0.0 W/m ²	occupancy
Occupancy Sensible Gain	20.0 W/m ²	1.0	0.0 W/m ²	occupancy
Occupancy Latent Gain	10.0 W/m ²	1.0	0.0 W/m ²	occupancy
Equipment Sensible Gain	5.0 W/m ²	1.0	0.0 W/m ²	occupancy
Equipment Latent Gain	0.0 W/m ²	1.0	0.0 W/m ²	
Pollutant Generation	0.0 g/hr/m ²	1.0	0.0 g/hr/m ²	

Figure 7 - Summary of the internal conditions used in the test model, during occupied hours

The inputs stated here are for reference only.

Please note that Breathing Buildings advise that the heating set-point is kept below 19°C, so that it does not conflict with the summertime opening profile of the e-stack units.

4.1 Create and assign Constructions

The construction used for the e-stack panes in the building simulator will have a relatively minor impact on the overall internal temperatures of the applied zones, as it represents a small proportion of the external roof area. For the purposes of this model, the construction given in Figure 8 has been used.

Layer	M-Code	Width (mm)	Conducti...	Convecti...	Vapour D...	Density (...)	Specific ...
1	Aluminium sheet	5.0	160.0	0.001	9999.000	2800.0	880.0
2	Insulation 1	5.0	0.03	0.001	9999.000	40.0	1450.0
3	Aluminium sheet	5.0	160.0	0.001	9999.000	2800.0	880.0

Figure 8 – Breathing Building Unit construction used in the guide. This does not necessarily reflect the actual construction of the unit.

Once the construction has been created, it should be assigned to the appropriate building elements. In the case of the test model, this is “R-Series Unit-pane”. (Figure 9)

Name	Description	Construction
Null	Null Building Element	
✓ R-Series Unit-pane		BB Unit
✓ External Wall		Notional External Wall 1

Figure 9 - Assigning the R-Series Construction

4.2 Create and assign unit Apertures

Two apertures will need to be created for each e-stack unit type present in the building being modelled. One should be called ‘[e-stack name] – Day’, and the other ‘[e-stack name] – Night’.

[e-stack name] – Day

The day aperture for each unit should be setup as in Figure 10; the openable proportion is the same for the Day and the Night aperture, and will be calculated in the next section.

Ensure that a schedule representing the occupied hours is setup for this aperture, and that it applies to all day types. In this guide, the occupied schedule is between 9am and 6pm. If your zone occupancy changes during lunch time, the schedule for the e-stack unit should **not** be modified to reflect this.

[e-stack name] – Night

The night aperture for each unit should be setup as in Figure 11; the openable proportion is the same for the Day and the Night aperture, and will be calculated in the next section.

The units’ night aperture should apply to all day types and should have a schedule applied that includes the hours between 9pm and 3am.

Please note that in some cases it may be appropriate to alter the aperture opening temperatures, depending on the heating set-point selected in the model and also any window restrictors that may be present.

Aperture Control Function

Control Logic

Scheme:

Variable:

External Temperature Cut-off

Controls: Zone Temperature External Temperature

Mixed Mode Cut-off Pollutant

Wind Speed

Parameters

Control:

Lower Zone Temp.: Lower External Temp.:

Upper Zone Temp.: Upper External Temp.:

Lower Zone Pollutant:

Upper Zone Pollutant:

Openable Proportion:

Description

Aperture opening is controlled by the dry bulb temperature in a single zone.
 The aperture will begin to open if the temperature in the adjacent zone exceeds 19.0 °C. It will be fully open if the temperature reaches 24.0 °C.
 If the external dry bulb temperature exceeds the dry bulb temperature in the adjacent zone, the aperture will begin to close.
 The aperture will begin to open if the external temperature exceeds 16.0 °C. It will be fully open if the external temperature reaches 16.5 °C.
 The aperture will begin to open if the pollutant level in the adjacent zone exceeds 600 ppmv (CO2). It will be fully open if the pollutant level reaches 1500 ppmv(CO2). This overrides all other concerns.

Figure 10 - e-stack Day aperture settings. This is the same for all e-stack units; the only variable is the openable proportion; the procedure for determining the correct openable proportion is detailed in the next section of this document.

Aperture Control Function

Control Logic

Scheme:

Variable:

External Temperature Cut-off

Controls: Zone Temperature External Temperature

Mixed Mode Cut-off Pollutant

Wind Speed

Parameters

Control:

Lower Zone Temp.:

Upper Zone Temp.:

Openable Proportion:

Description

Aperture opening is controlled by the dry bulb temperature in a single zone.
 The aperture will begin to open if the temperature in the adjacent zone exceeds 18.0 °C. It will be fully open if the temperature reaches 18.5 °C.
 If the external dry bulb temperature exceeds the dry bulb temperature in the adjacent zone, the aperture will begin to close.

Mnemonic code: zdwon

Figure 11- e-stack Night aperture settings. This is the same for all e-stack units; the only variable is the openable proportion

4.2.1 Calculating the Openable Proportion

If the e-stack has been setup in the 3D modeller as described in section 3.1, the surface corresponding to the frame and the surface corresponding to the pane of the e-stack unit in the building simulator will have the same area (Figure 12).

No.	Orientation	Inclination	Altitude (...)	Altitude ...	Plan Peri...	Type	Area (m²)	O...	Building Element	Side facing ...
1	Floor	180.0	0.025	0.0	21.9	Ground	29.71		Ground Floor	Inner
2	150.0 (SE)	90.0	1.585	3.125	0.0	Exposed	7.472		External Wall	Inner
3	150.0 (SE)	90.0	1.25	1.5	0.0	Exposed	0.68		Window 1-frame	Inner
4	150.0 (SE)	90.0	1.25	1.4	0.0	Exposed	5.32		Window 1-pane	Inner
5	150.0 (SE)	90.0	2.25	0.5	0.0	Exposed	0.48		Window 2 (openable)-frame	Inner
6	150.0 (SE)	90.0	2.25	0.4	0.0	Exposed	1.52		Window 2 (openable)-pane	Inner
7	240.0 (S...	90.0	1.57	3.045	0.0	Null Link	16.819		Internal Wall	Outer
8	330.0 (N...	90.0	1.435	2.825	0.0	Exposed	13.987		External Wall	Inner
9	60.0 (NE)	90.0	1.57	3.045	0.0	->Witho...	16.819		Internal Wall	Inner
10	330.0 (N...	3.0	3.0	0.3	21.9	Exposed	28.227		Roof	Inner
11	330.0 (N...	3.0	2.915	0.045	8.818	Exposed	0.76		R-Series Unit-frame	Inner
12	330.0 (N...	3.0	2.915	0.03	3.72	Exposed	0.76		R-Series Unit-pane	Inner

Figure 12 - If the e-stack unit has been setup as advised in this guide, the frame and pane surfaces will have the same area in the zone they serve

The openable proportion is given by the equivalent orifice area of the unit divided by the pane area in TAS. For the R-Series unit⁵:

$$\text{openable proportion} = \frac{\text{Equivalent Orifice Area (see Table 4)}}{\text{Area of Pane in TAS}} = \frac{0.78m^2}{0.76m^2} \approx 1.02$$

Setting the frame percentage of the e-stack to 50% in the 3D modeller effectively halving the units area in the building simulator; as a direct result, the openable proportion may seem quite high, and can even be greater than 1.

The openable proportion calculated here should be entered into both the day and night apertures openable proportion field.

Once the aperture has been created, it should be assigned to the appropriate building element. In this case, the “R-Series -Pane”, should have the ‘R-series – Day’ aperture applied, and the ‘R-Series – Frame’ building element should have the ‘R-Series – Night’ aperture applied as in Figure 13.

Name	Description	Construction	Substitute Element	Aperture Type
✓ R-Series Unit-frame		E-Stack		R-Series Night
✓ R-Series Unit-pane		E-Stack		R-Series Day

Figure 13 – R-Series building element with an aperture assigned

⁵ The figures used here are indicative of an R-series unit used in conjunction with an egg-crate grille on the base of the unit.

4.3 Create and assign apertures to the openable windows

Breathing Buildings recommend that the openable windows in the rooms with e-stack units reflect the operation of the e-stack units, and as such will generally start to open at 19°C and be fully open at 24°C.

If a window has a particularly small restrictor and therefore quite small openable proportion, the occupants may be more likely to fully open the window at a lower temperature and different opening profiles could be applied accordingly.

4.4 Modifying the zones' internal conditions

The additional ventilation provided by the fan boost of the units is at a fixed rate, and is accounted for by including a mechanical ventilation function in the internal conditions for the zones that have an e-stack unit.

It is important to note that only one mechanical ventilation function can be assigned per internal condition; this may cause problems if a space already has mechanical ventilation; if a zone does have mechanical ventilation and an e-stack unit, the mechanical ventilation may have to be modelled using IZAMs.

In the test model, zone 1 has a unit and the other does not. There is one occupied internal condition for both of these zones, so a copy will be made for each such that one has the e-stack ventilation applied and the other does not.

To assign the appropriate function to the ventilation, click on the word "Ventilation" in the internal gain tab of the internal condition. In the resulting dialogue box, change the **type** from **value** to **function** and select 'tcbvc' and enter the values as in Figure 14.

Section	Parameter	Value
Day (Summer)	Lower Setpoint	24.0 °C
	Upper Setpoint	25.0 °C
	Max. Flow Rate	[Green Bar]
	Lower Pollutant	600 ppmv(CO2)
	Upper Pollutant	1500 ppmv(CO2)
	Max. Flow Rate	0.0 l/s
Day (Winter)	Seasonal Cut-off	16.0 °C
	Lower Pollutant	600 ppmv(CO2)
	Upper Pollutant	1500 ppmv(CO2)
	Max. Flow Rate	[Green Bar]
Night	Lower Setpoint	18.0 °C
	Upper Setpoint	22.0 °C
	Max. Flow Rate	[Green Bar]
	Last hour override*	6
	First hour override*	4

Figure 14 - e-stack mechanical ventilation tcbvc settings. Note that the day and night max flow rates depend on the unit being modelled, and the number of units in the zone; details regarding how to calculate the max flow rate for day and night operation is provided in the next section.

It is also imperative to change the schedule of the mechanical ventilation function (tcbvc) to match the occupied hours schedule applied to the e-stack apertures.

NOTE: Currently, the fan boost operation of the units is ignored at weekends. Ideally, a duplicate internal condition for each space with a unit needs to be created for the closed day types, and be identical with regards to ventilation function but having no internal gains.

4.4.1 Determining the flow rates

The day and night max flow rates for the e-stack units are typically those given in Table 1 and Table 3. If there are multiple units serving a zone, the flow rates of each unit should be summed together.

For example, if a zone had two R-series units, the day flow rate would be: $2 \times$ day flow rate. If a zone had an R-series unit and an S-series unit, the day flow rate would be:
R-series day flow rate + S-series day flow rate.

The same principle applies to the night flow rates.

In the case of the test model, which has a single R-Series unit serving it, the dialogue should reflect Figure 15.

Section	Parameter	Value
Zone	Zone	Applied Zone
	Day (Summer) - Temperature Control	
Day (Summer) - Temperature Control	Lower Setpoint	24.0 °C
	Upper Setpoint	25.0 °C
	Max. Flow Rate	100.0l/s
Day (Summer) - Pollutant Control	Lower Pollutant	600 ppmv(CO2)
	Upper Pollutant	1500 ppmv(CO2)
	Max. Flow Rate	0.0l/s
Night	Lower Setpoint	18.0 °C
	Upper Setpoint	22.0 °C
	Max. Flow Rate	240.0l/s
	Last hour override*	6
	First hour override*	4
*Set to 0 to disable override		
Day (Winter)	Seasonal Cut-off	16.0 °C
	Lower Pollutant	600 ppmv(CO2)
	Upper Pollutant	1500 ppmv(CO2)
	Max. Flow Rate	160.0l/s

Figure 15 - TCBVC function for a single R-Series unit.

Internal Gain | Heating Emitter | Cooling Emitter | Thermostat

Name:

Description:

Radiant Proportion

Lighting:

Occupant:

Equipment:

View Coefficient

Lighting:

Occupant:

Equipment:

Gain	Value	Factor	Setback Value	Schedule
Infiltration	0.3 ach	1.0	0.0 ach	
Ventilation	Function	1.0	0.0 ach	e-stack Day
Lighting Gain	10.0 W/m ²	1.0	0.0 W/m ²	occupancy
Occupancy Sensible Gain	20.0 W/m ²	1.0	0.0 W/m ²	occupancy
Occupancy Latent Gain	10.0 W/m ²	1.0	0.0 W/m ²	occupancy
Equipment Sensible Gain	5.0 W/m ²	1.0	0.0 W/m ²	occupancy
Equipment Latent Gain	0.0 W/m ²	1.0	0.0 W/m ²	
Pollutant Generation	0.0 g/hr/m ²	1.0	0.0 g/hr/m ²	

Figure 16 - The TCBVC function MUST be used in conjunction with a schedule.

5 Results & Comments

Figure 17 shows the overheating results against the PSBP FOS criteria for the test building when one R Series unit is installed. Compared to an identical adjacent room without a unit, the room is significantly cooler.

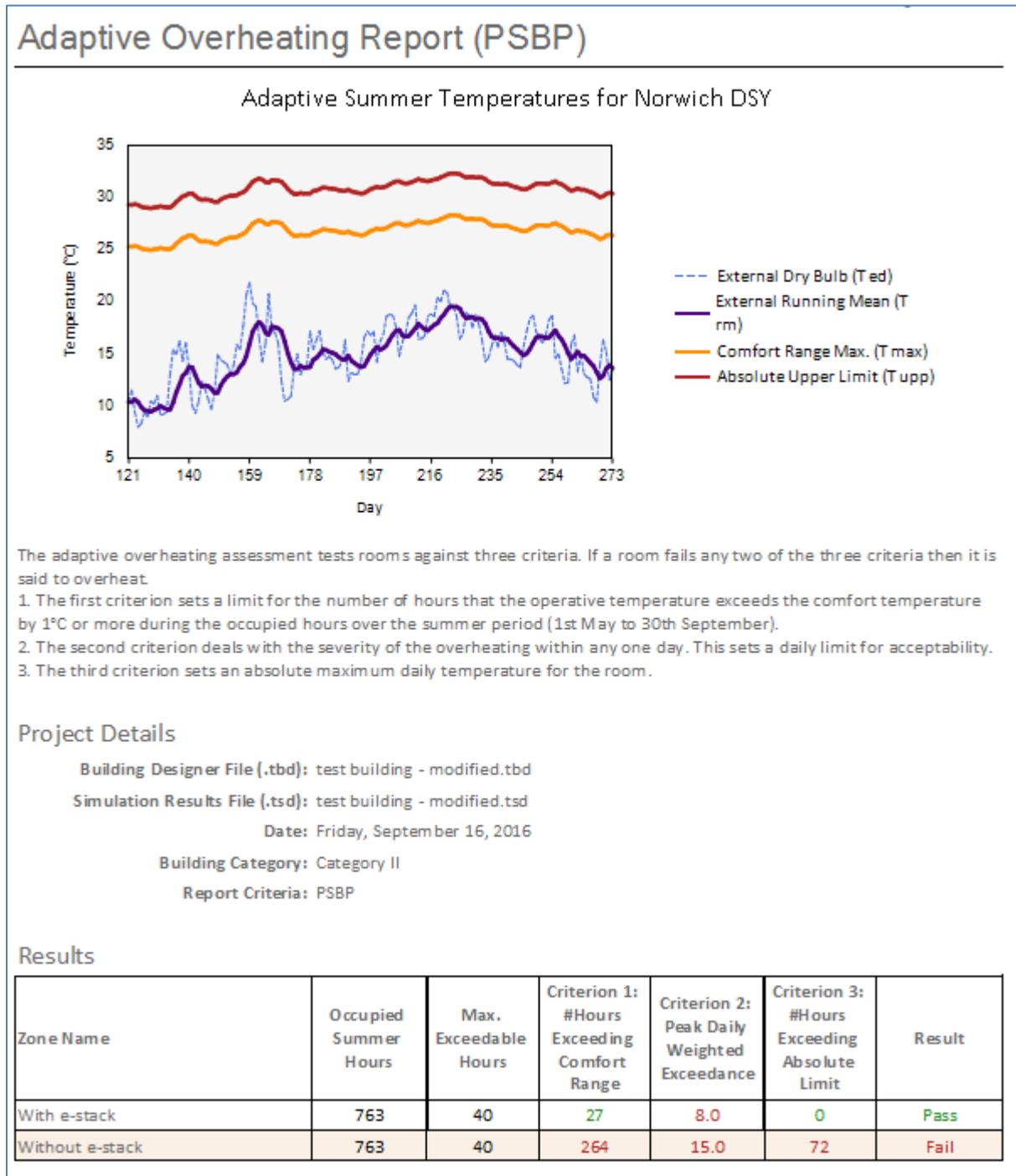


Figure 17- PSBP FOS Overheating results for the test building.

5.1 Verifying the unit is modelled correctly

To ensure the operation of the unit is modelled correctly, the .tsd file produced when the building is simulated can be examined.

- If the external temperature is greater than 16°C and the internal temperatures are greater than 24°C, there is mechanical ventilation to the zone
- If the zone temperature is <24°C, there should be no mechanical ventilation unless the external temperature is <16°C and the pollutant level is >600ppmv.
- If the external temperature is >16°C and if the zone temperature is >19°C but <24°C, there should be aperture flow through the units pane and the openable windows.
- If the internal temperature is > external temperature, and internal temperature > 18°C at 2am, there should be aperture flow through the unit but no mechanical ventilation. During hour 3 to 6, if the internal temperature > 18°C there should be no aperture flow through the unit but there should be fan boosted ventilation.

6 Contact

If you require assistance with modelling Breathing Buildings' e-stack systems, please contact the EDSL support department on 01908 261 461, or email support@EDSL.net.

If you require further information or have any queries regarding the systems themselves, please contact Breathing Buildings on 01223 450060 , or email info@breathingbuildings.com.