Solatube H1 Code Compliance Statement

Solatube Tubular Daylighting Devices are a daylighting system designed to deliver daylight to a multitude of spaces. Through the advanced optics in the externally mounted dome, known as the capture area, to the highly reflective tubing (the transfer zone) Solatube's deliver a higher volume of light per area over longer distances than traditional top lighting methods such as Skylights and Roof Windows. Just as relevant over short distances as well Solatubes aid in compliance with NZBC Clause G7 and can be combined with integrated ventilation at the diffuser (the delivery zone) to also assist with G4 compliance.

Solatube systems are suitable for use in both commercial and domestic buildings with a variety of roof mounting options to comply with NZBC E2 and B2. For many applications, there are additional custom flashings to match the roof type making the system suitable without extended tray flashings/over flashing systems. Compatibility for the roof matched flashing is from 5-45deg inclusive, outside of these parameters (such as membrane roof systems for flat or nominally flat roofs, non-compatible profiles and extra high or SED wind zones) upstands and over flashings can be used.

However, for NZBC H1 it's the high levels of light delivery combined with the small penetrations areas that allow Solatube Tubular Daylighting Devices to deliver quality daylighting without compromising heat retention[1].

Prescriptive Sizing and Equivalencies

This document presents a prescriptive sizing method for equating equivalent heat loss through a roof mounted Solatube to heat loss through a window.

In the table below $A_{equiv.}$ is the equivalent window area using each climate zones scheduled window R-value ($R_{Ref.w}$) applied to the difference in heat loss between a roof insulated to the reference building standard of R6.6. This window area can then be deducted from the prescribed 30% window area of a compliant building under H1/AS1 2.1.3 Calculation Method.

The Prescriptive Sizing table on page 2 gives easy window area % reductions to offset each Solatube. Alternatively, the area's below can be applied to the window area percentage for the given building.

$A_{equiv.}$ Calculation Table

	Solatube 160DS		Solatube 290DS	
$A_{SOL} = \pi(\frac{d}{2})^2$	d = 0.25; A_{SOL} = ~0.05m^2		d = 0.35; A_{SOL} = ~0.1m^2	
$HL_{SOL} = \frac{A_{SOL}}{R_{SOL}}$	R_{SOL} = 0.35; HL_{SOL} = ~0.14$W/\Delta K$		R_{SOL} = 0.35; HL_{SOL} = ~0.27$W/\Delta K$	
	Climate Zones 1-4	Climate Zones 5&6	Climate Zones 1-4	Climate Zones 5&6
$A_{equiv.} = HL_{SOL} \times R_{Ref.w}$	$R_{Ref.w}$ = 0.46; $\boldsymbol{A_{equiv.}}$ = 0.062m^2	$R_{Ref.w}$ = 0.5; $\boldsymbol{A_{equiv.}}$ = 0.067m^2	$R_{Ref.w}$ = 0.46; $\boldsymbol{A_{equiv.}}$ = 0.120m^2	$R_{Ref.w}$ = 0.5; $\boldsymbol{A_{equiv.}}$ = 0.131m^2

Example: *In Climate Zone 3, a house with 96m^2 of walls including 28.8m^2 of windows (or 30% window area) can reduce the window area by 0.120m^2 to offsets the heat loss through the Solatube to within the acceptable solution parameters.*

[1] Lux levels and performance in relation to G7 is not considered here as we have focused purely on the insulation levels. However, comparison between lighting from skylights and windows to tubular daylighting devices (TDD) lends great weight to the argument for using a TDD over traditional fenestration products.

For perspective these areas are equivalent to the below window sizes based on set heights.

	Assumed Window Height		
	1500mm	1200mm	900mm
Solatube 160DS in Climate Zones 1-4	41mm wide	51mm wide	68mm wide
Solatube 160DS in Climate Zones 5&6	45mm wide	56mm wide	74mm wide
Solatube 290DS in Climate Zones 1-4	80mm wide	100mm wide	134mm wide
Solatube 290DS in Climate Zones 5&6	87mm wide	109mm wide	145mm wide

Prescriptive Sizing for Solatube Compliance with H1
using % Window Reduction on different Floor Areas across all Climate Zones

	Solatube without Thermal Panel			
Climate Zones 1-4	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.12%	0.23%
	60	74.36	0.08%	0.16%
	90	91.07	0.07%	0.13%
	120	105.16	0.06%	0.11%
Climate Zones 5&6	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.13%	0.25%
	60	74.36	0.09%	0.18%
	90	91.07	0.07%	0.14%
	120	105.16	0.06%	0.12%

	Solatube with Thermal Panel			
Climate Zones 1-4	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.08%	0.16%
	60	74.36	0.06%	0.11%
	90	91.07	0.05%	0.09%
	120	105.16	0.04%	0.08%
Climate Zones 5&6	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.09%	0.18%
	60	74.36	0.06%	0.12%
	90	91.07	0.05%	0.10%
	120	105.16	0.05%	0.09%

Understanding the Solatube NZBC H1 Code Compliance Equivalency Calculations

The following pages breakdown how the H1 equivalency calculations have been applied and validated.

H1 Energy Efficiency (AS1 Fifth Edition – 29 November 2021)

Based on the nature of a Solatube Daylighting system Solatubes are considered akin to skylights for the purposes of NZBC H1, as such for compliance with H1/AS1 they must meet the acceptable solution scheduled standards or be assessed using the prescribed calculation method. Alternatively, Solatubes can be included in building energy use modelling As Solatubes typically achieve more illuminance per area than alternative top lighting methods they can be used to avoid excessive skylight areas as well as window areas when being used to achieve building code G7 lighting requirements.

The H1 acceptable solution scheduled method gives guidelines on the buildings it can be used on; limiting glazing area to 30% of wall area and skylight area to no more than 1.5m2 or 1.5% of the total roof area (whichever is greater). Minimum construction values for skylights in building elements not containing embedded heating systems are reproduced from H1/AS1 in the Construction R-value table below. Construction R-values for Skylights are determined in accordance with Appendix E.2 and include both the glazing and frame materials – they can be calculated from the U value as follows:

$$\text{Equation: } R_{Skylight} = \frac{1}{U_w}$$

Where $R_{Skylight}$ is the construction R-value of the skylight $(m^2.{}^{K}/_{W})$; and
U_w is the thermal transmittance of the skylight $(W/(m^2.K))$, determined in accordance with ISO 10077-1 using BS EN673 for thermal transmittance of the glazing and ISO 10077-2 for thermal transmittance of the frame. It is worth noting here that a lower U-value has better insulating properties than a high one, while a higher R-value has better insulating properties than a lower one.

Building element	H1/AS1 Construction R-values (m^2 K/W)(1)					
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5	Climate zone 6
Roof(2)	R6.6	R6.6	R6.6	R6.6	R6.6	R6.6
Wall	R2.0	R2.0	R2.0	R2.0	R2.0	R2.0
Floor slab-on-ground floors	R1.5	R1.5	R1.5	R1.5	R1.6	R1.7
Floors other than slab-on-ground	R2.5	R2.5	R2.5	R2.8	R3.0	R3.0
Windows and doors(3)	R0.46(3)	R0.46(3)	R0.46	R0.46	R0.50	R0.50
Skylights	R0.46	R0.46	R0.54	R0.54	R0.62	R0.62

Notes:
(1) Climate zone boundaries can be found in NZBC H1/AS1 Appendix C

Solatubes are rated using NFRC values[2]. For the purposes of this proof the NFRC values are used and considered equivalent to the ISO tested values. The latest NFRC results for Solatube products can be found at the following link and translated from imperial to metric using the below equation.
NFRC Values: https://search.nfrc.org/search/cpd/cpd_search_productline.aspx

$$\text{Equation: } U_{Metric} = 5.678 \times U_{Imperial}$$

The above equation is the conversion method from imperial to metric U-values (as used in NZ), NFRC values are given in imperial.

Solatube 160DS and 290DS have an R-value of 0.35 or R0.48[3] with the inclusion of a Thermal Insulation panel. The thermal panel brings residential Solatube's within the acceptable solution compliance standard for NZBC H1/AS1 for Climate Zones 1 and 2 by exceeding the minimum Skylight R-value of R0.46.

For the remaining climate zones or for installation without the thermal panel and when building energy modelling software isn't being used the calculation method should be used. The calculation method demonstrates the minimal heat loss from Solatubes in a typical residential build and the minor accommodations, if any, that can be made. The calculation relies on a reference building to compare to. The following detail from H1/AS1 2.1.3.4 outlines this reference building. The reference building allows for no skylight area and assumes exactly 30% of the total wall area is considered glazing. Based on this any adjustment for a skylight (or Solatube) in the final design can be accounted for by adjusting wall glazing area down by a proportional amount using the scheduled R-values or insulation levels up.

Climate zone (1)	Reference building heat loss equation (3)
1 and 2(2)	$HL_{Reference} = \frac{A_{roof} + A_{Skylight}}{6.6} + \frac{A_{70\%\ of\ the\ total\ wall\ area}}{2.0} + \frac{A_{slab-on-ground\ floor}}{1.5} + \frac{A_{other\ floor}}{2.5} + \frac{A_{30\%\ of\ total\ wall\ area}}{0.46}$
3	$HL_{Reference} = \frac{A_{roof} + A_{Skylight}}{6.6} + \frac{A_{70\%\ of\ the\ total\ wall\ area}}{2.0} + \frac{A_{slab-on-ground\ floor}}{1.5} + \frac{A_{other\ floor}}{2.5} + \frac{A_{30\%\ of\ total\ wall\ area}}{0.46}$
4	$HL_{Reference} = \frac{A_{roof} + A_{Skylight}}{6.6} + \frac{A_{70\%\ of\ the\ total\ wall\ area}}{2.0} + \frac{A_{slab-on-ground\ floor}}{1.5} + \frac{A_{other\ floor}}{2.8} + \frac{A_{30\%\ of\ total\ wall\ area}}{0.46}$
5	$HL_{Reference} = \frac{A_{roof} + A_{Skylight}}{6.6} + \frac{A_{70\%\ of\ the\ total\ wall\ area}}{2.0} + \frac{A_{slab-on-ground\ floor}}{1.6} + \frac{A_{other\ floor}}{3.0} + \frac{A_{30\%\ of\ total\ wall\ area}}{0.50}$
6	$HL_{Reference} = \frac{A_{roof} + A_{Skylight}}{6.6} + \frac{A_{70\%\ of\ the\ total\ wall\ area}}{2.0} + \frac{A_{slab-on-ground\ floor}}{1.7} + \frac{A_{other\ floor}}{3.0} + \frac{A_{30\%\ of\ total\ wall\ area}}{0.50}$

For these equations, $HL_{Reference}$ is the heat loss of the reference building, and
A_{roof} is the roof area of the proposed building (m^2), and
$A_{skylight}$ is the skylight area of the proposed building (m^2), and
$A_{70\%\ of\ total\ wall\ area}$ is 70% of the total wall area of the proposed building thermal envelope (m^2), and
$A_{30\%\ of\ total\ wall\ area}$ is the 30% of the total wall area of the proposed building thermal envelope (m^2), and
$A_{slab\text{-}on\text{-}ground\ floor}$ is the area of slab-on-ground floors in the proposed building thermal envelope (m^2), and
$A_{otherfloor\ is\ the\ area}$ of other floors in the thermal envelope of the proposed building (m^2).
Comment:
The reference building used in these equations has the minimum construction R-values for each climate zone given in the schedule method in Table 2.1.2.2B. It is assumed that the reference building has the same roof area, skylight area, and areas of floor as the proposed building. The

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[2] ISO and NFRC testing methods use different barrier conditions and material heat transfer relationships that mean there are no clear pathways to harmonisation (Ebanks & Richman, 2018). However, the NFRC in general are considered to have more stringent testing requirements and resulting higher U-values (worse) than ISO tested windows (Hanam, Jaugelis, & Finch, 2014). Hanam, Jaugelis & Finch also concluded that the NFRC values (modelled at a greater temperature differential, lower outdoor temperature and higher wind values) gave a more accurate worse case prediction of heat loss at peak loads while the ISO gave more accurate results for annual energy calculations. The results of these studies support the use of NFRC values as equivalent to ISO in these simplified calculations due to the tendency for NFRC results to yield more conservative results leading to higher estimated heat loss levels.

[3] Values calculated March 2022 for the purposes of this report. At the time NFRC values were 0.51 for single dome with lens and 0.37 for single dome with lens and thermal panel. These should be compared each time and included equations used to reconfirm. This is because NFRC values are continuously refined based on changing conditions.

total wall area in the reference building is assumed to contain a glazing area of 30%. As $A_{Skylight}$ is included with A_{Roof} the implication is no allowance is made for skylight heat loss beyond that as for the minimum R-value for a roof.

For climate zones 1-4 the R-value of the windows is 0.46, for climate zones 5 & 6 it increases to 0.5. Using the following equations, it's possible to calculate the equivalent window area to a given Solatube provided the correct inputs.

$$A_{SOL} = \pi(\frac{d}{2})^2$$

$$HL_{SOL} = \frac{A_{SOL}}{R_{SOL}}$$

$$A_{equiv.} = (HL_{SOL} - HL_{Roof}) \times R_{Ref.w}$$

where A_{SOL} is the penetration area of the Solatube using the given diameter (d): Solatube 160DS – 250mm diametre, Solatube 290DS – 350mm diametre;
And HL_{SOL}, is the heat loss for the given Solatube in $W/\Delta K$ based on A_{SOL} and the selected Solatubes current R-value (R_{SOL}),
The result is $A_{equiv.}$ The equivalent window area using the climate zones scheduled window R-value ($R_{Ref.w}$) applied to the difference in heat loss between a roof insulated to the reference building standard of R6.6[4].

Using the below inputs standard equivalent window areas can be arrived at, these are then used to determine the percentage reduction in window area for a given buildings wall area:

	Solatube 160DS		Solatube 290DS	
$A_{SOL} = \pi(\frac{d}{2})^2$	d = 0.25; A_{SOL} = ~0.05m^2		d = 0.35; A_{SOL} = ~0.1m^2	
$HL_{SOL} = \frac{A_{SOL}}{R_{SOL}}$	R_{SOL} = 0.35; HL_{SOL} = ~0.14$W/\Delta K$		R_{SOL} = 0.35; HL_{SOL} = ~0.27$W/\Delta K$	
	Climate Zones 1-4	**Climate Zones 5&6**	**Climate Zones 1-4**	**Climate Zones 5&6**
$A_{equiv.} = HL_{SOL} \times R_{Ref.w}$	$R_{Ref.w}$ = 0.46; $A_{equiv.}$ **= 0.062m^2**	$R_{Ref.w}$ = 0.5; $A_{equiv.}$ **= 0.067m^2**	$R_{Ref.w}$ = 0.46; $A_{equiv.}$ **= 0.120m^2**	$R_{Ref.w}$ = 0.5; $A_{equiv.}$ **= 0.131m^2**

For perspective these areas are equivalent to the below window sizes based on set heights.

	Assumed Window Height		
	1500mm	1200mm	900mm
Solatube 160DS in Climate Zones 1-4	41mm wide	51mm wide	68mm wide
Solatube 160DS in Climate Zones 5&6	45mm wide	56mm wide	74mm wide
Solatube 290DS in Climate Zones 1-4	80mm wide	100mm wide	134mm wide
Solatube 290DS in Climate Zones 5&6	87mm wide	109mm wide	145mm wide

For a nominal 108m^2 rectangular house, with a 2.4m high stud and estimated 110m^2 total wall area you would expect to need a decrease of window area from the prescribed 30% by only 0.059-0.125% per Solatube based on the reference building insulation levels (varying by climate zone and Solatube size. Given the low percentage change one or even multiple Solatubes can be accommodated with minimal window reduction. The thermal panel would only serve to decrease the reduction rate.

Compliance could also be achieved by a minimal increase in roof insulation values above the schedule R6.6.

[4] *Note: schedule values for skylights and windows are different.*

The final table(s) gives a variety of house sizes with approximated wall areas and the resulting percentage window reduction for each of the most common Solatube sizes (160DS and 290DS). Based on these results a house with <29% glazed area could accommodate up to 4 Solatubes anywhere in the country and compare favourably to the reference building (based on a 0.25% reduction for a 290DS Solatube on a 30m2 house with ~52.6m2 wall area).

Prescriptive Option for Solatube Compliance with H1 using Window Reduction

	Solatube with Thermal Panel			
Climate Zones 1-4	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.12%	0.23%
	60	74.36	0.08%	0.16%
	90	91.07	0.07%	0.13%
	120	105.16	0.06%	0.11%
Climate Zones 5&6	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.13%	0.25%
	60	74.36	0.09%	0.18%
	90	91.07	0.07%	0.14%
	120	105.16	0.06%	0.12%
	Solatube without Thermal Panel			
Climate Zones 1-4	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.08%	0.16%
	60	74.36	0.06%	0.11%
	90	91.07	0.05%	0.09%
	120	105.16	0.04%	0.08%
Climate Zones 5&6	**Floor Area (m2)**	**Wall Area (m2)**	**160DS**	**290DS**
	30	52.58	0.09%	0.18%
	60	74.36	0.06%	0.12%
	90	91.07	0.05%	0.10%

Note: from the table smaller houses have a larger percentage reduction due to the proportionality of the equation. The table also assumes a square house with 2.4m high walls.
As the houses shape gets more complex or the walls get higher the percentage reduction gets smaller meaning these percentage reduction recommendations are a worst-case scenario calculation.

These last equations are one simple final check for an individual house based on wall area.

$$A_{\%Reduct.} = \frac{A_{equiv.}}{A_{wall}}$$

$A_{\%Reduct.}$ is the percentage reduction rate taking $A_{equiv.}$ (from the earlier table for your preferred Solatube size and Climate Zone) as a fraction of the given wall area (A_{wall}).

$$Check: \Sigma A_{\%Reduct.} < 30\% - A_{\%Window}$$

If the sum of the percentage reduction for the number of Solatubes desired is less than the difference between 30% and the true window percentage then the building complies.

Works Cited

Ebanks, P.-G., & Richman, R. (2018). TOWARDS HARMONIZING THE NFRC AND CEN WINDOW PERFORMANCE SIMULATION METHOD. *Canadian Journal of Civil Engineering*.

Hanam, B., Jaugelis, A., & Finch, G. (2014). ENERGY PERFORMANCE OF WINDOWS: NAVIGATING NORTH AMERICAN AND EUROPEAN WINDOW STANDARDS. *Canadian College of Business, Science & Technology*.