Harmony House

RESULTS AND FINDINGS

Goals

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To monitor the characteristics and performance of a net-zero energy home thoroughly utilizing natural ventilation.

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To investigate the effects of climate, architectural design, and construction on achieving natural ventilation in the Pacific Northwest.

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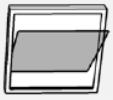
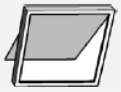
To investigate, in depth, the characteristics of awning windows and horizontal skylights, and the role they play to facilitate natural ventilation.

Properties of different window types when opened at a typical angle	Side hung, opening to inside	Bottom hung, opening to inside	Sliding, opened pane always covers part of window	Horizontal pivoted, lower part opening to outside	Top hung, opening to outside
					
Weather protection	–	+	–	O	O
Max. achievable ventilation rate	+	–	O	+	O
Adjustability of opening size	+	–	+	+	+
Flexibility for placement of furniture	–	+	+	O	+

Goals

To monitor the characteristics and performance of a net-zero energy home thoroughly utilizing natural ventilation.

To investigate the effects of climate, architectural design, and construction on achieving natural ventilation in the Pacific Northwest.

To investigate, in depth, the characteristics of awning windows and horizontal skylights, and the role they play to facilitate natural ventilation.

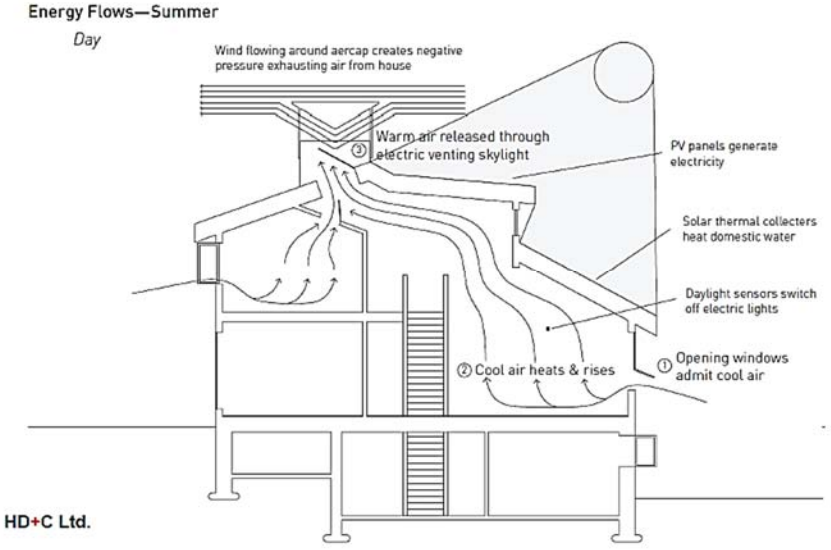
To investigate what makes the Harmony House so effective at keeping the interior conditions comfortable without using any mechanical systems

Indirect goals

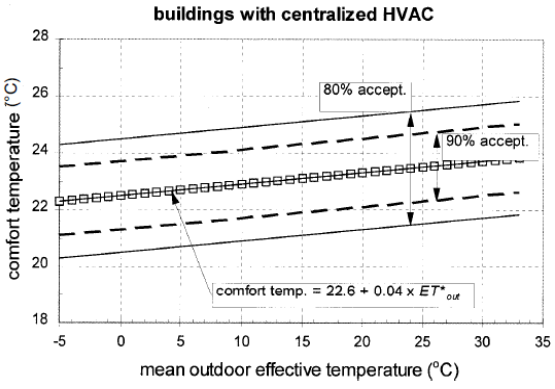
Investigate if and how accurately a net-zero energy house can be modeled using the coupling of whole-building energy modeling and CFD softwares.

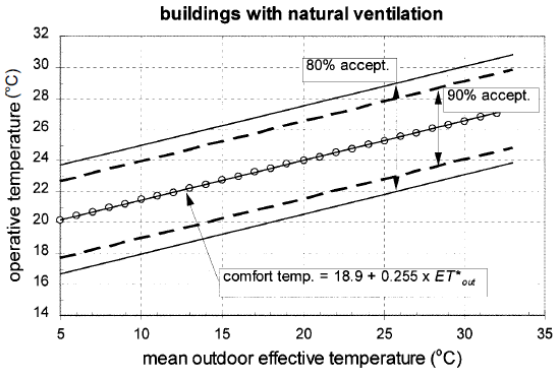
To investigate the feasibility of quantifying the effect of some passive technologies and strategies using aforementioned computer software models in enhancing natural ventilation, thermal comfort, and energy performance in net-zero energy houses.

Natural Ventilation



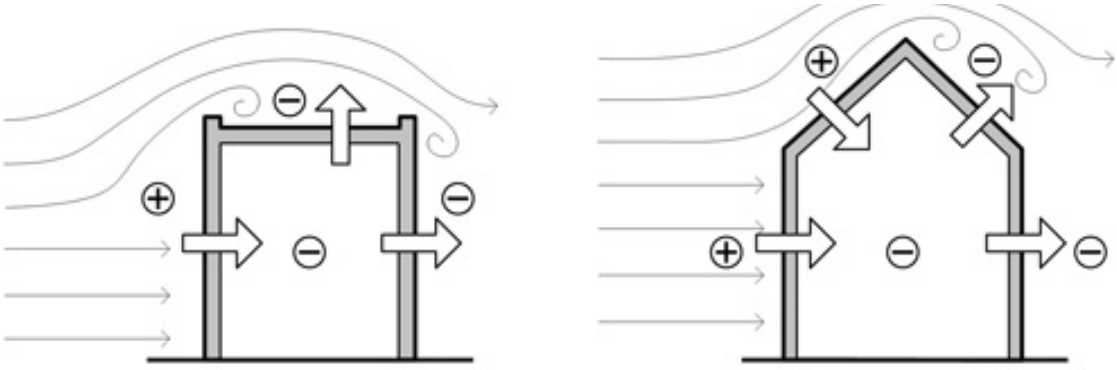
Adaptive Thermal Comfort





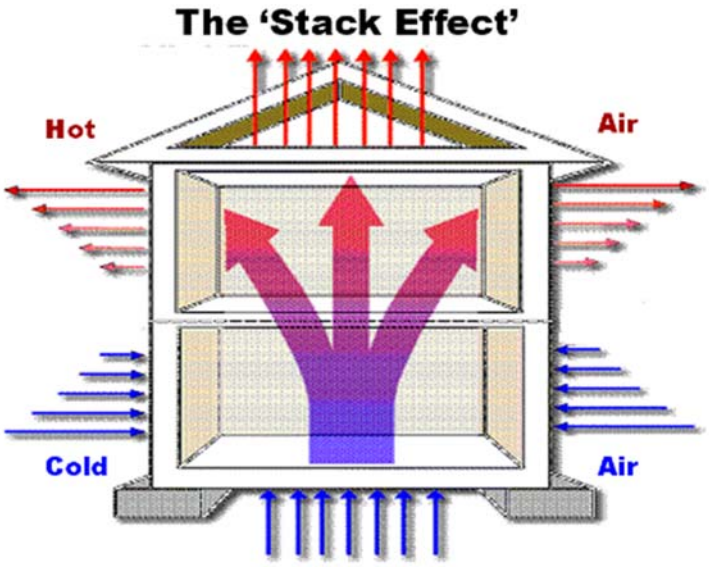
How does natural ventilation work?

Wind

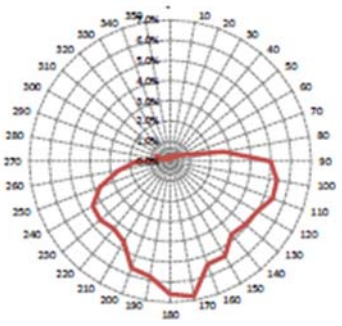


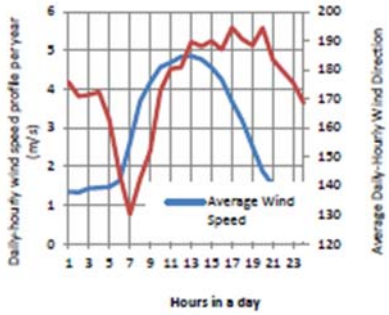
How does natural ventilation work?

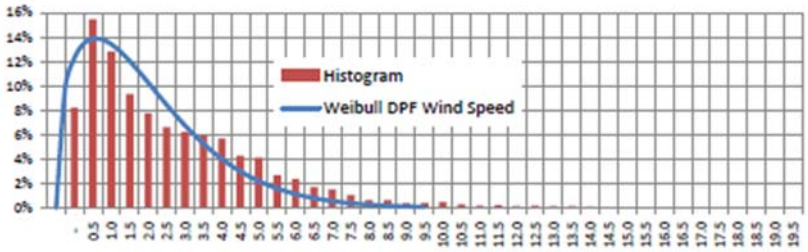
Stack effect and air buoyancy



The Climate







Challenges and difficulties

Too much air flow may cause discomfort

Too much air flow will disturb the temperature stratifications in the house

Larger temperature differences between head and foot level

Fluctuating wind levels

Fluctuating weather conditions

Predicting use of thermal mass

Predicting use of solar gains

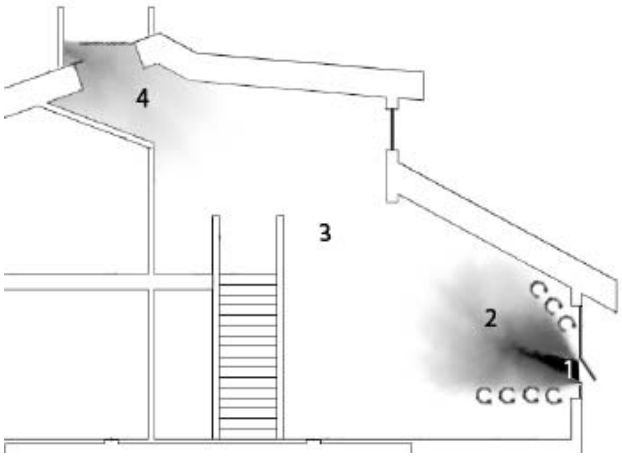
Ultimately, natural ventilation is very difficult to predict and it is hard to leverage the climate in just the way you want.

Specifics of Natural Ventilation in the Harmony House

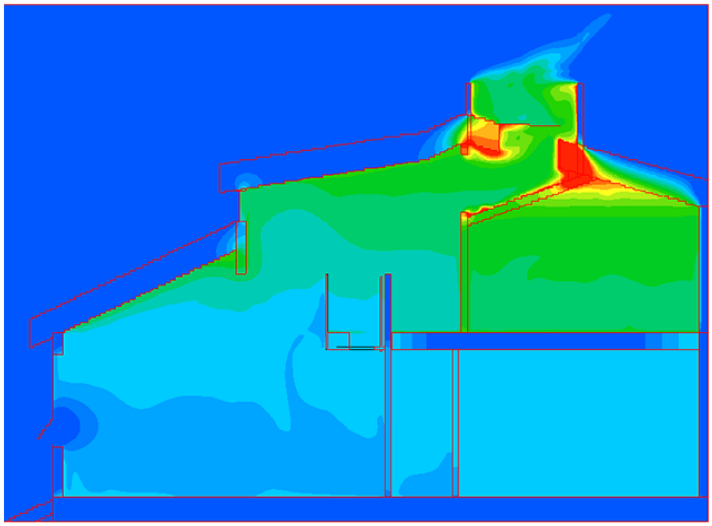
The atrium is a great component to facilitate natural ventilation.

- It allows for good air stratification
- It allows for good air movement
- It has a high ceiling level
- Solar gains through the windows warms the air (including at the chimney), generating a high buoyant force on the air, pushing it out of the house

Air velocity in the house



Air Stratification in the Harmony House

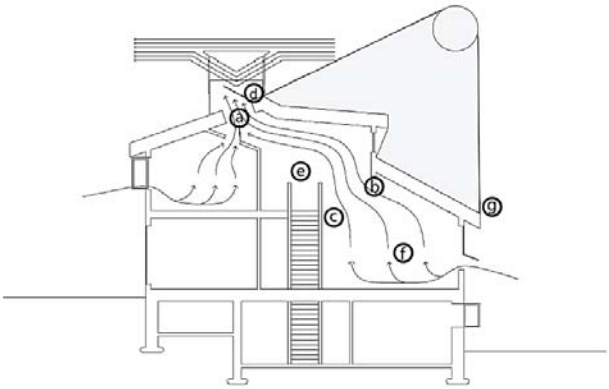


Methodology

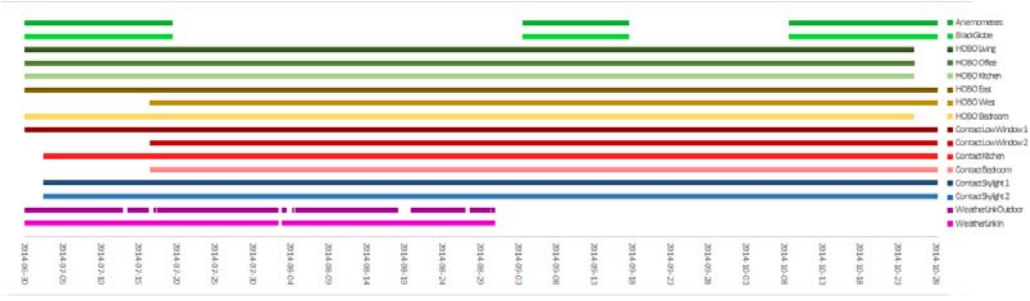
The methodology revolves around three main parts,

- 1. Monitoring
- 2. Measuring
- 3. Modeling

Monitoring



Monitoring



Measuring

We had planned pressure test at the Harmony House but these did not work the way we were hoping.

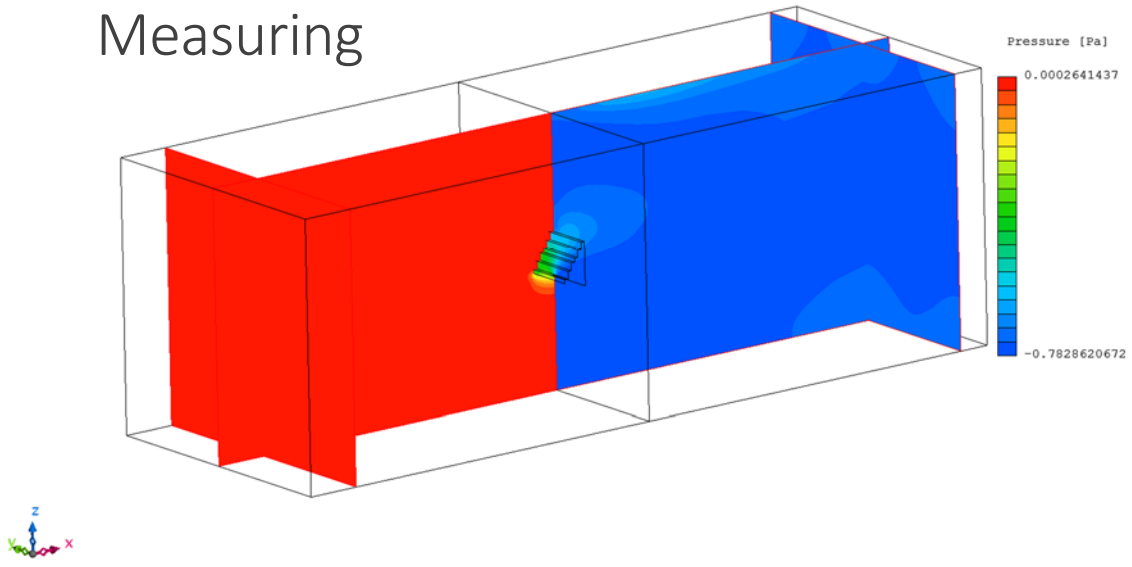
The plan was to obtain the discharge coefficients to input into the models as it was a critical input in the models.

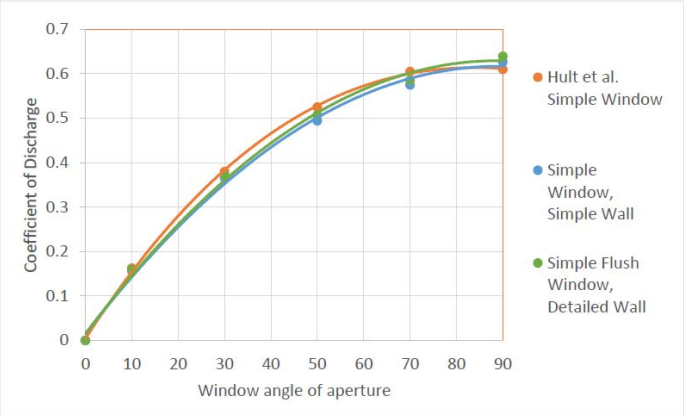
The theory was to use the orifice equation:

$$Q = C_d A \left(\frac{2\Delta P}{\rho}\right)^2$$

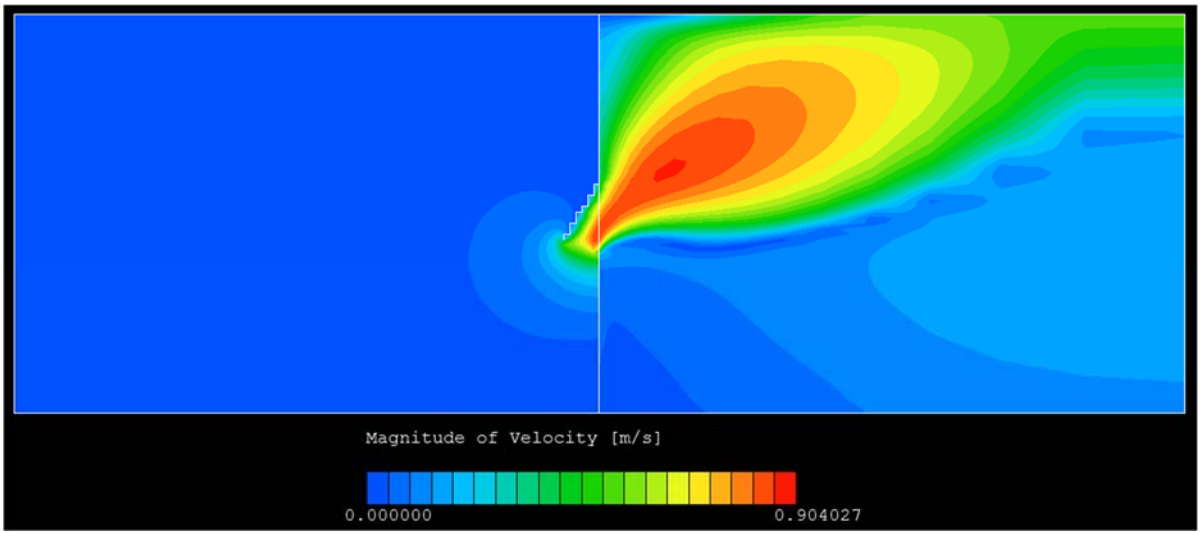
$$C_d * A = Q \left(\frac{\rho}{2\Delta P}\right)^2$$

Measuring




0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Coefficient of Discharge
0
10
20
30
40
50
60
70
80
90
Window angle of aperture
Hult et al. Simple Window
Simple Window, Simple Wall
Simple Flush Window, Detailed Wall

Measuring


Magnitude of Velocity [m/s]
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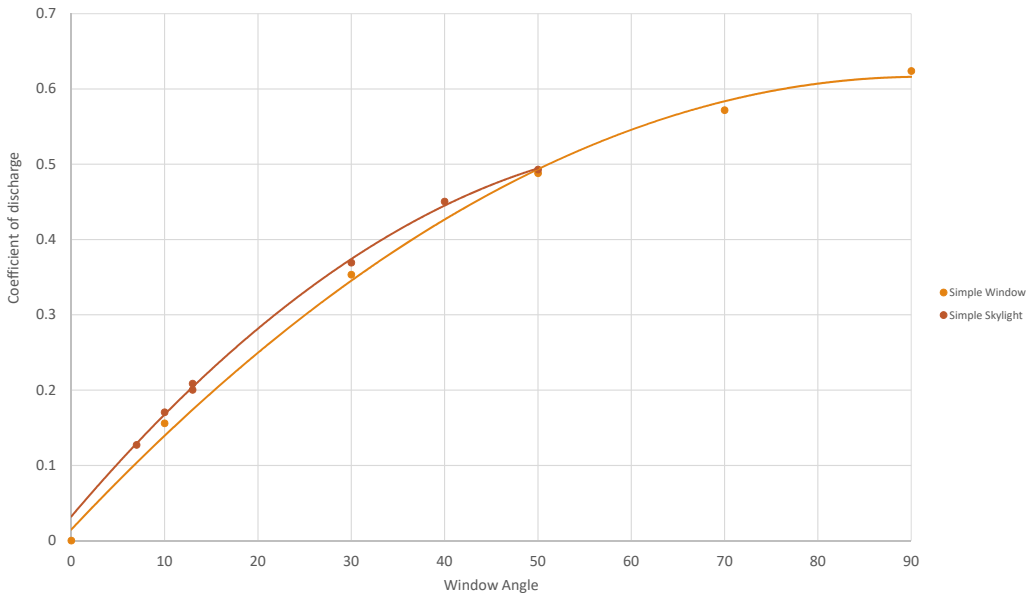
0.904027



Modeling

As indicated in the methodology, two simulation models are used in this study to model the Harmony House.

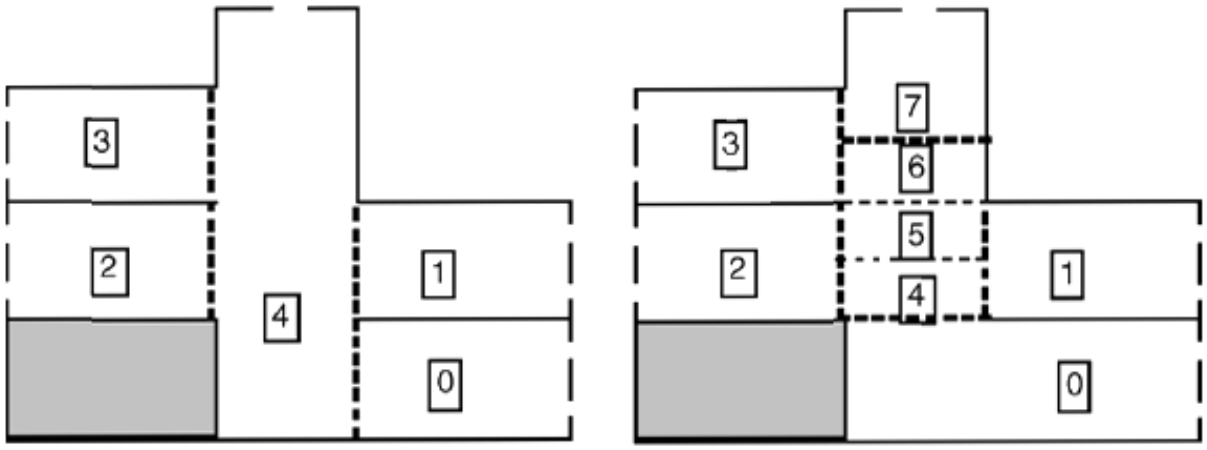
Each model has its own advantages.

The Computational Fluid Dynamics (CFD) model is used for an accurate thermal-fluid characterization of the airflow in the open atrium space;

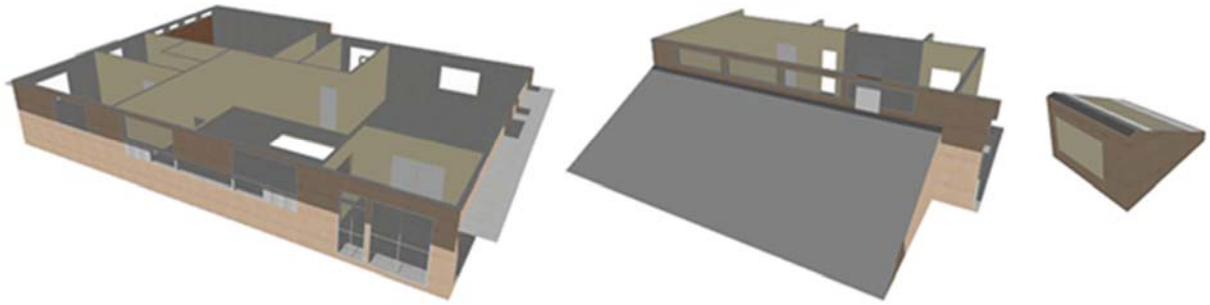
The hourly energy simulation thermal model is used for whole-house thermal and airflow simulations that are used to predict thermal comfort conditions.

The models were coupled manually by selecting representative days and hours from the measured data, and comparing indoor and outdoor temperatures and airflows with our models. The intent in combining these two types of models was to capture the precise thermal-fluid dynamics of the indoor environment.

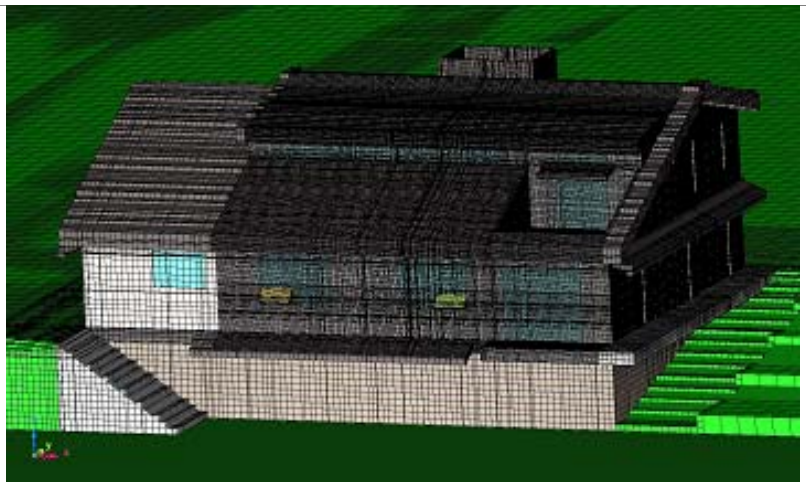
Dynamic Thermal Model



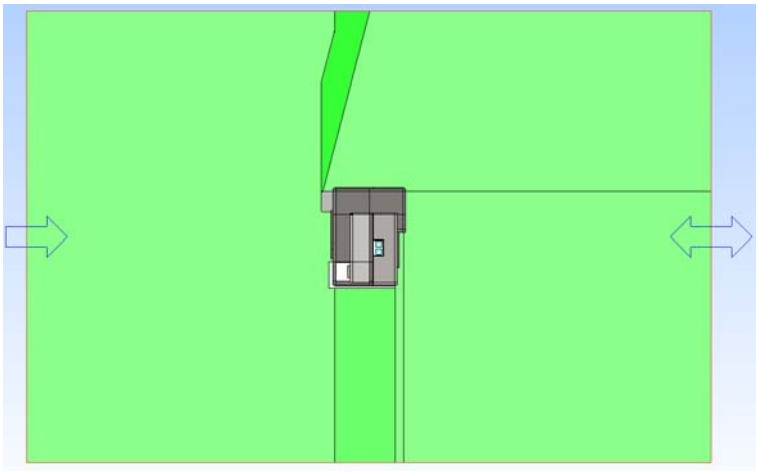
Dynamic Thermal Model



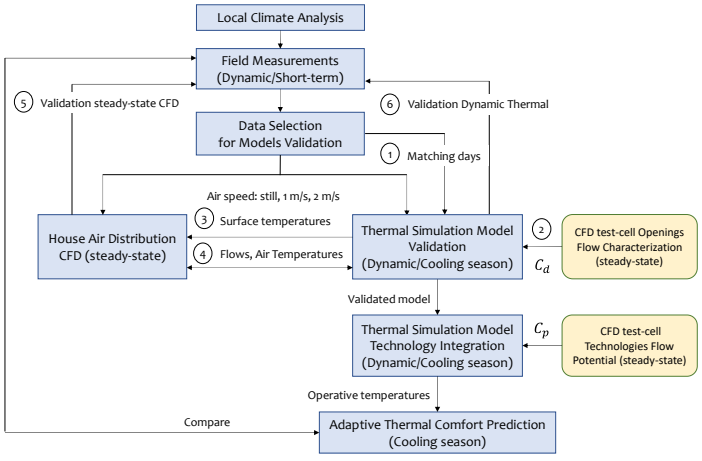
CFD Model

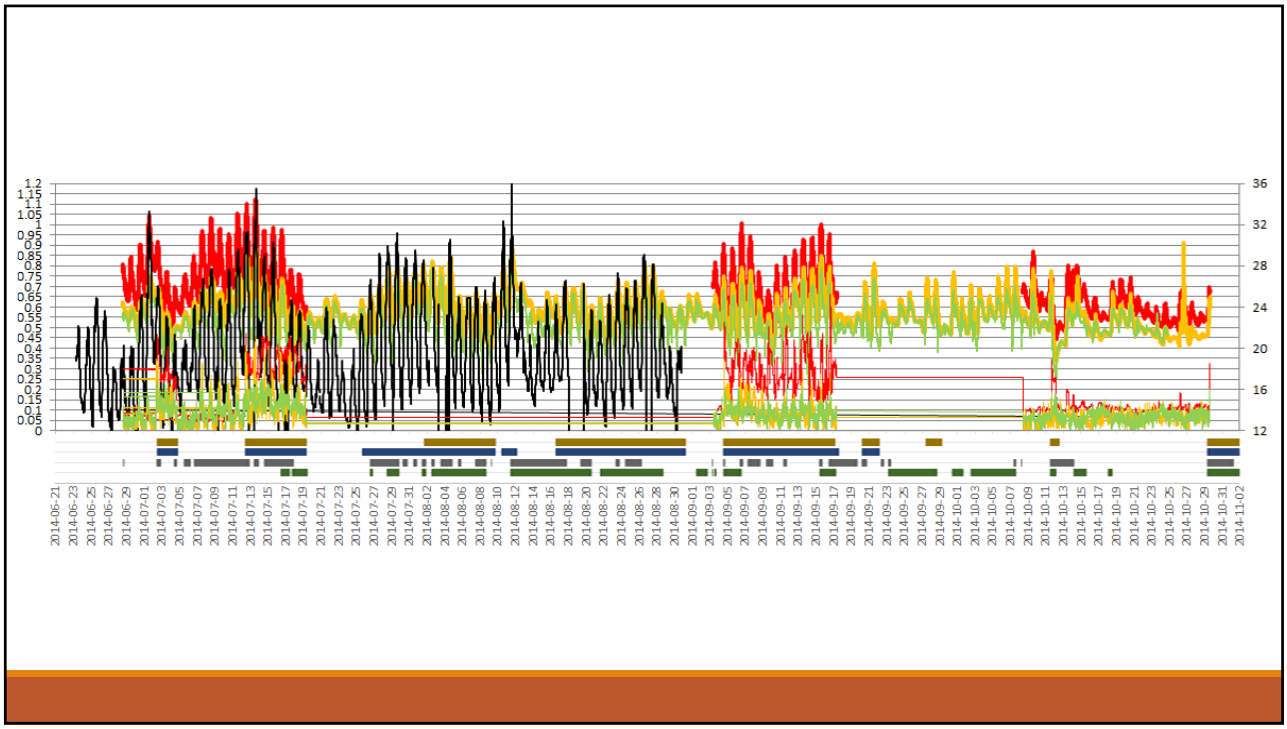


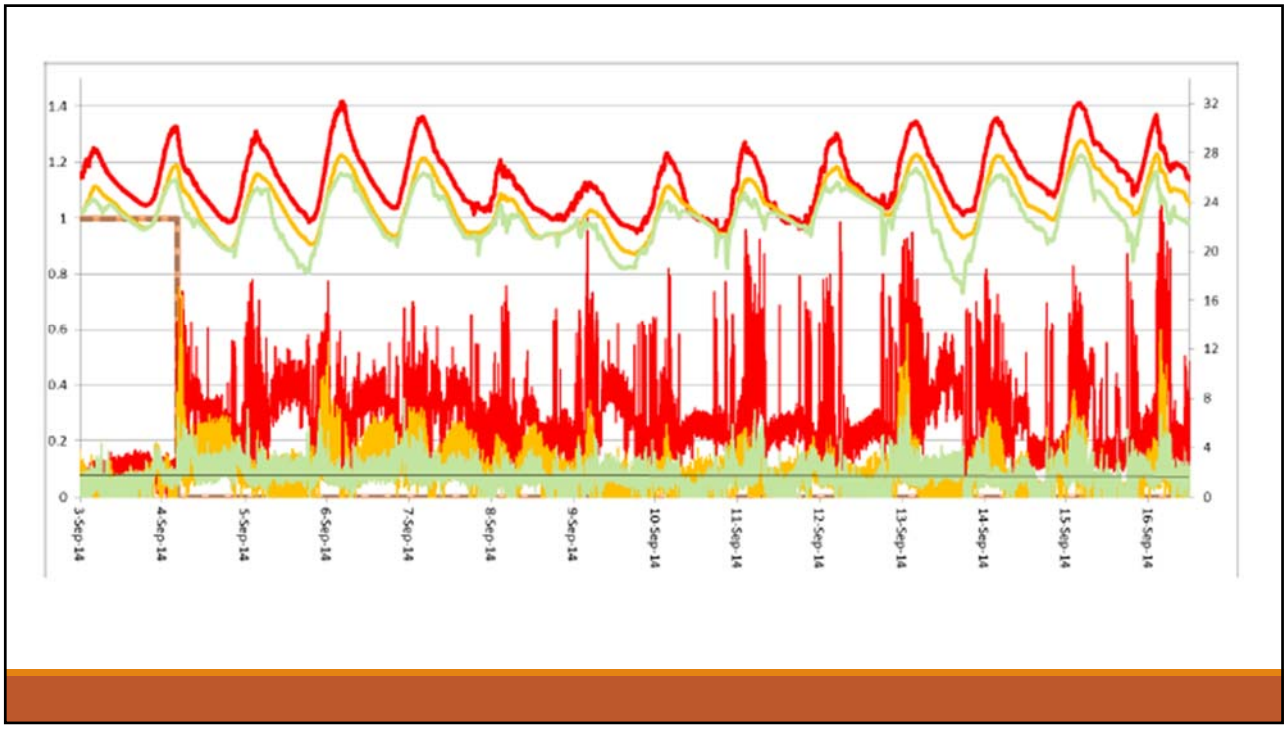
CFD Model



Methodology






3-Sep-14
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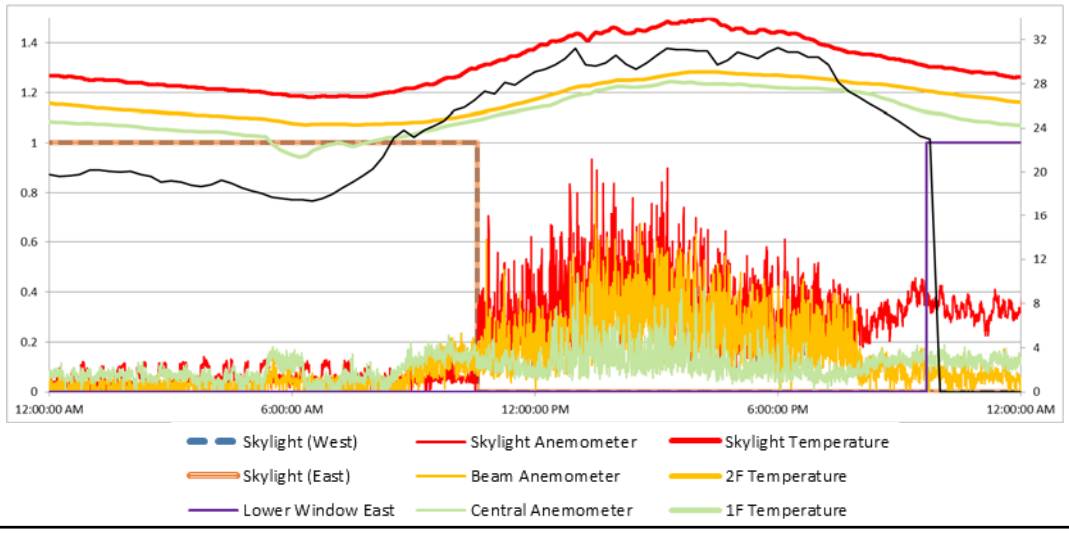
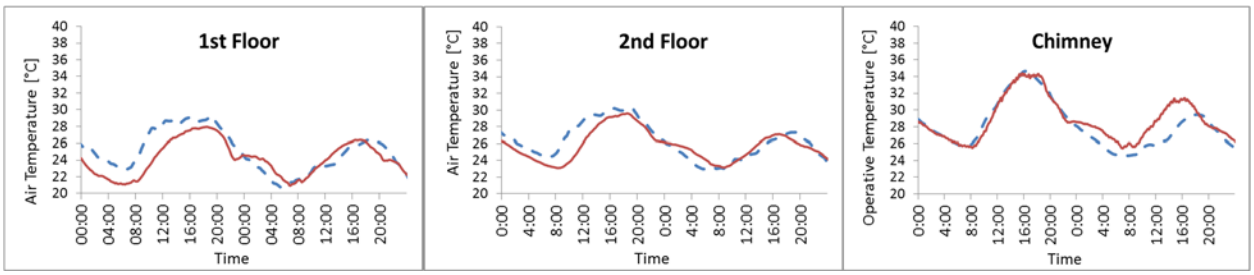
16-Sep-14

Monitoring



Results of the Dynamic Thermal Model



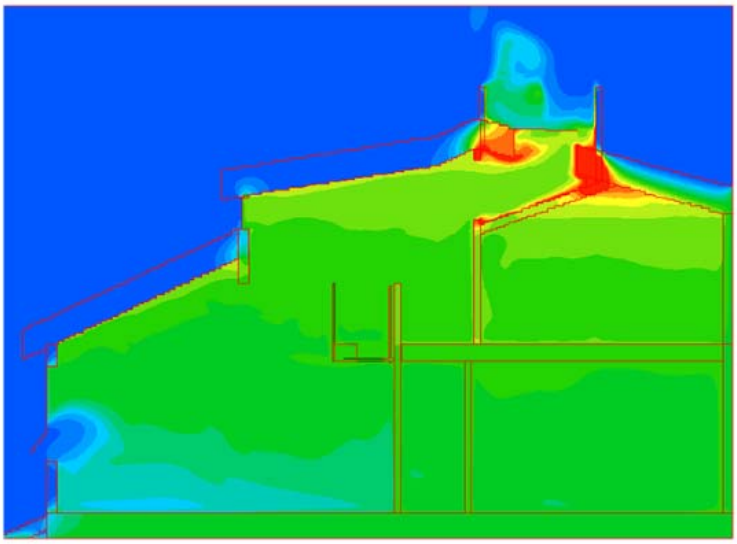
	Cool day		Typical day		Warm day	
	Data	DB	Data	DB	Data	DB
Date	18-Jul	06-Jul	16-Jul	24-Jul	13-Jul	22-Jul
1F T_{air}	23.1	24.0	26.0	27.4	27.7	28.7
2F T_{air}	23.6	24.3	26.7	28.2	29.6	30.2
Sky T_{op}	27.1	27.1	31.2	31.5	33.9	34.0
T_o	23	21	23	23.5	32	28

Surface Temperatures

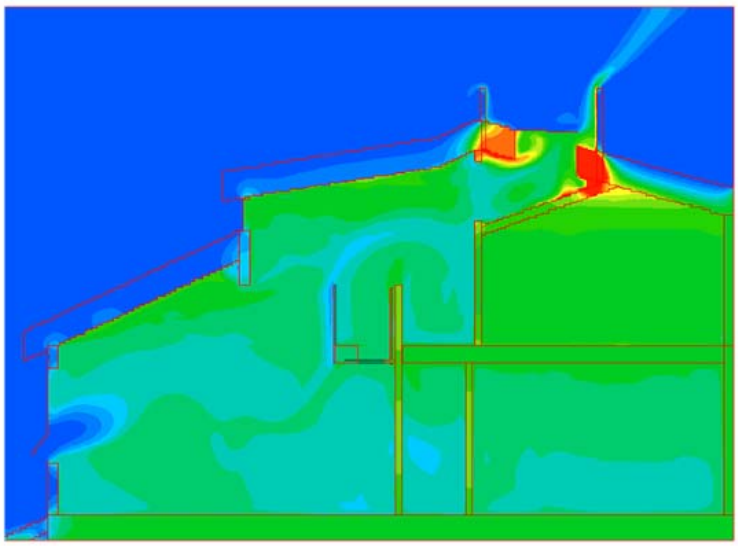
From the whole building simulations, the software can output the surface temperature at each level of the house.

These were input into the CFD simulations

Results of the CFD Model



Results of the CFD Model



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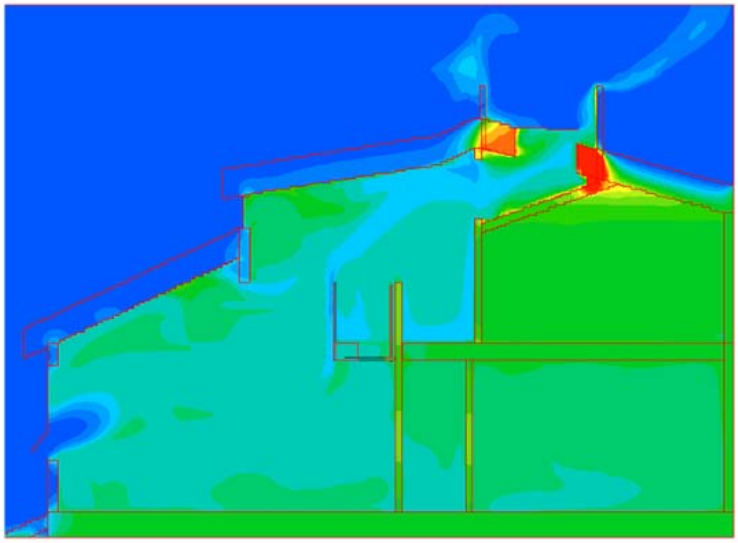
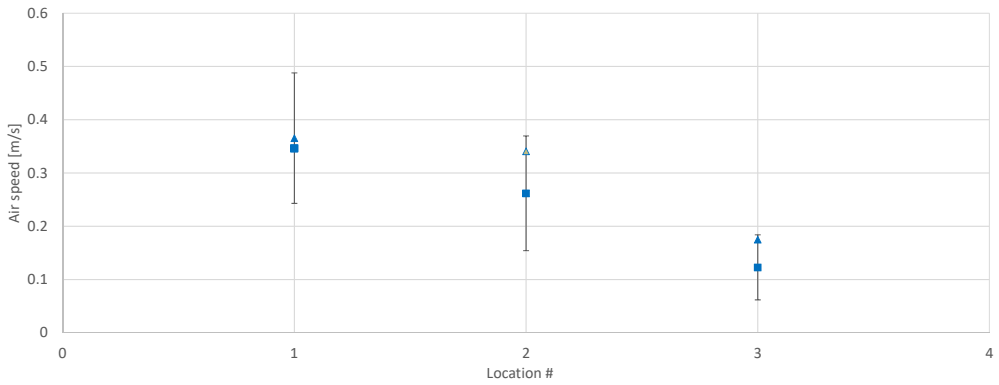


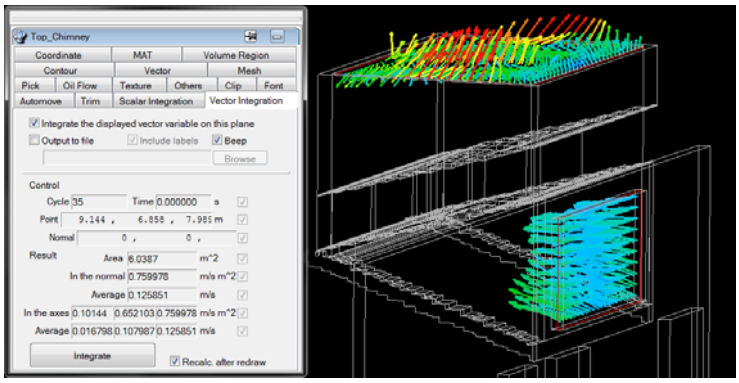
Results of the air speeds



Results of the temperatures

Location	Values		
	CFD	Recorded Data	DB
1F	26.74	26	27.5
2F	27.84	27	29
Skylight	28.18 / n/a*	31.5*	32*

Results of the flow rate

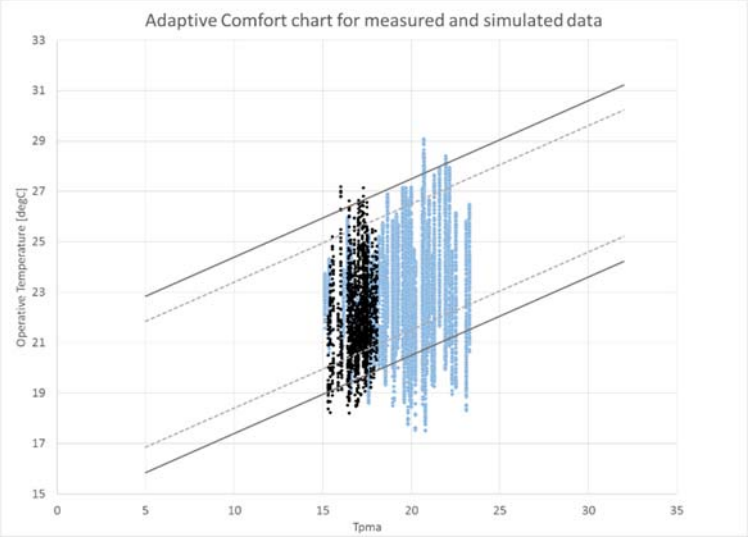


Location	CFD	Dynamic-Thermal
Skylight Outlet	0.760	0.617
Lower Window West	0.373	0.281
Lower Window East	0.364	0.281
Lower Windows Total	0.738	0.563

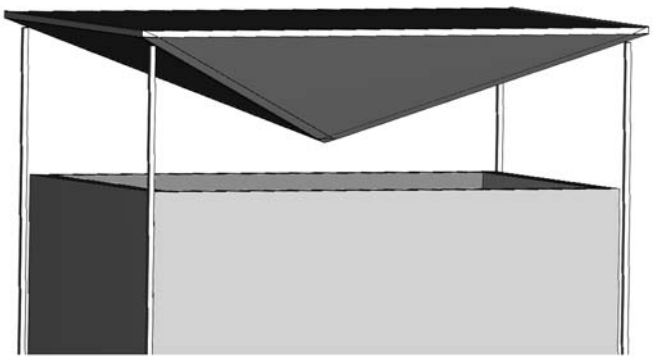
Findings

Thermal comfort chart,

ASHRAE 55



What if the Aerocap had been installed?



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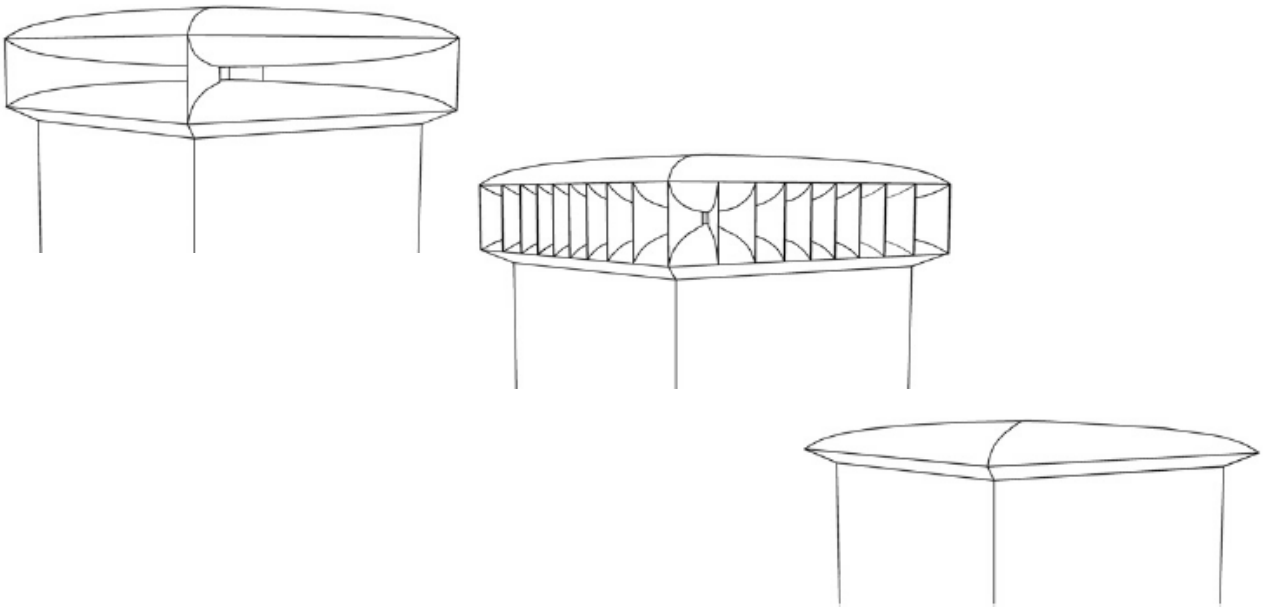

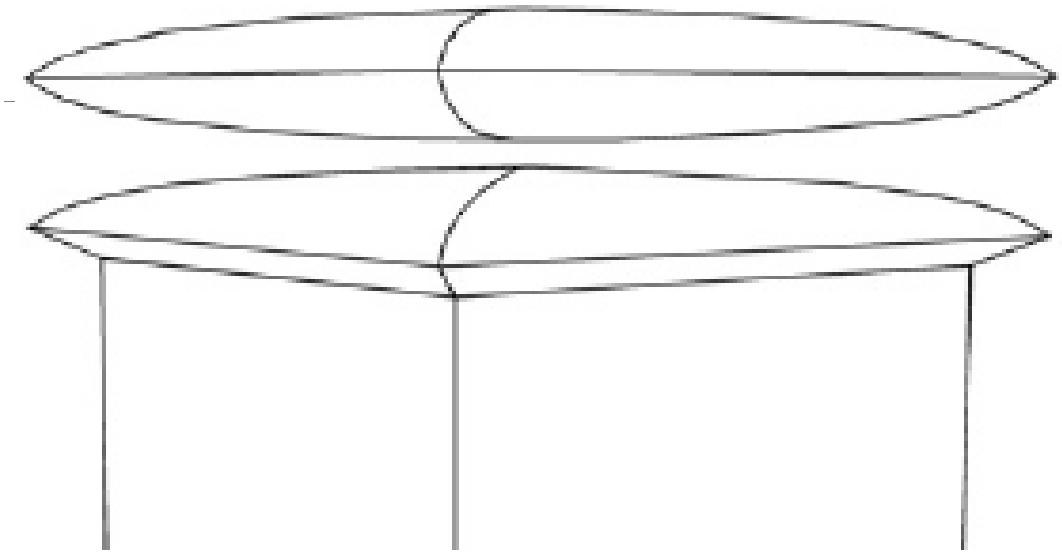

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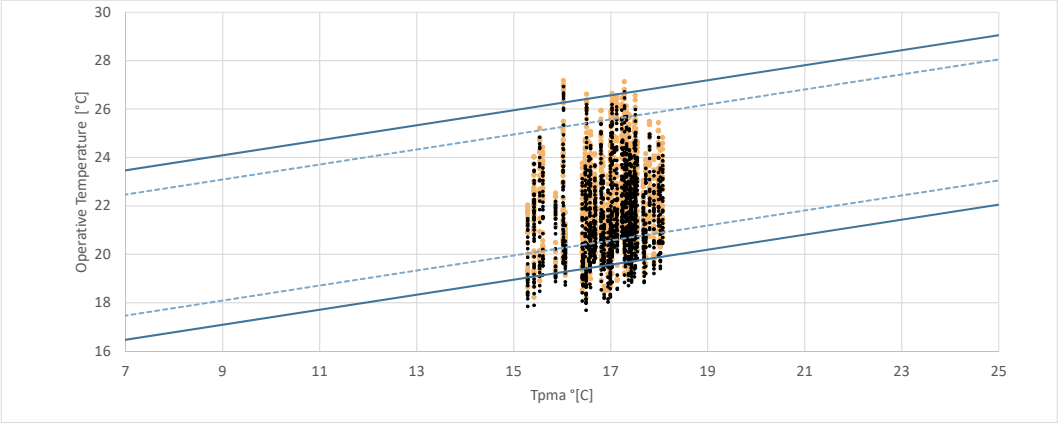

Conclusions

The house performs perfectly through good architectural design.

The atrium offers exceptional cooling through use of wind and stack effect.

The selection and decisions regarding the window type were sound.

There was no need to install the Aerocap – the positives may have not outweighed the negatives.