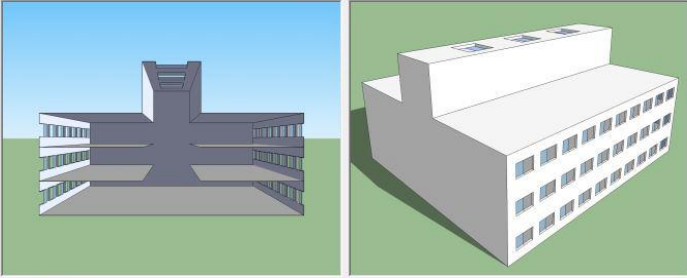


## INPUTS: Central atrium; Jun

Simulation type  
☒ Transient (24 hour) ☐ Steady state (snapshot)

Building type  
 Central atrium



Internal heat loads  
 Heat source level: Educational 40 W/m<sup>2</sup>  
 Occupancy schedule: From 9 hours to 24 hours  
*All zones but the atrium zones (if any) are assigned heat loads.*  
 Off peak equipment load fraction: 0.2

Terrain properties  
 Terrain type: Urban, industrial or forest area

Building dimensions

Number of floors: 6

Floor length: 33 m

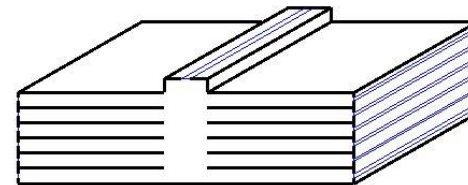
Floor (bay) width: 33.8 m

Floor-to-floor height: 3.5 m

Floor-to-ceiling height: 3 m

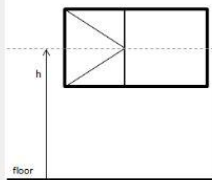
Chimney width: 10 m

Chimney height: 3 m



Side windows dimensions

☒ In each floor, there is only one opening per window (see schematic)  
☐ In each floor, there are two openings separated vertically per window (see schematic). REQUIRED for single-sided ventilation



Window glazing area per floor per facade, fixed and operable (to calculate solar gains through windows): 7 m<sup>2</sup>

Operable window area per floor (used to calculate air flowrate): 2 m<sup>2</sup>

Height from floor to mid-opening (h): 1.75 m

Operable lower window area per floor per facade: 1 m<sup>2</sup>

Height difference between upper and lower opening (Delta H in figure): 1 m

Roof opening dimensions  
 Roof operable area: 1 m<sup>2</sup>  
*Note: CoolVent does not account for solar heat gains through the roof opening(s)*

Internal opening dimensions  
 Internal opening area per floor: 20 m<sup>2</sup>  
 Advanced internal opening options: Advanced...

Additional opening options  
 More window options and opening specifications: Advanced...

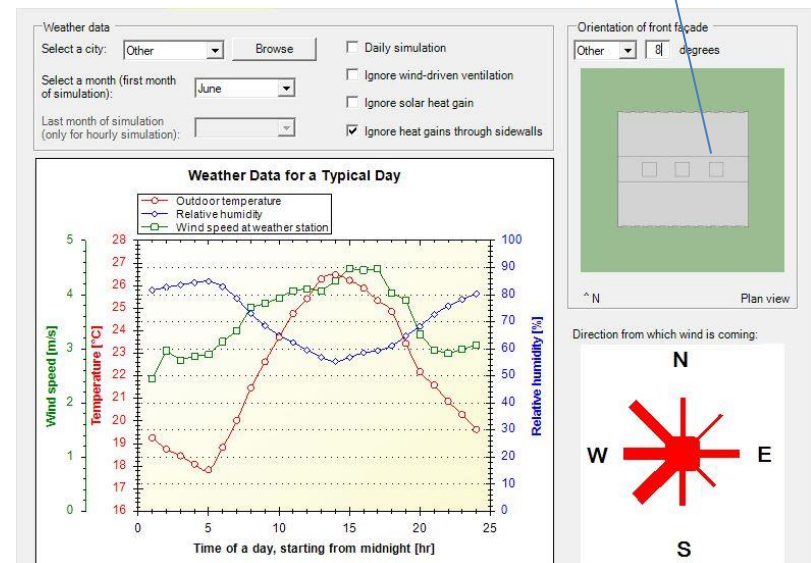
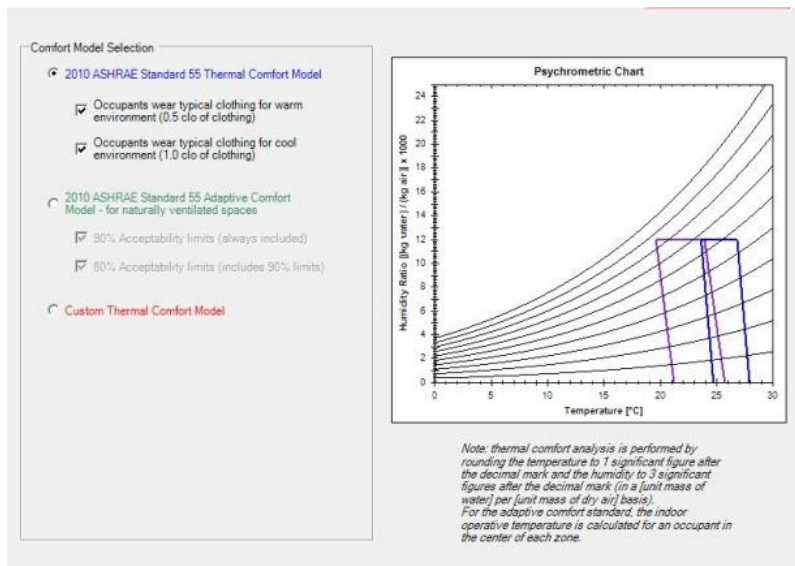
Thermal mass  
☐ Include slab thermal mass  
 Floor / roof slab thickness: 5 cm  
 Floor slab material: Concrete  
 Floor type: Exposed  
 Ceiling type: Exposed  
 Exposed area: 90 % of floor area

Night cooling  
☐ Use night cooling: Windows open at nighttime, when the air is cold enough to cool down the thermal mass. Windows close (down to 10%) during daytime to prevent hot outdoor air from entering the building. If the building has a fan, it will be used to assist night cooling.  
☒ Time controlled: close all windows at 7 hours, open windows at 19 hours  
☐ Temperature controlled: close windows in zones where temperature is lower than outdoor temperature; close windows otherwise

Window operation  
☐ Close windows when the outdoor air temperature drops below 16 °C  
☐ Close Window and turn on heating when any internal zone temperature drops below 18 °C

Hybrid ventilation mode  
☒ Use hybrid mechanical-natural ventilation  
☐ Turn on fan when any internal zone temperature is above 24 °C or humidity ratio is above 0.012 (kg water) / (kg air). Windows will open even if using night cooling.  
☐ Close windows, turn off fan and turn on AC when any internal zone temperature is above 26 °C or humidity ratio is above 0.012 (kg water) / (kg air)  
☐ Allow independent window and AC control in each zone  
 Define fan / AC operating characteristics: Specify fan / AC

INPUTS: Central atrium; Jun



The above images show all the relative inputs for the simulation of the type 1: central atrium

## REPORT: Central Atrium; Jun

## CoolVent Thermal Comfort Results

USA\_PA\_Philadelphia.Intl.AP.724080\_TMY3

2010 ASHRAE Standard 55 Thermal Comfort Model

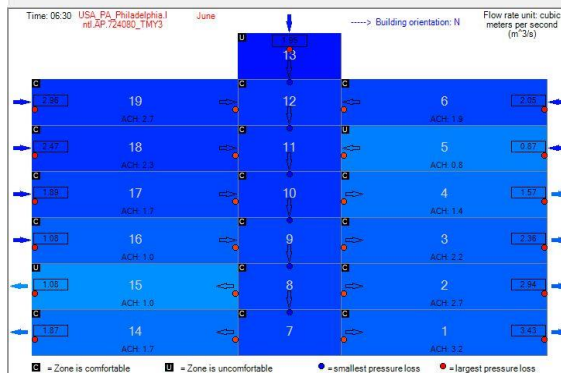
## Temperature Pie Charts

		13		
	19		6	
	18	12	5	
	17	11	4	
	16	10	3	
	15	9	2	
	14	8	1	
		7		

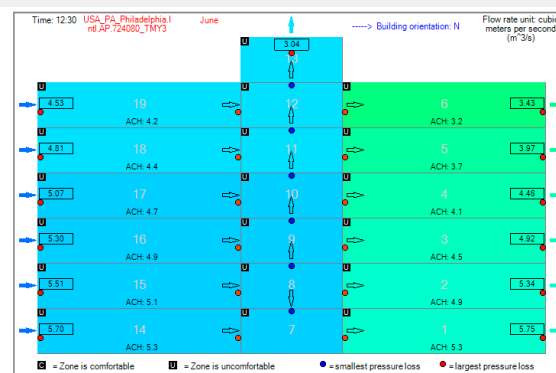
The pie charts represent temperature concerns for comfort in non-atrium zones of the building.

Red represents the percent of total occupied hours that a given zone is too hot.  
Blue represents the percent of total occupied hours that a given zone is too cold.

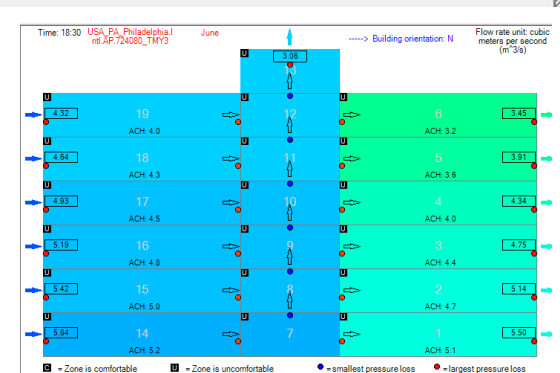
Humidity concerns are not addressed in the pie charts.



6:30



12:30



18:30

The report for the type 1: central atrium shows the building is too hot in June

Specifically, the three images show the ventilation condition at 6:30 – 12:30-18:30. At 6:30, the building is almost comfortable; however at 12:30 or 18:30 the building is totally uncomfortable.

### IMPROVEMENT TESTS: Central Atrium; Jun

- Thus, the first strategy to improve the comfort condition is **to include slab thermal mass**

Thermal mass

☒ Include slab thermal mass

Floor / roof slab thickness  cm

Exposed area  % of floor area

Floor slab material

Floor type

Ceiling type

Then the comfort results improved around 20%-50%.

			13			
	19	43.3% hot 0% cold 56.7% comfort of total number of occupied hours	12		6	63.3% hot 0% cold 36.7% comfort of total number of occupied hours
	18	48.3% hot 0% cold 48.3% comfort of total number of occupied hours	11		5	23.3% hot 0% cold 76.7% comfort of total number of occupied hours
	17	48.3% hot 0% cold 48.3% comfort of total number of occupied hours	10		4	21.7% hot 0% cold 78.3% comfort of total number of occupied hours
	16	48.3% hot 0% cold 48.3% comfort of total number of occupied hours	9		3	20% hot 0% cold 80% comfort of total number of occupied hours
	15	45% hot 0% cold 45% comfort of total number of occupied hours	8		2	18.3% hot 0% cold 81.7% comfort of total number of occupied hours
	14	16.7% hot 0% cold 83.3% comfort of total number of occupied hours	7		1	13.3% hot 0% cold 86.7% comfort of total number of occupied hours

And then, I tried to **change the material from concrete to brick**

Thermal mass

☒ Include slab thermal mass

Floor / roof slab thickness  cm

Exposed area  % of floor area













Floor slab material

Floor type

Ceiling type

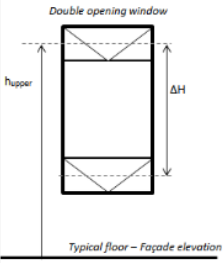
☐ Night cooling

But the result does not change dramatically

		13		
	19			6
	18	12		5
	17	11		4
	16	10		3
	15	9		2
	14	8		1
		7		

- The second strategy is to change **the side windows type from only one opening per window to two openings**

Side windows dimensions



☐ In each floor, there is only one opening per window (see schematic)  
☒ In each floor, there are two openings separated vertically per window (see schematic). REQUIRED for single-sided ventilation

Window glazing area per floor per facade, fixed and operable (to calculate solar gains through windows):  m<sup>2</sup>

Operable upper window area per floor (used to calculate air flowrate):  m<sup>2</sup>

Height from floor to upper opening (hupper):  m

Operable lower window area per floor per facade:  m<sup>2</sup>

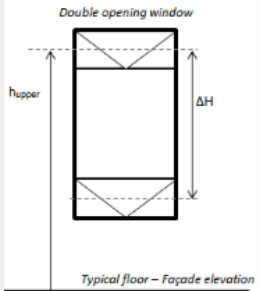
Height difference between upper and lower opening (Delta H in figure):  m

And then the comfort result improved around 2%-20%

		13		
	19		6	
	18	12	5	
	17	11	4	
	16	10	3	
	15	9	2	
	14	8	1	
		7		

And then I tried to double the window glazing area













Side windows dimensions



☐ In each floor, there is only one opening per window (see schematic)  
☒ In each floor, there are two openings separated vertically per window (see schematic). REQUIRED for single-sided ventilation













Window glazing area per floor per facade, fixed and operable (to calculate solar gains through windows):  m<sup>2</sup>  
 Operable upper window area per floor (used to calculate air flowrate):  m<sup>2</sup>  
 Height from floor to upper opening (hupper):  m  
 Operable lower window area per floor per facade:  m<sup>2</sup>  
 Height difference between upper and lower opening (Delta H in figure):  m

However, the result does not change a lot:

			13			
	19	98.3% hot 0% cold 1.7% comfort of total number of occupied hours	12		6	98.3% hot 0% cold 1.7% comfort of total number of occupied hours
	18	98.3% hot 0% cold 1.7% comfort of total number of occupied hours	11		5	98.3% hot 0% cold 1.7% comfort of total number of occupied hours
	17	98.3% hot 0% cold 3.3% comfort of total number of occupied hours	10		4	98.3% hot 0% cold 1.7% comfort of total number of occupied hours
	16	98.3% hot 0% cold 10% comfort of total number of occupied hours	9		3	98.3% hot 0% cold 1.7% comfort of total number of occupied hours
	15	98.3% hot 0% cold 13.3% comfort of total number of occupied hours	8		2	98.3% hot 0% cold 0% comfort of total number of occupied hours
	14	98.3% hot 0% cold 16.7% comfort of total number of occupied hours	7		1	98.3% hot 0% cold 1.7% comfort of total number of occupied hours

But when I tried to double operable upper area per floor:



			13			
	19	60% hot 0% cold 40% comfort of total number of occupied hours	12		6	98.3% hot 0% cold 1.7% comfort of total number of occupied hours
	18	0% hot 0% cold 40% comfort of total number of occupied hours	11		5	100% hot 0% cold 1.7% comfort of total number of occupied hours
	17	0% hot 0% cold 40% comfort of total number of occupied hours	10		4	100% hot 0% cold 1.7% comfort of total number of occupied hours
	16	0% hot 0% cold 40% comfort of total number of occupied hours	9		3	100% hot 0% cold 1.7% comfort of total number of occupied hours
	15	0% hot 0% cold 40% comfort of total number of occupied hours	8		2	100% hot 0% cold 1.7% comfort of total number of occupied hours
	14	0% hot 0% cold 41.7% comfort of total number of occupied hours	7		1	100% hot 0% cold 3.3% comfort of total number of occupied hours

The comfort result in 14-19 zones improved a lot, around 40%

IMPROVEMENT STRATEGY: Central Atrium; Jun

In conclusion,

I combined the different strategies which work efficiently: include slab thermal mass and use the window which has two openings separated vertically (and the operable area per floor is doubled)

The final result is showing as following :



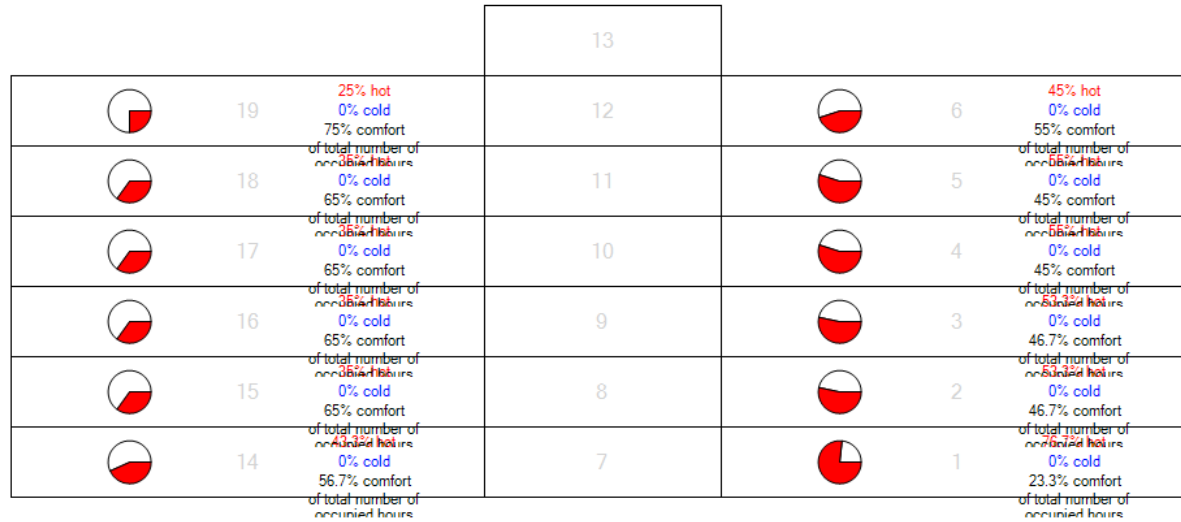
## IMPROVED REPORT: Central Atrium; Jun

## CoolVent Thermal Comfort Results

USA\_PA\_Philadelphia.Intl.AP.724080\_TMY3

2010 ASHRAE Standard 55 Thermal Comfort Model

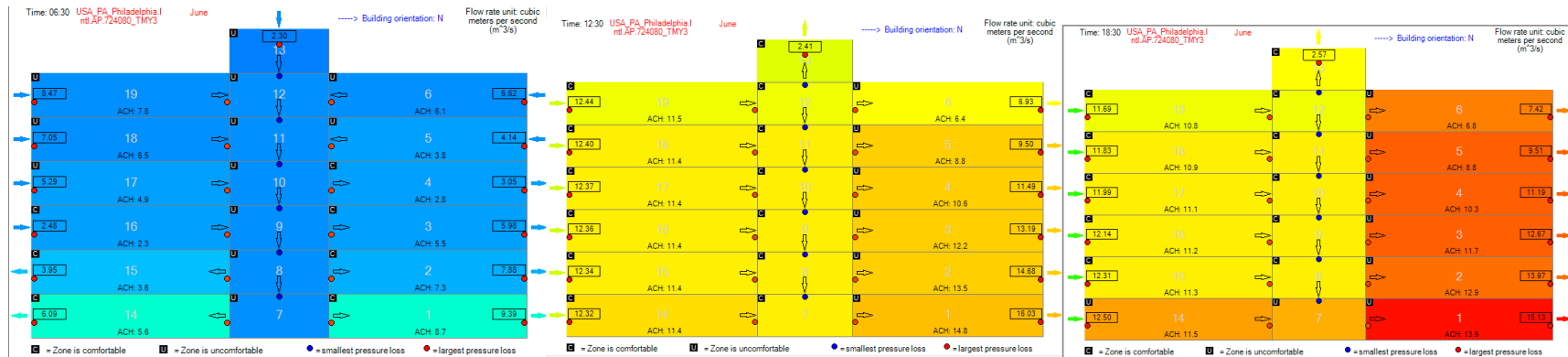
## Temperature Pie Charts



The pie charts represent temperature concerns for comfort in non-atrium zones of the building.

Red represents the percent of total occupied hours that a given zone is too hot.  
Blue represents the percent of total occupied hours that a given zone is too cold.

Humidity concerns are not addressed in the pie charts.



6:30

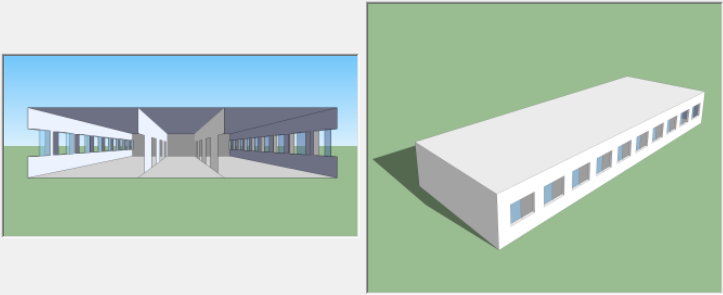
12:30

18:30

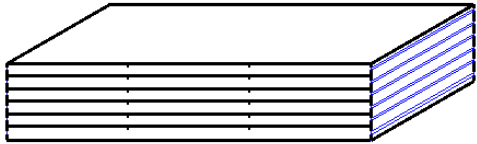
We can find from the new report that the comfort condition improved by 23% to 75%.

However, at 6:30 the comfort condition is poorer than the previous one. But at both 12:30 and 18:30, the comfort condition are improved a lot.

INPUTS: Cross ventilation; Jun

<b>Simulation type</b> <input checked="" type="radio"/> Transient (24 hour) <input type="radio"/> Steady state (snapshot)	
<b>Building type</b> Cross ventilation	
	
<b>Internal heat loads</b> Heat source level: Educational 40 W/m <sup>2</sup> Occupancy schedule: From 9 hours to 24 hours <i>All zones but the atrium zones (if any) are assigned heat loads.</i> Off peak equipment load fraction: 0.2	
<b>Terrain properties</b> Terrain type: Urban, industrial or forest area	

<b>Building dimensions</b>	
Number of sections:	3
Number of floors:	6
Floor length:	33 m
Section width:	33.8 m
Floor-to-floor height:	3.5 m
Floor-to-ceiling height:	3 m



The Second type is cross ventilation. The other inputs are exactly the same as that of the first type(central atrium) which is shown in the page 1 and 2.

### REPORT: Cross Ventilation; Jun

## CoolVent Thermal Comfort Results

USA\_PA\_Philadelphia.Intl.AP.724080\_TMY3

2010 ASHRAE Standard 55 Thermal Comfort Model

### Temperature Pie Charts

	18	100% hot 0% cold 0% comfort of total number of occ		17	100% hot 0% cold 0% comfort of total number of occ		16	100% hot 0% cold 0% comfort of total number of occ
	15	100% hot 0% cold 0% comfort of total number of occ		14	100% hot 0% cold 0% comfort of total number of occ		13	100% hot 0% cold 0% comfort of total number of occ
	12	100% hot 0% cold 0% comfort of total number of occ		11	100% hot 0% cold 0% comfort of total number of occ		10	100% hot 0% cold 0% comfort of total number of occ
	9	100% hot 0% cold 0% comfort of total number of occ		8	100% hot 0% cold 0% comfort of total number of occ		7	100% hot 0% cold 0% comfort of total number of occ
	6	100% hot 0% cold 0% comfort of total number of occ		5	100% hot 0% cold 0% comfort of total number of occ		4	100% hot 0% cold 1.7% comfort of total number of occ
	3	100% hot 0% cold 0% comfort of total number of occ		2	100% hot 0% cold 0% comfort of total number of occ		1	100% hot 0% cold 1.7% comfort of total number of occ

The pie charts represent temperature concerns for comfort in non-atrium zones of the building.

Red represents the percent of total occupied hours that a given zone is too hot.  
Blue represents the percent of total occupied hours that a given zone is too cold.

Humidity concerns are not addressed in the pie charts.

The comfort condition is too hot

## IMPROVEMENT TESTS: Cross Ventilation; Jun

- The first strategy to improve the comfort condition is **to include slab thermal mass**

Thermal mass

☒ Include slab thermal mass

Floor / roof slab thickness  cm



















Floor slab material

Floor type

Exposed area  % of floor area

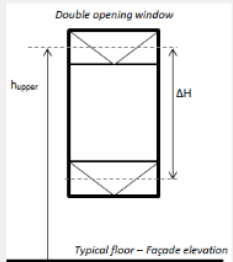
Ceiling type

However the result does not change at all.

	18	100% hot 0% cold 0% comfort of total number of occ		17	100% hot 0% cold 0% comfort of total number of occ		16	100% hot 0% cold 0% comfort of total number of occ
	15	100% hot 0% cold 0% comfort of total number of occ		14	100% hot 0% cold 0% comfort of total number of occ		13	100% hot 0% cold 0% comfort of total number of occ
	12	100% hot 0% cold 0% comfort of total number of occ		11	100% hot 0% cold 0% comfort of total number of occ		10	100% hot 0% cold 0% comfort of total number of occ
	9	100% hot 0% cold 0% comfort of total number of occ		8	100% hot 0% cold 0% comfort of total number of occ		7	100% hot 0% cold 0% comfort of total number of occ
	6	100% hot 0% cold 0% comfort of total number of occ		5	100% hot 0% cold 0% comfort of total number of occ		4	100% hot 0% cold 0% comfort of total number of occ
	3	100% hot 0% cold 0% comfort of total number of occ		2	100% hot 0% cold 0% comfort of total number of occ		1	100% hot 0% cold 0% comfort of total number of occ

- The second strategy is to change the side windows type from only one opening per window to two openings

Side windows dimensions



☐ In each floor, there is only one opening per window (see schematic)  
☒ In each floor, there are two openings separated vertically per window (see schematic). REQUIRED for single-sided ventilation

Window glazing area per floor per facade, fixed and operable (to calculate solar gains through windows):  m<sup>2</sup>

Operable upper window area per floor (used to calculate air flowrate):  m<sup>2</sup>

Height from floor to upper opening (hupper):  m



















Operable lower window area per floor per facade:  m<sup>2</sup>

Height difference between upper and lower opening (Delta H in figure):  m

And then the comfort result improved around 2%-8%

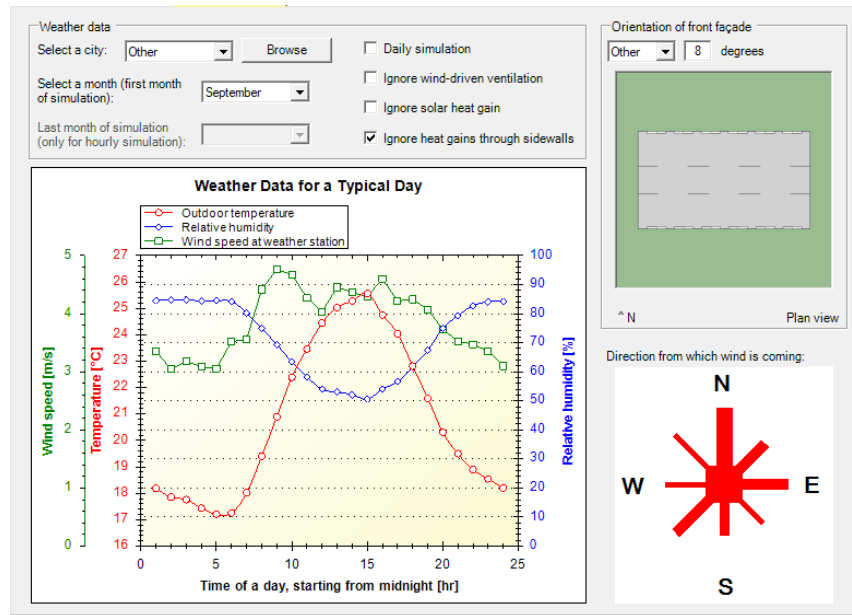
	18	100% hot 0% cold 0% comfort of total number of occ 100% hot		17	100% hot 0% cold 0% comfort of total number of occ 100% hot		16	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot
	15	0% cold 0% comfort of total number of occ 100% hot		14	0% cold 0% comfort of total number of occ 100% hot		13	0% cold 1.7% comfort of total number of occ 98.3% hot
	12	0% cold 0% comfort of total number of occ 100% hot		11	0% cold 0% comfort of total number of occ 100% hot		10	0% cold 1.7% comfort of total number of occ 98.3% hot
	9	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot		8	100% hot 0% cold 0% comfort of total number of occ 100% hot		7	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot
	6	95% hot 0% cold 5% comfort of total number of occ 91.7% hot		5	100% hot 0% cold 0% comfort of total number of occ 100% hot		4	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot
	3	91.7% hot 0% cold 8.3% comfort of total number of occ		2	100% hot 0% cold 0% comfort of total number of occ		1	98.3% hot 0% cold 1.7% comfort of total number of occ

Then I tried to double operable upper area per floor:

	18	83.3% hot 0% cold 16.7% comfort number of occ of total		17	98.3% hot 0% cold 1.7% comfort number of occ of total		16	98.3% hot 0% cold 1.7% comfort number of occ of total
	15	83.3% hot 0% cold 16.7% comfort number of occ of total		14	98.3% hot 0% cold 1.7% comfort number of occ of total		13	98.3% hot 0% cold 1.7% comfort number of occ of total
	12	83.3% hot 0% cold 16.7% comfort number of occ of total		11	98.3% hot 0% cold 1.7% comfort number of occ of total		10	98.3% hot 0% cold 1.7% comfort number of occ of total
	9	83.3% hot 0% cold 16.7% comfort number of occ of total		8	98.3% hot 0% cold 1.7% comfort number of occ of total		7	98.3% hot 0% cold 1.7% comfort number of occ of total
	6	83.3% hot 0% cold 16.7% comfort number of occ of total		5	98.3% hot 0% cold 1.7% comfort number of occ of total		4	98.3% hot 0% cold 1.7% comfort number of occ of total
	3	83.3% hot 0% cold 16.7% comfort number of occ of total		2	98.3% hot 0% cold 1.7% comfort number of occ of total		1	98.3% hot 0% cold 1.7% comfort number of occ of total

The comfort result improved around 20%-40%, however, the change only happened in one side of the building.

INPUTS: Cross ventilation; Sep





















Then I tried the condition in September instead of June. The type is still cross ventilation and the other inputs are exactly the same as the inputs in page 1 and 2.

Then the comfort result is shown as following:



## REPORT: Cross Ventilation; Sep

	18	98.3% hot 0% cold 1.7% comfort of total number of occ		17	98.3% hot 0% cold 1.7% comfort of total number of occ		16	98.3% hot 0% cold 1.7% comfort of total number of occ
	15	98.3% hot 0% cold 1.7% comfort of total number of occ		14	98.3% hot 0% cold 1.7% comfort of total number of occ		13	98.3% hot 0% cold 1.7% comfort of total number of occ
	12	98.3% hot 0% cold 1.7% comfort of total number of occ		11	98.3% hot 0% cold 1.7% comfort of total number of occ		10	98.3% hot 0% cold 1.7% comfort of total number of occ
	9	98.3% hot 0% cold 1.7% comfort of total number of occ		8	98.3% hot 0% cold 1.7% comfort of total number of occ		7	98.3% hot 0% cold 3.3% comfort of total number of occ
	6	98.3% hot 0% cold 1.7% comfort of total number of occ		5	98.3% hot 0% cold 1.7% comfort of total number of occ		4	90% hot 0% cold 10% comfort of total number of occ
	3	98.3% hot 0% cold 1.7% comfort of total number of occ		2	98.3% hot 0% cold 1.7% comfort of total number of occ		1	86.7% hot 0% cold 13.3% comfort of total number of occ

Compared with the result in June, the comfort result is a little bit better in zone 4 and 1 but it is still too hot in the other zones.

## IMPROVEMENT TESTS: Cross Ventilation; Sep

- The first strategy to improve the comfort condition is **to include slab thermal mass**

Thermal mass

☒ Include slab thermal mass

Floor / roof slab thickness  cm



















Exposed area  % of floor area

Floor slab material

Floor type

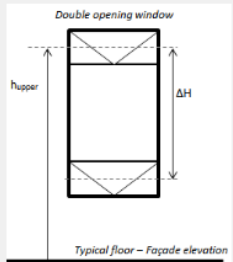
Ceiling type

The result improved by around 5%-10%

	18	100% hot 0% cold 0% comfort of total number of occ 100% hot		17	100% hot 0% cold 0% comfort of total number of occ 100% hot		16	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot
	15	0% cold 0% comfort of total number of occ 100% hot		14	0% cold 0% comfort of total number of occ 100% hot		13	0% cold 6.7% comfort of total number of occ 93.3% hot
	12	0% cold 0% comfort of total number of occ 100% hot		11	0% cold 0% comfort of total number of occ 100% hot		10	0% cold 11.7% comfort of total number of occ 88.3% hot
	9	0% cold 0% comfort of total number of occ 100% hot		8	0% cold 0% comfort of total number of occ 100% hot		7	0% cold 13.3% comfort of total number of occ 86.7% hot
	6	0% cold 0% comfort of total number of occ 100% hot		5	0% cold 0% comfort of total number of occ 100% hot		4	0% cold 15% comfort of total number of occ 85% hot
	3	0% cold 0% comfort of total number of occ 100% hot		2	0% cold 0% comfort of total number of occ 100% hot		1	0% cold 10% comfort of total number of occ 90% hot

- The second strategy is to change the side windows type from only one opening per window to two openings

Side windows dimensions



Double opening window

hupper

ΔH

Typical floor - Façade elevation

☐ In each floor, there is only one opening per window (see schematic)

☒ In each floor, there are two openings separated vertically per window (see schematic). REQUIRED for single-sided ventilation

Window glazing area per floor per facade, fixed and operable (to calculate solar gains through windows):  m<sup>2</sup>

Operable upper window area per floor (used to calculate air flowrate):  m<sup>2</sup>

Height from floor to upper opening (hupper):  m

Operable lower window area per floor per facade:  m<sup>2</sup>

Height difference between upper and lower opening (Delta H in figure):  m

The result improved by around 3%-15% in both sides of the building.

	18	98.3% hot 0% cold 1.7% comfort of total number of occ 96.7% hot		17	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot		16	85% hot 0% cold 15% comfort of total number of occ 81.7% hot
	15	98.3% hot 0% cold 1.7% comfort of total number of occ 90% hot		14	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot		13	85% hot 0% cold 15% comfort of total number of occ 76.7% hot
	12	98.3% hot 0% cold 1.7% comfort of total number of occ 86.7% hot		11	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot		10	85% hot 0% cold 15% comfort of total number of occ 71.7% hot
	9	98.3% hot 0% cold 1.7% comfort of total number of occ 85% hot		8	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot		7	85% hot 0% cold 15% comfort of total number of occ 70% hot
	6	98.3% hot 0% cold 1.7% comfort of total number of occ 85% hot		5	98.3% hot 0% cold 1.7% comfort of total number of occ 98.3% hot		4	85% hot 0% cold 15% comfort of total number of occ 70% hot
	3	98.3% hot 0% cold 1.7% comfort of total number of occ		2	98.3% hot 0% cold 1.7% comfort of total number of occ		1	85% hot 0% cold 15% comfort of total number of occ

### IMPROVEMENT STRATEGY: Cross Ventilation; Sep

I used the same strategies as before which work efficiently: include slab thermal mass and use the window which has two openings separated vertically (and the operable area per floor is doubled)

The final result is showing as following :

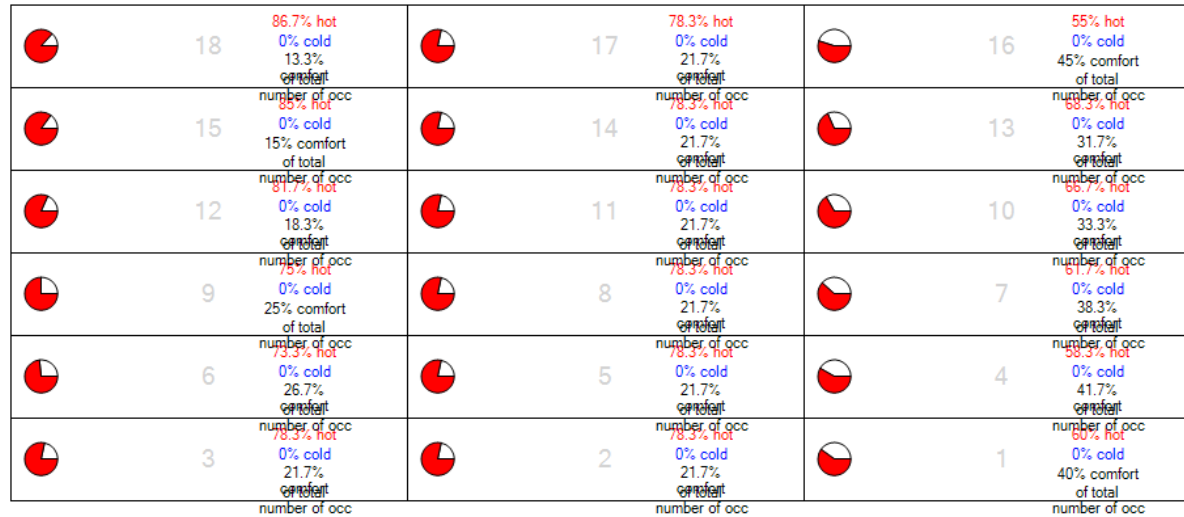
## IMPROVED REPORT: Cross Ventilation; Sep

## CoolVent Thermal Comfort Results

USA\_PA\_Philadelphia.Intl.AP.724080\_TMY3

2010 ASHRAE Standard 55 Thermal Comfort Model

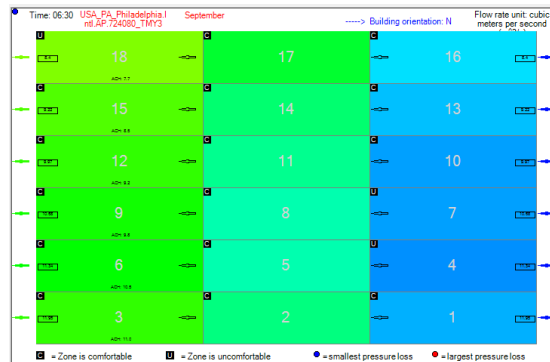
## Temperature Pie Charts



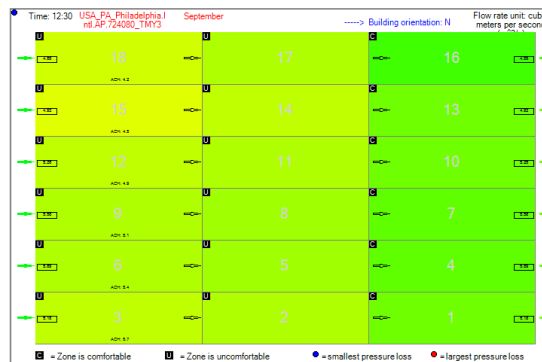
The pie charts represent temperature concerns for comfort in non-atrium zones of the building.

Red represents the percent of total occupied hours that a given zone is too hot.  
Blue represents the percent of total occupied hours that a given zone is too cold.

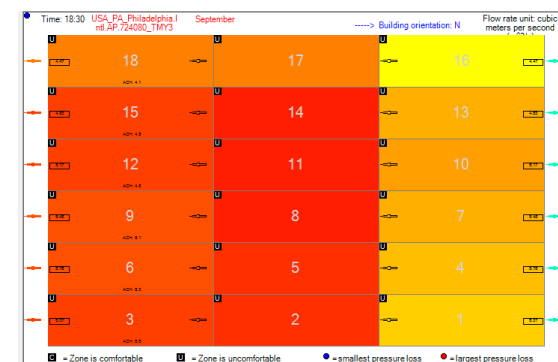
Humidity concerns are not addressed in the pie charts.



6:30



12:30



18:30

Although the comfort result has improved due to the ventilation strategies, it is still uncomfortable at 18:30 in the whole building.