BUILDING ENERGY 15
MARCH 3-5, 2015 AT THE SEAPORT WORLD TRADE CENTER

AIA Provider: Northeast Sustainable Energy Association

Provider Number: G338

# Solar Air Heating 2.0

Course Number BE1538


## Mick Dunn


Wednesday March 4th, 2014

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Solar Air Heating – Solar Hot Water

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Sustainability Podcast
iTunes & www.sustainacast.com

# Course Description

This course is an introduction to the use of Solar Air Heating as a renewable energy solution in commercial, industrial and residential applications.

The course covers a description of the most common forms of solar air heating designs and technology, with a focus on performance data to provide participants with an understanding of the impacts of various design considerations.

# Learning Objectives

At the end of the this course, participants will be able to:

1. **Technologies:** Understand the differences in solar air heating technologies that are currently the most widely used.

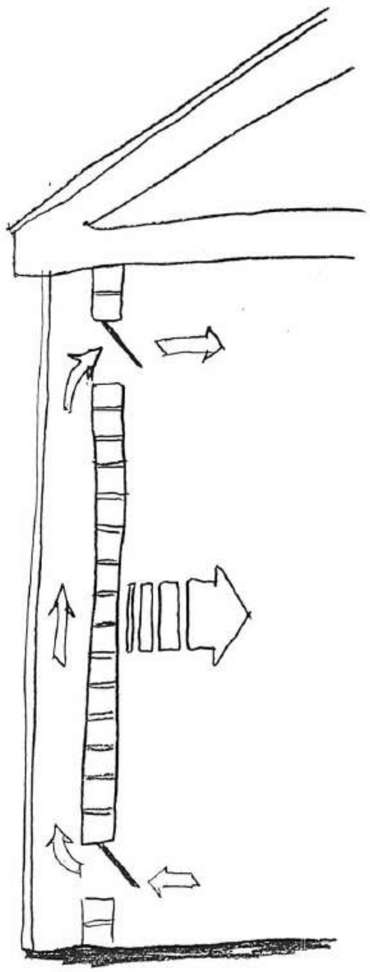
2. **Design Principals:** Identify the key design and operating principals of various design techniques, and where to use specific designs.

3. **Costs:** Understand cost of material and install for most common systems/technologies

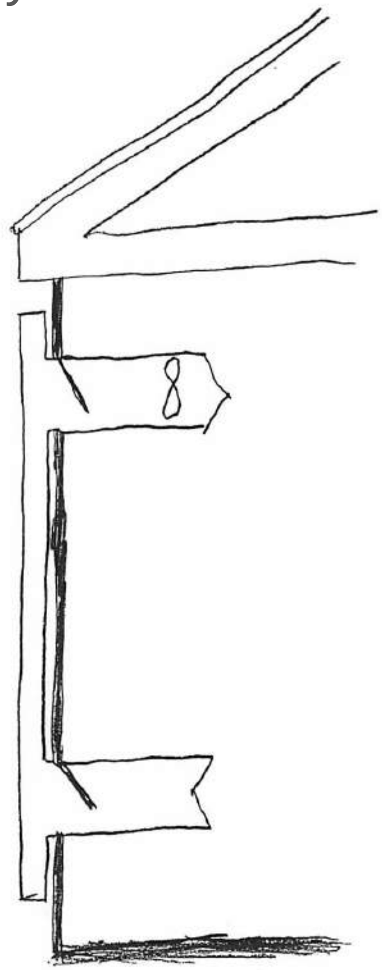
4. **Performance:** Assess basic performance data to understand the relationship of impacts on temperature, air flow, system size and energy savings.

# Solar Air Heating

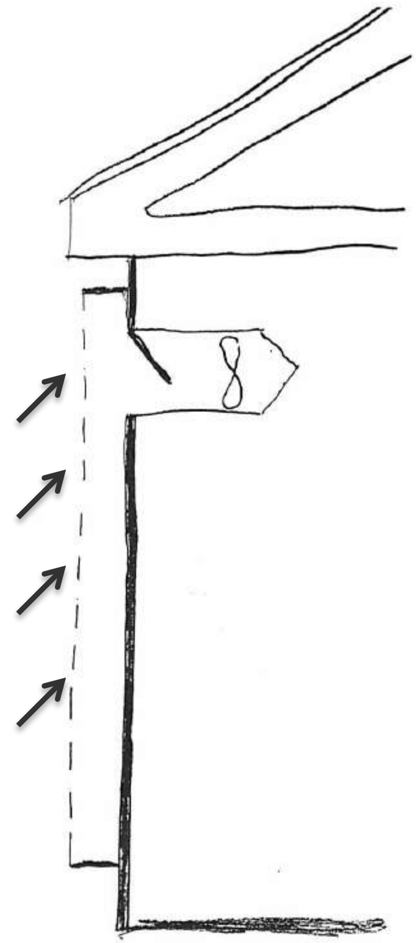
## Common Solar Air Heating Systems



Trombe

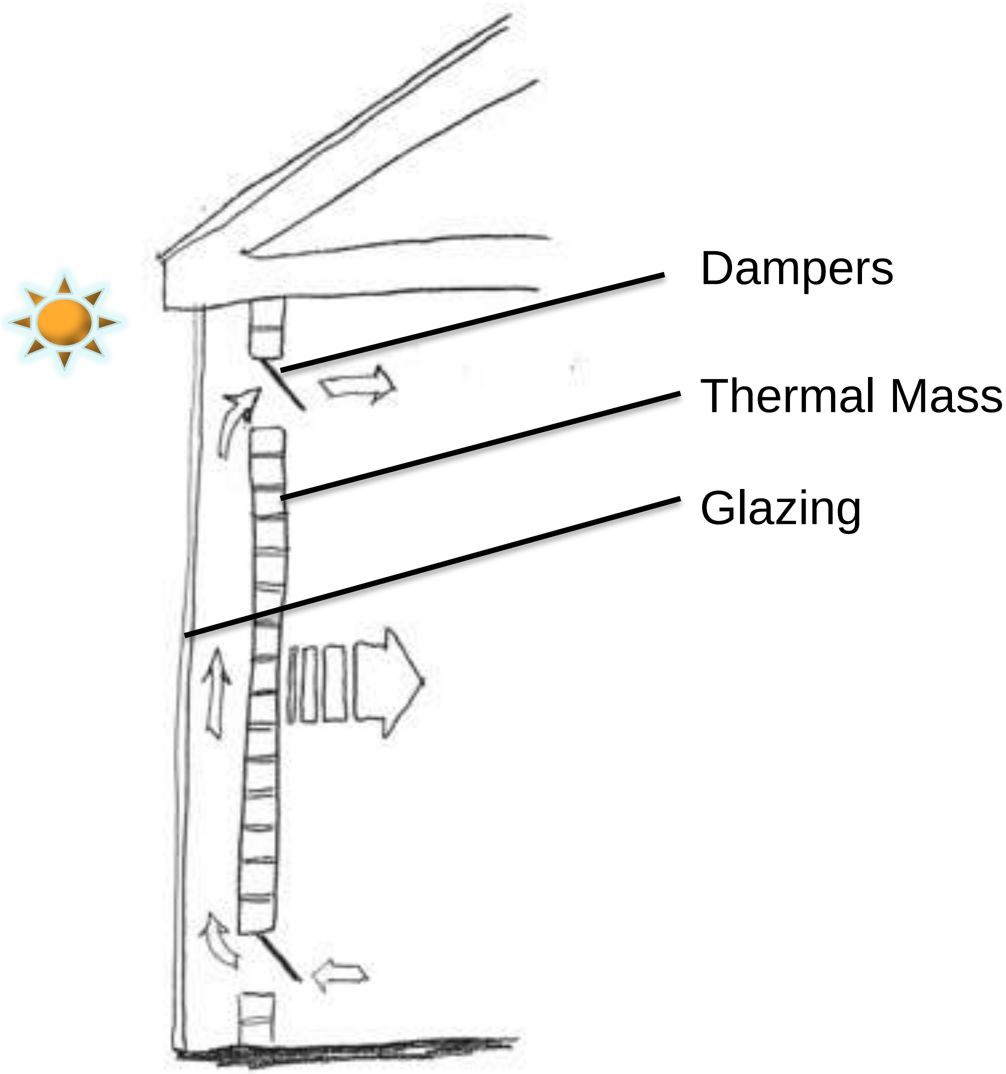


Recirculating

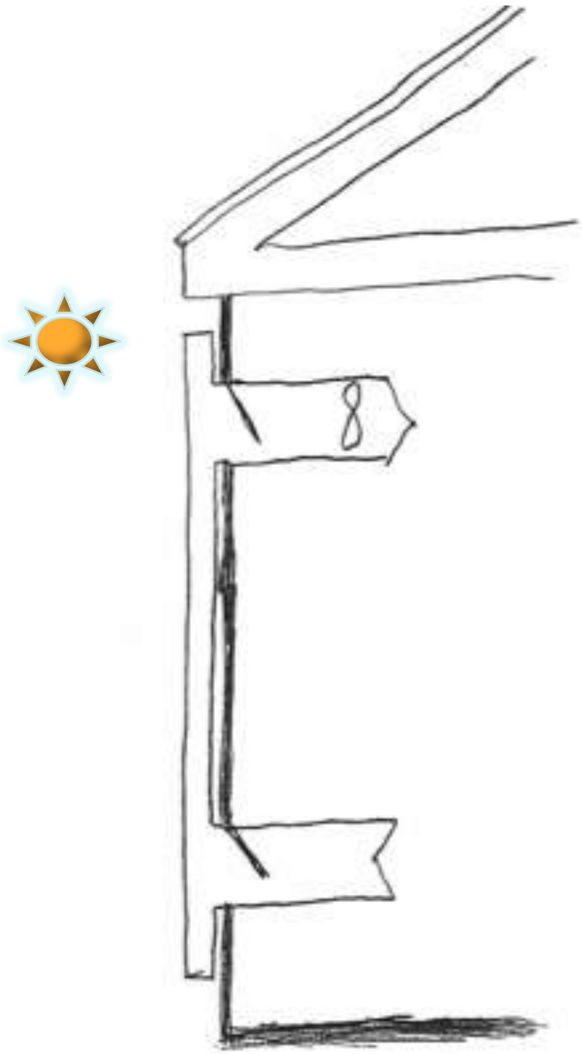


Transpired

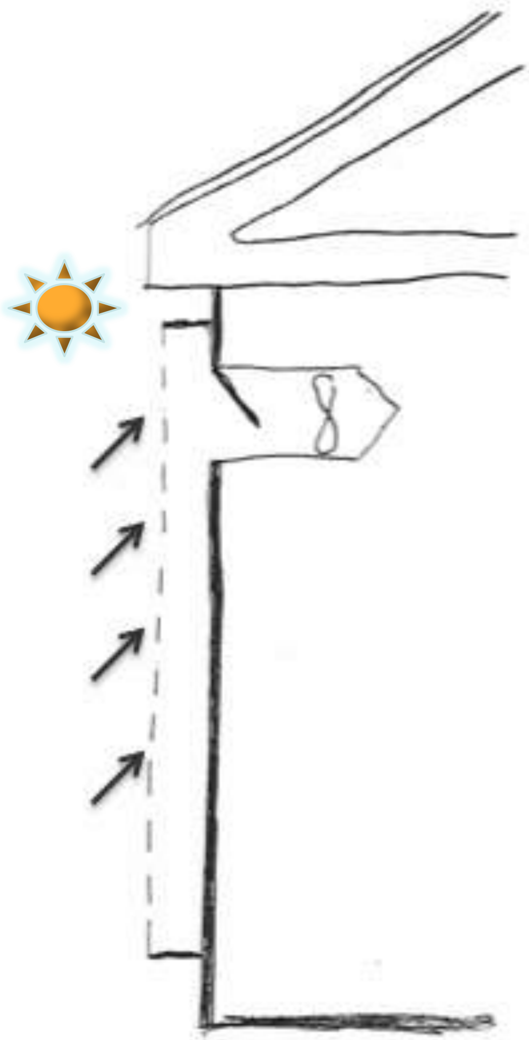
# Trombe Wall




# Recirculating Collector



# Transpired Collector



# Transpired Metal – Bentley University, Waltham MA

18 Ga. Galv Framing

# Transpired Metal – Bentley University, Waltham MA

# Transpired Metal – Bentley University, Waltham MA

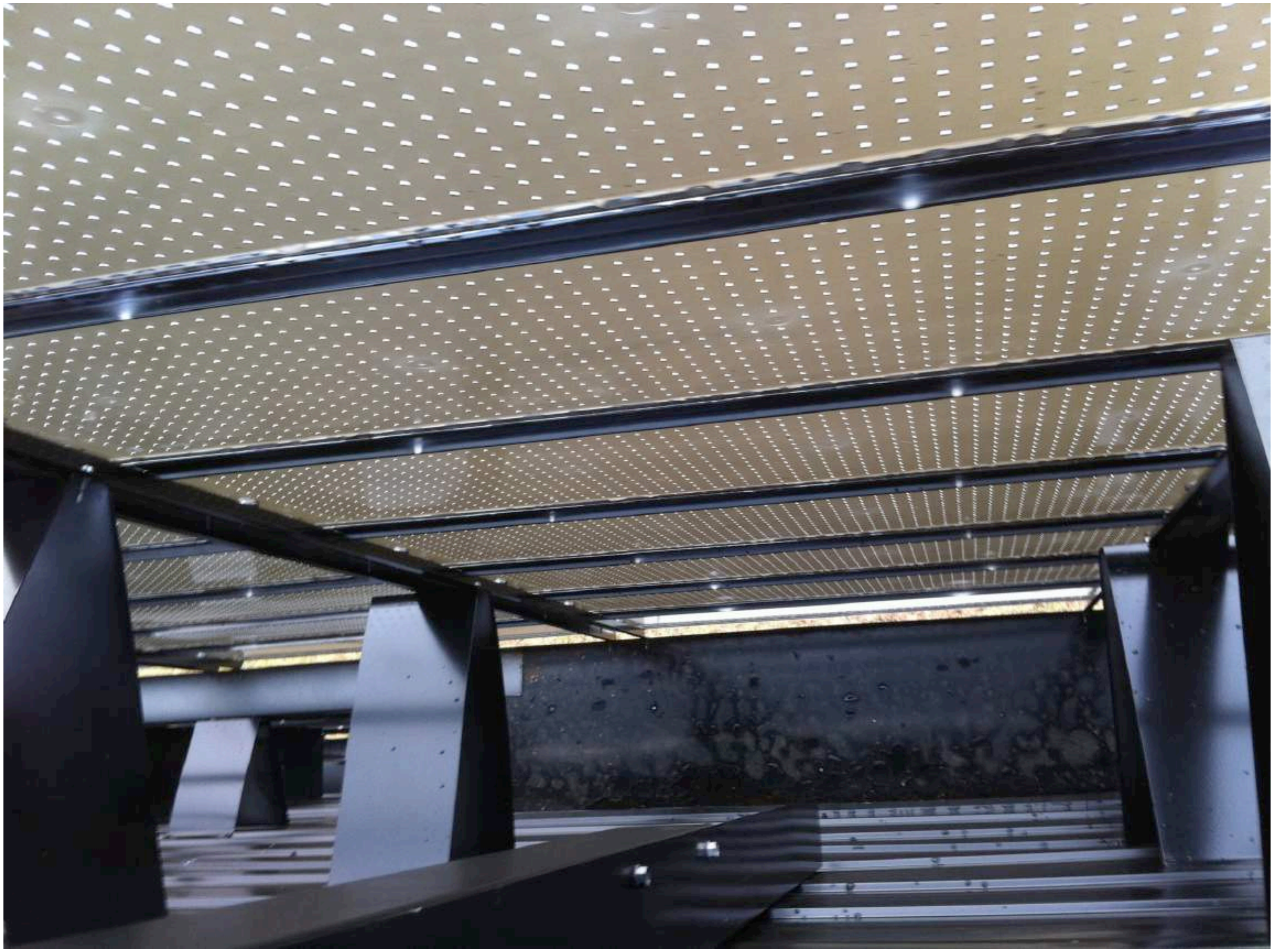
Solar Intake for RTU

# Transpired Metal – Various Projects

# Transpired/Perforated Glazing

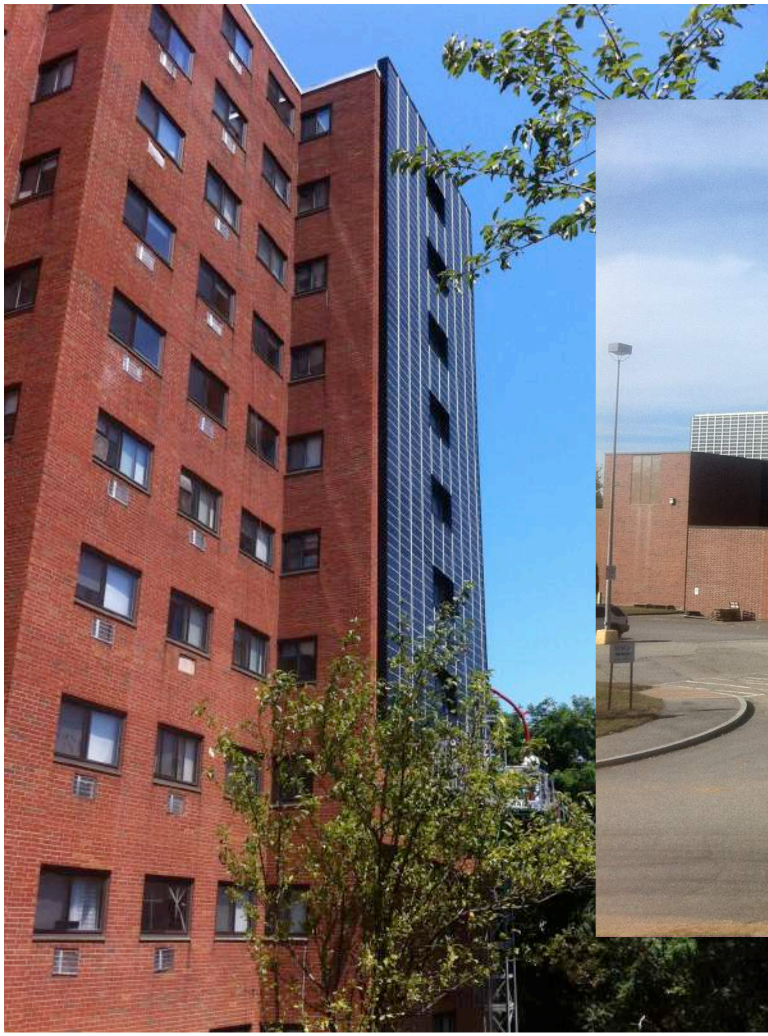
# Transpired/Perforated Glazing

# Transpired/Perforated Glazing



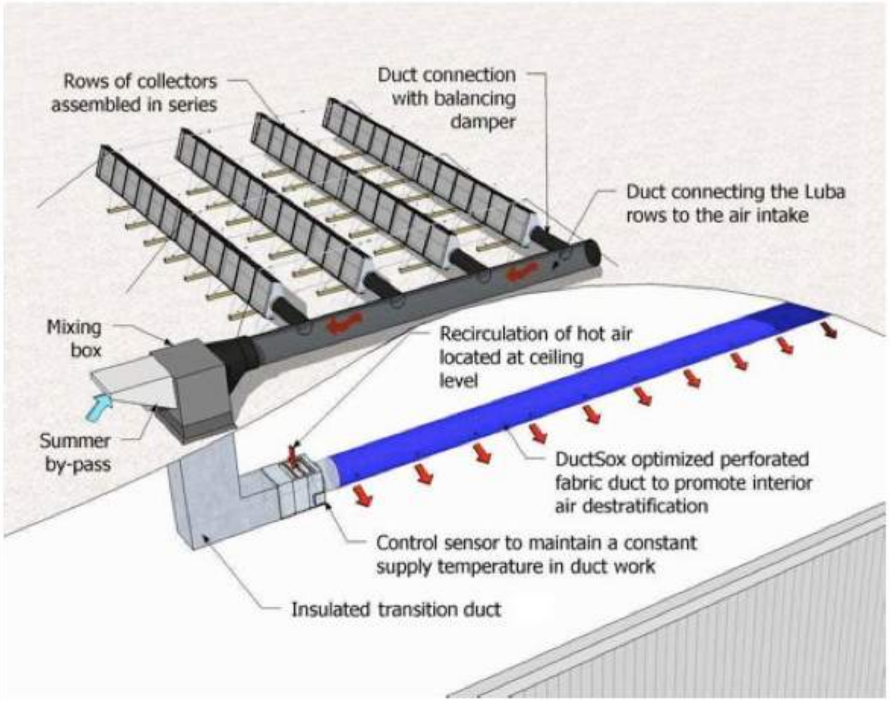
# Transpired/Perforated Glazing – Various Projects

# Transpired/Perforated Glazing – Various Projects

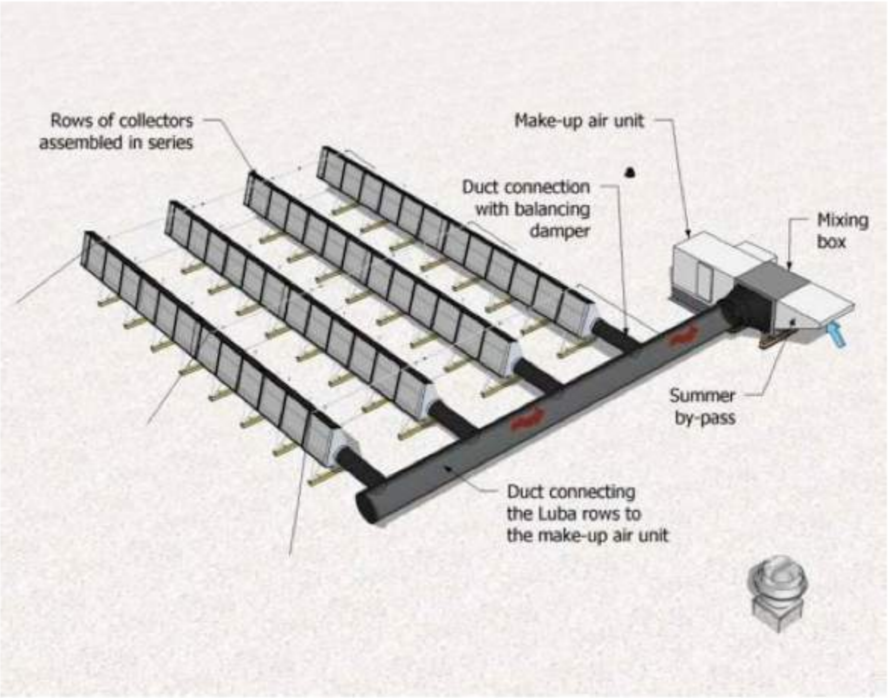


# Transpired/Perforated Roof Top Units

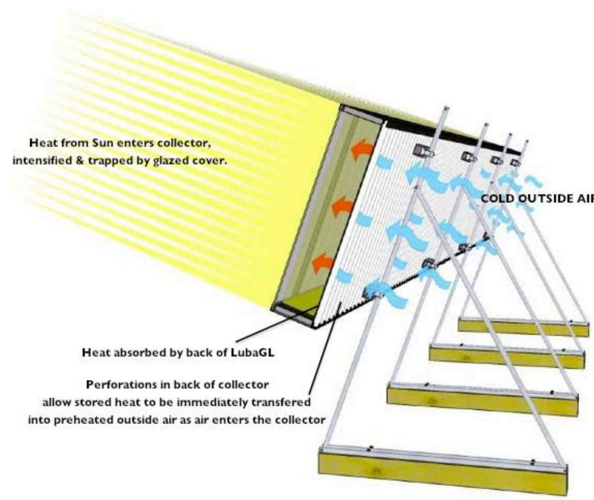
Direct supply by ventilation



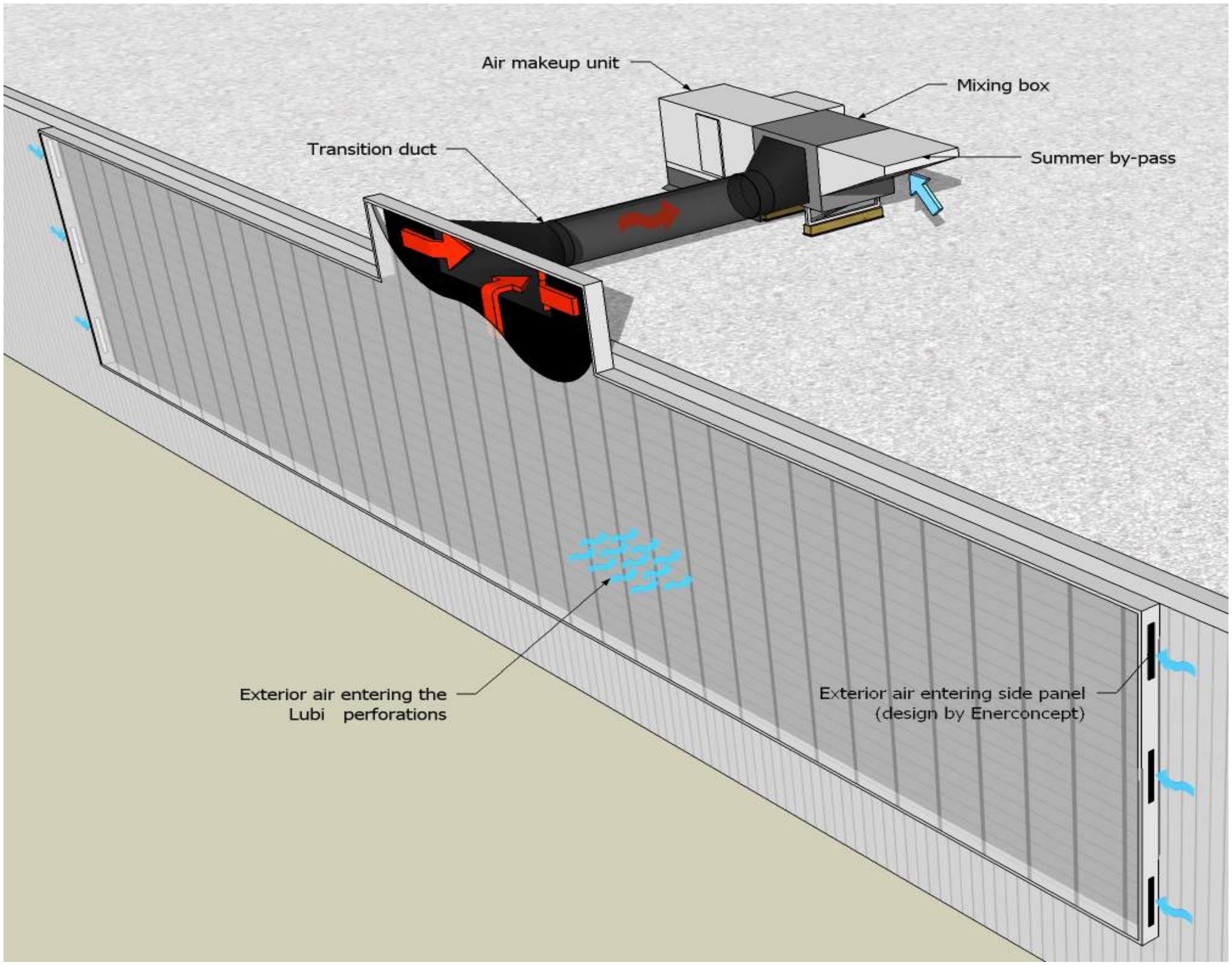

Tied to make-up air unit



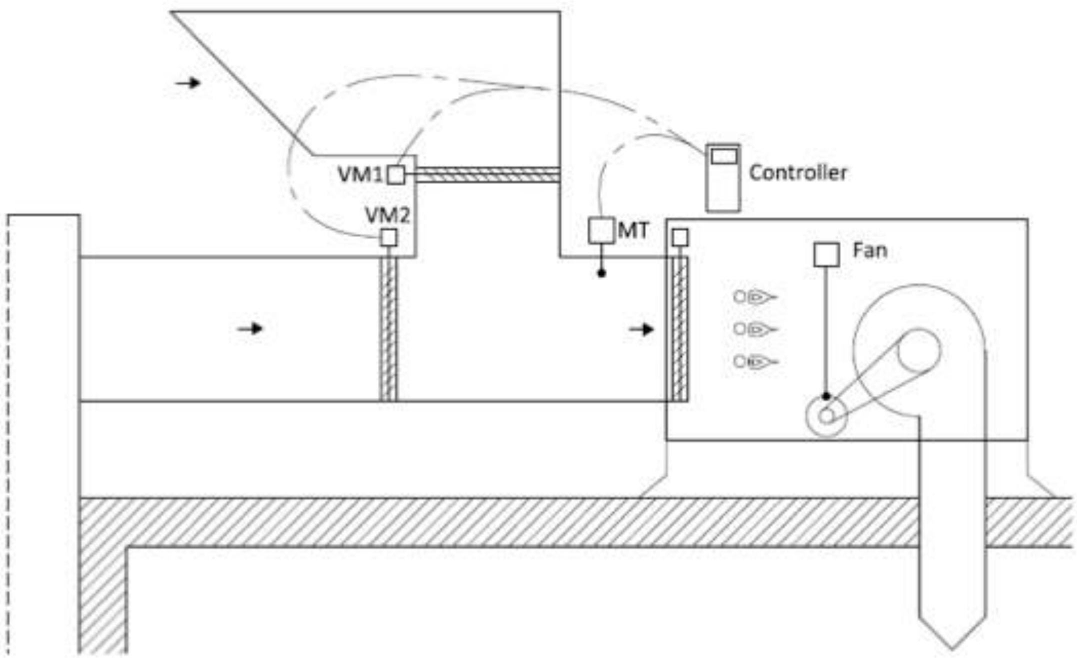
# Transpired/Perforated Roof Top Units




# System Designs



# System Designs

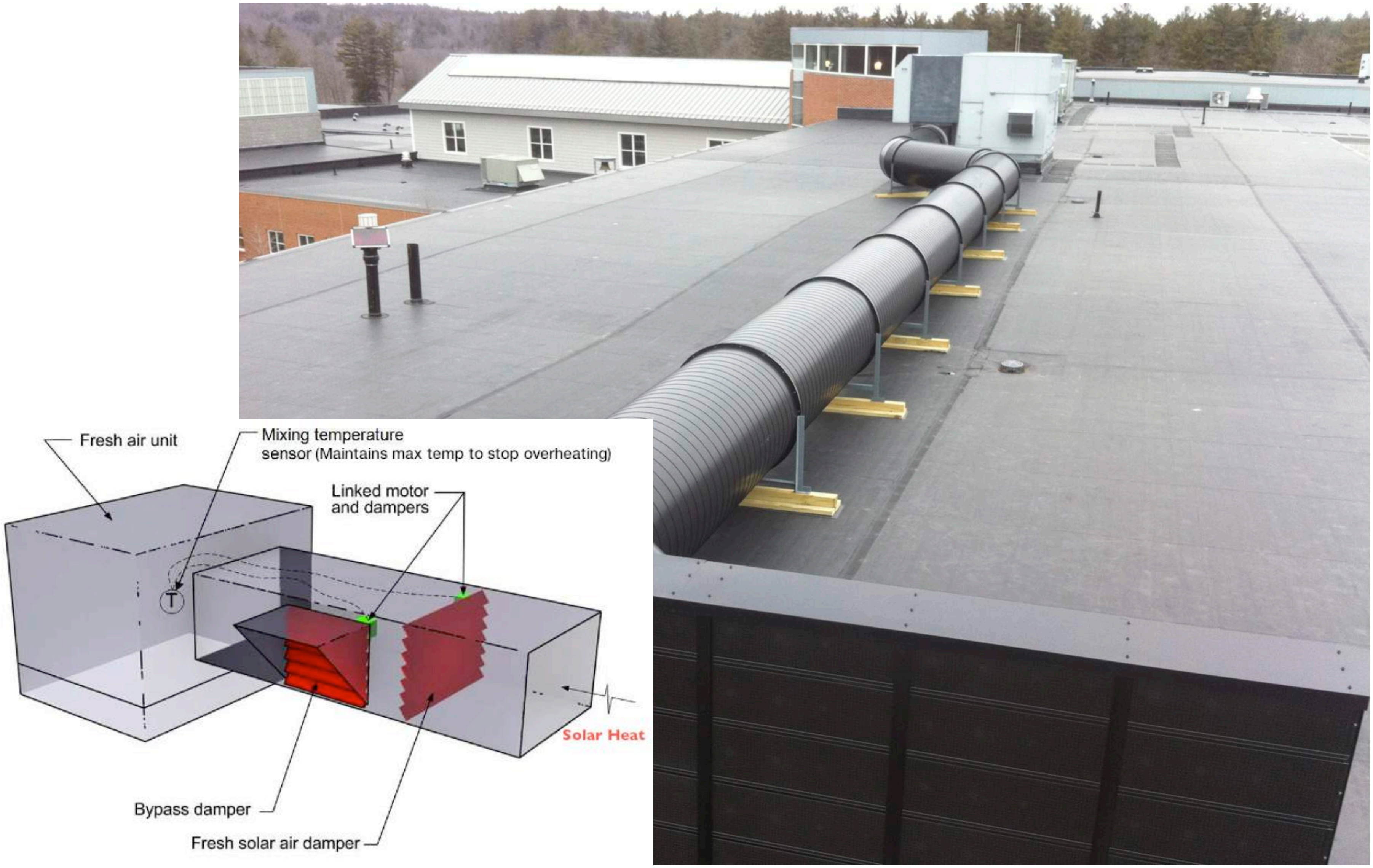



<u>Operation Sequence</u>

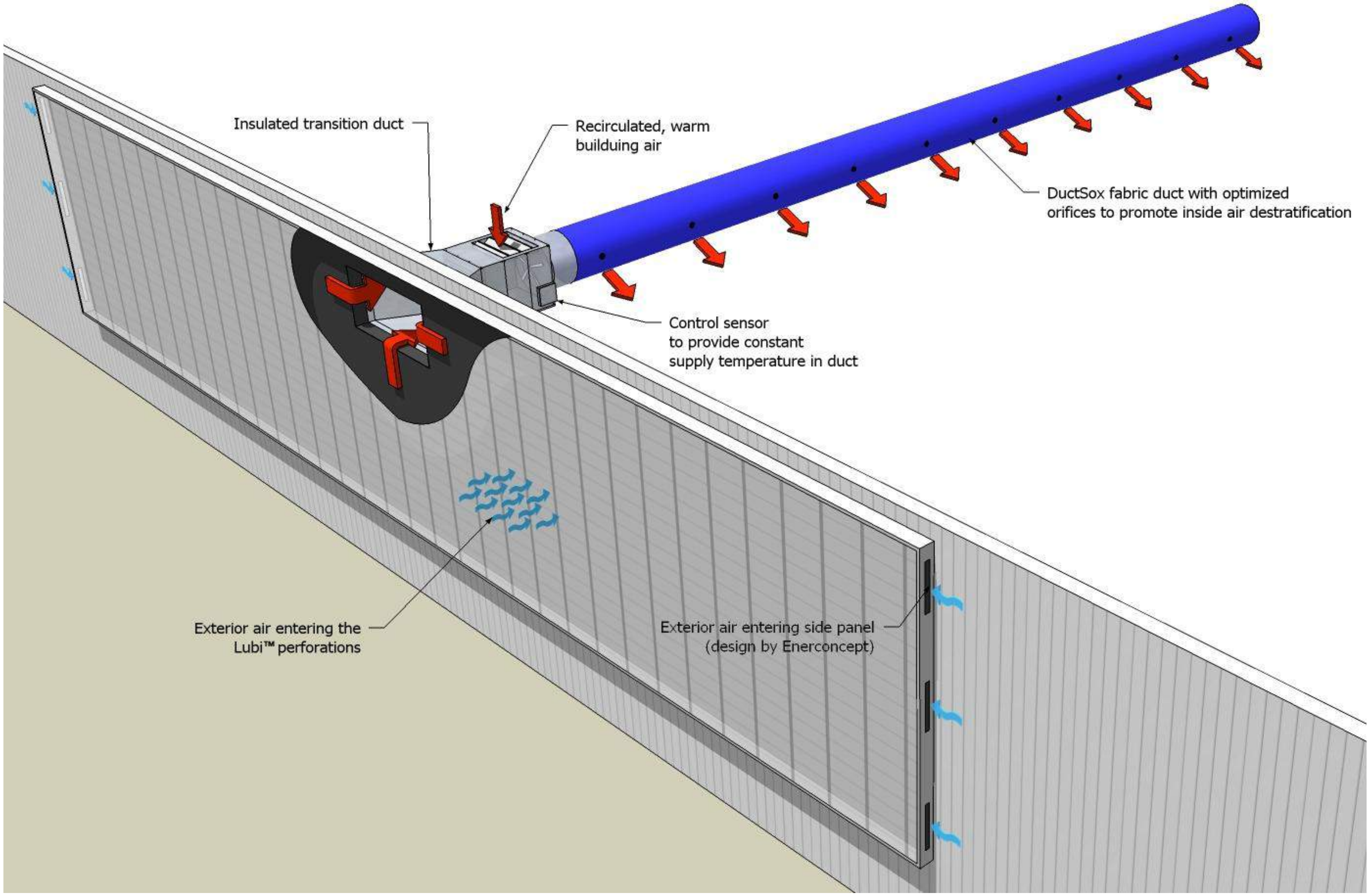
<u>System turned off:</u>
The fan is stopped, the damper VM1 is closed VM2 is open.

<u>System in function:</u>
The fan is working, the damper VM2 is fully open and VM1 is closed. When mixing temperature is beyond ___°C the dampers VM1 and VM2 modulate to maintain MT set point (___°C).

# Controls/Bypass



# System Designs



# System Designs

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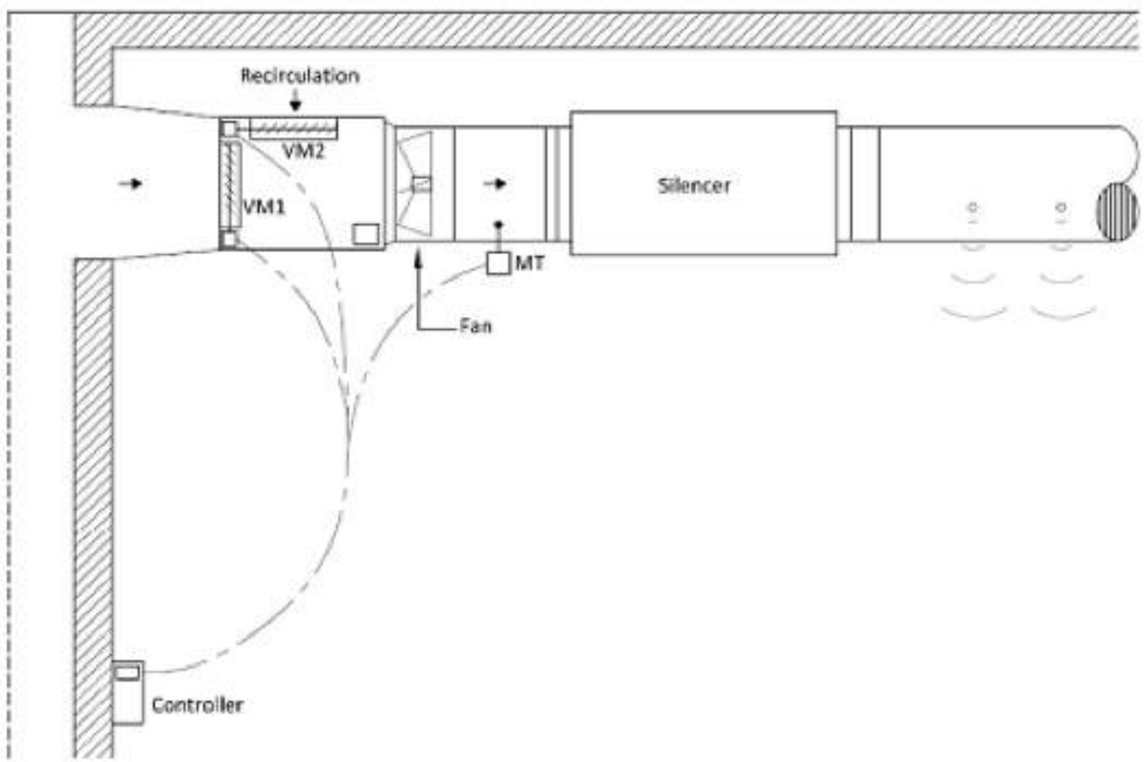
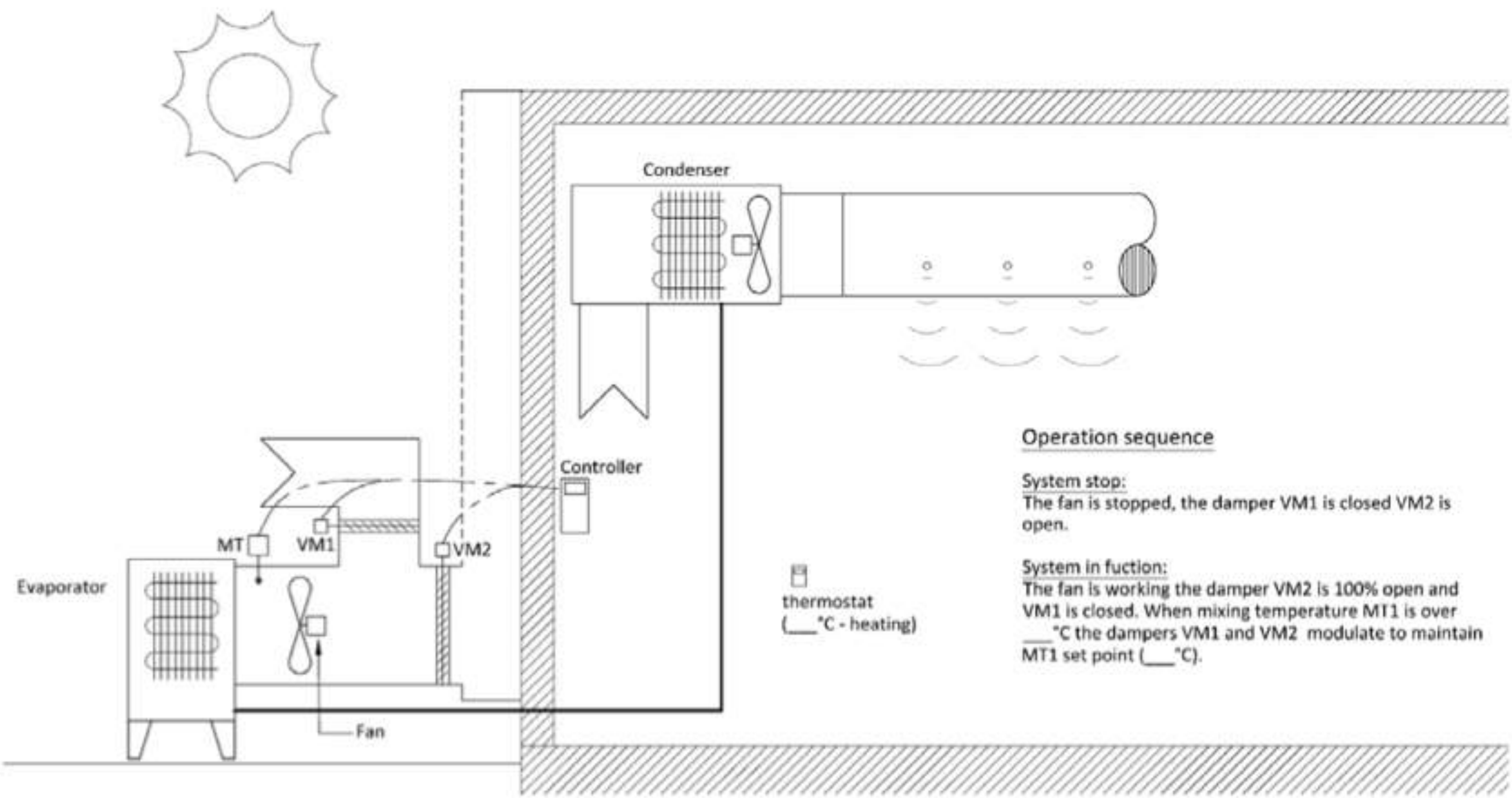



Applications :

The system is running from September to May, in summer the air is drawn into the building in a different way. Example: garage doors open during the summer.

# System Designs

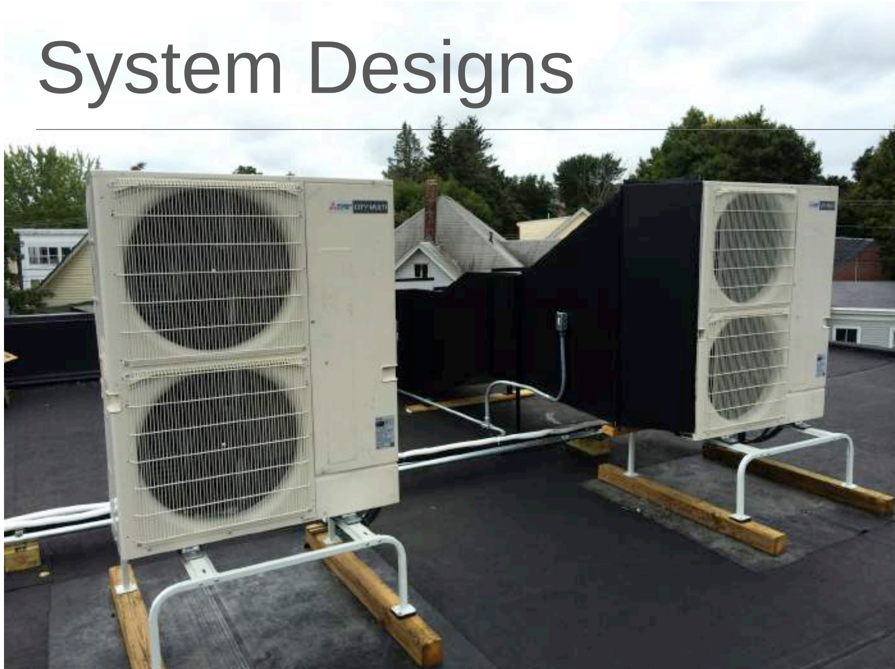
# System Designs




**Applications:**

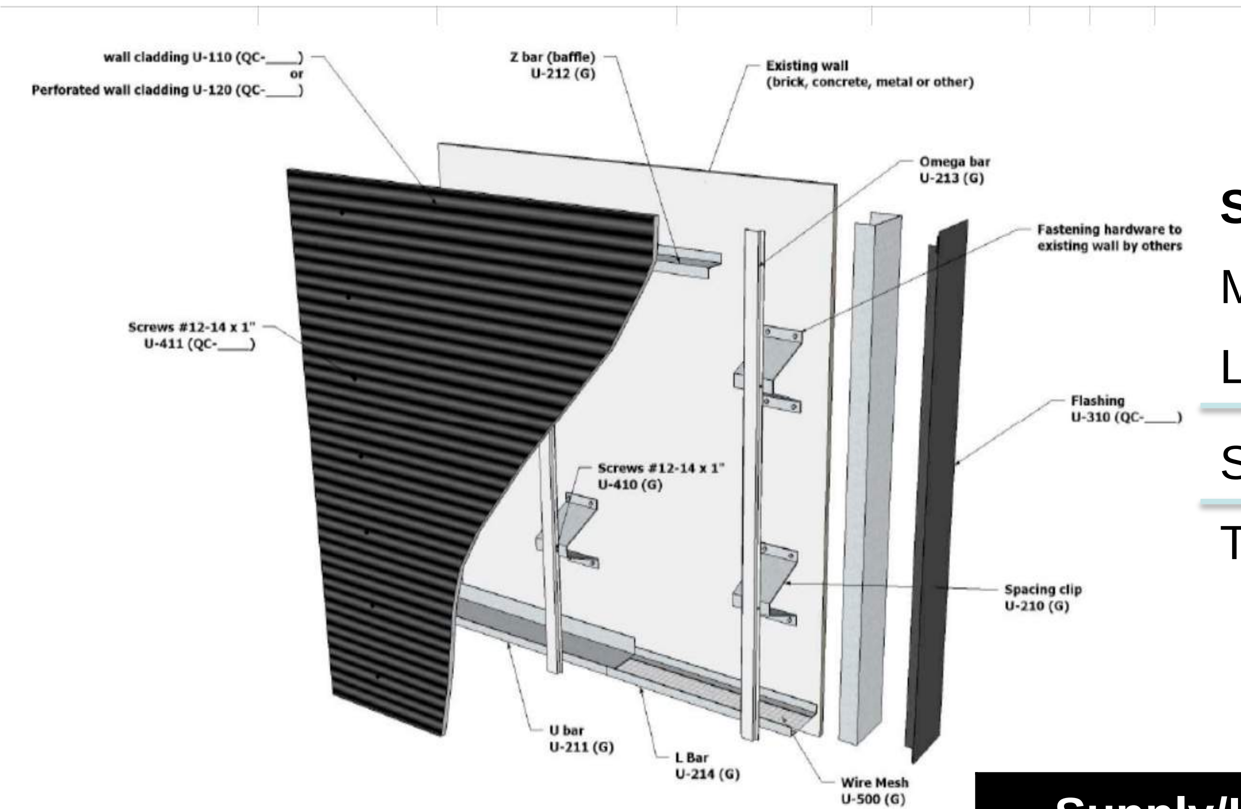
Increases Coefficient of Performance (COP) of air-sourced heat pump during cold, sunny days.

# System Designs



# Cost

## Transpired Metal




**Supply & Install Costs**

Material - $10 to $15/sf

Labor - $5 to $10/sf

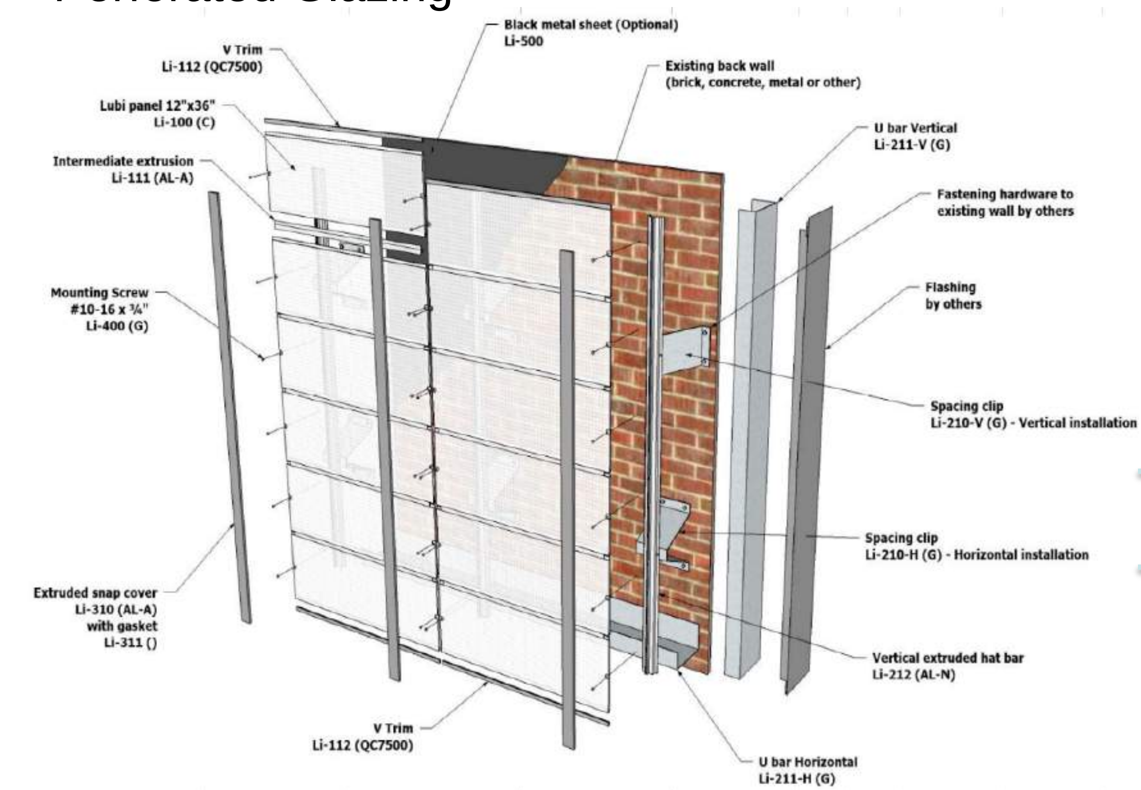
Sub-Total - $15 to $25/sf

Turnkey Add - $10 to $20/sf

| | |
|---|---|
| **Supply/Install Only:** | **$15 - $25/sf** |
| **Turnkey:** | **$30 - $40/sf** |

# Cost

## Perforated Glazing




**Supply & Install Costs**

Material - $20 to $30/sf

Labor - $5 to $10/sf

Sub-Total - $25 to $40/sf

Turnkey Add - $10 to $20/sf

| | |
|---|---|
| **Supply/Install Only:** | **$15 - $25/sf** |
| **Turnkey:** | **$35 - $45/sf** |

# Cost

Recirculated Glazed System

**Supply & Install Costs**

Material - $10 to $15/sf

Labor - $5 to $10/sf

Sub-Total - $15 to $25/sf

Turnkey Add - $10 to $15/sf

| | |
|---|---|
| **Supply/Install Only:** | **$15 - $25/sf** |
| **Turnkey:** | **$25 - $40/sf** |

# Modeling - RETScreen

## Project information

*See project database*

| | |
|---|---|
| Project name | |
| Project location | Bangor, ME |
| Prepared for | |
| Prepared by | |
| Project type | Heating |
| Technology | Solar air heater |
| Analysis type | Method 1 |
| Heating value reference | Higher heating value (HHV) |
| Show settings | ☑ |
| Language - Langue | English - Anglais |
| User manual | English - Anglais |
| Currency | $ |
| Units | Imperial units |

## Site reference conditions

*Select climate data location*

| | |
|---|---|
| Climate data location | Bangor International Ap |
| Show data | ☑ |

| | Unit | Climate data location | Project location |
|---|---|---|---|
| Latitude | ˚N | 44.8 | 44.8 |
| Longitude | ˚E | -68.8 | -68.8 |
| Elevation | ft | 194 | 194 |
| Heating design temperature | °F | -2.2 | |
| Cooling design temperature | °F | 84.2 | |
| Earth temperature amplitude | °F | 37.7 | |

| Month | | Air temperature | Relative humidity | Daily solar radiation - horizontal | Atmospheric pressure | Wind speed | Earth temperature | Heating degree-days | Cooling degree-days |
|---|---|---|---|---|---|---|---|---|---|
| | | °F | % | kWh/m²/d | Inch Hg | mph | °F | °F-d | °F-d |
| January | | 18.5 | 69.2% | 1.56 | 29.7 | 5.5 | 18.0 | 1,423 | 0 |
| February | | 21.9 | 65.7% | 2.36 | 29.7 | 5.6 | 20.8 | 1,189 | 0 |
| March | | 30.9 | 64.7% | 3.31 | 29.7 | 6.3 | 30.1 | 1,038 | 0 |
| April | | 42.8 | 63.5% | 4.40 | 29.6 | 6.4 | 42.5 | 648 | 0 |
| May | | 54.0 | 67.1% | 5.02 | 29.7 | 5.6 | 54.3 | 324 | 123 |
| June | | 63.7 | 70.0% | 5.64 | 29.6 | 5.2 | 64.4 | 22 | 410 |
| July | | 68.7 | 71.8% | 5.44 | 29.6 | 4.7 | 69.4 | 0 | 580 |
| August | | 67.5 | 72.8% | 4.91 | 29.7 | 4.4 | 68.2 | 0 | 541 |
| September | | 59.4 | 74.3% | 3.69 | 29.7 | 4.9 | 60.2 | 151 | 281 |
| October | | 48.0 | 71.3% | 2.46 | 29.7 | 5.3 | 48.0 | 508 | 0 |
| November | | 37.8 | 70.8% | 1.49 | 29.7 | 5.6 | 36.8 | 799 | 0 |
| December | | 25.7 | 70.3% | 1.21 | 29.7 | 5.3 | 24.8 | 1,200 | 0 |
| **Annual** | | 45.0 | 69.3% | 3.46 | 29.7 | 5.4 | 44.9 | 7,301 | 1,936 |
| Measured at | ft | | | | | 32.8 | 0.0 | | |

*Complete Energy Model sheet*

RETScreen4 2013-08-27



NRCan/CanmetENERGY

# Modeling - RETScreen

**RETScreen Energy Model - Heating project**

**Heating project**

| | | | |
|---|---|---|---|
| Technology | | **Solar air heater** | |
| **Load characteristics** | | | |
| Application | | ⦿ Ventilation<br>○ Process | |

| | Unit | Base case | Proposed case |
|---|---|---|---|
| Facility type | | Commercial | |
| Indoor temperature | °F | 68.0 | 68.0 |
| Air temperature - maximum | °F | 150.0 | 150.0 |
| R-value - wall | ft² - °F/(Btu/h) | 21.0 | 21.0 |
| Design airflow rate | cfm | 3,500 | 3,500 |
| Operating days per week - weekdays | d/w | 5.0 | 5.0 |
| Operating hours per day - weekdays | h/d | 24.0 | 24.0 |
| Operating days per week - weekends | d/w | 2.0 | 2.0 |
| Operating hours per day - weekends | h/d | 24.0 | 24.0 |

☑ **Percent of month used**

| **Month** | Base case | Proposed case |
|---|---|---|
| January | 100% | 100% |
| February | 100% | 100% |
| March | 100% | 100% |
| April | 100% | 100% |
| May | 50% | 50% |
| June | 0% | 0% |
| July | 0% | 0% |
| August | 0% | 0% |
| September | 0% | 0% |
| October | 100% | 100% |
| November | 100% | 100% |
| December | 100% | 100% |

| | Unit | Base case | Proposed case | Energy saved | Incremental initial costs |
|---|---|---|---|---|---|
| **Heating** | million Btu | 702 | 702 | 0% | |

**Resource assessment**

| | | |
|---|---|---|
| Solar tracking mode | | Fixed |
| Slope | ° | 90.0 |
| Azimuth | ° | 0.0 |

# Modeling - RETScreen

**2 cfm/sf = 1,750sf**

| **Solar air heater** | | | | | |
|---|---|---|---|---|---|
| Type | Transpired-plate | | | | |
| Design objective | High temperature rise | | | | |
| Manufacturer | | | | | *See product database* |
| Model | | | | | |
| Solar collector absorptivity | | 0.95 | | | |
| Performance factor | | 1.20 | | | |
| Solar collector area | ft² | 1,750 | 1,778 | | |
| Solar collector shading - season of use | % | | *Wind speed* | | |
| Incremental fan power | W/ft² | | | | |
| Electricity rate | $/kWh | | | | |

☑ **Show data**

| | | |
|---|---|---|
| Solar collector fan flow rate | m³/h/m² | 36.6 |
| Solar collector flow rate | m³/h/m² | 36.6 |
| Air temperature - average rise | °F | 16.8 |
| Solar air heater - seasonal efficiency | | 20.9% |

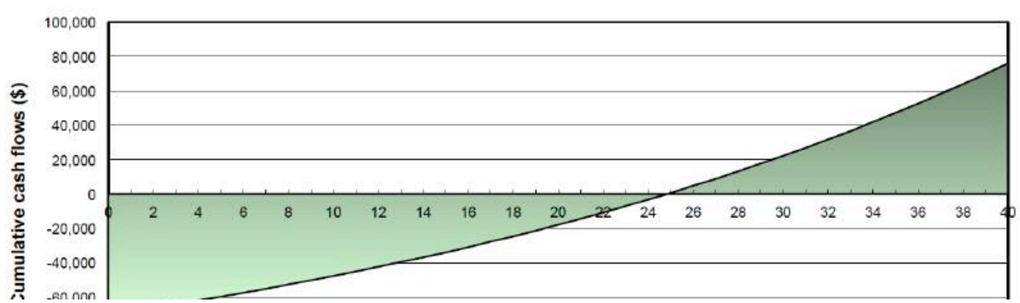
| **Summary** | | |
|---|---|---|
| Incremental electricity - fan | MWh | 0.0 |
| Heating delivered | million Btu | 146.4 |
| Building heat loss recaptured | million Btu | 13.6 |

| **Heating system** | | **Base case** | **Proposed case** | | |
|---|---|---|---|---|---|
| ☐ Project verification | | | | | |
| Fuel type | | Natural gas - therm | Natural gas - therm | | |
| Seasonal efficiency | | 85% | 85% | | $ 70,000 |
| Fuel consumption - annual | therm | 8,260.2 | 6,378.6 | therm | |
| Fuel rate | $/therm | 1.000 | 1.000 | $/therm | |
| Fuel cost | $ | 8,260 | 6,379 | | |

## Financial Analysis

| **Financial parameters** | | | |
|---|---|---|---|
| Inflation rate | % | 3.0% | |
| Project life | yr | 40 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 70,000 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 70,000 | 100.0% |
| **Incentives and grants** | $ | | 0.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 6,379 | |
| Other | $ | | |
| **Total annual costs** | $ | 6,379 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 8,260 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 8,260 | |
| **Financial viability** | | | |

**Cumulative cash flows graph**



# Modeling - RETScreen

**7 cfm/sf**

**Solar air heater**

| | | | |
|---|---|---|---|
| Type | | Transpired-plate | |
| Design objective | | High temperature rise | |
| Manufacturer | | | |
| Model | | | |
| Solar collector absorptivity | | 0.95 | |
| Performance factor | | 1.20 | |
| Solar collector area | ft² | 500 | 1,778 |
| Solar collector shading - season of use | % | | *Wind speed* |
| Incremental fan power | W/ft² | | |
| Electricity rate | $/kWh | | |

*See product database*

☑ **Show data**

| | | |
|---|---|---|
| Solar collector fan flow rate | m³/h/m² | 128.0 |
| Solar collector flow rate | m³/h/m² | 128.0 |
| Air temperature - average rise | °F | 9.3 |
| Solar air heater - seasonal efficiency | | 40.2% |

**Summary**

| | | |
|---|---|---|
| Incremental electricity - fan | MWh | 0.0 |
| Heating delivered | million Btu | 80.6 |
| Building heat loss recaptured | million Btu | 4.1 |

**Heating system**

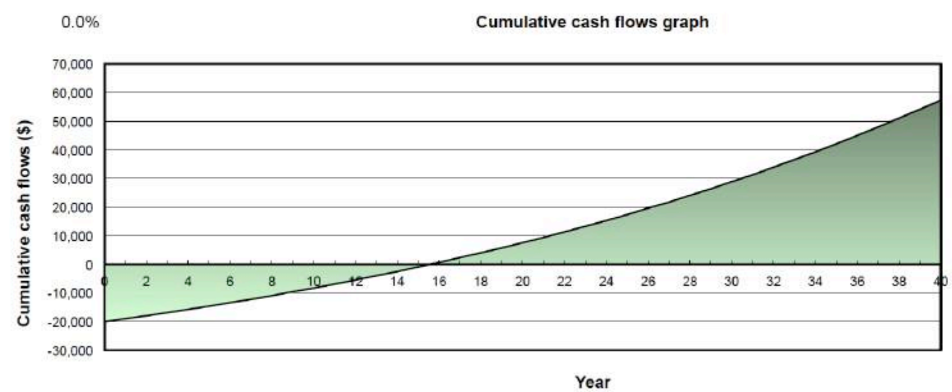
☐ Project verification

| | | Base case | Proposed case | |
|---|---|---|---|---|
| Fuel type | | Natural gas - therm | Natural gas - therm | |
| Seasonal efficiency | | 85% | 85% | $ 20,000 |
| Fuel consumption - annual | therm | 8,260.2 | 7,262.9 | therm |
| Fuel rate | $/therm | 1.000 | 1.000 | $/therm |
| Fuel cost | $ | 8,260 | 7,263 | |

## Financial Analysis

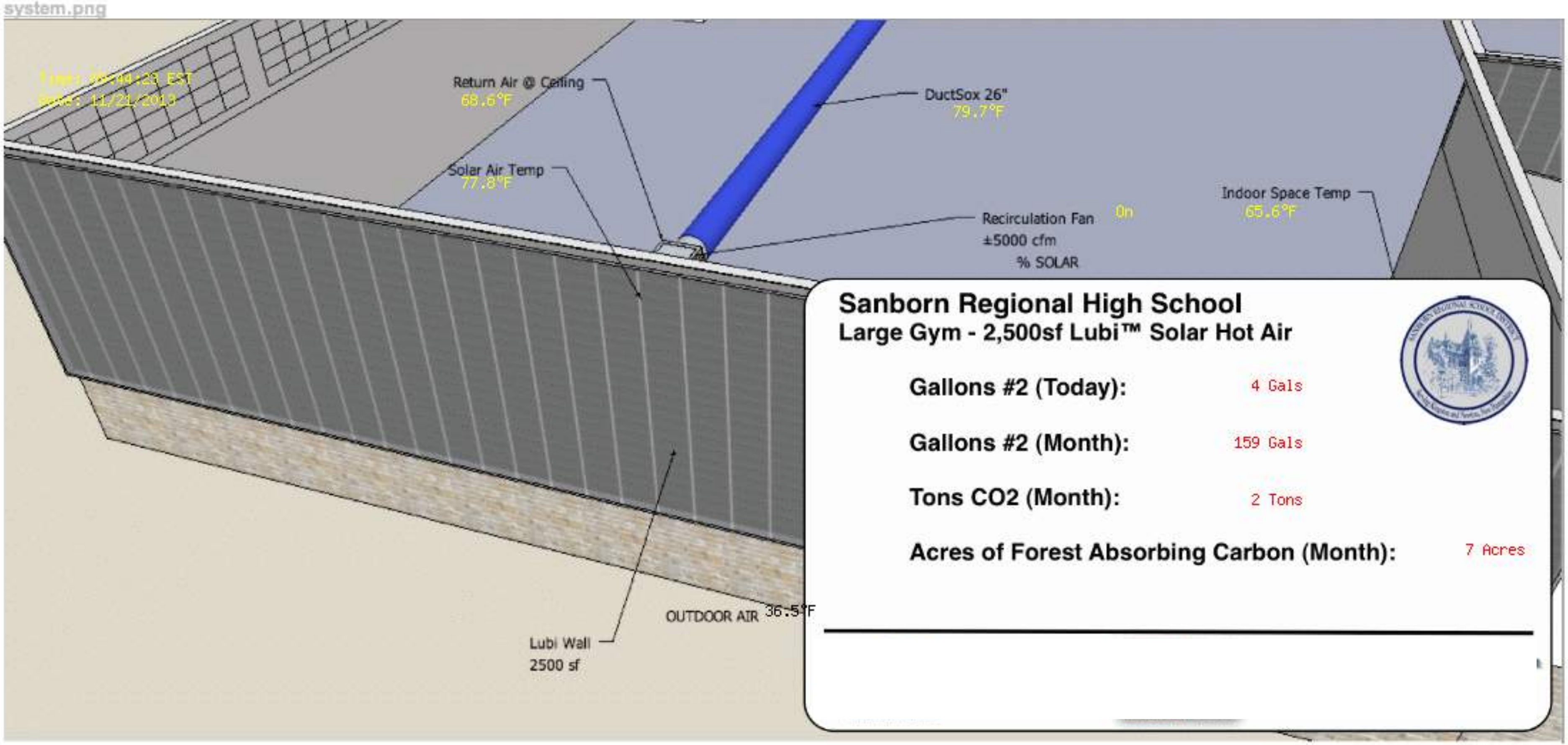
**Financial parameters**

| | | | |
|---|---|---|---|
| Inflation rate | % | 3.0% | |
| Project life | yr | 40 | |
| Debt ratio | % | | |
| **Initial costs** | | | |
| Heating system | $ | 20,000 | 100.0% |
| Other | $ | | 0.0% |
| **Total initial costs** | $ | 20,000 | 100.0% |
| **Incentives and grants** | $ | | 0.0% |
| **Annual costs and debt payments** | | | |
| O&M (savings) costs | $ | | |
| Fuel cost - proposed case | $ | 7,263 | |
| Other | $ | | |
| **Total annual costs** | $ | 7,263 | |
| **Annual savings and income** | | | |
| Fuel cost - base case | $ | 8,260 | |
| Other | $ | | |
| **Total annual savings and income** | $ | 8,260 | |
| **Financial viability** | | | |
| Pre-tax IRR - assets | % | 7.0% | |
| Simple payback | yr | 20.1 | |
| Equity payback | yr | 15.6 | |



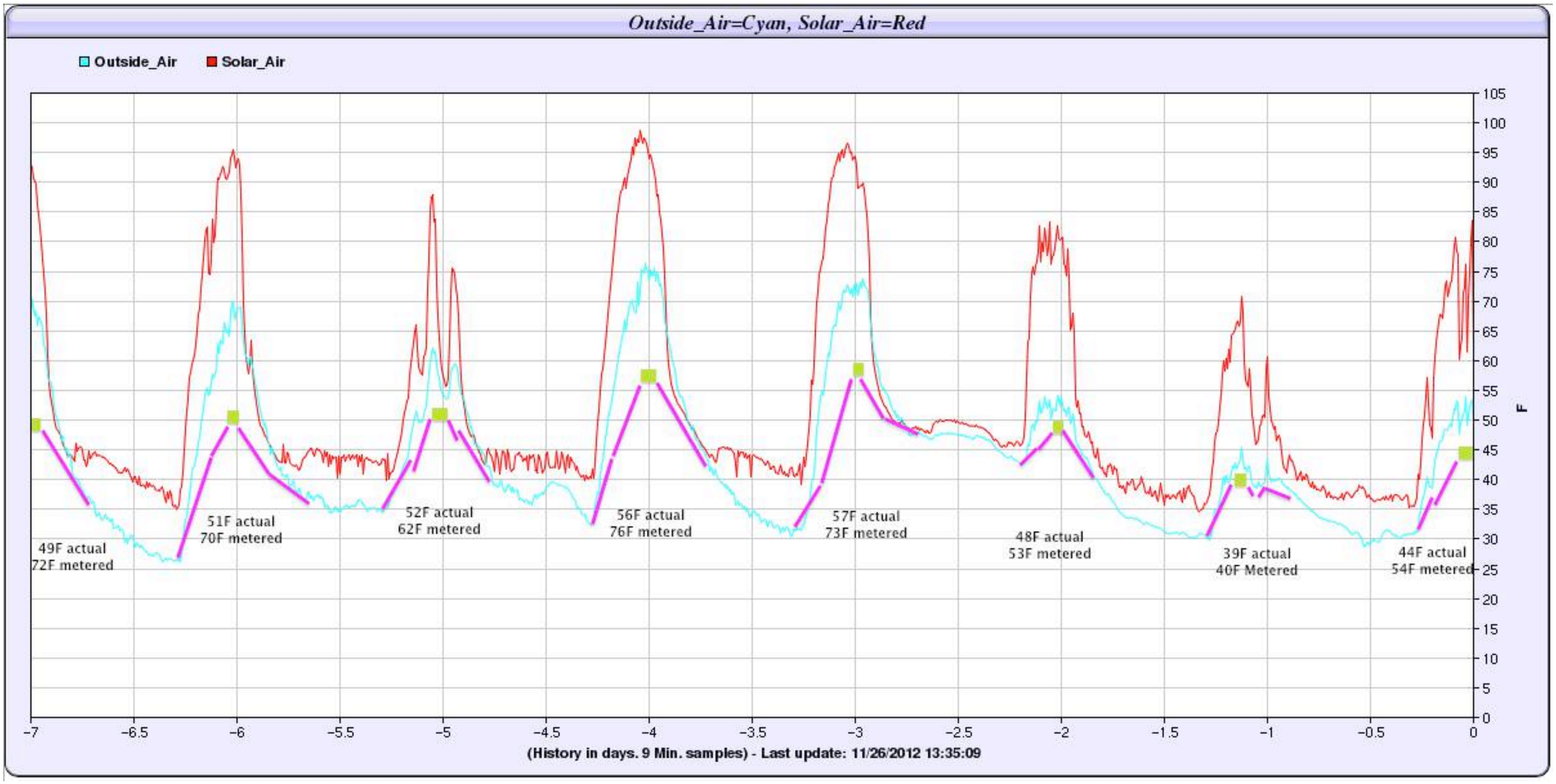
# Case Studies & Performance

system.png

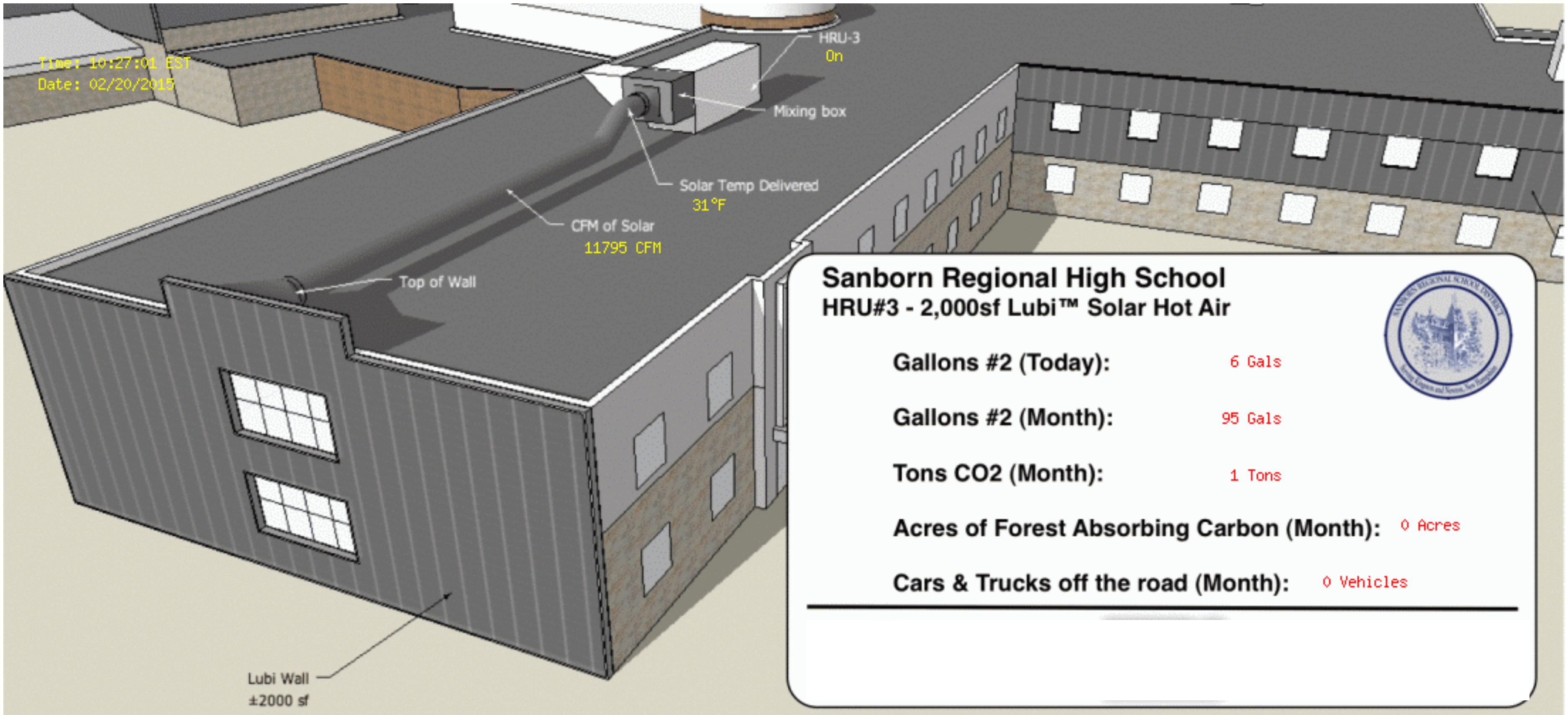


# Case Studies & Performance

2 cfm/sf

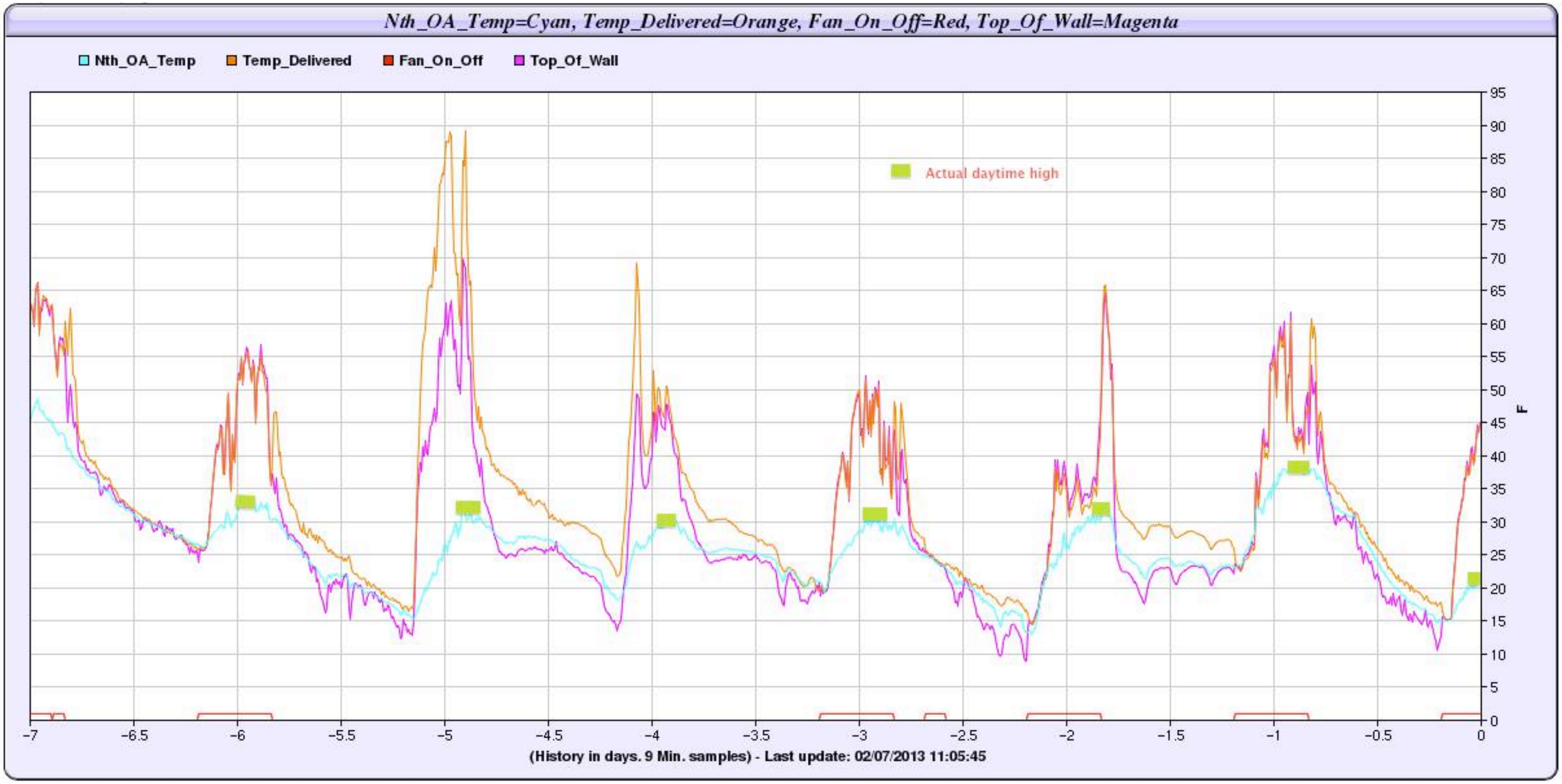


# Case Studies & Performance



# Case Studies & Performance

5.5 cfm/sf

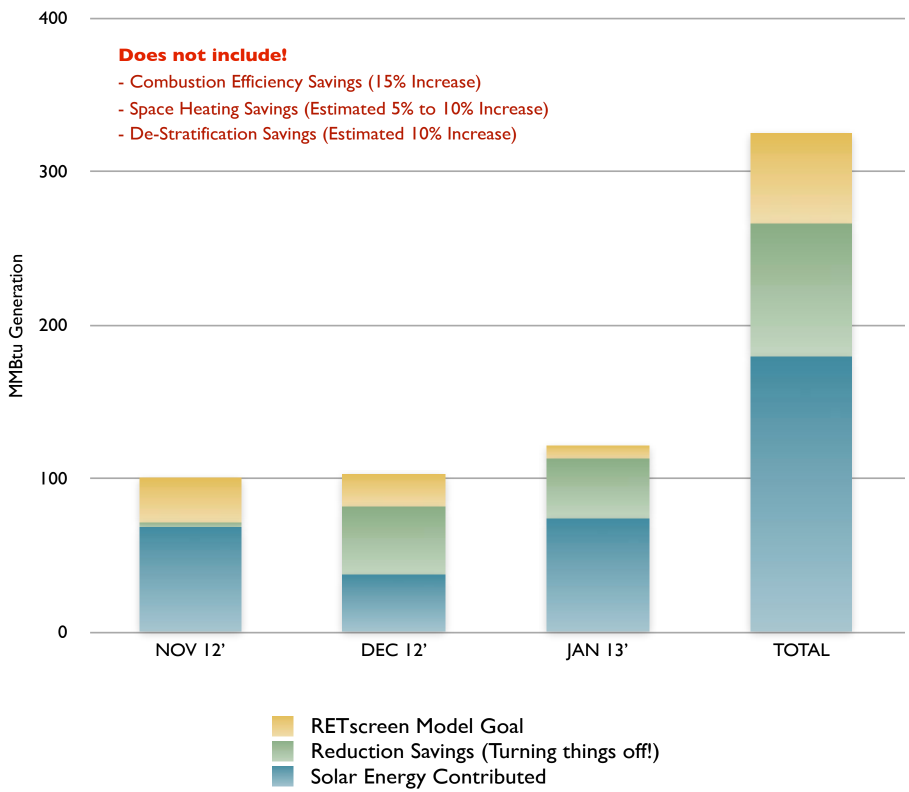


# Case Studies & Performance

**MMbtu Savings**

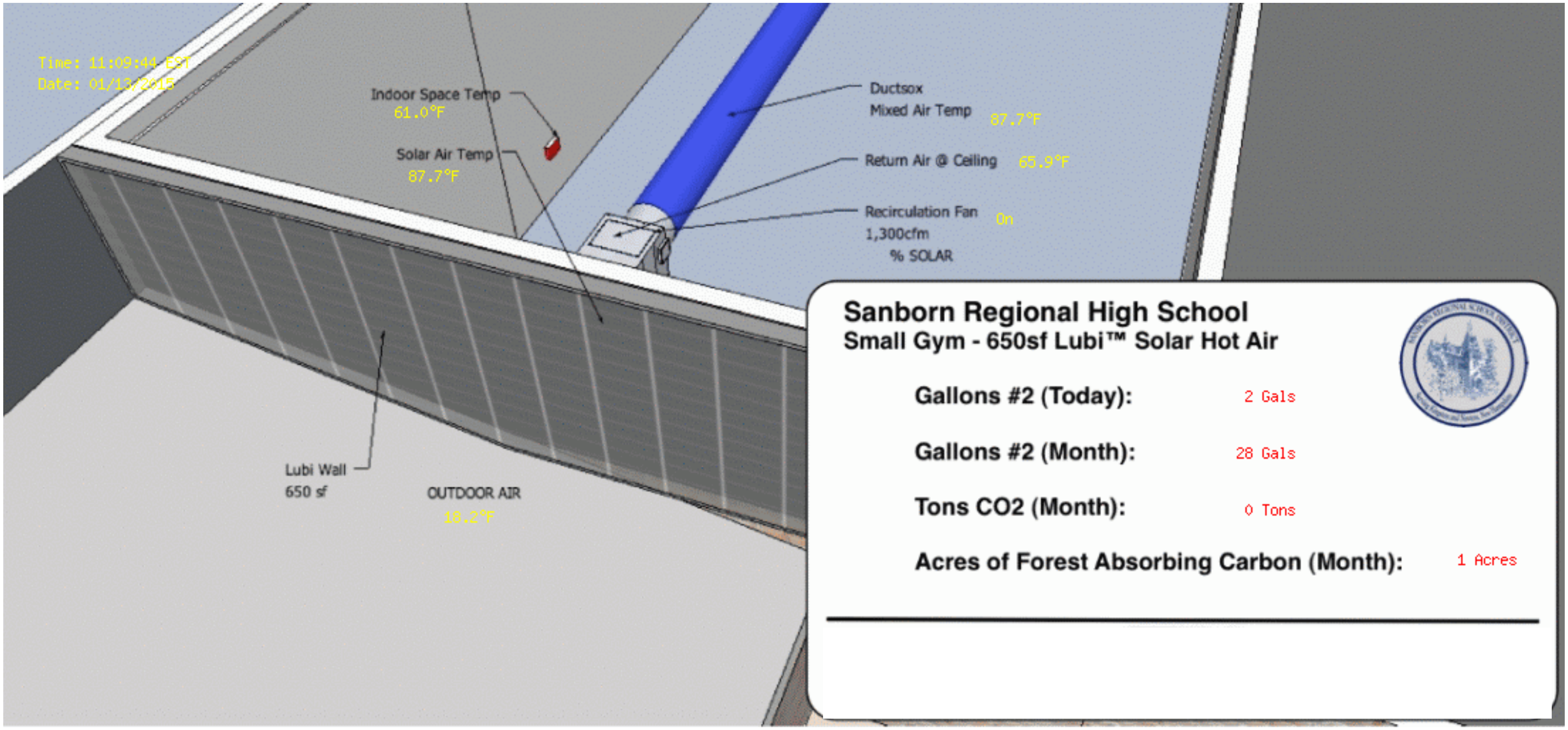
| RANGE | NOVEMBER | DECEMBER | JANUARY |
|---|---|---|---|
| RETScreen Savings Goal | 118 | 118 | 133 |
| Solar Energy + Reduction Savings | 88 | 97 | 125 |
| Solar Energy | 91 | 52 | 86 |

**MMBtu Generation by Month**



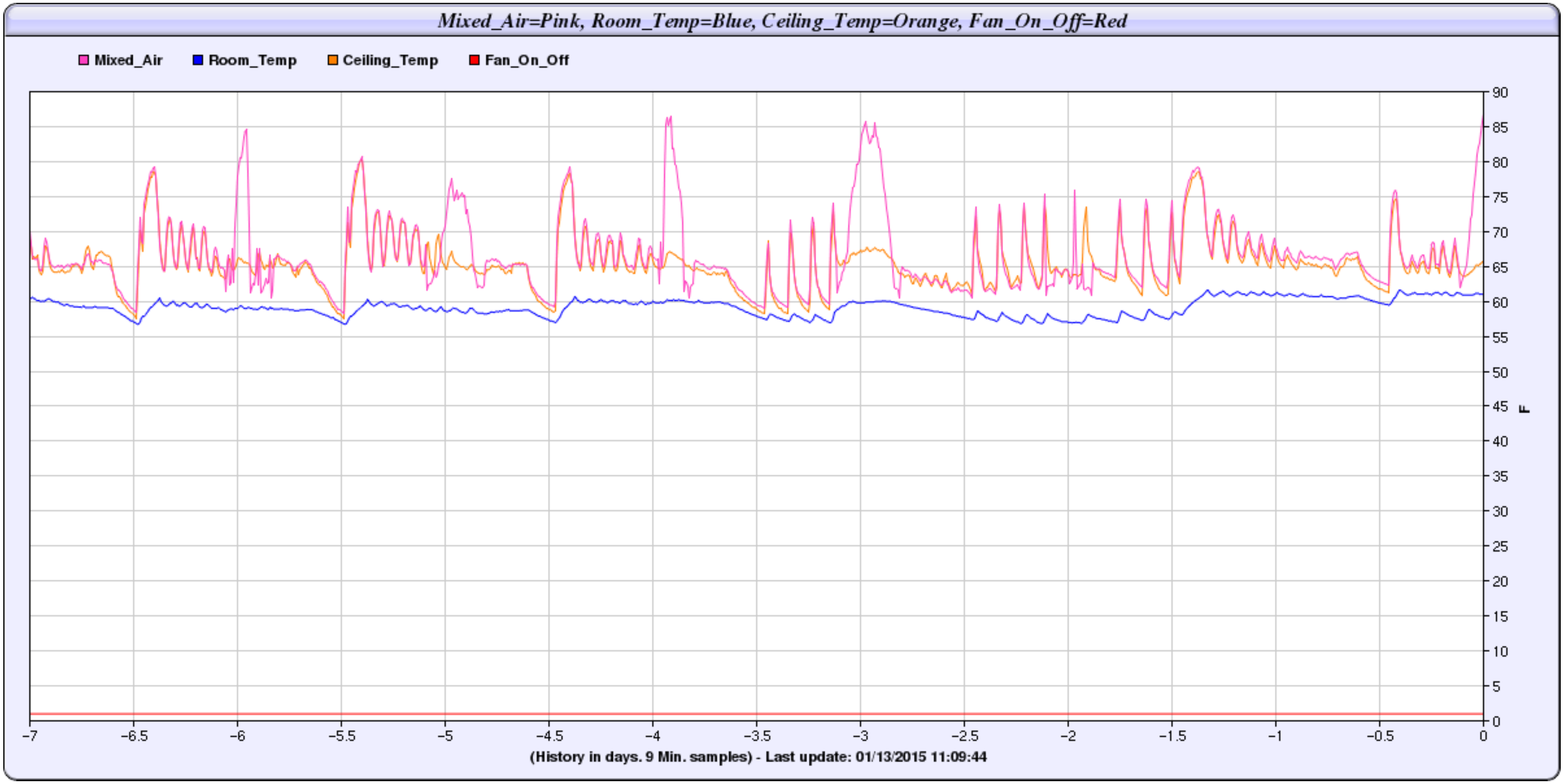

It's better to turn things off, than to use solar pre-heated air. This data shows the result of using "less" cfm's of outside air than planned in an energy model on a project that was analyzed. The bldg used approx 30% less hours of ventilation vs baseline design.

# Case Studies & Performance



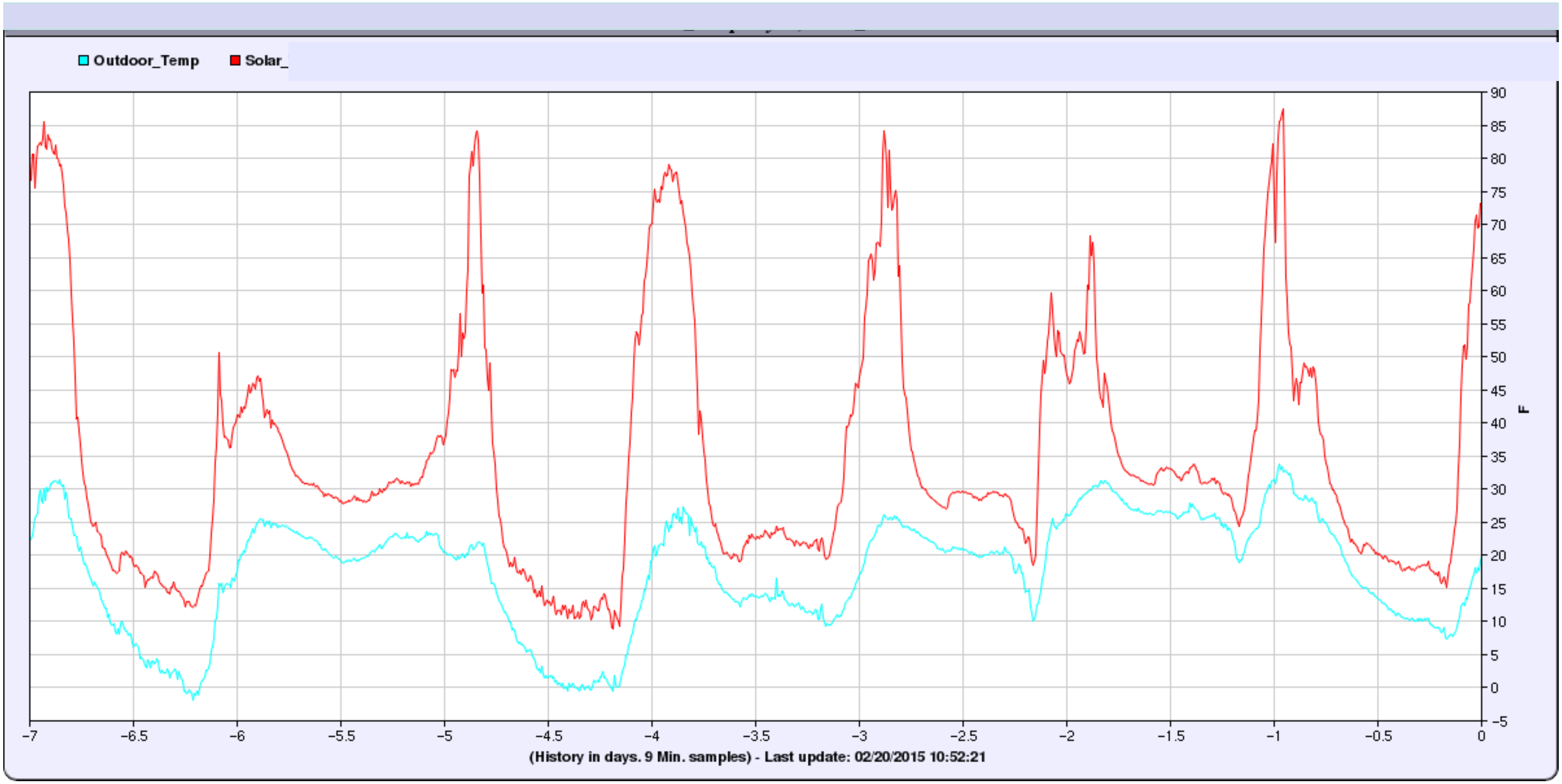
# Case Studies & Performance

**2 cfm/sf**



# Case Studies & Performance

**2 cfm/sf**




Note: OA temp was still reading high vs weather data

# Case Studies & Performance

## Integrating with Heat Pumps

# Case Studies & Performance

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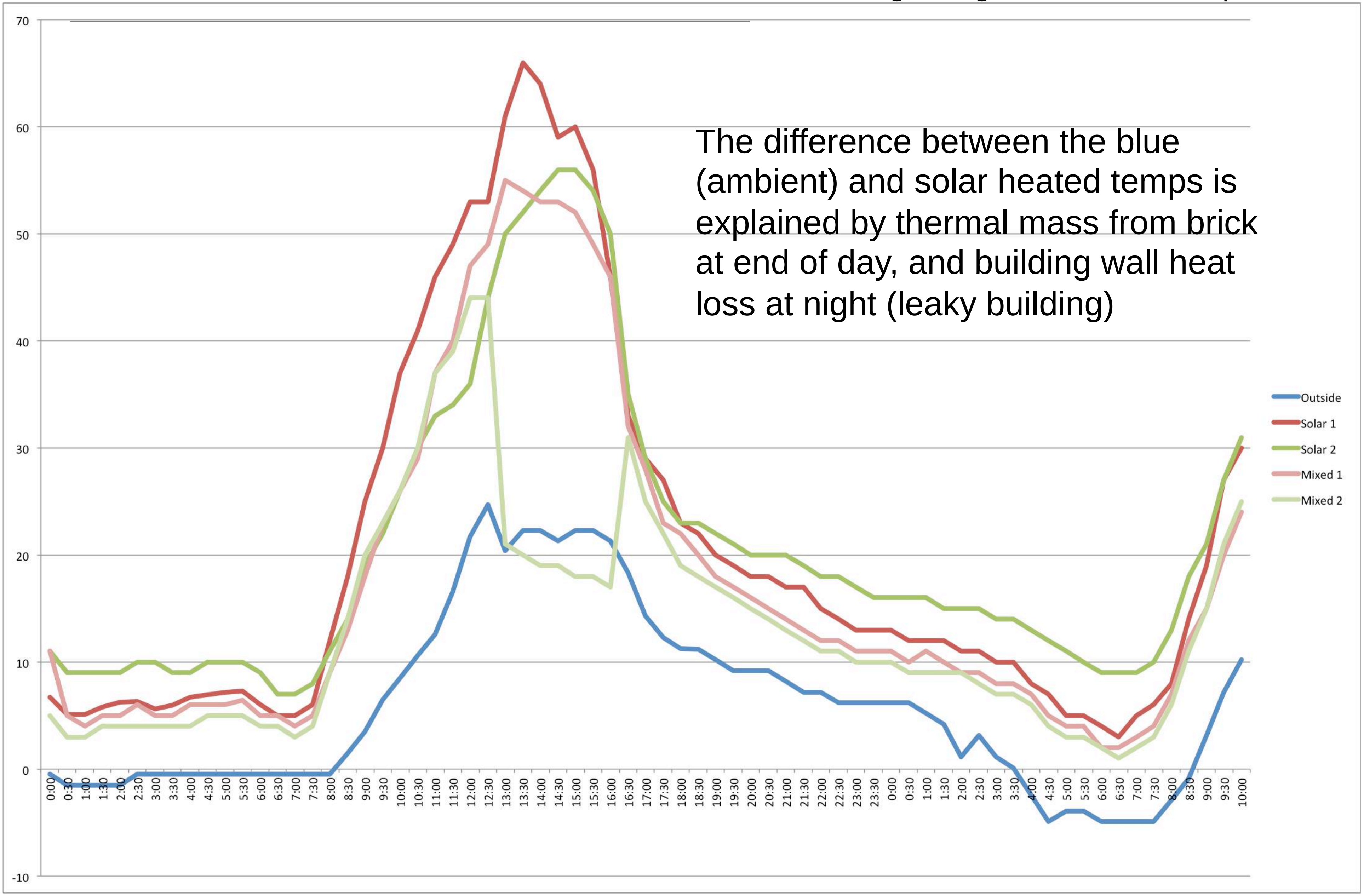
# Case Studies & Performance

## Integrating with Heat Pumps




The difference between the blue (ambient) and solar heated temps is explained by thermal mass from brick at end of day, and building wall heat loss at night (leaky building)

# Case Studies & Performance

This presentation shared further live monitoring data on various projects and testing applications. Please contact the presenter for further information if required.

# Best Applications

- Wastewater Treatment Plants
- Indoor Pools
- Lab's
- Classroom Wings
- Gymnasiums
- Commercial Kitchens
- Gym's
- Industrial Facilities/Factories
- Affordable Housing
- Warehouses
- Any applications with high ventilation loads, or where ventilation is designed as the largest energy consumer.

- ALL NEW CONSTRUCTION PROJECTS WITH GOOD SOUTHERN EXPOSURE & USE OF ARCHITECTURAL CLADDING SYSTEMS!!

This concludes The American Institute of Architects Continuing Education Systems Course

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