

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. This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

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

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Trombe Wall











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



Transpired/Perforated Roof Top Units







System Designs



System Designs



Operation Sequence

System turned off:

The fan is stopped, the damper VM1 is closed VM2 is open.

System in function:

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



System Designs



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



Cost



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

	ormation		See project databas	<u>e</u>					
Pr Proi	roject name iect location	Bangor, ME							
		Dangoi, wit							
P P	Prepared for Prepared by								
F	Project type		Heating]			4	
	Technology	Solar air heater							
Ar	nalysis type	Method 1							
Heating value	e reference	Higher heating value (HHV)							
Sh	now settings								
Languag	ge - Langue Iser manual		English - Anglais						
0.	Currency				1				
	22		*						
	Units		Imperial units]				
Site reference o	conditions	Se	elect climate data loca	ation					
Site reference o	conunions				1				
Climate da	ata location		Bangor International	Ар	1				
	Show data								
atituda	Unit	Climate data location	Project location						
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude	Unit °N °E ft °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7	Project location 44.8 -68.8 194						
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude	Unit °N °E <u>ft</u> °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7	Project location 44.8 -68.8 194	Daily solar radiation -	Atmospheric		Earth	Heating	Cooling
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Wonth	Unit °N °E ft °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature	Project location 44.8 -68.8 194 Relative humidity	Daily solar radiation - horizontal With rogid	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Wonth January	Unit [°] N [°] E ft °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5	Project location 44.8 -68.8 194 Relative humidity % 69.2%	Daily solar radiation - horizontal kWh/m²/d 1.56	Atmospheric pressure Inch Hg 29.7	Wind speed mph 5.5	Earth temperature °F 18.0	Heating degree-days °F-d 1,423	Cooling degree-days °F-d 0
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February	Unit [°] N [°] E ft °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36	Atmospheric pressure Inch Hg 29.7 29.7	Wind speed mph 5.5 5.6	Earth temperature °F 18.0 20.8	Heating degree-days °F-d 1,423 1,189	Cooling degree-days °F-d 0 0
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February Varch	Unit °N °E °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 30.9	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7% 64.7% 64.7%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31	Atmospheric pressure Inch Hg 29.7 29.7 29.7	Wind speed mph 5.5 5.6 6.3	Earth temperature °F 18.0 20.8 30.1	Heating degree-days °F-d 1,423 1,189 1,038	Cooling degree-days °F-d 0 0 0
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February Warch April	Unit [°] N [°] E [°] F [°] F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7% 64.7% 63.5% 67.1%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.00	Atmospheric pressure lnch Hg 29.7 29.7 29.7 29.7 29.6 20.7	Wind speed mph 5.5 5.6 6.3 6.4 5.6	Earth temperature °F 18.0 20.8 30.1 42.5 6.4 2	Heating degree-days *F-d 1,423 1,189 1,038 648 224	Cooling degree-days °F-d 0 0 0 0
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February Varch April Vay	Unit 'N 'E ft °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7% 64.7% 63.5% 67.1% 67.1% 70.0%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64	Atmospheric pressure lnch Hg 29.7 29.7 29.6 29.6 29.6	Wind speed mph 5.5 5.6 6.3 6.4 5.6 5.2	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4	Heating degree-days °F-d 1,423 1,189 1,038 648 324 22	Cooling degree-days °F-d 0 0 0 0 123 410
Latitude Longitude Elevation Heating design temperature Construction temperature Earth temperature amplitude Month January February March April May June July	Unit 'N 'E tr °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 68.7	Project location 44.8 -68.8 194 Relative humidity % 69.2% 66.7% 64.7% 63.5% 67.1% 70.0% 71.8%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64	Atmospheric pressure Inch Hq 29.7 29.7 29.7 29.6 29.7 29.6 29.7	Wind speed mph 5.5 5.6 6.3 6.4 5.6 5.2 4.7	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 69.4	Heating degree-days °F-d 1,423 1,189 1,038 648 324 22 0	Cooling degree-days °F-d 0 0 0 0 123 410 580
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February March April Vay June June Juny August	Unit 'N 'E ff °F °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 68.7 67.5	Project location 44.8 -68.8 194 -68.7 -69.2% -69.2% -65.7% -64.7% -63.5% -67.1% -71.8% -71.8% -72.8%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64 5.44 5.44 4.91	Atmospheric pressure Inch Hg 29.7 29.7 29.6 29.7 29.6 29.6 29.6 29.6	Wind speed mph 5.5 6.3 6.4 5.6 5.2 4.7 4.4	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 68.2	Heating degree-days 9 ^{-F-d} 1,423 1,189 1,038 648 324 22 0 0	Cooling degree-days °F-d 0 0 0 0 123 410 580 541
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February March April June June July August September	Unit 'N 'E ft °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 68.7 67.5 59.4	Project location 44.8 -68.8 194 Relative humidity % 69.2% 64.7% 64.7% 63.5% 67.1% 67.1% 71.8% 72.8% 72.8% 74.3%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64 5.44 5.44 4.91 3.69	Atmospheric pressure Inch Hg 29.7 29.7 29.6 29.6 29.6 29.6 29.6 29.6 29.7 29.6 29.7 29.6	Wind speed mph 5.5 5.6 6.3 6.4 5.6 5.2 4.7 4.4 4.9	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 69.4 68.2 60.2	Heating degree-days °F-d 1,423 1,189 1,038 648 324 22 0 0 0 0 151	Cooling degree-days °F-d 0 0 123 410 580 541 281
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February March April May June July June July September October	Unit 'N 'E 'F °F 'F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 68.7 63.7 68.7 59.4 44.0	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7% 64.7% 63.5% 67.1% 70.0% 71.8% 72.8% 74.3% 71.3%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64 5.64 5.64 5.44 4.91 3.69 2.46	Atmospheric pressure Inch Hg 29,7 29,7 29,6 29,6 29,6 29,6 29,6 29,7 29,7 29,7 29,7 29,7 29,7	Wind speed mph 5.5 5.6 6.3 5.6 5.2 4.7 4.4 4.9 5.3	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 69.4 68.2 60.2 48.0	Heating degree-days °F-d 1,423 1,189 1,038 648 324 22 0 0 0 151 508	Cooling degree-days °F-d 0 0 0 123 410 580 541 281 0
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February March April May June July August September October	Unit 'N 'E °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 67.5 59.4 48.0 37.8	Project location 44.8 -68.8 194 8 8 8 9 9 6 9 7 8 3 5% 6 5.7% 6 3.5% 6 7.1% 7 0.0% 7 1.8% 7 2.8% 7 4.3% 7 0.8% 7 1.3% 7 0.8% 7 0.8%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64 5.64 5.64 4.91 3.69 2.46 1.49 1.49	Atmospheric pressure Inch Hg 29.7 29.7 29.6 29.7 29.6 29.7 29.6 29.7 29.6 29.7 29.7 29.7 29.7 29.7 29.7	Wind speed mph 5.5 6.3 6.4 5.6 6.2 4.7 4.4 4.9 5.3 5.6	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 69.4 68.2 60.2 48.0 36.8 36.8 2 60.2	Heating degree-days °F-d 1,423 1,189 1,038 648 324 22 0 0 0 151 508 799 4 507	Cooling degree-days °F-d 0 0 0 123 410 541 281 0 0 0
Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February March April May June July August September October Vovember December	Unit 'N 'E f °F °F °F	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 67.5 59.4 48.0 37.8 25.7 45.0	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7% 64.7% 63.5% 67.1% 67.1% 70.0% 71.8% 74.3% 71.3% 71.3% 70.3% 90.9%	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.62 5.64 5.64 5.64 4.91 3.69 2.46 1.49 1.21 1.21 2.46	Atmospheric pressure Inch Hg 29.7 29.7 29.7 29.6 29.7 29.6 29.7 29.6 29.7 29.7 29.7 29.7 29.7 29.7 29.7 29.7	Wind speed mph 5.5 5.6 6.3 6.4 5.6 5.2 4.7 4.9 5.3 5.6 5.3 5.6	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 68.2 60.2 48.0 36.8 24.8 24.8 44.9	Heating degree-days "F-d 1,423 1,189 1,038 648 324 22 0 0 151 508 799 1,200 7 301	Cooling degree-days °F-d 0 0 0 123 410 580 541 281 0 0 0 0 0 0
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Latitude Longitude Elevation Heating design temperature Cooling design temperature Earth temperature amplitude Month January February Warch April Wary June July August September October Socomber Annual Weasured at	Unit N 'E ff oF oF oF oF t	Climate data location 44.8 -68.8 194 -2.2 84.2 37.7 Air temperature °F 18.5 21.9 30.9 42.8 54.0 63.7 67.5 59.4 48.0 37.8 25.7 45.0	Project location 44.8 -68.8 194 Relative humidity % 69.2% 65.7% 64.7% 63.5% 67.1% 64.7% 63.5% 67.1% 70.0% 71.8% 70.0% 71.8% 70.3% 69.3% plete Energy Model	Daily solar radiation - horizontal kWh/m²/d 1.56 2.36 3.31 4.40 5.02 5.64 5.44 4.91 3.69 2.46 1.21 3.46	Atmospheric pressure Inch Hg 29.7 29.7 29.7 29.6 29.6 29.6 29.7 29.7 29.7 29.7 29.7 29.7 29.7 29.7	Wind speed mph 5.5 5.6 6.3 6.4 5.6 5.2 4.7 4.4 4.9 5.3 5.6 5.3 5.4 32.8	Earth temperature °F 18.0 20.8 30.1 42.5 54.3 64.4 68.2 60.2 48.0 36.8 24.8 44.9 0.0	Heating degree-days °F-d 1,423 1,189 1,038 648 324 22 0 0 151 508 799 1,200 7,301	Cooling degree-days °F-d 0 0 0 123 410 580 580 581 281 0 0 0 0 1,936

Modeling - RETScreen

RETScreen Energy Model - Heating project

Heating project					
Technology		Solar a	air heater		
Load characteristics					
Application	•	Ventilation			
	0	Process			
	Unit	Base case	Proposed case		
Facility type		Com	mercial		
Indoor temperature	°F	68.0	68.0		
Air temperature - maximum	°F	150.0	150.0		
R-value - wall	ft ² - °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				
	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%		
					Incremental initial
	Unit	Base case	Proposed case	Energy saved	costs
Heating	million Btu	702	702	0%	
_					
Resource assessment	-		-		
Solar tracking mode		Fixed	-		
Slope	°	90.0			
Azimuth	٥	0.0			

Modeling - RETScreen

2 cfm/sf = 1,750sf

Solar air heater Type Design objective Manufacturer Model Solar collector absorptivity Performance factor Solar collector shading - season of use Incremental fan power Electricity rate	Tr High ft ² % W/ft ² \$/kWh	0.95 1.20 1,750 1,778 Wind speed		☑ Show data Solar collector fan flow rate Solar collector flow rate	m³/h/m² m³/h/m²	<u>See product database</u> 36.6 36.6
Summary Incremental electricity - fan Heating delivered Building heat loss recaptured	MWh million Btu million Btu	0.0 146.4 13.6		Air temperature - average rise Solar air heater - seasonal efficiency	°F	16.8 20.9%
Heating system Project verification Fuel type Seasonal efficiency Fuel consumption - annual Fuel rate Fuel cost	therm \$/therm \$	Base case Proposed ca ural gas - therm Natural gas - th 85% 85% 8,260.2 6,378.6 1.000 1.000 8,260 6,379	ase herm therm \$/therm	\$ 70,000		
Financial Analysis Financial parameters Inflation rate Project life Debt ratio	% yr %	<u>3.0%</u> 40				
Initial costs Heating system Other Total Initial costs	\$	70,000	100.0% 0.0% 100.0%			
Incentives and grants	\$		0.0%		Cumulative cash flows graph	
Annual costs and debt payments O&M (savings) costs Fuel cost - proposed case Other Total annual costs	\$ \$ \$	6,379	100,000 80,000 \$ 60,000 \$ 40,000			
Annual savings and income Fuel cost - base case Other Total annual savings and income	\$ \$ \$	8,260 8,260	0,000,02 0,000,02- 0,000,02- 0,000,02-	2 4 6 8 10 12 14 16	18 20 22 24 26 28 30	32 34 36 38 40
Financial Viability			-en 000	And the second se		



Case Studies & Performance



Case Studies & Performance

Outside_Air=Cyan, Solar_Air=Red Outside_Air Solar_Air 105 100 - 95 - 90 - 85 - 80 - 75 - 70 - 65 - 60 - 55 ш. - 50 - 45 In Minin MINMM montiment mar 40 mon - 35 52F actual 56F actual 57F actual 51F actual 62F metered 76F metered 73F metered 48F actual 70F metered - 30 49F actual 53F metered 44F actual 39F actual 72F metered **40F Metered** 54F metered-25 - 20 15 10 -5 -0 -7 -6.5 -6 -5.5 -5 -2.5 -2 -0.5 -4.5 -3.5 -3 -1.5 -4 -1 0 (History in days. 9 Min. samples) - Last update: 11/26/2012 13:35:09

2 cfm/sf

Case Studies & Performance



Case Studies & Performance

Nth_OA_Temp=Cyan, Temp_Delivered=Orange, Fan_On_Off=Red, Top_Of_Wall=Magenta Nth_OA_Temp Temp_Delivered Fan_On_Off Top_Of_Wall - 95 - 90 85 Actual daytime high - 80 -75 -70 65 60 - 55 -50 1 45 40 - 35 - 30 25 20 15 10 -5 -0 -5.5 -2.5 -6.5 -5 -4.5 -3.5 -1.5 -0.5 -7 -4 -3 -2 -1 0 (History in days. 9 Min. samples) - Last update: 02/07/2013 11:05:45

5.5 cfm/sf

Case Studies & Performance

MMbtu Savings RANGE NOVEMBER DECEMBER JANUARY **RETScreen Savings** 118 118 133 Goal 88 97 125 Solar Energy + **Reduction Savings** 91 Solar Energy 52 86 **MMBtu Generation by Month** 400 **Does not include!** - Combustion Efficiency Savings (15% Increase) - Space Heating Savings (Estimated 5% to 10% Increase) - De-Stratification Savings (Estimated 10% Increase) 300 MMBtu Generation 200 100 0 NOV 12' DEC 12' JAN 13' TOTAL **RETscreen Model Goal**

Reflection Savings (Turning things off!) Solar Energy Contributed 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

Integrating with Heat Pumps

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

