

**SOLAR PREHEATER FOR
MULTIFAMILY BUILDING VENTILATION**

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**NEW YORK STATE
ENERGY RESEARCH AND
DEVELOPMENT AUTHORITY**





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Vincent A. DeIorio, Esq., Chairman
Francis J. Murray, Jr. President and Chief Executive Officer

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Final Report

Prepared for the
**NEW YORK STATE
ENERGY RESEARCH AND
DEVELOPMENT AUTHORITY**

Albany, NY
www.nyserda.org

Robert Carver
Senior Project Manager

Prepared by:
TAITEM ENGINEERING, PC
Ithaca, NY

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ABSTRACT

A solar ventilation preheater was installed on a high-rise multifamily building to demonstrate and evaluate its application in New York. Objectives included determining whether the technology could be cost-effectively integrated into existing ventilation systems, assessing applicability to multifamily buildings, and evaluating a variety of performance issues. The solar preheater was installed on a 13-story, high-rise, multifamily building and integrated with a roof-mounted, gas-fired makeup air system. Monitoring was conducted for over a year. The solar preheater and controls worked as anticipated and delivered energy savings as predicted. The cost of the installation was higher than expected, but the duration of installation (less than two weeks), manpower required (typically two people on site), and known material costs indicate that the construction cost could have been significantly lower than what was bid. Energy savings persisted over the period of monitoring, with no observed deterioration of performance. The controls, integrated into the existing ventilation system, appeared to work well. Applicability to other buildings was evaluated, with positive findings. Potential installation on buildings in New York City would likely be more limited than for upstate buildings, due to shading issues and lack of available wall space. The manufacturer of the solar collector has recently developed a rooftop product that offers an alternative to the wall-mounted collector, and so could be an option where wall-mounting is not feasible.

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SUMMARY

A solar ventilation preheater was installed on a high-rise, multifamily building to demonstrate and evaluate its application in the New York climate. Objectives included: determining whether the technology could be cost-effectively integrated into existing ventilation systems, assessing the applicability to multifamily buildings in New York State, and evaluating a variety of performance issues. The 1,079 square foot solar preheater was installed on a 186-unit, 13-story, high-rise, multifamily building in Syracuse, NY, integrated with an existing roof-mounted, gas-fired makeup air system. Monitoring of energy savings was conducted for over a year.

The solar preheater and controls worked as anticipated and delivered energy savings as predicted. Annual energy savings were \$1,600. It is estimated that the energy savings would have been \$1,733 if a gap had not been left along the width of the plenum at the top of the collector. The cost of the installation, which was bid out to contractors through a public bid process, was higher than expected. However, the observed duration of the installation (less than two weeks), manpower required (typically two people on site), and known material costs, indicate that the construction cost could have been significantly lower than what was bid (\$38,300 instead of bid at \$55,269).

Energy savings persisted over the period of monitoring, with no observed deterioration of performance over time. The controls, integrated with the existing ventilation system, appeared to work well. Applicability to other buildings was evaluated, and the technology generally was found to be applicable to other multifamily buildings. Potential installation on buildings in New York City would likely be much more limited than for upstate buildings, due to shading issues and lack of available wall space. The manufacturer of the solar collector has recently developed a rooftop product that offers an alternative to the wall-mounted collector, and so could be an option where wall-mounting is not feasible.

BACKGROUND

Over the past few years, a solar preheater for ventilation makeup air has been developed by Conserval Systems, Inc, of Buffalo, NY, and Conserval Engineering Inc. of Toronto. The solar preheater, called the SolarWall®, incorporates a corrugated galvanized steel cladding, which typically is mounted on a south-facing wall of a building. The patented cladding has perforations through which air is drawn between the cladding and the building wall. Heating of the makeup air reportedly takes place on a thermal boundary layer adjacent to the cladding. Solar-heated air flows up the side of the building, where it is drawn into the makeup air heater on the top of the building.

A solar preheater was installed at Almus Olver, a high-rise, multifamily building in Syracuse, NY, to preheat the ventilation air before it was drawn into an existing rooftop air handler and makeup air heater. The preheater was instrumented and monitored for over a year in order to quantify the performance and determine the cost-effectiveness of this technology.

DEMONSTRATION BUILDING

Almus Olver is a concrete and masonry, high-rise, multifamily building, located in downtown Syracuse, which provides housing to the elderly. It is surrounded by low-rise buildings, parking lots, vacant parcels, and roads. There are 186 apartments in a three-wing, T-shaped arrangement. Wing A forms the base of the T and is 10 stories tall. Wings B and C form the cross of the T and are 11 and 13 stories tall, respectively. Total heated area is 170,588 square feet.

The solar preheater was installed on the southwest-facing wall of Wing B, between two columns of windows, across an expansion joint. The total area available on the building was 96 feet from ground to roof by 15 feet between the windows. The solar preheater begins 12 feet off the ground and is 87 feet tall, including the collector canopy at the top, which extends above the roof and connects to the rooftop ductwork.

The pre-existing ventilation system was a roof-mounted, gas-fired makeup air unit that provides outdoor air to the corridors. The air handler was located on the Wing B roof, near the solar preheater installation, minimizing roof ductwork.

The wall of Wing B, on which the solar preheater was installed, was found to be oriented 35 degrees west of due south. The wall was shaded for portions of the day by Wing A.

FEASIBILITY STUDY

Preliminary energy savings estimates were produced using SWIFT (Solar Wall International Feasibility Tool), a software tool developed by National Resources Canada (NRCan). The original projected energy delivered by a solar preheater for Almus Olver was 126.5 MMBtu per year. If this heat was provided instead by an 80% efficient furnace, this would translate to 158.1 MMBtu per year of natural gas. At \$0.637 per therm for natural gas, the fuel cost at the time of the feasibility study, this was equivalent to approximately \$1,000 per year of cost savings.

The initial projected construction cost for the solar preheater at Almus Olver was \$22,100 for construction and \$5,100 for engineering, for a total of \$27,200. The construction cost was based on numbers provided by Conserval of \$11 per SF for materials and labor for the solar preheater itself, assumed a 740 SF solar preheater, and used standard estimating methods for the non-collector components of the project (ductwork, controls, etc.).

SOLAR PREHEATER INSTALLATION

The preheater collector was installed in a little over five days by two workers on a lift (see Figures 1–5). Another two days were used to construct the collector canopy (see Figures 6–7), which connects the preheater to the ductwork. The ductwork on the roof, including supports and insulation, connects the solar preheater and the air handler. After the ductwork and the preheater were connected, an insulation contractor installed duct insulation and a waterproof membrane, and a controls contractor installed and tested controls for dampers that control airflow through the system.



Figure 1: Starting the frame (Day 1)



Figure 2: Continuing the frame (Day 2)



Figure 3: Finishing the frame (Day 3)



Figure 4: Installing the cladding (Day 4)



Figure 5: Completing the cladding (Day 5)



Figure 6: Constructing the canopy (Day 6)



Figure 7: Collector canopy complete (Day 8)

CONSTRUCTION COSTS

The actual construction cost of \$55,269 was 153% higher than the original projection of \$22,100. In part, this can be explained by the larger than anticipated square footage — 1,079 SF vs. 740 SF, a 46% increase. However, only 53% of the original estimate was based on “per SF” costs of the solar preheater, so the increase in square footage only accounts for a portion of the total increase. It appears that the contractor’s bid was excessive, ostensibly due to the unfamiliarity with this kind of work. For example, the bid breakdown shows \$11.80 per SF for materials and \$9.82 per SF for installation of the solar preheater itself, compared to estimates of \$6.00 and \$5.00 as provided by Conserval. This is a premium of 96% over the original estimate, on a per SF basis. The other, non-solar preheater costs (ductwork, insulation, electrical, controls, mobilization) together came to 133% more than the original estimate, which is more than double.

An analysis of the bid and construction process for the solar preheater at Almus Olver led to the development of a revised cost estimate. The new estimate was based on the observed actual time spent on construction of the Almus Olver solar preheater, including time that the mechanical contractor used to lay out the materials on the shop floor to become familiar with the technology and to make sure all the parts were there. Updated unit labor costs from a R.S. Means Mechanical Cost Data 2005 handbook were applied to these actual hours to develop labor costs. The revised cost breakdown was:

| | |
|------------------------|----------|
| Fixed Costs, each wall | \$11,300 |
| Costs per LF of Duct | \$229 |
| Costs per SF of Wall | \$15.50 |

Table 1: Revised per Unit Cost Estimates for Solar Preheater Installation

Using this cost breakdown, the installation at Almus Olver should have cost \$38,300, instead of either the original projection of \$22,100, which was underestimated, or the low bid of the \$55,269, which was likely overestimated by the contractor because of the unfamiliar technology.

CONSTRUCTION QUALITY

There were several quality problems that resulted from the contractor not following the manufacturer's recommendations. At the bottom of the preheater, the contractor neglected to install cladding material, leaving several 1-inch diameter holes and a gap at the expansion joint, which increased the open area by 21 square inches. With the location at the very bottom of the preheater, this likely did not affect performance greatly.

More significant was the incorrect installation of the plenum at the top of the preheater. The contractor left a 1/4-inch to 3/8-inch wide gap over the 13-foot width of the plenum. This resulted in a 43-square inch gap. Given the location at the very top of the preheater, this gap probably had a larger impact on performance than the holes at the bottom.

Finally, incorrect fastening of sheet metal in the plenum resulted in a portion of the plenum coming loose during a strong wind and then bending. After emergency repairs, there were still approximately 13 square inches of gap in the plenum. This probably also had an impact on performance, though the damage did not occur until about half-way through the monitoring period.

There also were problems with the installation of the duct insulation. The insulation and waterproofing on the underside of the ductwork near the solar preheater came loose and sagged, allowing birds to build nests in the resulting cavity.

DATA ACQUISITION SYSTEM

A data logger monitored the system continuously.

Air velocity in the ductwork was measured using two 3-cup rotating wind speed sensors. These sensors were mounted vertically using custom-made mounting brackets in holes cut in the bottom of the ducts.

Solar radiation was measured using two silicon pyranometers. One was mounted horizontally, to measure the incoming solar radiation on a horizontal surface, which is a standard measurement given in solar

radiation resource maps. The other pyranometer was mounted vertically, parallel to the solar preheater, and was used to measure the radiation striking the preheater.

The primary temperature measurements inside the ductwork and for the outside air were taken with thermistors. The sensors in the ductwork were suspended in the middle of the ductwork on baling wire stretched across the duct. The outdoor temperature sensor was placed inside a six-plate radiation shield.

Backup temperature measurements were taken with type T thermocouples at each of the locations where thermistors were located. In addition, two thermocouples were installed in the brick face of the building next to the solar preheater, and two thermocouples were installed in the brick face of the building behind the solar preheater. These thermocouples were used to determine how much the wall of the building behind the preheater was heated above ambient.

Two residential-style gas meters, piped in parallel, were used to measure the amount of gas consumed by the air handler. Two meters were required because the gas flow was larger than the capacity of one meter.

Location of Sensors

- OAT - Outdoor Air Temperature (F)
- CSAT - Collector Supply Air Temperature (F)
- MAT - Mixed Air Temperature (F)
- HSAT - Heater Supply Air Temperature (F)
- CAV - Collector Air Velocity (FPM)
- MAV - Mixed Air Velocity (FPM)
- HorizSun - Horizontal plane solar radiation
- VertSun - Vertical plane solar radiation

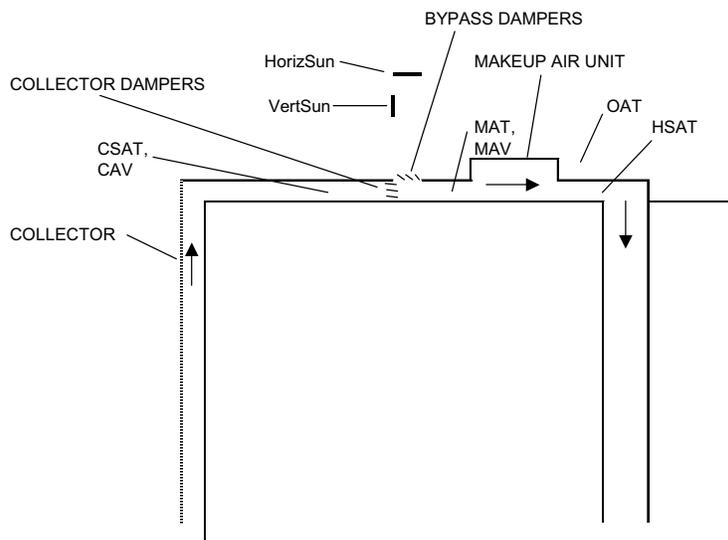


Figure 8: Instrumentation Location Schematic

ENERGY SAVINGS

Two different methods were used to calculate energy savings. One method involved calculating the difference in temperature between outdoor air and the air leaving the solar preheater. The volume of the air that flowed from the preheater for each minute was calculated as the product of the cross sectional area of the duct and the velocity of the air in the duct during that one minute. The energy needed to heat the volume of air was computed for each minute, and then all of the energy was summed.

The second method was based on the natural gas consumption of the air handler and the difference in temperature between the outdoor air and the air leaving the air handler. The volume of air through the air handler was assumed to be 3,575 CFM, which is the cross sectional area of the duct multiplied by the average velocity of the air from the preheater when 100% of the air is flowing through the preheater. The total energy needed to heat the volume of air was computed for each hour. From this total, the amount of heat supplied to the air by the natural gas consumed, based on 80% efficiency and 1,020 Btu/CF, was calculated and subtracted. The remainder of the heat was assumed to be supplied by the solar preheater. During times that the velocity from the preheater was zero, then the amount of heat supplied was also set equal to zero.

A correction of 1.3 F was applied to the difference between the outdoor air and the air leaving the air handler, since the temperature leaving the air handler was consistently 1.3 F higher than the outside air during times when they should have been identical, such as when the heater on the air handler was not operating.

Both methods resulted in very similar total 12-month energy savings— within 3%. It is important to note that both calculation methods are very sensitive to small inaccuracies in temperature measurement or airflow rates.

Energy delivered by the solar preheater for a 12-month period was calculated at 94.9 MMBtu. However, there were 40 days in the winter during which the ventilation system was not operating. If the energy delivered were normalized based on heating degree-days, then the total energy delivered would be 121.2 MMBtu. At a reported cost of \$1.05 per therm for natural gas during the period of operation, and assuming 80% efficiency in the furnace, this translates into a savings of \$1,591. After applying a correction for the problems relating to air leakage, it is estimated that the savings would have been \$1,733 if there had not been gaps left during the installation.

Possible reasons for the savings being lower than predicted include: gaps in the collector assembly that resulted in air bypass; the collector facing 35 degrees from true south; and the collector being partially shaded by another wing of the building.

While the annual energy delivered — 121.2 MMBtu — was below the prediction of 158.1 MMBtu, the resulting annual energy cost savings of approximately \$1,600 was greater than the predicted cost savings of \$1000 because of the higher-than-anticipated natural gas cost.

A significant portion of the total energy savings achieved occurred at night, presumably because the solar preheater was recapturing heat the building would have otherwise lost to the atmosphere. Thirty-three percent of the 94.9 MMBtu delivered by the solar preheater occurred during hours when there was no sun (defined as an average solar insolation of less than 9.9 W/m² during that hour). It is important to note that building heat loss recapture likely does not occur only at night. It is logical to assume, therefore, that a portion of the heat recovery during times when solar insolation is greater than 9.9 W/m² is also caused by building heat loss recapture. If so, one might speculate that as much as 50% of the total heat recovered for the year could be attributed to building heat loss recapture.

When the actual construction cost of \$55,269 is applied to the savings of \$1,600, the simple payback is 34.5 years. However, if the construction cost were reduced to \$38,300, as is estimated to be plausible, and if the savings had been \$1,733, as estimated if gaps had not been left during the installation, the simple payback would have been 22.1 years. These payback estimates do not include the benefits of solar tax credits or NYSERDA support.

DAMPER LEAKAGE

Based on a report from the balancing contractor, it appears that there was some leakage past the collector dampers (see Figure 8). When the dampers were in the closed position, there should have been no flow between the preheater and the air handler. However, there was still 170 CFM of flow at 85.5 F.

Collector damper leakage is not a major energy concern, as it only occurs during the summer when the dampers are 100% in bypass mode. Leakage could result in a slight overheating of the corridors as the air from the preheater could be warmer than the outdoor air, especially on a sunny day. On the other hand, there did not seem to be significant leakage past the bypass dampers (see Figure 8). When the bypass dampers were in the closed position, the flow was 3,800 CFM at 84.1 F before the dampers, and 3,810 CFM at 83.9 F after the dampers. The outside air temperature was approximately 68 F.

PERSISTENCE OF ENERGY SAVINGS

Persistence of energy savings was evaluated by examining whether energy delivered towards the end of the project differed significantly from the beginning, to assess, for example, if dirt that accumulated on the collector and/or in collector perforations caused deterioration of the system's performance.

Two separate comparisons were performed (see Table 2). Energy delivered for each month was normalized by the amount of sun hitting a vertical surface. The amount of energy delivered in February 2006 was 4.0% less than the amount of energy delivered in February 2005. However, the amount of energy delivered in April 2006 was 13.6% higher than in April 2005. We conclude there is not a deterioration of energy delivered over time.

| | Avg Vert Sun [W/m^2] | Average Outdoor Temp [F] | Energy delivered [MMBtu] | Normalized Energy delivered [MMBtu per W/m^2] | % change |
|--------|-----------------------------|--------------------------------|--------------------------------|--|----------|
| Feb-05 | 105 | 28.6 | 15.0 | 0.143 | |
| Feb-06 | 93 | 28.7 | 12.8 | 0.138 | -4.0% |
| Apr-05 | 122 | 49.8 | 11.7 | 0.096 | |
| Apr-06 | 119 | 49.1 | 12.9 | 0.109 | 13.6% |

Table 2: Persistence of Energy Savings

MAINTENANCE

After 23 months of operation, an investigation was made to determine whether there was any scuffing or clogging of the preheater. A cherry picker was used to get 25 feet off the ground, and the preheater was examined. There was no evidence of scuffing or dust buildup on the surface that could reduce the effectiveness of the preheater. There were a few holes that were partially obstructed by what appeared to be small bits of Styrofoam. It is likely that the Styrofoam became loose in the vicinity of the preheater, was carried up by the wind, and was sucked into the holes. However, less than 1% of the perforations were even partially clogged, and the actual percentage was probably on the order of 0.5%. Styrofoam was only observed in the areas of the panel that were inspected.

No maintenance of the solar preheater was required over the course of the field investigation, other than to correct construction deficiencies and to deal with breakdowns in the air handler, which would have occurred, even without the solar preheater. For example, the induced draft fan in the air handler burned out

twice, so the furnace would not heat, and the unit had to be turned off. This problem was with the existing air handler and had nothing to do with the solar preheater.

INDOOR COMFORT

There were no complaints about overheating of apartments behind the preheater or of supply air or corridors being too warm, according to the facilities manager.

AESTHETICS

The facilities manager reported that he received no feedback (from tenants, staff, etc.) about the aesthetics of the preheater. He pointed out that, since it is out of the way (on a back wall), it was not aesthetically objectionable.

DISCUSSION OF SHADING AND AZIMUTH NOT DUE SOUTH

The A-wing of Almus Olver, to the southeast of the solar preheater, blocked some of the morning sun that would have hit the solar preheater. Shading is more of a factor with direct sun; according to the research literature and computer modeling, diffuse light is unaffected by shading.

Shading was measured a few times during the year to determine at what time the preheater was completely unshaded:

| Date | Beginning of Sun | Full Sun |
|-------------|-------------------------|--------------------------|
| March 17 | 30% exposed at 9:50 AM | 90% exposed at 11:50 AM |
| July 19, 20 | 35% exposed at 11:15 AM | 100% exposed at 11:50 AM |
| January 19 | 35% exposed at 11:15 AM | 90% exposed at 1:08 PM |

Table 3: Shading of Solar Preheater

According to computer modeling of the building and collector, the deviation of 35 degrees from due south had a moderate impact on total solar energy delivered. It is reported that “azimuth deviations from due south up to about ± 30 degrees result in penalties of roughly 15% of the due south value.” (David Ashley thesis¹, 2007)

¹ Ashley, David R. *Reducing Ventilation Energy Demand in Multifamily High Rise Buildings Through Preconditioning: Two Modeling Studies*. Masters Thesis, Cornell University, Ithaca, NY. 2007. Mr. Ashley’s thesis was conducted with a focus on the Almus Olver solar preheater project.

FURTHER EVALUATIONS OF SOLAR PREHEATER FEASIBILITY

Four other medium or high-rise multifamily buildings were examined analytically, to assess the potential for applying the solar ventilation preheater, potential costs, and potential savings. Construction costs were estimated on the basis of the Almus Olver project costs, assuming a fixed cost of \$11,300 and adjusting for each building on the basis of collector area and length of ductwork required. Energy savings were estimated using a method developed by Ashley², which accounts for collector height and width, air flow rate, R-value of building wall, temperature of the building, setpoint temperature of the supply air, collector orientation from due south, and various physical properties of the solar preheater itself.

The maximum area of each solar preheater was dictated by ventilation airflow rate. In order to maintain minimum velocity through the preheater, it was sometimes necessary to presume a preheater smaller than the available area.

A summary of modeling results is shown in Table 4. The buildings are real buildings in Syracuse (not Almus Olver), Batavia, Ithaca, and New York City. Estimated payback ranged from 28 years to 82 years, and averaged 46 years. These paybacks are without any solar tax credits or NYSERDA support.

The payback on the Syracuse building was hurt by the fact that the ventilation airflow is quite low, so only a small solar preheater is required. The resulting energy delivered also is low, but the cost of installing the wall is still significant due to high fixed costs. In addition, the preheater for the Syracuse building was assumed to be mounted on an elevator tower. Because of this, the temperature behind the exterior wall was lower than in the other buildings, and the amount of energy flowing through the exterior wall and recovered by the preheater was less than in the other three buildings.

The amount of energy recovered by the building in Ithaca was the highest of the four buildings due to the large available area and the favorable solar orientation. However, the payback was hurt by the fact that the air handler in this building is in the basement, requiring much more ductwork and subsequently higher construction costs than in any of the other buildings modeled.

The Batavia and New York City buildings both had similarly sized preheaters. The energy delivered at the Batavia building was greater than for the New York City building, but the New York City building showed a better payback because the price of natural gas was assumed to be higher: \$1.50 per therm vs. \$1.05 in Batavia.

| Description | Syracuse | Batavia | Ithaca | NYC |
|--|-----------------|----------------|---------------|------------|
| Ventilation Airflow, CFM | 1100 | 6000 | 5815 | 6000 |
| Length of Duct Required, feet | 60 | 154 | 240 | 110 |
| Solar preheater area, square feet | 275 | 693 | 1454 | 726 |
| Estimated Construction Cost, \$ | \$29,400 | \$57,400 | \$88,800 | \$47,800 |
| Orientation of wall | S 23 E | S 9 W | due S | S 29 W |
| Azimuth | -23 | 9 | 0 | 29 |
| Width Available, feet | 10 | 9 | 18 | 11 |
| Available Height, feet | 52 | 77 | 123 | 66 |
| Height of Solar Preheater, feet | 27.5 | 77.0 | 80.8 | 66.0 |
| Wall R-value | 8.0 | 0.6 | 8.0 | 14.0 |
| Natural Gas Cost, \$/therm | \$1.05 | \$1.05 | \$1.05 | \$1.50 |
| Efficiency of Gas Heater, % | 80% | 80% | 80% | 80% |
| Makeup Air Setpoint Temperature, F | 70 | 70 | 70 | 70 |
| Temperature Inside Building Under Preheater, F | 70 | 73 | 73 | 73 |
| Results | | | | |
| Heat Recovered, therms/year | 274 | 1210 | 1689 | 924 |
| Savings, \$/year | \$360 | \$1,587 | \$2,217 | \$1,733 |
| Payback, years | 82 | 36 | 40 | 28 |

Table 4: Summary of Solar Preheater Feasibility Modeling

POTENTIAL APPLICABILITY TO BUILDINGS IN NEW YORK STATE

In order to estimate the applicability of the solar preheater to existing multifamily medium- and high-rise buildings (four stories and higher) in the state, a sample of ten upstate and ten downstate buildings was examined. Each building was evaluated based on three criteria:

1. Does the building have a wall that faces south?
2. If so, does the wall have any significant areas that could be used for a solar collector?
3. If so, are these areas free from shading, whether shading by trees, adjacent buildings, or protruding portions of the building itself?

Interestingly, almost all upstate buildings successfully met these three criteria and would be candidates for solar preheaters, and almost all downstate (New York City area) buildings did not and would not be candidates for solar preheaters.

Of the ten upstate buildings, all have a south-facing wall, with two partial exceptions:

1. One is one of a twin set of buildings, and the building's twin does not have a south-facing wall.

2. One has two wings, each oriented 45 degrees from south. Each wing has 4400 SF of free wall space, with the total available collector area is so great that half of the collectors facing southeast and the other half southwest would be sufficient to supply ventilation makeup air heating needs when the sun is shining throughout the day.

All ten upstate buildings have significant wall areas that could be used for a solar collector, either blank stair tower walls or blank vertical sections of wall area between windows. One of the ten has a smaller area (660 SF) that is free from shading, and two larger areas (2,600 SF) each of which would be partially shaded by a stair tower (on the building itself) for portions of the day. Another building has protruding porches, which likely would shade the available collector area by less than 10%. All ten buildings generally are free from shading by trees or adjacent buildings: One 10-story building would be shaded on its lower two or three floors, but this still leaves sufficient unshaded area for a solar collector (1,800 SF). Another building, with 2,400 SF of available wall area, has four trees on the property that shade approximately 40% of the wall area and would need to be cut down or significantly trimmed to eliminate shading.

The New York City buildings examined present the opposite picture, with very little ability to use wall-mounted solar collectors. Interestingly, the biggest obstacle is not shading by adjacent buildings, but rather the high density of windows, which crowd out available wall space for collectors. Five out of ten buildings have so many windows that there is no free wall space. Though not a dominant obstacle, shading by adjacent buildings was still observed on three of ten buildings. In one case, a south-facing wall is entirely shaded by an adjacent high-rise. In two cases, significant shading of the lower portion of a building by adjacent buildings reduces the available wall area below what would make for a viable solar installation. Only two out of ten buildings have sufficient available wall area that is not shaded and would allow for installation of wall-mounted solar collectors. Of these two, one would require mounting collectors on east and west facing walls, as the south-facing wall is not available due to windows covering the wall.

On the basis of this limited sample, over 90% of upstate buildings, but only 10%–20% of New York City buildings, could be considered candidates for solar preheaters.

The manufacturer of the solar collector has recently developed a rooftop product that offers an alternative to the wall-mounted collector, and so could be an option where wall-mounting is not feasible.

CONCLUSIONS AND OVERALL PROJECT FINDINGS

The solar preheater and controls worked as anticipated and delivered energy savings as predicted. Annual energy savings were \$1,591 and could have been as high as \$1,733 if gaps had not been left in the collector assembly. Savings derive both from solar heating and from recapture of heat lost through the walls of the building. The cost of installation, which was bid out to contractors through a public bid process, was higher than anticipated. The actual cost was \$55,269, compared to the original projection of \$22,100. However, the observed duration of the installation (less than two weeks), manpower required (two people on site), and known material costs indicate that the construction cost could have been far lower than what was bid. We estimate that in a mature market, if bidding contractors were familiar with the technology, the installation cost would have been \$38,300, for a simple payback of 22 years without any solar tax credit or NYSERDA funding.

Energy savings were measured to persist over the period of monitoring; in other words savings did not deteriorate over time. Visual observations made after a year of operation showed no significant scuffing of the solar panel or clogging of its metal perforations through which the air flows. The controls, integrated with the existing ventilation system, appeared to work well.

Several issues arose relating to quality of the installation. Undesirable holes and gaps were left in various locations of the collector and plenum, inadequate fastening of sheet metal in the same plenum caused it to come loose in a strong wind, and exterior duct insulation came loose. Despite these problems, the system still delivered savings close to what had been predicted. However, the problems point to the need for quality control when installing a new technology.

A variety of issues were evaluated parametrically:

1. Damper leakage was measured and found to be negligible on one of two sets of dampers (the bypass dampers) but unacceptably high on the second set of dampers (collector dampers), indicating another area for caution during installation and a need for commissioning.
2. The modulating bypass damper control was found to work effectively.

No maintenance of the solar preheater was required over the course of the field investigation. There were no comfort complaints relating to the operation of the solar ventilation preheater during the course of the field investigation. The aesthetics of the solar collector were found to be acceptable by the building owner.

An analysis of the application of the solar preheater technology to four additional buildings determined that the technology is broadly applicable to other buildings, even with variations in building type and orientation. However, building-specific conditions can increase the construction cost relative to savings.

To install the collector on existing buildings, several characteristics of an existing building make consideration of the technology more appropriate:

1. Substantial contiguous south-facing (or close to south-facing) wall area.
2. Existing makeup air system, preferably roof-mounted, with modulating supply air temperature control (preferably gas-fired) and preferably not too far from the potential collector location.

A sample of existing high-rise multifamily buildings around New York State was examined for potential applicability of the solar ventilation preheater. Upstate buildings were found to offer more options for available wall area and absence of shading. We estimate that the preheater could be installed on over 90% of upstate multifamily buildings but less than 20% of New York City buildings. The manufacturer of the solar collector has recently developed a rooftop product that offers an alternative to the wall-mounted collector, and so could be an option where wall-mounting is not feasible.

For information on other
NYSERDA reports, contact:

New York State Energy Research
and Development Authority
17 Columbia Circle
Albany, New York 12203-6399

toll free: 1 (866) NYSERDA
local: (518) 862-1090
fax: (518) 862-1091

info@nysERDA.org
www.nysERDA.org

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STATE OF NEW YORK

DAVID A. PATERSON, GOVERNOR

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

VINCENT A. DELORIO, ESQ., CHAIRMAN

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