NightSolar® - More than Solar

Solar Heating & Cooling

A NightSolar® system provides year round usage with winter heating and summer cooling. NightSolar® utilizes the most efficient and proven solar technology, the SolarWall® transpired collector, in an unique configuration to also take advantage of nocturnal radiation cooling, a previously ignored cooling phenomena. This unique design has additional benefits as it ventilates and shades the roof covering the main roof in darkness all day long and preventing unwanted summer heat from reaching and conducting through the roof. With most roofs responsible for half of the cooling load, a NightSolar system in many cases can reduce the cooling equipment size in half and the associated energy costs.

Roof shading

Roofs can reach 160°F (71°C) in the summer sun and that heat will conduct through the roof at the rate of 160°F (roof temp) – 75°F (indoor temp) x U factor (heat transfer rate which is inverse of R insulation value) = Btu/h.ft2 of roof area. Covering the roof with NightSolar panels shades the roof and lowers the roof temperature to within a few degrees of ambient (see fig.4) which means the heat transfer rate through the roof and corresponding daytime cooling demand is now reduced by as much as 70°F.

Above Sheathing Ventilation (ASV)

Oak Ridge National Laboratory (ORNL) states *"we serendipitously discovered the second major advance in roofs for our century: We found that elevating the roof cover from the roof deck to induce above-sheathing ventilation is as important as increasing solar reflectance and may be the stronger player in reducing heat gain into the attic. The two combined can reduce heat gain through the roof by 50% compared to nailed asphalt shingle roofs."*

NightSolar ventilated roofs prevent unwanted solar gain reaching the building and the solar heat dries any condensation or moisture that may have accumulated on the roof. NightSolar takes ASV one step further by not only ventilating the roof but doing it in a manner that either collects or expels the heat depending on the season and time of day. It incorporates a ventilated roof design which has precision micro perforations to collect or discharge the heat or cold boundary layer. A recent field monitored project in Europe is reporting as much as a 50% overall cooling savings on telecom buildings using existing fans and economizers.

Ventilated steep slope roofs rely on thermal stack effect to remove heat. Low slope roofs with long roof runs have insufficient height to remove heat whereas the NightSolar system is vented over the entire surface which eliminates the problem associated with ASV for low slope roofs.

Free Night Cooling

Nocturnal radiation cools roofs as much as 18°F (10°C) below ambient on clear nights and the chilled air adjacent to the roof has the ability to reduce or even displace conventional air conditioning from sunset to sunrise. As warm night air touches the cooler surface of the collector, it transfers its heat to that surface and the cooled air is then drawn in through the perforated surface.

NightSolar® cooling, developed by the inventors of SolarWall, is the first commercially available product that has been specifically designed to take advantage of this free sky energy to cool buildings.

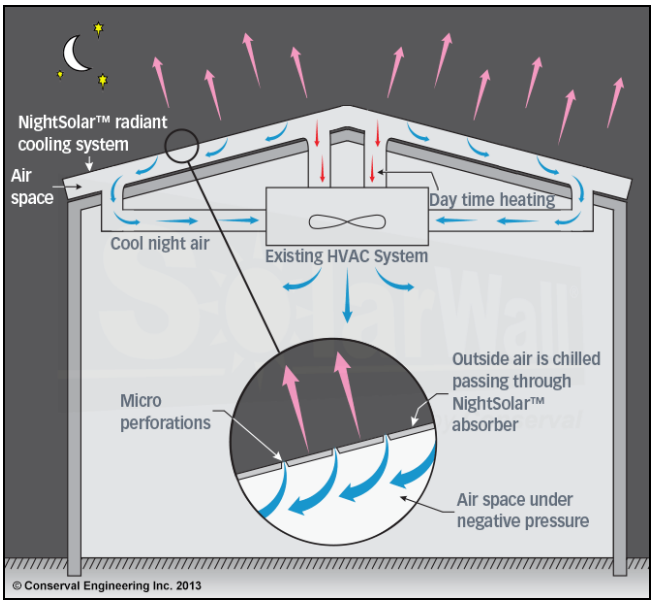

Figure 1: Night cooling air drawn off bottom and winter solar heated air drawn off top

Figure 2: Typical metal roof installation

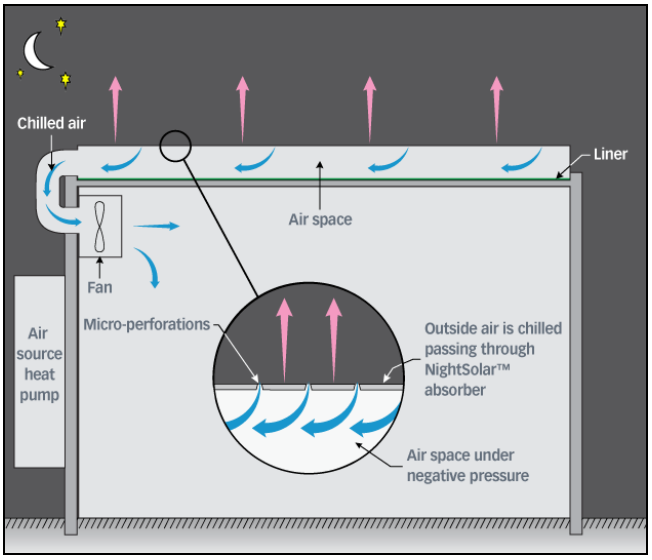

Figure 3: Typical flat roof installation connected to fan or HVAC unit with economizer cycle

NightSolar® Energy Savings are a combination of multiple Heating and Cooling benefits:

Heating Savings

1. **Solar Energy for Space Heating**
   The solar heating savings are calculated in RETScreen once the building location, dimensions and orientation are known.
2. **Roof Insulation**
   The creation of a second roof with an air cavity above the main roof increases the insulation value by R3 and creates a thermal break, especially important for metal roofs. This benefit applies year round for both heating and cooling seasons.
3. **Roof Conduction Savings**
   During the heating season, air moving over the roof collects essentially all thermal losses from the roof and returns it to the building as preheated air. At night, the main roof is also shielded from nocturnal radiation cooling which reduces heat loss through the roof.
4. **Destratification Savings**
   When installed with SolarWall fans and distribution ducting or in conjunction with other destratification fans, the continual air mixing of the solar heated air within the building minimizes or eliminates heat stratification between ceiling and floor.
5. **Hot Water**
   Any excess heat not used for space heating can be utilized for other purposes such as hot water heating via an air to water heat exchanger. The hot water usage is determined separately from the space heating load and is ideally suited to buildings located in warmer climates or if traditional solar hot water collectors are not suitable for the existing roof.

All of the above heating savings are easily calculated in RETScreen software available from Natural Resources Canada. (www.retscreen.us) Solar heating savings apply during the heating season months which vary between three and ten months depending on location.

Cooling Savings – Capital and Operating

1. **Shading roof from solar radiation reduces cooling capital costs by as much as 50%**
   The solar heating savings are calculated in RETScreen once the building location, dimensions and orientation are known.

(**Capital cost savings** can be calculated as follows:
Roof temperature of a 50,000 square foot building with R8 effective roof insulation covered with NightSolar panels is reduced from 160°F to 100°F for a 60°F reduction in solar load on roof. Heat load removed from HVAC system is (50,000 x (160-100) x 1/8)/12,000 = 31 tons. At $2,000 per ton, capital cost savings would be $62,000.)

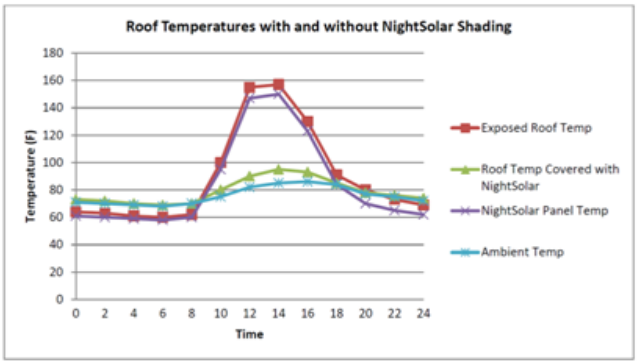

Figure 4: Roof temperatures with and without NightSolar panels shading a typical low slope roof

2. **Roof Conduction Savings**
   The savings by reduced conduction through the ceiling can be calculated as follows:
   It takes approximately 1.3 kW / hour to operate 1 ton of air conditioning. Assume 2000 hours per year at 15¢/kWh.
   Projected yearly cooling savings from roof shading is; 31 tons x 1.3kW x $0.15/kWh x 2000 hr = $12,090/yr
3. **Above Sheathing Ventilation**
   Oak Ridge National Laboratory found that above-sheathing ventilation and solar reflectance can reduce heat gain through the roof by 50%. A NightSolar

monitored installation has also confirmed the 50% overall cooling savings on a building. ORNL tests have also concluded that above sheathing ventilation provides an additional 200% cooling savings when compared with just cool roof colors.

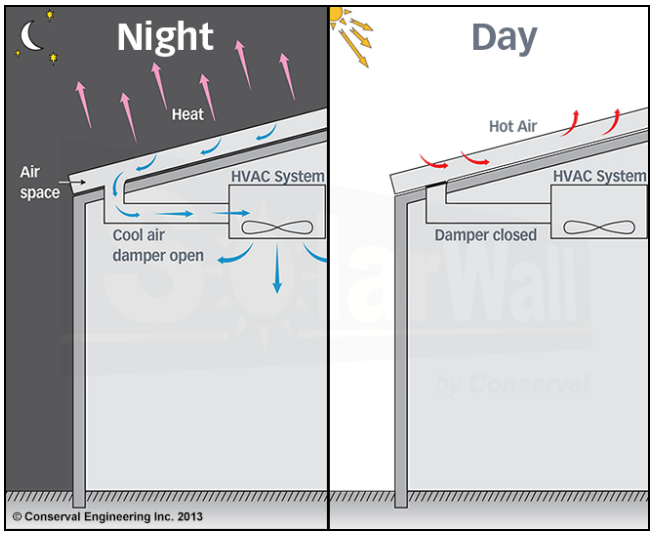

Figure 5: Summer Night cooling and Summer Day time roof shading operation

A NightSolar ventilated roof prevents unwanted solar gain reaching the building and the unwanted solar heat is naturally vented while drying any condensation that may have occurred on the roof or within the air cavity.

ASV also provides a benefit during the winter heating season and negates the heating penalty associated with cool roofs as the air space is an insulating buffer against heat loss to the night sky in the winter.

4. Cooling of ambient air at night

Radiation cooling to the night sky is based on the principle of heat loss by long-wave radiation from a warm surface (roof) to another body at a lower temperature (sky). On a clear night, a typical sky-facing surface can cool at a rate of about 25 BTU/hr.ft2 (75 W/m2). This means that a metal roof facing the sky will be colder than the surrounding air temperature, from 10°F to 36°F (5°C to 20°C) colder. Tests confirm that on clear nights at a ventilation rate of 2 cfm/ft2 of roof surface, the air is cooled an average of 5°F to 10°F (3°C to 5.5°C) below ambient from sunset to sunrise in the Great Lakes region.

The ASHRAE Handbook (2011) references cooling by nocturnal radiation and provides numerous maps illustrating the energy savings potential. See figure 7 for cooling potential in USA for July.

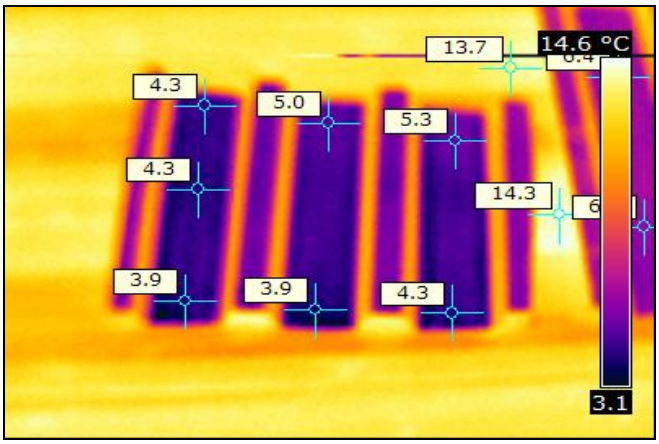

Figure 6: Panel temperature at night (infra-red camera) confirms ASHRAE value for Great Lakes area of 10°C (18°F) roof cooling below ambient

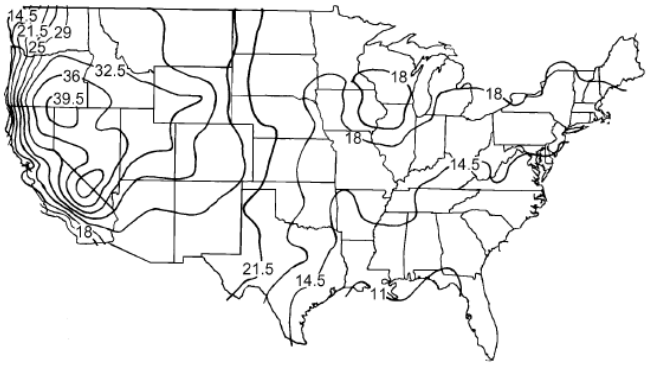

Figure 7: Average monthly sky temperature depression for July °F (ASHRAE Handbook 2011)

Over a 10 hour night in U.S.A. depending on the climate and location, the nightly average air cooling for the month of July can be 12 Btu/h.ft2 which means 1 ton of cooling is possible with 1000 ft2 of panels. Using the example of a 50,000 square foot building, the NightSolar system can displace 50 tons of cooling from sunset to sunrise. Assuming 800 hours of night cooling operation, the cost savings at 15¢/kWh is 50 tons x 1.3kW x $0.15/kWh x 800 hr = $7,800/yr.

Total cooling savings for a 50,000 ft2 building are:
Capital savings: $62,000
Operating savings: $12,090 + $7,800 = $19,890 per year

Now it is possible to obtain year round renewable energy savings with winter heating and summer cooling using the same panels and same ventilation or HVAC system.