INTRODUCTION

A number of solar energy systems are cost competitive for industrial applications, however, few industrial energy and facility managers know very much about solar energy technology. The most known solar technology is photovoltaics (PV) to produce electricity. However, until factories get credit for emission reductions at the boilers their utility owns, PV has no role in helping companies comply with emission reduction limits. Solar thermal systems can make boilers more efficient and reduce thermal loads they need to meet and have potential to help companies make their boilers and processes more energy efficient.

A Solar Industrial Process Heat program existed, but the U.S. Department of Energy abandoned it in the early 1990s. Thus ended already meager outreach on solar to industry. Cost competitiveness was an issue at the time due to low cost coal and, until the mid-2000s, a low price of natural gas. Another factor was that DOE was primarily focused on high temperature applications, for example, parabolic trough concentrators, and paid little attention to low temperature applications where solar systems were much more competitive. Glazed flat plate and concentrators technologies had difficulty meeting the payback criteria common among industrial decision makers.

Higher prices for gas have shifted the competitive environment. In addition, more stringent emission limits for boilers could well make solar cost competitiveness less a road block. Based on previous difficult experience marketing to industry, the solar industry needs to:

1: Overcome the fact that so few industrial solar energy installations exist,

2: Undertake effective outreach to the industrial sector about solar technologies that can deliver thermal energy at lower cost than fossil fuels,

3: Understand what is driving industry decision making related to the environment and energy sources,

4: Understand the cost to industrial and institutional boiler operators of complying with emission regulation and expressing them in a way to facilitate analysis of return on investment for solar energy systems,

5: Look for allies to help make government regulatory policies give industry and institutions adequate compliance credit for investments made in solar technologies to cut emissions.

Solar Energy System Applications

- Boiler combustion air heating
- Process water heating, low, medium and high temperature
- Steam production
- Building and laboratory ventilation
- Space heating
- Drying
- Nocturnal heat rejection <
- Boiler make-up water pre-heating <
- Refrigeration
- Cooling intake air temperature for gas turbine cogenerators
- Space cooling

Solar Collector Technologies for Industrial Applications

- Transpired air collectors
- Unglazed flat plates-- Metal, EPDM, Polypropylene
- Batch/Integral Collector Storage
- Thermosiphon
- Glazed medium temperature flat plates, hydronic and air
- Evacuated tube
- Parabolic trough
- Parabolic Dish
- Daylighting
- Solar pond
- Solar rejecting systems, radiant barrier, sunscreen, reflective coatings
- Sheet glass and passive solar buildings
- Photovoltaic flat plates and concentrators

SOLAR THERMAL ENERGY TECHNOLOGIES

SOLAR COLLECTORS

Flat plates
- Air
- Hydronic
- Evacuated tube/heat pipe

Concentrators
- Parabolic Troughs
- Parabolic Dishes
- Central Receivers
- Fresnel Lens

SOLAR THERMAL SYSTEM OUTPUT
- Heat for liquids or gases
- Cold Air or Liquids
- Steam
- Electricity

Dishes are mainly used for powering Stirling engines, Central receivers for utility scale electric power, Troughs for industrial process heat, water heating and electric power production

Range of temperatures delivered

Unglazed	10 - 50 deg F above ambient
Air collectors	50 - 160 deg F
Glazed flat plate	100 - 190 deg F
Evacuated tubes	120 - 240 deg F
Parabolic troughs	150 - 700 deg F

System Cost/square foot, installed

Unglazed hydronic panels	--- $ 12 - 15
Unglazed air collectors	--- $ 10 - 17
Glazed flat plate	--- $ 65 - 85
Evacuated tubes	--- $130 - 160
Parabolic troughs	--- $ 55 - 65

As output temperature rises, solar collector efficiency drops.
The drop is much lower for concentrating collectors.

LOW TEMPERATURE APPLICATIONS ARE THE LEAST COSTLY AND MOST EFFICIENT SOLAR THERMAL SYSTEMS. THEY ARE THE STARTING POINT FOR ECONOMIC APPLICATION OF SOLAR.

ADDING SOLAR THERMAL SYSTEMS TO A STEAM EFFICIENCY PROGRAM CAN SUBSTANTIALLY INCREASE SAVINGS

Potential Savings in Well-Managed Steam Systems

Boiler Tune-ups	1 - 2%
Heat Recovery Equipment	2 - 4%
Emission Monitoring & Control	1 - 2%
Traps Maintenance	3 - 5%
Insulation	5 - 10%

Solar Thermal Savings Potential
A typical solar thermal system design that aims to employ solar collectors most efficiently with regard to seasonal factors will generally offset 50 to 65% of an end use thermal load.

Two Approaches:

1: Make the boiler itself more efficient

2: Solar heat process and boiler served building loads to reduce fuel consumption

COMMERCIAL SOLAR THERMAL INSTALLATIONS

Solar Heating System with Unglazed Panels for Commercial Pool

Generator Heating Collector Built on Chain Link Fence, USPS Bolger Training Center, Maryland

Atlanta Solar Heating System for Olympic Pool Also Rejected Heat at Night to Maintain Temperature

Solarwall Transpired Collector Ventilation Air Heating System

American Solar Boiler Combustion Air Heating US Geological Survey, Reston, Virginia

BOILER COMBUSTION AIR HEATING

Every 40 degrees F. one raises boiler combustion air temperature increases efficiency of an operating boiler by 1%

Calculated Efficiency Gain:

Gas-fired boiler with net stack temperature of 370 deg F. and 5% O2 in the flue gas.
Under these conditions, boiler efficiency is 1 - 19.6% = 80.4%

Raising the combustion air temperature by 40 degrees F lowers net flue gas temperature to 330 deg F. Now boiler efficiency, still with 5% O2, is : 1 - 18.5 % = 81.5 %

System efficiency gain is expressed as 80.4 / 81.5 = .987

If the boiler were consuming 100,000 units of energy, adding combustion air heating will cut consumption to 98,700 units, a 1.3% savings in cost.

Using solar energy to preheat the boiler air could reserve recovered energy from a stack economizer to use for feed water heating, where every 10 degree F rise in temperature can raise boiler efficiency as much as 1% in systems with low condensate recovery.

Note: Higher combustion temperatures increase NOx emissions.


National Geological Survey HQ, Boiler Plant Solar Heating

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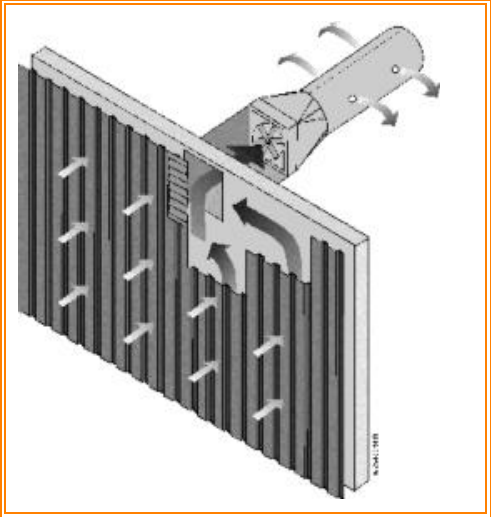
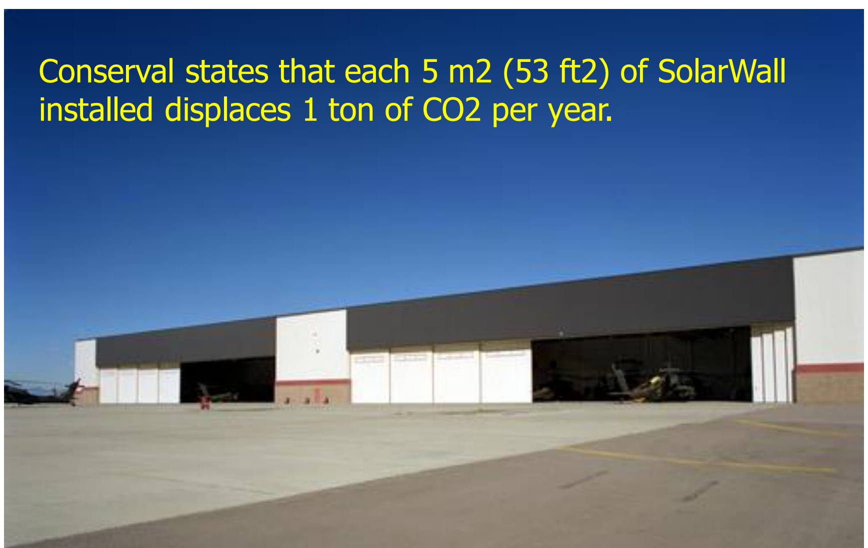
SOLAR THERMAL TRANSPIRED COLLECTORS FOR PREHEATING VENTILATION AIR



Conserval installations included a 1990 project with a 50,000 square foot SOLARWALL system on a Ford Motor Company Buffalo, New York, stamping plant. This particular installation covered the SOLARWALL with a glazing material to raise the output temperature. 25 fans and 5500 feet of fabric ducting deliver 350,000 cubic feet per minute of air to the building. This system cost $615,000 about 20 years ago, and was saving $194,000 per year.

The Federal Energy Management Program has cited a GM installation in Canada with 4520 ft2 of SOLARWALL delivering 40,000 cfm. The system cost $14.72 per ft2 to install, for a total of $66,530. Savings equaled 940 million Btu per year, 678 million from the heated air, and 262 million by recapturing heat loss from the wall. If the HVAC system delivered energy costing $9.00 per million Btu, the savings would amount to $8460 per year. Federal investment incentives would reduce the initial cost to less than $60,000, and depreciation would make the payback close to 6 years.

The U. S. Air Force has installed 10 of the solar wall structures at eight Air Force bases in the past six years.



MINING EXISTING WALLS FOR SOLAR HEAT

Over Dock Door
Heating Ducts

Dock Ceiling
Duct Outlets

Interior Plenum Outlets

CAPITAL SUN GROUP
6503 81st Street, Cabin John,
MD 20818 301 229-0671

SOLAR AIR HEATING SYSTEM DESCRIPTION

Capital Sun Group installed a solar energy system to contribute to space heating for the US Postal Service Processing and Distribution Center in Merrifield, Virginia. The system was fabricated using a concept developed by American Solar, Incorporated. Instead of installing new solar thermal panels, the system uses the existing metal wall on the roof near the South Dock of the building as the solar collector. Heat that builds up behind the existing wall when the sun shines on it is extracted and routed to the ventilation air duct that brings in outside air to a hot water fired air handler that is dedicated to the South Dock area in the building

Solar Heat Source:
The wall space converted to a solar collector has 15 metal panels that are 68 3/4” wide by a nominal 12 feet long. The actual construction consists of 6 inch wide sections. The total collection area amounts to 1031 square feet and it should be capable of delivering 100 Btu/ft2/hour, hence ~100,000 Btu per hour for the wall. During the planning stage for the project, a site visit conducted in April 2007 measured a wall a skin surface temperature of 122 degrees on a sunny day with ambient temperature near 78 degrees. The air pulled from the inside the wall cavity was 116 degrees.

To extract hot air from the interior of the wall, the metal wall panels are perforated outside to draw air into an insulated duct that traverses the exterior of the wall. A fan inside the building attached via a duct to the solar plenum extracts the heat. A solar differential temperature controller operates the system by sensing the wall air temperature and the temperature of the outside entering one of the building ventilation air ducts for the South Dock. The solar system uses a bulb thermostat to override the solar control when the ambient temperature is high enough that the building does not require the incoming air to be heated.

Solar Collection: Capital Sun installed the American Solar designed hot air plenum on the exterior of the metal wall because access to the inside surface was restricted. Each of the metal wall panels has a 6 inch diameter hole drilled into it. Eighty five of these holes span the 100 foot distance. The total area of the openings is 150.2 square inches. The plenum is constructed so that it balances the air flow from the entire wall by dividing it.

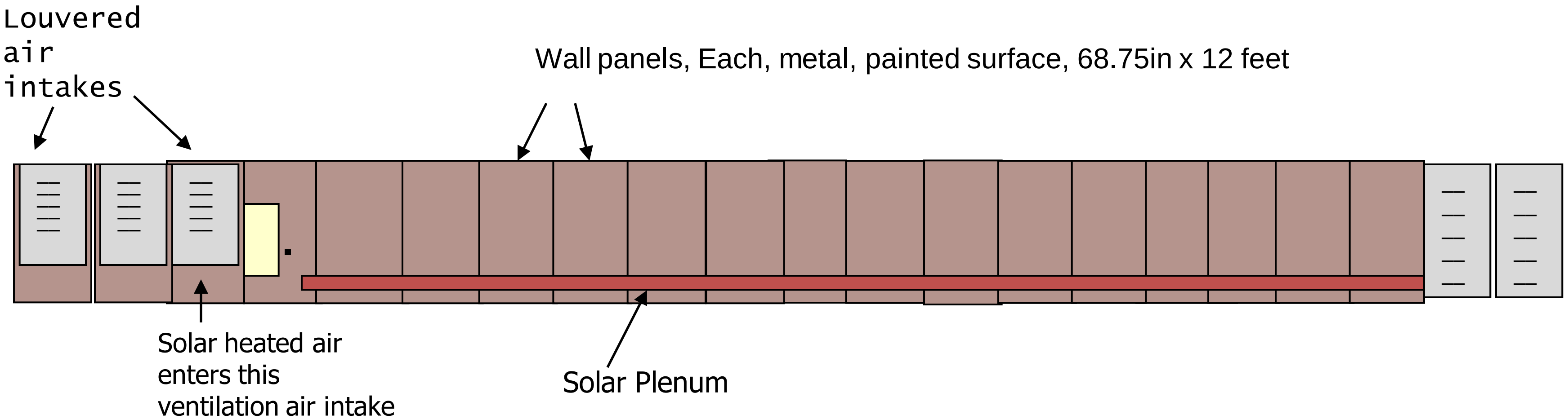
MERRIFIELD SOLAR AIR HEATING SYSTEM SPECIFICATIONS

- Solar Collecting Wall Dimensions: 86 feet by ~12 feet
- Energy Delivery: 15 metal panels, each 68.75in wide by 12ft long.
- The total collection area of 1031 square feet should be capable of delivering 100 Btu/ft^2/hour, or 103,000Btu/hour.
- Nominal Air Flow: 1000 cfm
- Fan: Fantech Model FKD 12 XL
- Solar Control Independent Energy GL30 Differential Controller, w 10,000 ohm sensors
- Solar Plenum Materials: 24 gauge galvalume steel, pre-painted with Kynar or Hylar to match building color from Metfab or MBCI, 8" x 3.75"
- Plenum Orientation: Outdoor plenum located 15 to 24 inches above the brick concourse at the base of the metal wall
- Draft Loss: 1.00 inch H_2O

Interconnection

The strategy employed directs solar heated air from the wall into the existing air flow system, not to a small specific area in the building. The solar duct feeds heat to the fresh air intake of an air handler that serves the South Dock working area. The air handler is heated with hot water from the building boilers. The air handler that is solar assisted is located within 8 feet of the outside roof access door where the solar heated air is pulled into the building with the fan unit. Two large distribution ducts exit the air heating unit, one delivering air to outlets over the doors, the second delivering air to long round registers hung from the ceiling.

EXTERIOR SCHEMATIC

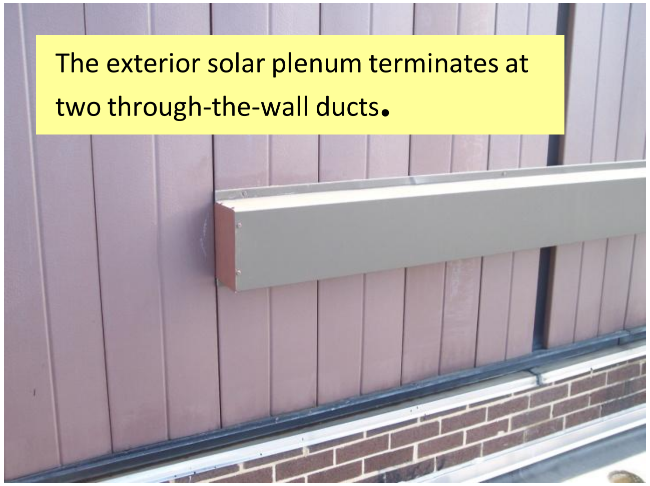


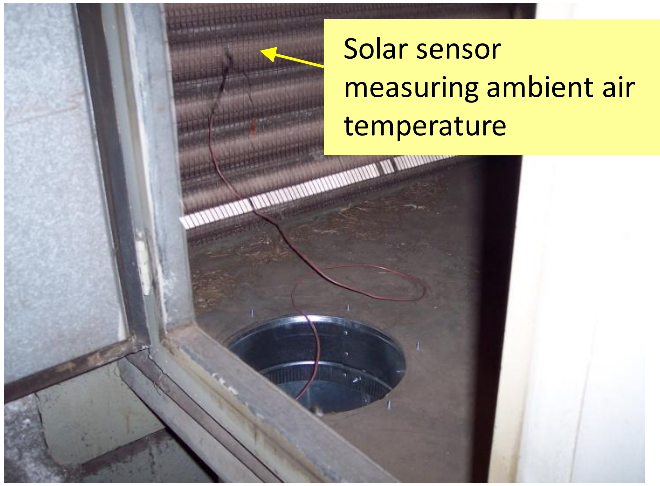
Due to a significant obstruction of the interior surface of the wall, the solar air heating plenum was installed outdoors at the base of the wall. The dark blue rectangle shows the outdoor location.

The plenum duct employs a interior baffle to create two passages in the duct to balance the draw of heated air all along the plenum. From the middle section, the interior of the plenum is divided into two ducts, one fed by half the wall panels on the east end, the second fed by the remaining half of the panels.

The baffle divided solar heat plenum has two openings through the wall, one for the east section of the wall and the second for the west section.

Solar System Sensors

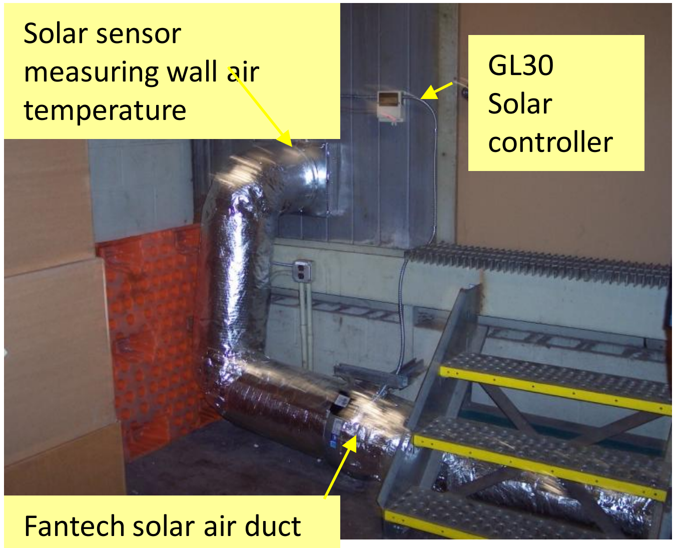




The solar GL30 differential controller has two temperature sensors. The "Tank" sensor for the load is mounted in the ventilation air intake right where the outside air enters the louvers.

The "Solar" sensor for the collector is mounted inside the wall in the solar plenum duct. When the outside air ("tank") is 12 degrees colder than the wall heated air (solar collector), then the controller turns on the solar fan to draw air from the wall and feed it into the air intake duct that feeds the space heating air handler.

A Honeywell T6031 Refrigeration Temperature Controller (Not Shown) has been added to the system to interrupt the solar collector sensor input to the GL30 solar controller when the ambient temperature is above 60 degrees F. This prevents the solar wall from sending hot air when the building has no heating load.



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FABRICATED METAL WALL FOR VENTILATION AIR HEATING
AMERICAN UNIVERSITY

Fabricated air heating systems will cost $12.00 per square foot or more to install.

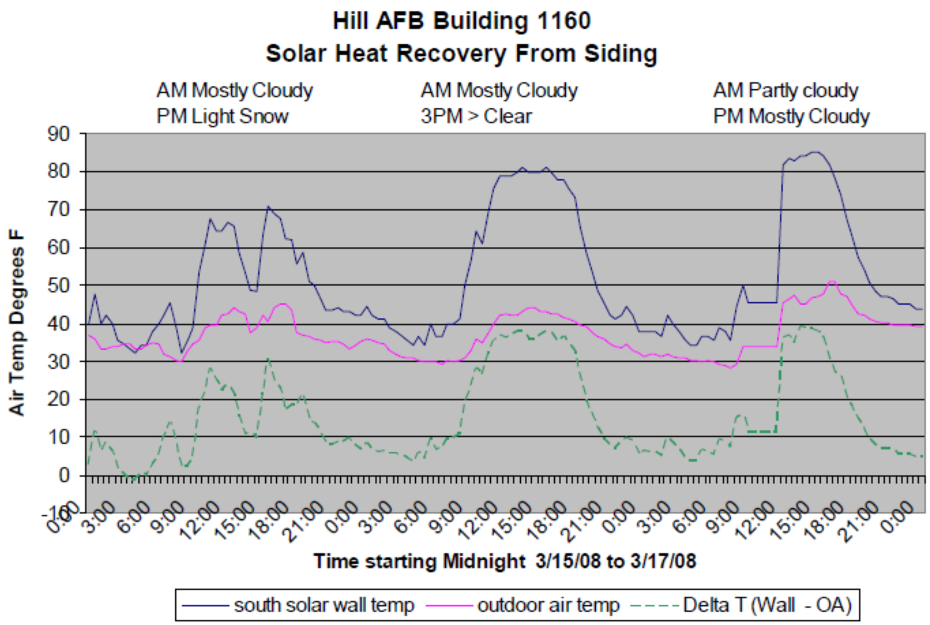
This site built collector delivers 150,000 BTU/sq ft/yr for year round applications.

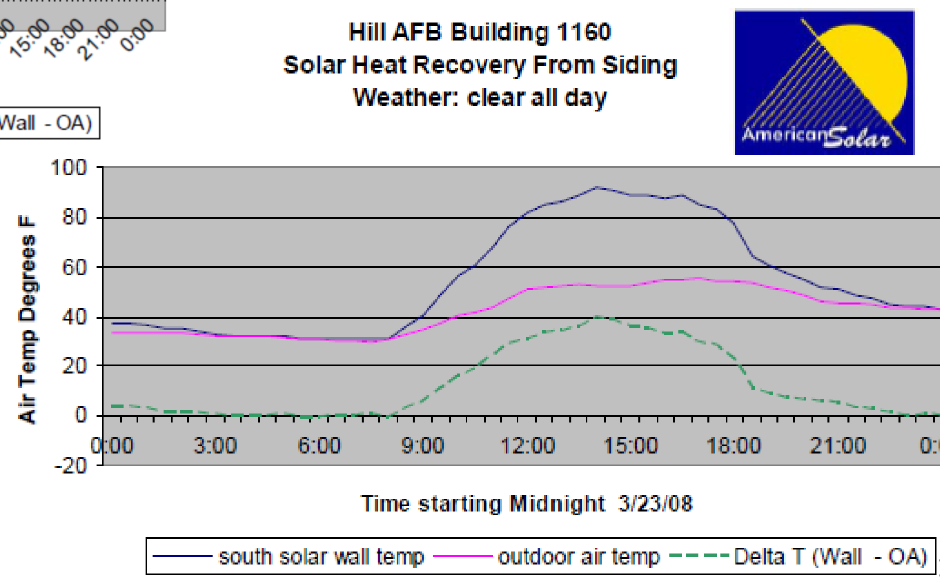
Output is 75,000 BTU.sq ft/yr winter only applications

Typical operating temperature is 40-50 F above ambient temperature
Maximum Btu are delivered when operating at 10-20 F above ambient
15 year delivered cost of energy = $4.00 per million BTU

Capital Sun Group

The graphed data below was collected from an Air Force installation on March 23, 2008; a sunny day with winds varying from 3.5 to 16 miles per hour. Outdoor temperatures varied from 30F in the morning to 55F at mid day. Sunrise and sunset were 7 AM and 7 PM local daylight savings time. A local solar monitoring station showed solar insolation levels peaking at 950 Watts per square meter at mid-day





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REROOFING BUILDINGS CAN CREATE SOLAR THERMAL HEATING SYSTEMS

- Solar metal re-roof over central portions of roof
- Conventional metal roof panels retrofit over membrane
- New membrane around perimeter and equipment
- Vents and fans carried up through new roof or replace vents with shorter vents to fewer fans

A solar thermal roof is eligible for a 30% federal tax credit and 5 year depreciation

- ~$600,000 installed cost of solar roof, before taxes
- $260,000 total tax savings
- $40,000 per year energy savings
- Breakeven in 2.5 years versus non-solar option
- Roof pays for itself in 8 years from energy and tax savings

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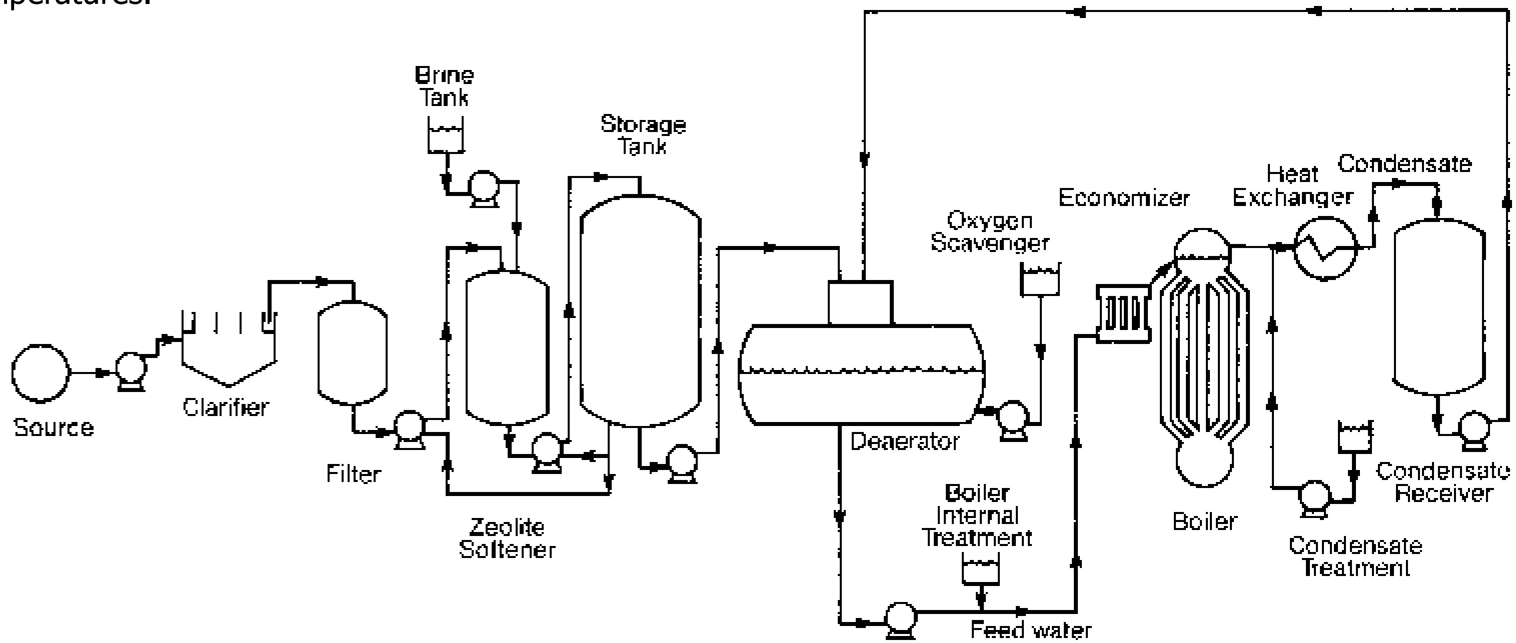
BOILER EFFICIENCY GAIN BY MAKEUP WATER HEATING

When one can recover heat from another source, feed water is one of the best streams in which to inject it. The higher the temperature of the feed water going to the boiler, the more efficiently a boiler operates.

"For every 10 deg F rise in boiler feedwater temperature, there is approximately a 1% savings in fuel."
Steingress and Frost: *High Pressure Boilers*

A number of considerations determine how solar can be integrated into a boiler system. Typically, solar heating of make up water would reduce the steam load at the vent condenser or open deaerater. Even low temperature Btus contribute to less fuel consumption by raising the temperature of the source water. Depending on boiler size and the load requirements, solar thermal technology options are varied because different types of collectors offer a wide range of output temperatures.



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SOLAR POTENTIAL AT A CORN ETHANOL PLANT

Two Gas Boilers, Run At 30,000 To 35,000 Lbs Of Steam Per Hour

5 Mwe CHP Turbine Delivering Electricity And 20 Psi Steam

Load is 79 To 80,000 Lbs Per Hour At 120 Psi
Condensate Recovery is 75 To 80 % Returned at 140 Deg F.

TWO IDENTIFIED APPLICATIONS

1: Pre-heat boiler make-up water

RO units consume 80 gallons per minute of well water
Ground water temperature is 57 deg f

Heating water from 57 to 180 degrees requires ~4.9 mmbtu per hour
A medium temperature solar thermal system could contribute 60 to 70% of this energy

2: Heat corn feedstock, especially in winter

42,000 bushels throughput per day = 2,352,000 lbs / day

Shelled Corn is 56 pounds per bushel (US Standard)
Normandy Giant crossed with Gardner, Avg specific gravity is 1.1736

Targeted 50 deg F. temperature rise = Corn heating load from 50 to 100 mmbtu per day

The RO water heating was a fairly obvious application. The idea of heating the feedstock for the ethanol plant originated with the plant engineer responsible for the boiler system. In short, not so obvious, viable solar applications can be found in many facilities.

UNGLAZED HYDRONIC SOLAR PANEL APPLICATIONS

The first low temperature solar technology choice for make up water heating is unglazed solar panels commonly used for heating swimming pools. They are the least expensive and operate at high efficiency, 70 to 80% solar radiation to heat, because they operate at near ambient temperatures.

Solar Array -- Polymer olefin or EPDM flat plate, unglazed panel

Tested Output -- Can be as high as 1014 Btu/ft2/day (Florida Solar Energy Center)
Solar Collector Efficiency solar energy to heat flow at 2 gpm = 70 %
flow at 4 gpm = 80 %

Unglazed polymer panels are capable of delivering water at temperatures 20 to 30 deg F above ambient air temperature.

Unless drainback configured, system would operate only in non-freezing months.

Small retrofit swimming pool heating systems typically have simple paybacks of 3 to 4 years when replacing natural gas. Panels have 10 to 15 year performance guarantees.

EPDM panels can have transparent covers added to them at modest cost to make a higher temperature collector and extend operations through winter months. This has rarely been applied, however.

A typical application would be to supply solar heated make-up water to a deaerator in parallel with condensate and condensing turbine condensate.

A 5000 square foot array would have an estimated overnight cost of $40,000.
A system this large could deliver 2.73 billion Btu from April to October in the mid-Atlantic climate.

COMPETITIVENESS OF UNGLAZED HYDRONIC SOLAR PANELS

Solar Rating and Rating Corporation Performance	Highest rated, polymer olefin solar panel	
		= 1042 Btu/ft2/day
Mid-Atlantic Region Assumptions	Panel output	= 900 Btu/ft2/day
April – November Insolation		= 5.5 peak hours per day
Operate 270 days		= 243,000/Btu/ft2/partial year
System thermal losses of 10% gives reduced yield		= 218,700 Btu/ft2/partial yr
Installed cost per square foot, collector only, no storage		= $7.35 (Net incentives)
Cost of delivered energy in year 1		= $33.61 per million Btu [$3.66/Therm]
Cost of delivered energy over fifteen years,		= $2.24 per million Btu
Industrial delivered gas, Average YTD 2010 price		= $5.86 per million Btu

Solar estimated cost could be higher depending on pumping and control, and if storage is included

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EPDM INDOOR POOL HEATING SYSTEM

Solar return pipes   Water to water heat exchanger

SAVINGS ESTIMATE FOR MAKE UP WATER HEATING

An unglazed solar thermal panel system can supply make-up water to a deaerator in parallel with recovered condensate.

A 30,000 square foot array would have an estimated overnight cost of $300,000. Energy output from April to October would amount to 55,370 therms.

30% Federal tax incentive lowers system cost to $210,000. Depreciation lowers first year corporate taxes at a tax rate of 35% by $17,340. Combined, the first year cost of the solar system equals $192,660.

First year net cost of 55,370 therms equals $3.47 per therm.

Fives years of depreciation at a 35% corporate tax rate comes to $89,250. Net system cost drops to $120,750.

Five years output equals 276,850 therms. Post-incentive capital cost per delivered solar thermal energy comes to $0.44 a therm. Maintenance costs and pump operation will raise this a few cents per therm.

Solar heated water is injected just in front of recirculation loop heat exchanger Based on typical flow rates, one can expect about a 6 degree F temperature rise per pass of a quantity of water through a single pool heating panel. Collector efficiency depends on the flow rate as well as incoming water temperature and ambient conditions. For unglazed panel applications, with a faster flow rate, 4 gpm, for example efficiency can be 80%. Slowing the flow rate to 2 gpm would lower the conversion efficiency to 70%, but deliver hotter water.

MEDIUM TEMPERATURE COLLLECTORS WITHOUT PUMPS AND CONTROLS

The simplest solar collectors for medium temperatures consistent with service water heating are the batch heater that the solar industry has named an Integral Collector Storage Collector, and a Themosiphon collector.

A batch heater stores water in the collector itself.
A thermosiphon water heater has the tank installed above the panel and solar heating forces circulation.

These systems are most prominent in areas with non -freezing climates because they are primarily "Open" systems. The water heated passes through the collector and then into the plumbing system. Thermosiphon collectors can be made with a heat exchanger to protect the panel from freezing.

Images courtesy of SunEarch Inc.

Capital Sun Group

GLAZED FLAT PLATE COLLECTORS

The glazed flat plate collector is the workhorse of the solar water heating market segment in the United States.

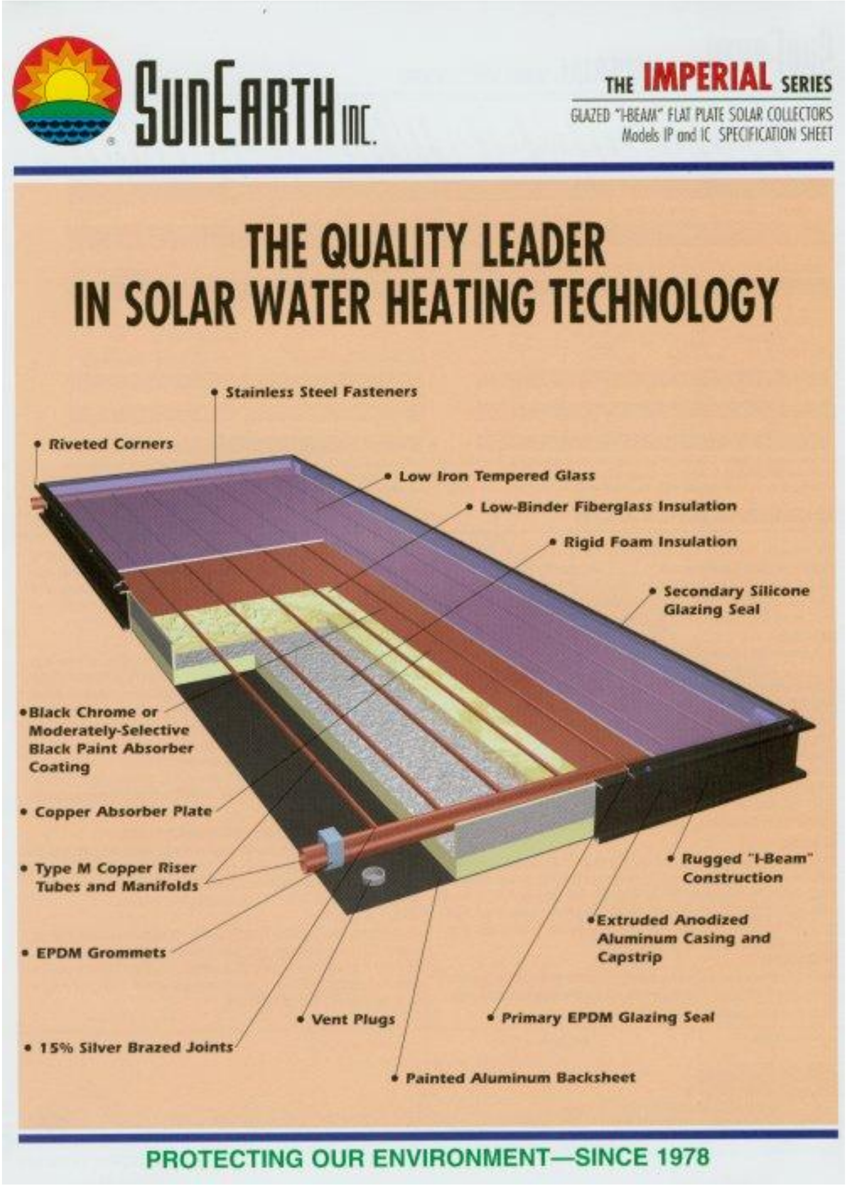
The more efficient panels have a selective black chrome absorber plate and water white crystal glazing that is tempered. Isocyanurate heat resistant foam is commonly employed for the back plate insulation. The panels come in several sizes, 3 x 6 ft, 3 x 8 ft, 4 x 8 ft, 4 x 10 ft and 4 x 12 ft. The flow path in the absorbers is parallel.

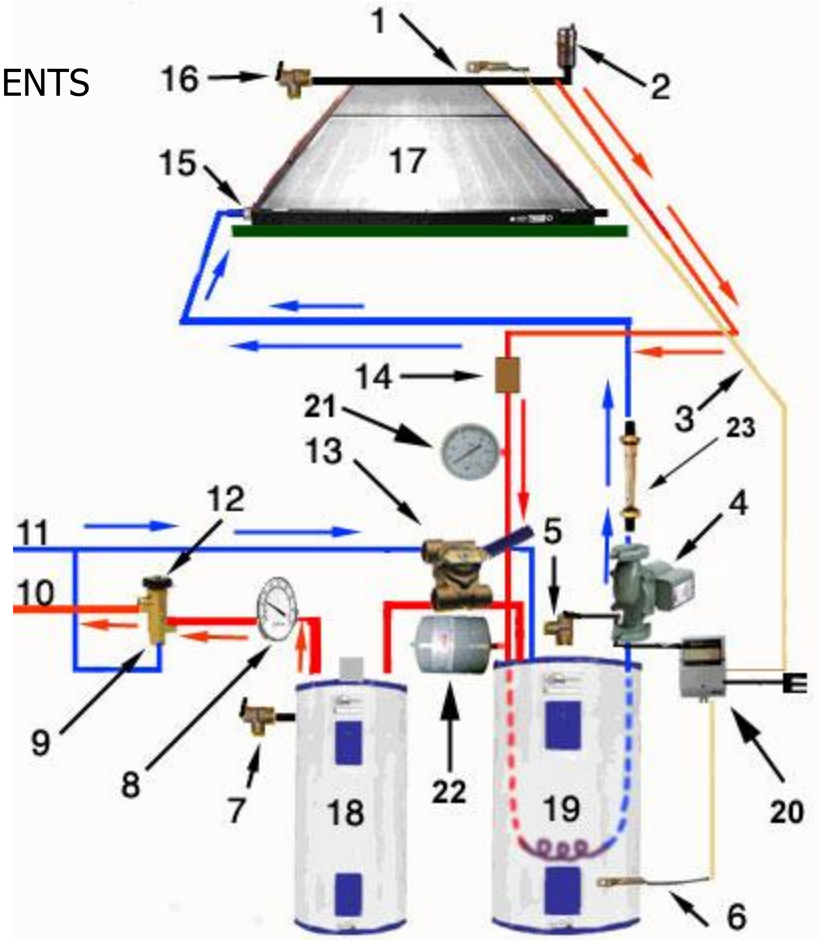
Some serpentine flow panels are also manufactured. They are likely to be less efficient, but offer a lower cost absorber, as well as higher exit temperatures when fabricated with double glazed polymer covers, e.g. Lexan. One brand of available panels is 20 inches by 6 or 12 feet long.

In 2003, Industrial Solar Technology commissioned a solar hot water system comprising 142 SunEarth model EC-40-1.5 collectors at the North Boulder Recreation Center, a LEED Silver certified public building in Colorado. The solar collectors cover all the available space on the roofs of the gym and the lap pool for a gross aperture area of 5,680 square feet. An installed Btu meter confirmed excellent wintertime performance.

Energy Savings: Modeling done by a Boulder LEED consultant showed avoided annual energy costs of just over $56,000 for the added conservation measures plus solar heating. With the incremental cost to reach LEED silver at $540,000, the project had a simple payback period of 9.6 years. The relatively long payback is due primarily to the inclusion of the solar water heating system without benefit of a solar tax credit. The solar system offsets natural gas and will deliver an estimated 50% of the annual heating load of the swimming pools. At 2003 prices for natural gas, the solar panels would account for $15,000 - $20,000 of the annual savings. Solar system cost, counting building modifications, was $265,000, amounting to $46.65/ft2 of array in 2003 dollars.

BASIC CLOSED LOOP SOLAR WATER HEATER COMPONENTS





CLOSED LOOP GLYCOL ANTIFREEZE

Most common in this area due to being fail safe in frigid winter weather.

Relatively simple but does require periodic maintenance.

Non-toxic anti-freeze (propylene glycol) should be flushed and changed every 5 yrs.

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DESIGN TO INTEGRATE SOLAR ATTRIBUTES

The solar system equipment pictured is at a winery. The array consists of five Sunearth flat plate collectors with a total gross area of 152 square feet. The fuel fired tank is a condensing gas-fired HTP Phoenix Evolution water heater that is factory equipped with heat exchangers for the solar thermal loop. The Evolution tank volume is a nominal 120 gallons and an auxiliary solar preheat storage tank has been added to provide another 80 gallons of hot water storage. The temperature requirement for cleaning process piping and equipment at the Chrysalis Winery is ~170 degrees F.

A differential solar controller energizes the solar loop pump when sun is available and the solar collectors heat the tanks to between 140 and 190 degrees F. By design, storage water is stratified in the Evalution tank, and it has first priority in the solar control scheme. When the lower layer of water in the evolution tank reaches 190º F, a Honeywell aquastat energizes a three-way diverting valve that sends the solar heat to the auxiliary 80 gallon tank. The Phoenix tank receives its make-up water from the auxiliary tank, which increases the value of the solar system since any water preheated above the incoming well/ground water temperature lowers propane energy consumption.

The heating strategy employed captures more energy because the solar system is delivering and storing usable heat whenever the sun is out. Two tank systems are inherently more efficient because the storage with the fossil fuel heating always fills from the solar auxiliary tank, and there is a gain even if that tank is not delivering water at the fossil tank temperature set point.

This concept can be used for large industrial and institutional applications.

GLAZED FLAT PLATE SYSTEM PAYBACK

For a small commercial solar water heater the following estimates the savings and the payback in years. This system would have 2,289 square feet of net aperture area using high end flat plate collectors. The solar energy delivered is estimated from Palmdale insolation data. To determine savings, the price of gas is fixed at $1.00 per therm for ten years. No operating costs are included in the calculation, just the capital costs to install the solar system. No other savings such as reductions in water treatment costs and boiler maintenance are included either.

Array size Glazed flat plate, black chrome 4 x 10 2289 ft2 net aperture

Solar Energy Delivered per Year 6,548 mmBtu

Estimated Installed Cost $73.00 $/ft2

Installed cost for system $144,207

10 Year Natural Gas Cost Avg $1.00 per therm

Steam system efficiency 70%

Natural gas therms offset by solar 9,354 therms/yr

Annual savings in fuel cost $9.354

The spread sheet shows the effect of the federal solar tax credit and accelerated depreciation. A postulated gas company incentive is also included, set at $0.60 per therm saved in the first year of operation by the solar energy system. On this basis, the simplified payback is just under seven years.

Glazed flat plate WH ft2		2289		
At $73/ft2 installed				
Installed cost		$167,097		
Gas utility incentive		$5,613	if eligible at $0.60/therm	
Net cost w/ utility payme		$161,484		
30% Fed Inv Credit		$48,445		
Net		$113,039		
Depreciation basis 85%		$142,032		
Net cost w/ depreciation		$63,328		
$ 28,406	Year one depreciation			
$ 45,450	Year two depreciation			
$ 27,270	Year three depreciation			
$ 16,362	Year four deprecation			
$ 16,362	Year five depreciation			
$ 8,181	Year six depreciation			
$ 142,032	Sum depreciation			
0.35	Effective tax rate			
$ 49,711	Value of depreciation			
	Payback	6.8	years	

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VACUUM TUBE COLLECTORS

Evacuated tubes are considered flat plate solar collectors but employ a vacuum instead of insulation to isolate the absorber and retain collected heat.

The first versions circulated water in pipe inside the vacuum tube or used heat pipes to transfer heat with a condensing heat exchanger to a fluid header.

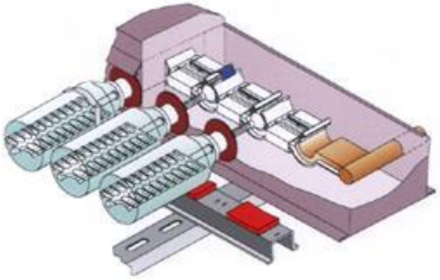
While heat pipe models dominated the market, now other versions are appearing, including evacuated flat plate collectors. Vacuum tubes will deliver hotter temperatures in cold conditions and those with heat pipes and condensing fluid headers heat up faster.

The original Phillips patent has expired and a number of Chinese firms now manufacture them. Vacuum tube thermo siphon systems dominate the water heating market in China.

Capital Sun 360 Tube Service Hot Water Installation: Social Security Admin. Philadelphia, PA

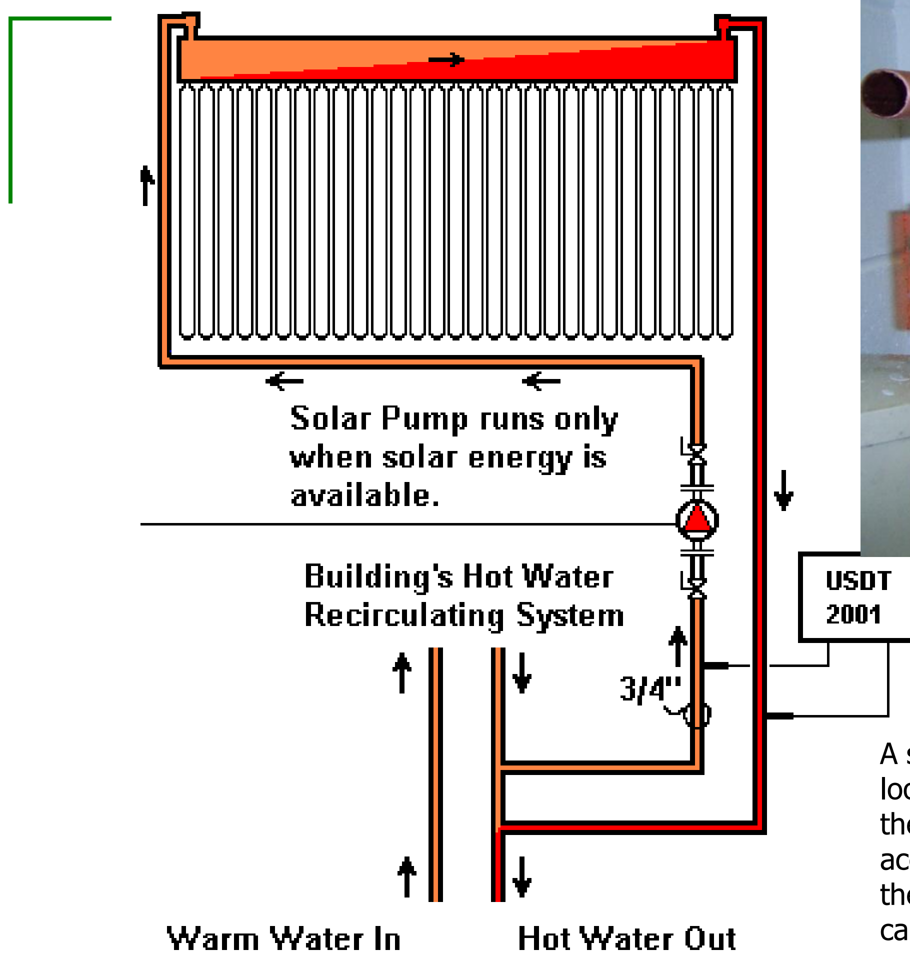
Evacuated Tube "Thermosiphon"

Heat Pipe Header Heat Exchange



Roof Mount Tube Pumped Collector

SOLAR INTERFACE AND CONTROL WITH EXISTING RECIRCULATION HOT WATER SYSTEM



SSA-Philadelphia

Solar Interface and Control

A strategy employed is to feed solar heat into a circulation heating loop at a point where it returns to the boiler. This strategy eliminates the need for a solar storage tank, but the design must take into account the ability of the solar technology to deliver heat at or above the temperature of the returning water in the loop. Evacuated tubes can deliver higher temperatures in winter conditions compared to flat plate collectors, and have been used in this configuration at the Pentagon, Social Security Administration and Department of Health and Human Services.

CONCENTRATOR TECHNOLOGY FOR HIGH TEMPERATURE APPLICATIONS

Solar trough collectors focus solar radiation onto a linear receiver located at the focal point of the parabola. A glass enclosed receiver tube transports a circulating fluid to collect heat and transfer it to the load. Because parabolic troughs concentrate sunlight onto a small receiver, convection, conduction, and radiation heat losses are minimized compared to a flat plate solar thermal collector. Trough technology for industrial applications can serve thermal loads ranging from 100 degrees F (38^{o} C) for heating process water to 550 degrees F (288^{o} C) for generating steam. Large aperture toughs for electric power plants generate temperatures over 700 degrees F. Sandia National Laboratory tests of an Industrial Solar Technology trough concentrator have verified that thermal efficiency at 100 degrees C (212^{o} F) above ambient temperature was 68% and at 150 degrees C (302^{o} F) above ambient it was 61%.

Parabolic trough systems are cheaper per square foot of collector array to install than medium temperature flat plates and evacuated tubes. Current price is $55.00 - $65.00 per square foot installed.

Even though troughs only convert direct beam sunlight to energy, in sunny climates, troughs deliver as much energy annually as flat plate collectors due to their significantly higher efficiency

SOLAR HOT WATER HEATING AT THE FEDERAL CORRECTIONAL INSTITUTION, PHOENIX

The solar industry combines a wide range of raw materials and manufactured parts using unskilled, skilled and professional worker inputs to produce a system that converts abundant sunshine into energy we can use in our daily lives.

TROUGH MARKET DEVELOPMENT AND PERFORMANCE

Parabolic trough systems have been installed commercially in the United States since 1984. Industrial Solar Technology installed their first commercial trough heating system in Colorado at a recreation center and Luz International installed its first solar independent power producer, trough electric power plant, SEGS 1, the same year. When SEGS 9 was completed, Luz had deployed 27 million square feet of trough collectors in California that totaled 355 megawatts of electric capacity. These and subsequent systems aimed at the electric power sector use troughs with large apertures, typically 15 to 18 feet. After the 1980s, Industrial Solar Technology was the only U.S. company with a smaller trough suitable for commercial and industrial applications. Its products have 7 and 4 foot apertures. Even though production for process heating remains limited, in many applications troughs are less expensive to install than glazed flat solar thermal plate collectors. In 2006, Abengoa, a Spanish company engaged in solar thermal power, purchased IST.

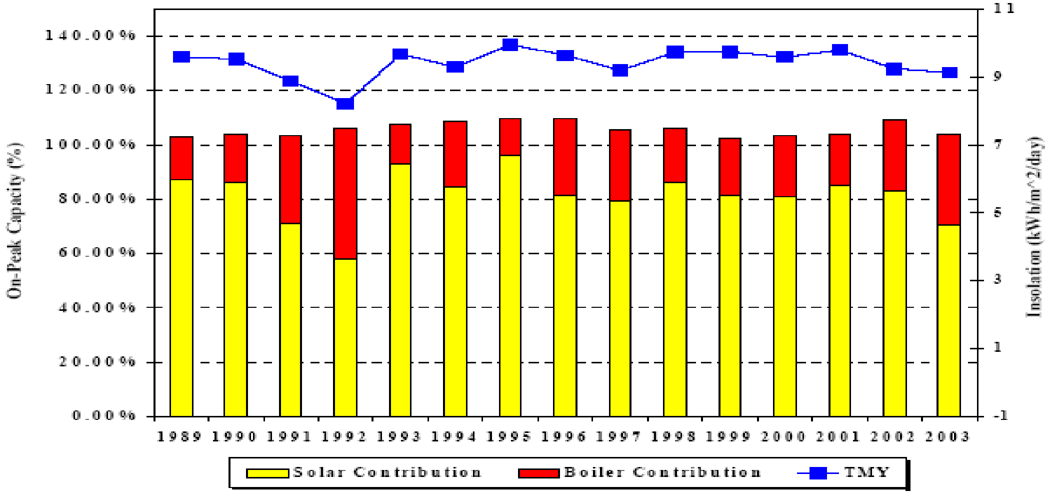


Figure I-4. Performance History of Parabolic Trough Plants at the Kramer Junction Site

The table above shows that over 15 years the solar trough plants were consistently reliable and provided 70% or more of the steam for the Luz International SEGS power plants. The first of these plants was installed in 1984.

The blue graph shows solar radiation data as average kWhs per square meter per day over the year. The on-peak capacity data reveal how closely the parabolic trough fields tracked the annual variations in available solar energy and the consistent reliability of the trough systems.

SOLAR WATER HEATING TESTIMONIAL
FCI PHOENIX 900 kWth PARABOLIC TROUGH SYSTEM

"On a sunny day the solar system delivers up to 50,000 gallons of hot water to the institution, displacing approximately 4,000 kWh of electricity daily.

"On a monthly basis, the system delivers an overall average of 300 million Btu/month, offsetting 89,000 kWh of electricity consumption and an estimated $5,600 of energy costs.

"Operational benefits include maintaining temperatures for domestic hot water (in the past the prison frequently ran out of hot water), reducing electricity peak demand for water heating by more than 200 kW, and reducing maintenance and replacement parts for the offset electric boilers.

"We save a lot of money on electric water heater elements, maintenance calls, and repairs," says the facilities manager." [Plus,] the calls we've gotten from the inmates about cold water have basically gone away.

" Operation and maintenance savings on the existing boilers are in addition to the reduced utility costs.

Furthermore, avoided emissions based on EPA eGRID 2000 factors for Arizona, amount to:

- 589 tons/yr of CO
- 2,655 lbs/yr of SO2
- 2,358 lbs/yr of NOx

This system was installed under a 20 year federal government energy service provider contract (prenegotiated ESPC agreement). The solar output is metered and the government only pays for what is delivered.

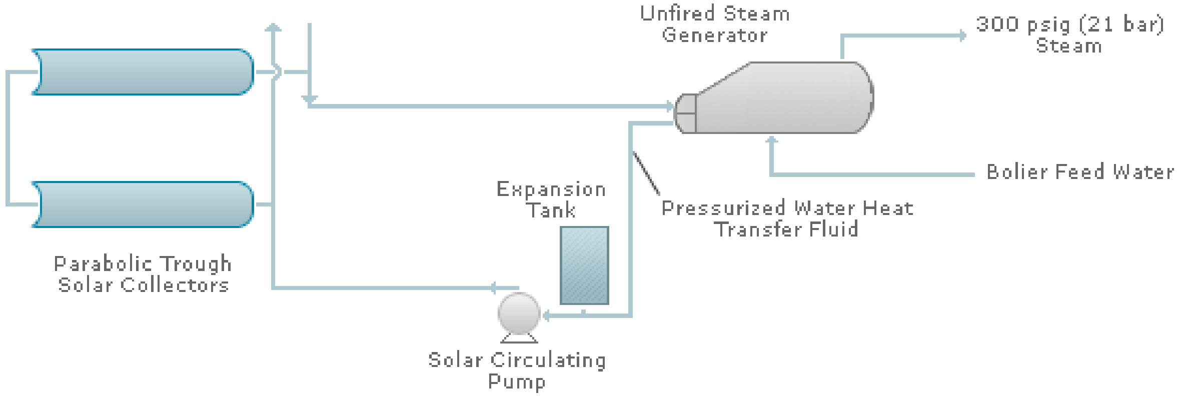
This model has been used for a number of trough systems in the U.S.
In the solar electric arena, they are called "Power Purchase Agreements."

FOOD PROCESSING SOLAR STEAM SYSTEM

One of the most recent industrial solar trough system installed in the US was an Abengoa-IST project purchased by Frito-Lay for its SunChips plant in Modesto, California. It has a 55,400 square foot array. The California Energy Commission PIER program contributed $700,000 to its cost

Land required was 172,249 square feet. The collectors operate at temperatures up to 480 F (249 C) to deliver high temperature pressurized water to an un-fired generator that produces steam at 300 psig at about 460 F. This system could produce over 8 million Btu/h (2.4 MW) of thermal energy under peak conditions. Reportedly, if it ran at full capacity, the solar system could generate 14.7 billion Btu a year.

The simplified graphic below illustrates a parabolic trough system with an un-fired steam generator. As noted above, the trough in this case delivers solar heated, pressurized water to the steam generator. The array requires one or more pumps and an expansion tank in the heating loop. In a California environment with mild winters, water without an antifreeze is used and a recirculation or drainback system can cope with freezing temperatures at night. On the boiler plant side, boiler feed water enters the unfired steam generator.



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What A Site Assessment for Solar Technology Requires

- Insolation Data
  - Solar Constant, Annual, Seasonal, Daily Levels
  - Average peak sun hours per day data
  - Transys and other data sources

- Site considerations
  - Array mounting options
  - Sun path angles and obstructions
  - Effect of orientation and tilt of collectors

- Diurnal and Seasonal Energy Output Pattern Related to Factory Energy Demand Profiles

Determining Return on Investment and Internal Relations Value

- Near and Mid-Term Energy Price Forecasts
- Solar Systems Cost and Equipment Price Trends
- Federal, State And Local Government Incentives
- Utility Incentives
- **Environmental Regulation Compliance Benefits**
- Operation and Maintenance Costs

COMMERCIAL EXAMPLE FREDERAL SOLAR TAX CREDIT

INCENTIVE PAYBACK, **NO INFLATION** IN FUEL COST

57.8	MMBtu delivered to load year 1	Output Nine EC32 SunEarth Flat Plate Solar Collectors
100000	Btu/therm	
$1.60	Cost / therm Avg	
578	Solar therms to load per year	
0.7	gas heating system annual efficiency	
826	Gas therms replaced	
$1,321	savings year 1, no inflation	
$11,217	Estimated Net installed cost	
8.5	years to incentive based simple payback, no inflation	

$15,345 10 year savings, cpi and gas inflator per NIST LCC Guide

System cost	$22,125.00	
Local incentive	$3,000.00	
Capital cost net state incentive	$19,125.00	
Fed Inv Credit	$5,737.50	
Net for depreciation,	$17,256.25	85% of net capital cost is depreciable
Net with Depreciation	$11,216.56	

3451.25	Year one depreciation
5522	Year two depreciation
3313.2	Year three depreciation
1987.92	Year four deprecation
1987.92	Year five depreciation
993.96	Year six depreciation
17256.25	Sum depreciation
0.35	Business tax rate
$6,039.69	Value of depreciation

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WHAT DOES THE SOLAR INDUSTRY NEED TO KNOW

EPA's list of expected list of measures that boiler owners will use to comply with the regulation are:

- Install bag houses
- Carbon injection systems
- Scrubbers
- Oxidation catalysts
- New burners

The focus is obviously on the boiler.

Solar thermal can increase efficiency at the boiler by raising boiler make up water temperature and by raising combustion air temperature. That is only part of the potential.

For the solar industry, a few key questions arise.

Will EPA accept/add these options to "expected" measures?

How does EPA measure emission performance of a boiler?

Is MACT compliance totally separate from facility emission performance? What are the time frames?

If boiler emission performance is based on average over a time period, how will load reductions that solar systems provide factor into the MACT compliance equation?

What are the key questions CIBO members have with regard to applicability of solar thermal technologies?

Could boiler owners advocate solar thermal systems that increase boiler operating performance <u>and</u> lower loads as a desired measure for complying with MACT regulations?

How do we do it?

Assessing a Plant Site for a Solar Energy System

- The process of determining solar applicability
- The truth about thermal efficiencies of combustion systems
- Energy cost and projected inflation
- Load and load pattern matching with solar output curves
- Complementing existing heating or refrigeration/cooling system
- Downsizing new heating or cooling systems capacity
- Plant building information
- Wall, roof and ground areas available for collectors
- Energy storage locations

Common Roadblocks and Potential Show Stoppers

- Roof warranties
- Structural requirements
- Solar access
- Piping runs
- Storage location
- Appearance
- Utility policy

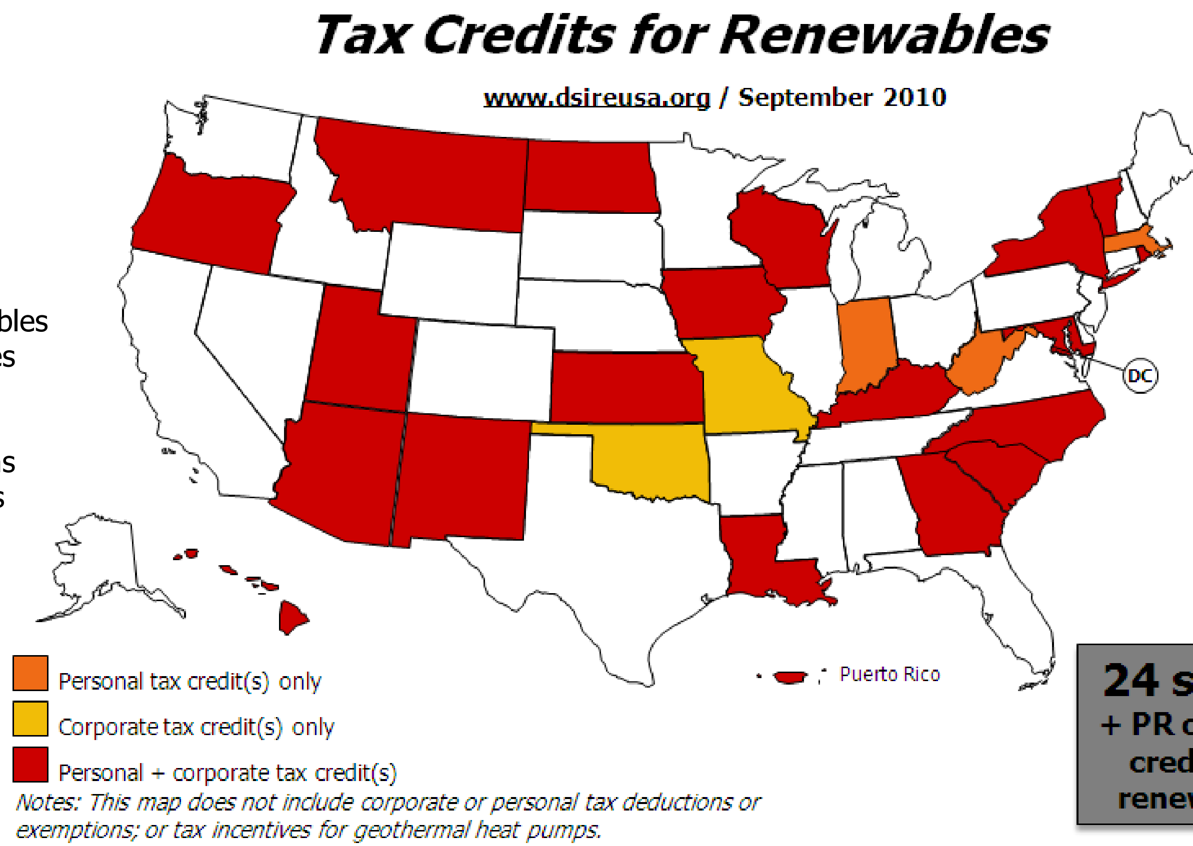
Designing Projects

- Estimating or Modeling Technology Performance
- Collector Conversion Efficiency Measurement
- What is a "peak rating"
- SRCC ratings
- Simulation software programs
- Using average peak sun hours per day and collector performance curves

FOR FEDERAL AND STATE INCENTIVES FOR SOLAR ENERGY
GO TO WWW.DSIREUSE.ORG

AVAILABLE MAPS

3rd-Party Solar PPA Policies
Grant Programs for Renewables
Interconnection Standards
Loan Programs for Renewables
Net Metering Policies
PACE Financing Policies
Property Tax Incentives for Renewables
Public Benefits Funds for Renewables
Rebate Programs for Renewables
RPS Policies
RPS Policies with Solar/DG Provisions
Sales Tax Incentives for Renewables
Tax Credits for Renewables



24 states + PR offer tax credits for renewables

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PARTIAL LIST OF NORTH CAROLINA INCENTIVE PROGRAMS

Corporate Tax Credit
* Renewable Energy Tax Credit (Corporate)

Green Building Incentive
* Asheville - Building Permit Fee Waiver
* Catawba County - Green Construction Permitting Incentive Pgrm
* Local Option - Green Building Incentives

Industry Recruitment/Support
* Renewable Energy Equipment Manufacturer Tax Credit

Local Loan Program
Local Option
* \- Financing Program for Renewable Energy and Energy Efficiency

PACE Financing
* Local Option - Clean Energy Financing

Performance-Based Incentive
* Duke Energy - Standard Purchase Offer for RECs
* NC GreenPower Production Incentive
* Progress Energy Carolinas - SunSense Commercial PV Incentive Pgrm
* Progress Energy Carolinas - SunSense Commercial Solar Water Heating

Incentive Program
* TVA - Generation Partners Program

Personal Tax Credit
* Renewable Energy Tax Credit (Personal)

Property Tax Incentive
* Active Solar Heating and Cooling Systems Exemption
* Property Tax Abatement for Solar Electric Systems

Sales Tax Incentive
* Sales Tax Holiday for Energy-Efficient Appliances

State Grant Program
* North Carolina Green Business Fund

State Loan Program
* Energy Improvement Loan Program (EILP)

State Rebate Program
* Housing Finance Agency –
  SystemVision Energy Guarantee Program
* Steam Trap Rebate Program

MACT Regulation Overview Industrial and Institutional Boilers

ICI Boiler MACT itself applies to boilers with hazardous air pollutant (HAP) emissions:
• Over 10 tons per year for one HAP
• Over 25 tons per year of all HAPs

Emission standards for:

Eleven subcategories of boilers based on fuel and process type.

“Surrogate" pollutants selected to establish limits:

- Mercury (hg)
- Hydrogen chloride (hcl)
- Particulate matter (PM)
- Carbon monoxide (CO)
- Dioxins/furans (D/F)

Control of these five pollutants are expected to minimize overall HAP emissions

Emission Limit: based on EPA collected data. emission rate of the top 12% of the best performing boilers,

Larger boilers must install continuous emission monitors for both PM and CO to demonstrate compliance

Compliance with remaining emission limits may be demonstrated through fuel analyses, performance tests, and parametric monitoring.

Existing Facilities:

Have three years to comply
May use any combination of controls

EPA expected measures:

- Install bag houses
- Carbon injection systems
- Scrubbers
- Oxidation catalysts
- New burners

New Sources

Clean Air Act requires that they match the emission levels of the single best performing source in the country.

Boilers that combust "any solid waste" will be regulated as a CISWI (Clean Air Act Section 129).

Added emission limits cover:

- Sulfur dioxide
- nitrogen oxides,
- Lead
- Cadmium

The MACT proposal divides CISWIs into five categories and lowers the required emission limits for some of them.

The proposed rule is for hazardous emissions -- heavy metals, polycyclic organic matter, PCBs. The standards are based on "generally available control technology" or GACT and affect a wide variety of industries, including agriculture, food service, and manufacturing. They are proposing to use particulate emissions as a surrogate for heavy metal emissions. The fuels of interest are coal, oil, and biomass, but not natural gas since it is clean burning. The standards are expressed in terms of pounds per trillion Btu. Thus, if you can reduce the amount of combustion needed by supplementing with solar, you will automatically reduce the number of pounds per TBtu.

Capital Sun Group

Thank You!

Carlo La Porta

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