Solar Thermal

[Strategy]

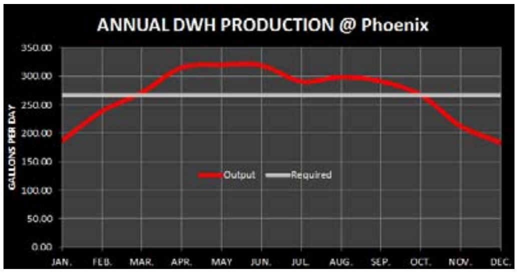
Brief Description

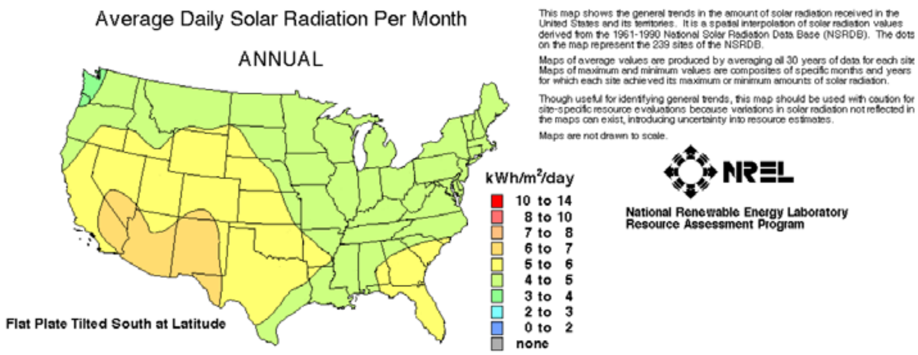
Solar domestic water heating (DWH) systems harvest the insolation from the sun and store its' heat energy in the form of hot water. There are a number of factors that influence the economic viability of solar domestic water heating systems. Some of these factors are labor costs, local weather, available solar insolation, and size of the system.

The *Sustainable Design and Development Policy Update* states, solar domestic hot water will be provided for a minimum of 30% of a facility's hot water demand for all new construction projects with an average daily domestic hot water requirement of 50 gallons or more, located in areas receiving an annual average of $4kW/M^2$-day.

The arguably largest factor is the type and cost of the available utility to be displaced, which in turn predicates the annual potential offset savings. The ideal location would have a large domestic hot water consumption, high local utility costs and a larger summer demand vs. the winter months.

The amount of insulation from the sun varies during the course of the day and the day of year, as well as the specific geographical location. A typical solar output vs. a fixed demand is illustrated below. Typically, a 30% offset proves to provide the best economics, but this is not always the case. Any short fall in production will need to be supplemented by conventional domestic water heating systems.





The illustration above is only for reference and exact location data is required to predict the amount of available solar insolation.

Solar Thermal

[Strategy]

Applications

The ideal candidate would be located in an area with solar insolation in excess of 4.5 suns, have above average utility costs and low labor costs.

- Economic viability seems to maximize around the 30% offset design.
- Passive systems in warmer climates prove to be more economically viable.
- Facilities with larger domestic hot water demands usually have viable economics.
- Heating indoor swimming pools

Design Notes

SITE SELECTION

- Sufficient area, either ground area or roof space must be available. There must be consideration for the added weight when designing a system as a roof mount.
- While there are many variables, typically the size of a system will be from 1 to 1.5 square feet net area per gallon of domestic hot water produced.
- The selected site must be free of all shading from other buildings or natural sources.
- Generally, fixed tilt panels should be tilted at the latitude and facing true South, not magnetic South.
- To optimize cost effectiveness collector to storage distances should be minimized.
- A conventional backup system must be provided and capable of producing 100% of the system demand.
- Systems that utilize a working fluid and a heat exchanger must maintain domestic hot water pressure above that of the working fluid to prevent leakage into the system. Typically the domestic water pressure is controlled by a pressure regulator. The working fluid pressure entering the heat exchanger must be below the domestic hot water system pressure to prevent possible contamination due to leaks.

FREEZE PROTECTION

- Freeze protection should be considered for all systems. This can be a drain down system or a system utilizing a working fluid such as propylene glycol.

WATER TEMPERATURE CONTROL

- In warm seasons, water temperatures may be above 140°F (60°C). Mixing valves must be installed to keep occupants from being scalded.

ESTIMATING HOT WATER CONSUMPTION (Source: Appendix E of UFC 3-420-01)

- Mix ratio to achieve 110°F hot water (110-Tc)/(140-Tc). Mix ratio to achieve 120°F hot water: (120-Tc)/(140-Tc). Where: Tc is the cold makeup water temperature. Assumes 140°F storage temperature.
- Showers @ 7 ½ minutes and 2.5 GPM @ 140°F.
- Lavatory use 2 minutes and 2.5 GPM @ 140°F

Solar Thermal

[Strategy]

- Assume 23.45 Gallons per occupant @ 140°F
- Assume storage tank sized for 12.5 gallons @ 140°F, per occupant.
- Facilities with washing machines, may be estimated to use 20 gallons of 120°F water per load and 3 loads per occupant per week.

MAINTENANCE

- It is important to train the facility managers and other personnel to properly maintain the solar domestic hot water systems.
- Although not recommended, direct systems collectors may require periodic treatment with a nontoxic solution, to remove any scale which would lower the overall efficiency.
- Current maintenance costs are estimated by NERL as 1% of the installed cost per year.

References

1. Solar Water Heating: Using the Sun to Heat Domestic Water Makes Sense in Almost Any Climate. http://www1.eere.energy.gov/femp/pdfs/26013.pdf
2. Greening Federal Facilities: An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers. http://www1.eere.energy.gov/femp/pdfs/29267.pdf
3. Solar Hot Water Resources and Technologies. http://www1.eere.energy.gov/femp/technologies/renewable_shw.html
4. Solar Water Heating: Well-Proven Technology Pays Off in Several Situations http://www1.eere.energy.gov/femp/pdfs/FTA_solwat_heat.pdf
5. Parabolic-Trough Solar Water Heating http://www1.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf
6. Solar Ready Buildings Planning Guide http://www1.eere.energy.gov/femp/pdfs/46078.pdf
7. Department of the Army Memorandum: Sustainable Design and Development Policy Update (Environmental and Energy Performance) July 8 and 16, 2010

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[Energy and Environment]

Energy Savings

WATER HEATING

- The economic peak appears around a 30% offset. The specific size, offset amount and economics depend on location, weather, labor costs and utility rates.

Social Benefits

Reducing conventional utility consumption will simultaneously reduce the amount of water consumed and the amount of CO2 released in producing the offset electricity. The amount is dependent upon the specific location and what sources they use to generate the power. For Natural Gas or LP heating, only a reduction in CO_2 will be realized.

Guideline Principals[1]

ON-SITE RENEWABLE ENERGY

- Per EISA Section 523, meet at least 30 percent of the domestic hot water demand through the installation of solar domestic hot water heaters, when life cycle costs are effective.

Associated LEED Credits

☒ Energy and Atmosphere (LEED 2009[2] BD+C)

- EAc2 On-Site Renewable Energy (1-7 points): While solar domestic water heating offset is only a fraction of the overall building renewable energy, it does contribute to the potential LEED savings.
- Use on-site renewable energy systems to offset building energy costs.

Percent Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

☒ Energy and Atmosphere (LEED v4[3] BD+C)

- Renewable Energy Production (1-3 points): Use renewable energy systems to offset building energy costs.

References

1. Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings www.wbdg.org/pdfs/hpsb_guidance.pdf
2. USGBC LEED Reference Guide for Green Building Design and Construction, 2009 Edition
3. USGBC LEED Reference Guide for Green Building Design and Construction, v4

Solar Thermal

[Product and Environment]

Product images

Typical flat Glazed solar water heating panels.
(Source: http://www.builditsolar.com/Projects/WaterHeating/DougsSolarWater.htm)

(Source: *http://www.Rheem.com/products/solar* water heating)

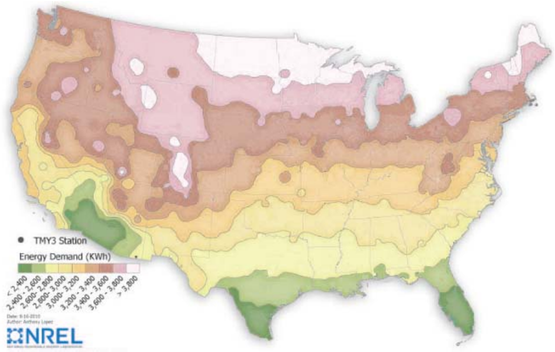
Vendors

Rheem Solar Water Heating Products

- http://www.rheem.com/products/solar_water_heating/

Cost Range

There are very many variables that influence the system installed cost. NREL quotes the 2017 pricing averages as \$162.00 /ft^2 +/- \$91.00 of solar panels. There are numerous costing factors associated with any specific location, and thus the large variance in cost.



The following table should be used for comparison only as there are many factors that will dictate the actual costs. These would include such items as labor rates, selected manufacturer, selected installer, shipping to location, and any local or state permits.

		Suitable system size	Cost/ft^2 for 40 ft^2 unless noted	Freeze tolerance	Hard water tolerance	Maintenance need
Low-Temperature Systems						
Unglazed		for pools	\$10-\$25 (400 ft^2)	none	good	very low
Passive Mid-Temperature Systems						
Integrated collector		small	\$50-\$75	moderate	minimal	very low
Thermosiphon	direct	small	\$40-\$75	none	minimal	low
	indirect	small	\$50-\$80	moderate	good	low
Indirect, Active, Mid-Temperature Systems						
Flat-plate, antifreeze		small	\$50-\$90	excellent	good	high
		large	\$30-\$50 (30,000 ft^2)			
Flat-plate, drain back		small	\$50-\$90	good	good	high
Direct, Active, Mid-Temperature Systems						
Drain down		small		corrections being developed	minimal	high
Recirculating		small			minimal	high
High-Temperature Systems						
Evacuated tube	direct	small	\$75-\$150	good	minimal	high
	indirect	large	\$75-\$150	excellent	good	high
Parabolic trough		large	\$20-\$40 (30,000 ft^2)	excellent	good	high

(Source: http://www1.eere.energy.goc//femp/pdfs/FTA_solwat_heat.pdf)

Product types

Collector types include un-glazed solar collectors, glazed solar collectors, and evacuated tube solar collectors. The systems are either direct or indirect, which can use pure water or an ethylene glycol solution. Glazed solar collectors are the most common systems for small to medium sized water heating needs. These systems achieve water temperatures up to 160 degrees Fahrenheit and meet domestic hot water needs. Some systems are more suited for specific climate zones.

Some systems are more suited for specific climate zones.

ACTIVE SOLAR WATER HEATER

- Active solar domestic solar water heating systems use a pump and controls to circulate water to the collectors and return to the water storage tank. These systems may use the direct or indirect method to circulate water.
- The direct method circulates the domestic water through the collector and back into the storage tank. This is best suited for a mild climate where temperatures seldom drop below freezing.

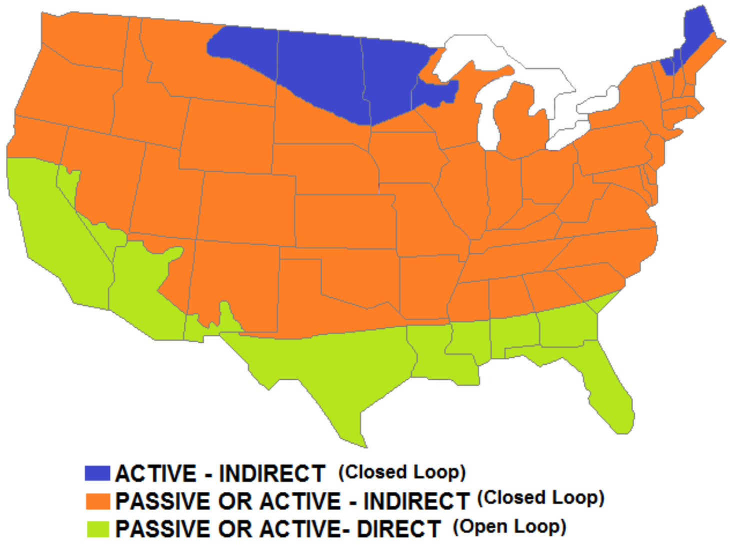
- The indirect method uses a non-freezing fluid which is circulated through the system. The gained heat is then transferred to the domestic water in a heat exchanger. This system is better suited for climates which have lower ambient temperatures and freezing is more likely. The indirect method is utilized more often in regions where low temperatures may cause pipes in a direct circulation system to freeze.

PASSIVE HEATING SYSTEM

- Passive solar domestic water heaters use natural convection to circulate water. Since the have fewer moving parts, they tend to last longer and maintenance costs. They do not have the overall efficiency of the active systems.
- Passive systems will operate during a power outage and are usually less expensive for technicians to install. The collector is installed below the storage tank, which enables the warm water to rise from the collector and into the tank naturally without a pump.

BASIC TYPES OF SOLAR COLLECTORS

- Unglazed swimming pool heaters (for low-temperature applications)
- Flat-plate collectors (for humid climates)
- Evacuated-tube collectors (operating at high temperatures with high efficiency) very expensive.
- Parabolic-trough collectors. (Highly efficient systems for nonresidential and institutional applications)



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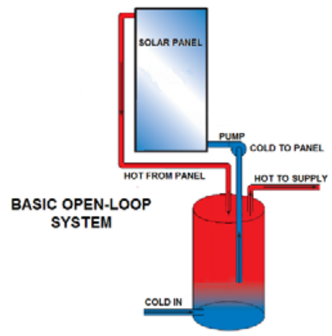
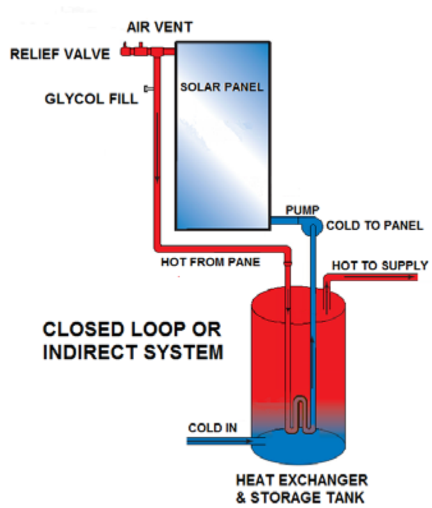
[Product and Environment]

ACTIVE DIRECT OR "OPEN-LOOP" SYSTEM



- 5-10 percent more efficient than indirect systems.
- Pump circulates water from the collectors to the storage tank.
- Suitable for mild and moderate climates with good water quality. These systems are not allowed where freezing occurs.
- Especially applicable to swimming pool heating.

ACTIVE INDIRECT OR "CLOSED-LOOP" SYSTEMS



- Pump circulates a fluid with a low freezing point (e.g. propylene glycol) in the collector loop.
- Suitable for most climates.

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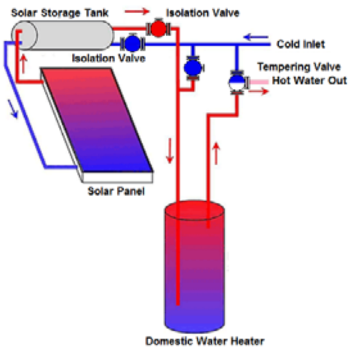
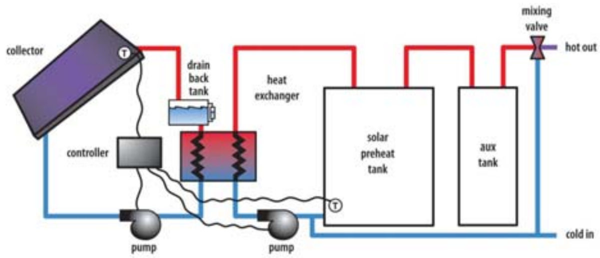
[Product and Environment]

PASSIVE INTEGRAL COLLECTOR-STORAGE (ICS) SYSTEMS



- A collector and storage tank are combined into one unit.
- Potable water (generally pressurized tap water) enters at the bottom of the ICS collector, and warm water is drawn from the top.
- Roof structures must be strong enough to support the storage tank.
- The systems do not need mechanical parts, so it is less expensive than an active solar heater and the maintenance requirements are minimal.

DRAIN BACK SYSTEM



- Allows for the systems to be used in a variety of climates.
- Addresses the challenge of buildings potentially being unoccupied for prolonged periods, such as during deployments.
- Increases the complexity and cost of the solar hot water system, and result in higher maintenance.
- Drain back systems are slightly more efficient if water is used in the loop, due to its higher thermal capacity.

Components

A passive solar domestic hot water system utilizes natural convection to circulate the water. They are not as efficient as an active system which uses a pump to circulate the water. Solar collector, storage tank, possibly a heat exchanger, controls, circulation pump and a drain back system constitute the major system components.

Solar Thermal

[Product and Environment]

Warranty Info Warranties vary depending on manufacturer, up to 20 years on certain panels.

Code Restrictions The Unified Facilities Criteria does not allow for direct pure water solar hot water systems to be installed in locations where freezing occurs unless there is a drain back system.

Solar Thermal

[Specifications]

Guidelines

SECTION 22 33 30. 00 10 – SOLAR WATER HEATING EQUIPMENT[4]

SYSTEM DESCRIPTION.

Provide a solar energy system arranged for preheating of service (domestic and/or process) water using flat plate liquid solar collectors. Include in the system components a solar collector array, storage tank, pump[s], automatic controls, instrumentation, interconnecting piping and fittings, [uninhibited food-grade propylene-glycol and water heat transfer fluid in a closed loop], [potable water heat transfer fluid in an open loop], [heat exchanger], [expansion tank], and accessories required for the operation of the system.

COLLECTOR SUBSYSTEM

A. Solar Collector Construction

Collectors shall be of the flat plate, liquid, internally manifold type. Each collector shall be provided with cover glazing, an absorber plate, heat transfer liquid flow tubes, internal headers, weep holes, insulation, and a casing. Collectors shall be of weather-tight construction. Solar collectors shall withstand a stagnation temperature of 177 °C (350 °F) and a working pressure of 862 kPa (125 pound per square inch) without degrading, out-gassing, or warping. Collector net aperture area shall be as shown and shall be a minimum of 2.6 square meters (28 square feet). Collector length, width, and volume shall be as shown.

B. Absorber Plate and Flow Tubes

Absorber sheet or plate shall be copper. Top of absorber plate shall be coated with selective surface of black chrome and shall have an emissivity less than 0.2 and absorptivity greater than 0.9. Flow tubes shall be Type L or Type M copper, and shall be soldered, brazed, or mechanically bonded to the absorber plate. Tubes shall be installed on the absorber plate so that they drain by gravity.

C. Cover Glazing

Each collector shall have a single layer of cover glazing made of clear float, water white or low iron type tempered glass. Glass shall meet ASTM C 1048. Cover glazing shall be completely replaceable from the front of the collector without disturbing the piping or adjacent collectors. Cover glazing shall be separated from the collector by a continuous gasket made of EPDM rubber.

[4]Specification language modified from the Whole Building Design Guide's Unified Facility Guide Specifications, Section 22 33 30.00 10 – Solar Water Heating Equipment. Accessed November 2017 at https://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/ufgs-22-33-30-00-10.

D. Insulation

Back and sides of the absorber plate shall be insulated. Insulation shall fill space between absorber plate and casing and shall have an R value of 4 minimum. Insulation shall conform to EPA requirements in accordance with Section 01 62 35 RECYCLED / RECOVERED MATERIALS and shall be fibrous glass, polyisocyanurate, urethane foam, or other material suitable for the intended purpose, and shall withstand the moisture, sun exposure, and stagnation temperature limitations of the solar collector. Polyisocyanurate insulation shall not come in contact with the absorber plate.

Solar Collector Performance

Thermal performance shall be plotted on the thermal efficiency curve in accordance with ASHRAE 93. The y-intercept shall be equal to or greater than 0.68, and the numerical value of the slope of the curve (FRUL) shall be between 0 and minus 5.7 watts per square meter per degree K (0 and minus 1.0 Btu per hour per square foot per degree F) 0 and minus 1.0 Btu per hour per square foot per degree F. Manufacturer's recommended volumetric flow rate and the design pressure drop at the recommended flow rate shall be as shown. Manufacturer's recommendations shall allow at least seven collectors to be joined per bank while providing for balanced flow and for thermal expansion considerations.

SOLAR COLLECTOR ARRAY

A. Net Absorber Area and Array Layout

Array shall consist of an assembly of solar collectors as shown with a minimum total array aperture area of [_ _] square meters (or square feet). Solar collectors shall be assembled as shown in banks of equal number of collectors. Banks shall consist of no less than 4 and no more than 7 collectors each. Collector array shall be oriented so that all collectors face the same direction and are oriented within 20 degrees of true south and with respect to true south as indicated. Collectors arranged in multiple rows shall be spaced so that no shading from other collectors is evident between 1000 hours and 1400 hours solar time on December 21. Minimum spacing between rows shall be as shown.

TRANSPORT SUBSYSTEM

A. Heat Exchanger

The heat exchanger construction and testing shall be in accordance with ASME BPVC SEC VIII D1. Minimum design pressure rating shall be 125 pounds per square inch (862 kPa). Heat exchanger shall be capable of returning a hot-side exit temperature of 120°F (49°C) or less given a hot-side approach temperature of 140°F (60°C) and a cold-side approach temperature of 100°F (38°C). Heat exchanger shall be capable of withstanding temperatures of at least 240°F (116°C) of at least 116°C (240°F). Heat exchanger shall be capable of operation at the flow rates as shown.

Solar Thermal

[Case Study]

Project Location	**Camp Pendleton, Oceanside, CA**
Project Name	Marine Corps Base

Description

FACILITY

U.S. Marine Corps Base Camp Pendleton is the largest expeditionary training facility on the West Coast. It accommodates more than 41,500 marines and family members, with a daytime population of approximately 100,000. It is located in climate zone 4.

The Camp Pendleton training pools provide daily training for Marine Corps personnel year round. The pools have a capacity of 500,000 gallons each and typically use natural gas for water heating and electricity for pumps and other mechanical equipment.

Technologies Used

APPROACH

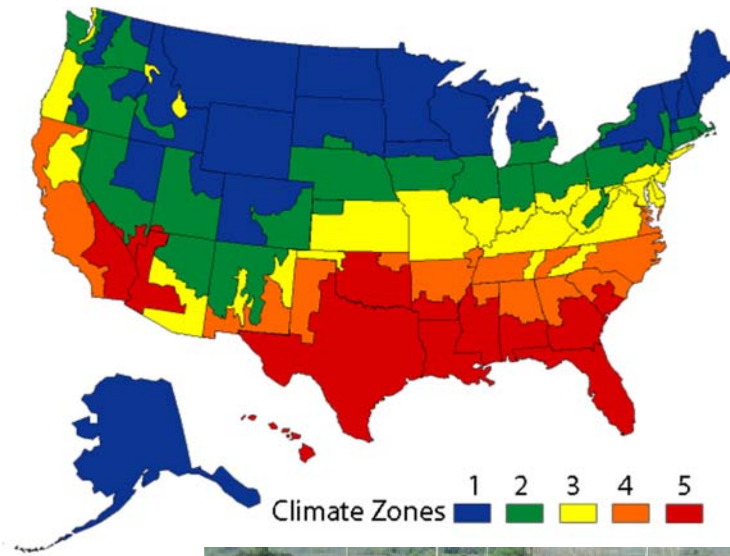
In the summer of 1995, a pilot study was completed. An inactive solar pool heating system for $10,000 was installed. The collector array has 2,560 square feet of unglazed collectors using copper pipes. In 2007, the base implemented two integrated solar thermal/PV systems at its 53 Area and 62 Area training pools. Each pool is equipped with 152 SHW collectors (covering 6,384 square feet) and 108 PV modules.

RESULTS

- The pool chosen as a pilot project is currently used only 3-4 months. If the pool was used year-round, it would save $8,000 per year in natural gas.
- At 53 Area and 62 Area training pools, each solar thermal collector produces 39,400 Btu of energy each day, resulting in combined annual energy production of 4,371 million Btu (MBTU) for both arrays. This eliminates the annual consumption of 54,726 Therms of natural gas for heating the two pools.
- The total cost of the integrated solar hot water/photovoltaic arrays was $1.1 million, with annual energy cost savings of $101,600. The project received a utility incentive of $90,285 and the payback period is 10 years
- The installed cost was approximately \$172.31 /ft^2 of collector area.

Solar Thermal

[Case Study]



(Source: http://www1.eere.energy.gov/femp/pdfs/46348.pdf)