RENEW LIFE

CANNONDESIGN

EVALUATING RENEWABLE ENERGY

This document provides useful design strategies and calculations to help you evaluate renewable energy systems for your project. It does not cover every renewable energy system, but it is intended to offer an overview of the most commercially viable technologies at the moment.

Think of this document as a starting point for looking at a range of technologies available for use on your project site and building so you can focus on the few that are viable.

Prior to getting started, consider some steps every project team should follow when thinking about renewable energy:

– Work to resolve the project's massing, orientation and envelope design early to improve energy efficiency prior to thinking about renewable technologies.

– Develop energy models of multiple options early in the design process and share the results of this modeling with all members of the design team.

– Conduct a workshop to help the client decide if the goal of incorporating renewable technology fits within the project goals.

– Establish an energy goal and the role of renewable energy with the client early in the project.

– Understand the implications of incorporating renewable technologies from multiple perspectives, which might include symbolic or aesthetic impact, fulfilling educational goals, meeting a LEED goal, obtaining grants or incentives, or developing a net zero or energy positive project.

– Prepare to discuss the cost implications—first cost and life cycle cost—of including renewable energy systems within the project and discuss the operations and maintenance expectations, upfront.

– Do the research upfront to confirm that a renewable technology will work on a given project. As architects, engineers and planners, it is our responsibility to figure out the renewable energy implications before presenting a design to clients.

Remember that in addition to an owner's energy goals, we have the CannonDesign goal of meeting the 2030 Commitment. Energy efficiency is our responsibility, and renewable technologies can support our efforts to reach these goals.

TYPICAL BUILDING LOADS

ENERGY SERVICES TEAM

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First, increase the building's energy efficiency, and then consider renewable energy sources to supply the building's remaining load. This chart is a rough guide to help estimate the renewable energy needed to offset some (or all) of the building's load.

There are many factors that affect the total load, and discussions need to occur among all members of the design team early in the process to determine the appropriate target.

Another factor to consider is the regional utility cost for a given building. In the Northeast, where electricity costs more are higher than in the Midwest, an all-electric building is not responsible.

LOAD DENSITY BY BUILDING TYPE	NON-ELECTRIC HVAC (VS/SF)	ELECTRIC HVAC (VA/SF)	LIGHTING (W/SF)	RECEPT. (W/SF)	MISC EQUIP (VA/SF)	TOTAL DESIGN CONNECTED LOAD (W/SF)	TOTAL EXPECTED DEMAND LOAD (W/SF)
K12 School	7.0	15.0	1.2	2.0	0.5	10.0–15.0	8.0–13.0
Higher Ed	7.0	15.0	1.2	2.0	0.5	10.0–15.0	8.0–13.0
Commercial Interior Fitout*	–	–	1.0	2.5	0.5	5.0–9.0	3.0–7.0
Corporate Office	6.0–8.0	14.0	1.0	2.0	0.5–0.75	9.0–17.0	7.0–15.0
Medical Office Building	10.0	17.0	1.0	2.5	0.5	14.0–21.0	12.0–19.0
Hospital	10.0	18.0	1.2	2.5	1.0	15.0–23.0	13.0–21.0
Laboratory	9.0	17.0	1.4	2.5	1.5	14.0–23.0	12.0–21.0
Dormitory	7.0	14.0	1.0	2.0	0.5	10.0–17.0	8.0–15.0
Parking Garage	1.0	5.0	0.3	0.5	0.3	2.0–6.0	1.0–4.0
Sports Arena	11.0	15.0	1.1	1.5	2.5	20.0–23.0	16.0–19.0
Warehouse	3.0	11.0	0.8	1.5	0.3	5.0–14.0	3.0–12.0

PHOTOVOLTAICS

Photovoltaic (PV) panels are a solid-state technology that converts solar radiation directly into electricity, with no moving parts, requiring no fuel and creating virtually no pollutants over its life cycle.

FACTORS

Climate

The amount of sunlight that arrives at the Earth's surface varies geographically, but the sun shines nearly everywhere for at least a few hours. The solar resource map (Fig. 1 on next page) illustrates the range in the United States.

Location

South-facing orientation, direct light, module angle tilt (use some pitch for snow melt). Greatest average energy output is when tilt angle matches the latitude of the site.

Possible Applications

Stand alone, roof top, integrated into glazing, as sun shades, as site coverings (parking), ground mounted stand alone.

Building Types

Photovoltaics can be used on any building drawing energy during day hours, especially during the summer. PV systems work well in new construction and major renovations and can be added to existing buildings as long as the structure has sufficient support. Buildings can also be engineered to provide for a future connection to PV.

System Size

PV arrays can be installed quickly and in any size. Set an energy goal for the portion of the building's total energy use to be fulfilled by a PV system, then engineer the arrays size accordingly. The building also needs to include room for the inverter(s), transformer and batteries (if included).

SYSTEM TYPES

Crystalline

- ~13-15% efficient
- Usually 10-15 W/sf
- Made from pre-existing material
- High price
- Economy of scale: an 83 W system weighs 18 lbs, while a 240 W system weighs 47 lbs

Thin-film

- ~5-7% efficient (undergoing constant advances)
- Usually 5-7 W/sf and very light
- Easier to manufacture than crystalline
- Very thin and can be integrated into materials such as building tiles
- New flexible thin film materials instead of glass can be incorporated in envelope (Building Integrated)

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STEPS FOR IMPLEMENTING PHOTOVOLTAICS ON A PROJECT

- Determine load that is to be supported with array. Calculate the square footage requirement of array.
- Analyze location, hours of sun, and angle of array with tools/programs.
- Survey site for calculated area, south exposure, shading (none/minimal from 9am-3pm).
- Review site considerations. Be aware of wind and snow loads. Allow space between panels to not cast shadows on each other and maintenance.
- Review codes.
- Look into grants and incentives to help lower overall cost.
- Coordinate with utility company for any additional requirements.
- Coordinate with structural and electrical system to make sure both can handle connection.
- Use standoffs to help with array cooling, water runoff and roof top. Investigate ways to integrate into building façade equipment.

SYSTEM COMPONENTS

Batteries

The capacity of the battery bank should be about 5 times the daily load and be able to provide power continuously for 5 days without recharging. Other considerations for batteries: temperature of the battery and its surroundings, maintenance, replacement and battery chemical type/equipment.

Battery Cost

Many flooded lead acid batteries designed for use with PV systems can be purchased at retail for under $1 per amp-hour. AGM/gel batteries cost more but require less maintenance.

Inverters

An inverter will be needed for systems that output AC power. Inverters can be provided in many forms: central inverters (one large inverter), string inverters (multiple medium sized inverters), and micro inverters (one small inverter per PV module). For grid connected systems, the input rating of the inverter should be equal to the PV array size to allow for safe and efficient system.

Inverter Cost

Inverters designed for small to medium size systems can be purchased at costs ranging from $0.50-0.75 per watt depending on the inverter type.

FINANCIAL CONSIDERATIONS

Cost

For a 30 kW system, average installed cost is $5.50 per Watt. In 2015 this cost is expected to be, on average, $3.00 per Watt. The larger the PV system, the lower the overall cost.

Net Metering

For photovoltaic systems that are connected to a utility grid, the owner is able to sell excess capacity back to the power company. Most states limit net-metering interconnections to 10kW, though some states have higher thresholds. PV systems cannot take the place of or be connected into emergency power systems.

O&M

Photovoltaic installations are silent, with few moving parts (if any) to maintain. Make sure the panels are located where they can be maintained on an annual basis with upkeep to wipe down if dirty or covered in heavy snow. PV systems have a long life span, and modules are technically proven with an expected service life of at least 30 years. You may want to put a hose bib on the roof to wash down. Another consideration is accommodating roof repair or replacement.

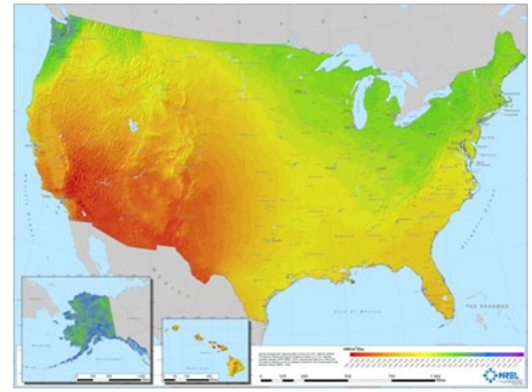

FIG. 1 US Photovoltaic Solar Resource

PHOTOVOLTAICS

SIZE CALCULATIONS

PV panel sizes and Wattage output vary per manufacture.

a) $\text{Panel W/sf} = \dfrac{\text{Size of panel Wattage}}{\text{Size of panel sf}}$

b) $\text{sf of PV panel needed} = \dfrac{\text{System designed Wattage}}{\text{Panel W/sf}} \times \dfrac{1}{\text{Efficiency}}$

c) $\text{Number of Panels needed} = \dfrac{\text{sf of PV panel needed}}{\text{Size of panel sf}}$

d) sf of array area needed = sf of panel *x* 2*

e) $\dfrac{\text{kW hours}}{\text{year}} = \dfrac{\text{Number of days}}{\text{year}} \times \dfrac{\text{Number of hours of peak sun}^{**}}{\text{day}} \times \text{kW}$

EXAMPLE

Given a 240 W panel that measures 17.5 sf and a wattage offset of 13kW for an array in Tampa, FL:

a) $13.7\ \text{W/sf} = \dfrac{240\ \text{W}}{17.5\ \text{sf}}$

b) $1266\ \text{sf} = \dfrac{13{,}000\ \text{W}}{13.7\ \text{W/sf}} \times \dfrac{1}{0.75}$

c) $72.3 = \dfrac{1266\ \text{sf}}{17.5\ \text{sf}} = 73\ \text{panels}$

d) 2532 sf = 1266 sf *x* 2

e) $24{,}675\ \dfrac{\text{kWh}}{\text{year}} = 13\ \text{kW} \times \dfrac{365\ \text{days}}{\text{year}} \times \dfrac{5.2\ \text{hours}}{\text{day}}$

(www.nrel.gov/rredc/pvwatts/)

Note: PV system efficiencies vary but a typical design number is 0.75 (75%).

* Factor used to account for space necessary for panel setbacks/shading, equipment access and working clearances.

** Hours of peak sun is an average of the number of 1,000 watts per square meter hours in a day per year based upon your location in the world. Referred to as solar insolation.

WIND TURBINE

The wind flows over the blades creating lift, like the effect on airplane wings, which causes them to turn. The blades are connected to a drive shaft that turns a generator to produce electricity.

FACTORS

Wind Speed / Conditions

Minimum average of 5 meters per second at 10 meters above ground level. The wind power resource map (Fig. 2 on next page) illustrates the range in the United States.

Elevation

Turbines should be at least 30 feet above any obstructions within 300 feet of the turbine. Raising a turbine from 60 feet to 100 feet involves a 10% greater cost, but can produce 25% more power.

Proximity to Other Building/Trees

The zone of turbulence from a blade can extend up to 20 times the height of the obstruction downwind and up to 2 times the height of the obstruction upwind. (Fig. 3 on next page)

Size Requirements

The electrical equipment for a wind turbine is relatively small and could fit into a standard electrical room.

SYSTEM TYPES

On Building

These are usually smaller units that can be installed on house roofs and other buildings. They are only recommended if your building has been designed to withstand lateral loads.

- Vertical Axis Wind Turbine
- Horizontal-Axis Wind Machine: Small turbines used to power a single home or business may have a capacity of less than 100 kW.

Tower (Fig. 4 on next page)

- Guyed towers are the least expensive and need to be hinged
- Free standing lattice towers can only be maintained by someone climbing up the structure and can be an expensive option
- Tapered tubular are the most costly option and should be hinged for lowering to the ground for servicing turbine

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RULES OF THUMB

- Wind speed is key, doubling wind speed increases power by 8 times
- Small increases in blade length/rotor diameter produce more power
- Doubling the tower height increases power by 34%
- Wind turbines are about 20-30% efficient
- Wind speeds typically increase with height
- Install a tower with the bottom of the rotor blade at least 30 feet above any obstacle within 300 feet of the tower

FINANCIAL CONSIDERATIONS

Cost

For small wind turbines under 100kW, costs can range between $3-5 per Watt. New technologies have decreased the cost of producing electricity from wind, and growth in wind power has been encouraged by tax breaks for renewable energy and green pricing programs. Many utilities around the country offer green pricing options that allow customers the choice to pay more for electricity that comes from renewable sources to support new technologies.

O&M

All wind turbines must be regularly inspected and serviced. It is important to anticipate how to access the wind turbine.

Code/Restrictions

Research potential zoning issues with height or noise restrictions. Sometimes these regulations prohibit the use of renewable energy systems for aesthetic or noise-control reasons. However, sometimes these regulations have provisions supporting renewable energy systems. In addition, you may want to discuss the intentions with neighbors to avoid any future public objections.

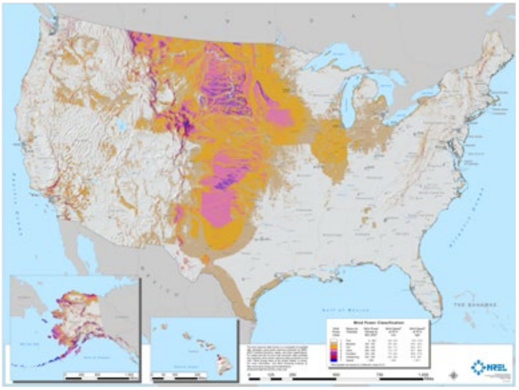


FIG. 2 US 50 Meter Wind Power Resource

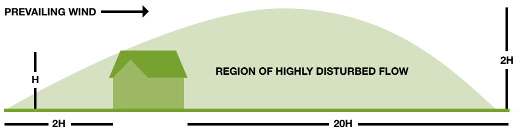


FIG. 3

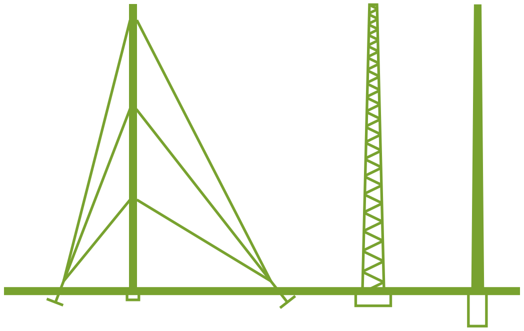


FIG. 4 From left to right: guyed mast, free-standing truss or lattice tower, free-standing or cantilevered tubular tower (BergeyWindpower)

WIND TURBINE

SIZE CALCULATIONS

$AEO=0.01328D^2V^3$

AEO = Annual energy output (kWh/year)

D = Rotor diameter (feet)

V = Annual average wind speed (mph) at the site

$P=1/2pAV^3C$

P = Power (Watts)

p = Air density (kg/sm)

A = Area intercepting the wind/swept area (sm)

V = Instantaneous wind velocity (m/s)

C= Coefficient of performance (≤ 0.59, typically 0.35)

Increasing any of these factors will increase power.

Air density changes with temperature and elevation. For example, any turbine will produce less power in the heat of the summer than in the cold of winter at the same wind speed.

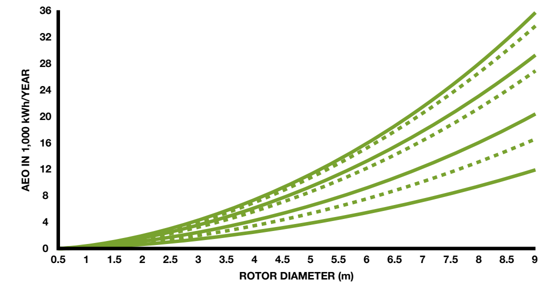
$$AEO = P\ (8760\ \text{hours/year})\ \frac{1\ \text{kW}}{1000\ \text{Watts}}$$

EXAMPLE

Given a location with wind velocity of 5.34 meters per second and a turbine that sweeps 16.7 square meters and air density of 1.2 kg/sm (typical at sea level).

$$AEO = \frac{1}{2}\ (1.2\frac{\text{kg}}{\text{sm}})\ (16.7\ \text{sm})\ (5.34\ \text{m/s})^3\ (.35)\ (8760\ \text{hours/year})\ (\frac{1\ \text{kW}}{1000\ \text{W}})$$

$$AEO = 4678\ \frac{1\ \text{kW}}{1000\ \text{Watts}}$$



Approximate annual energy output of small wind turbines

GEOTHERMAL EXCHANGE

While temperatures above ground change a lot from day to day and season to season, temperatures 10 feet below the Earth's surface hold nearly constant between 50° and 60°F. For most areas, soil temperatures are usually warmer than the air in winter and cooler than the air in summer. Geothermal heat pumps use the Earth's constant temperatures to heat and cool buildings. They transfer heat from the ground (or water) into buildings in winter and reverse the process in the summer.

FACTORS

Climate

For geothermal heat pumps, use can be almost world-wide. Unlike other kinds of geothermal heat, shallow ground temperatures are not dependent upon tectonic plate activity or other unique geologic processes.

Open Space Available

Geothermal heat pump systems utilizing the ground as a well field typically come in two different configurations: horizontal and vertical. Vertical well fields consist of boreholes drilled 200-650 feet into the ground typically in a rectangular configuration. Well spacing varies between 10-20 feet on center or 100-400 sf of space per well. The wells start below frost level and can be installed beneath parking lots, playing fields, and in some coordinated cases, the building itself. The other type of system, a horizontal bore field, installs horizontal loops 6-10 feet below grade. Horizontal fields require significantly more space, as much as 600 linear feet per ton (12,000 sf) of heat rejected.

Building Types

Geothermal heat pump systems can be configured to serve any kind of HVAC system for any type of building, however the system is more practical for certain building types. Ground source heat pumps systems derive the greatest performance from being able to serve simultaneous heating and cooling loads. Ideally, buildings zoned to continually cool interior spaces while heating exterior spaces in the winter can achieve exceptional efficiencies utilizing ground source heat pumps. Given the requirements for load balancing geothermal heat pump systems are not particularly practical for the following project types: Hospitals/ Labs in exceptionally warm climates, data centers, and buildings in extremely cold outdoor environments.

Outside Air/Ventilation

Typically ground source heat pumps are coupled with a dedicated outside air system (DOAS) that supplies load neutral air to the spaces or to the heat pumps themselves. Normal heat pump systems can only handle limited ratios of outside air so the DOAS method allows the system to separate the ventilation load from the sensible cooling load.

CANNONDESIGN EXPERTS

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Architectural Visibility

Geothermal heat pump systems can be easily integrated into the property with almost no visual impact.

Acoustical Criteria

The compressors in the heat pump are the primary source of noise. If located in the room, or in a mechanical closet, sound attenuation is typically required, especially in the return duct connection since that is typically the shortest path for mechanical noise. As heat pumps become more widely accepted, they are getting quieter.

Soil Types

Drill a test well to the estimated design specifications and test with a heating element that circulates water through the borehole for 48 hours to determine the thermal conductivity of the surrounding soil. The higher the conductivity the better, a higher diffusivity is generally better, but if the diffusivity is too high (>1.0) the well field can saturate too quickly and higher temperatures than acceptable may be seen.

SOIL CLASSIFICATION	THERMAL CONDUCTIVITY (BTU/HER-F)	THERMAL DIFFUSIVITY (SF/DAY)
Sand	0.44	0.42
Silt	0.96	–
Clay	0.64	0.50
Loam	0.52	0.46
Saturated Sand	1.44	0.86
Saturated Silt or Clay	0.96	0.61

SYSTEM TYPES

Lake Fields

The heat sink is a large body of water, either natural or man-made and a series of pipes are submerged within the water.

Open Underground Loops

Piping is buried into the earth and is routed to a natural underground reservoir of water. Water from this is directly pumped into the building and then this water is then rejected directly back into the same reservoir.

Closed Underground Loops: Horizontal Well Field

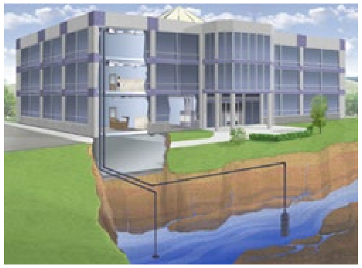
Requires a lot of open space. Series of pipes are buried within the earth and water or glycol fluid is pumped throughout these closed pipes. Heat is transferred through the piping walls.

Closed Underground Loops: Vertical Well Field

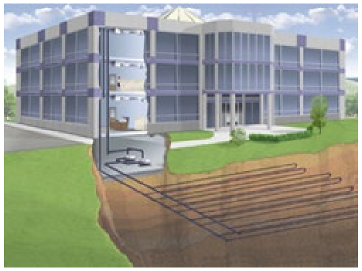
Requires piping buried between 100 to 550 feet and spaced at about 15 feet on center.

*Images courtesy of McQuay International. http://www.mcquay.com/McQuay/DesignSolutions/Geothermal

Lake Fields



Open Underground Loops



Closed Underground Loops: Horizontal Well Field

Closed Underground Loops: Vertical Well Field

FINANCIAL CONSIDERATIONS

Cost

Geothermal economics depend on several variables, including:

- Conductivity of the soil/availability of a lake river source
- Load Balance: projects with heating and cooling usage significantly out of balance will require larger fields
- Peak load profile
- Cost of labor (rural vs. urban)
- Available site area (depth vs. square footage)

Nominally, the premium for the system over a standard HVAC system is the cost of the well field itself. Prices per linear foot for a vertical well field are approximately $15-$17 per foot. A 200-foot well would cost approximately $3000 - $3400 and have a capacity of approximately 1 ton. Payback on the premium varies per project, and generally can be seven years or more, with some exceptions. Payback varies with utility cost.

O&M

Decentralized heat pump systems with several local heat pumps installed on a zone-by-zone basis may have more rigorous maintenance than a standard VAV or FCU system. Each heat pump has a compressor, or multiple compressors and those compressors require regular maintenance above and beyond the typical checks on a VAV terminal or fan coil. Verify that the building staff is trained to operate the system and is comfortable with the additional maintenance requirements.

Code Requirements/Restrictions

Some municipalities will require special permitting for deep excavation similar to permitting residential water wells. Typically closed loop ground coupled systems tied directly to a well field do not require special permitting beyond what is normally expected. Open loop systems are forbidden by many municipalities and typically require EPA approval as they relying on drilling wells directly into the aquifer and dumping heat to ground water. Loop systems that reject heat to a common body of water such as a river of lake often also require special municipal approval.

SIZE CALCULATIONS

- Vertical Well Field: 175 feet to 230 feet of depth per ton of heat rejected/absorbed
- Horizontal Well Field: 600 feet of linear length per ton (spacing varies from 10-20 feet)
- Pond/Lake systems: For a 12-foot deep pond (>10 feet recommended), 166.7 tons per acre. Capacity varies with depth
- Open Loop Systems: Injection wells must be sized to move 3 gallons per minute per ton

SOLAR THERMAL HEATING

A collector absorbs and transfers heat from the sun to water, which is stored in a tank until needed. A solar collector transfers heat from the sun to a heating transfer fluid, and then to domestic water indirectly via a heat exchanger. For maximum solar output, this heated domestic water is stored in a solar preheat tank. The solar hot water (SHW) system is meant to be the first source of heat for the domestic water, but supplemental to the conventional water heating system.

FACTORS

Climate

A project's location/climate is a big factor in solar thermal heating. The more sun available the better. In warmer climates, where freezing is not an issue, this heating transfer fluid is typically distilled water. For colder climates, this fluid is typically a mixture of antifreeze (a food grade glycol) and water.

Location

Collectors are typically installed on building rooftops or south-facing walls. Systems are often integrated into buildings or atop structures such as parking garages, requiring little to no additional land use. Systems can also be erected on adjacent open land. The panels should not be shaded by nearby buildings, mechanical penthouses or equipment.

Space Needed/Size

While the collector is tilted to face the sun, the space between collectors needs to be considered so they don't shade each other. A good rule of thumb is that each 10-foot panel requires 20 feet by 6 feet of roof space. The size of the solar preheat tank varies depending on the number of collector's installed. The rule of thumb is to provide a minimum of one gallon of storage for every square foot of collector surface area. Typical collectors have between 30 to 40 square feet of collector surface area, or 30-40 gallons per collector.

Building Types/Water Loads

Typically solar thermal heating systems are most cost-effective in:

- Small, residential-sized facilities that would otherwise depend on high-cost energy sources
- Large facilities that require large volumes of hot water (more than 1,000 gallons per day)
- Large facilities that use high-temperature hot water and swimming pools

A standard domestic water heating system should always be included to ensure domestic hot water is available year round, regardless of the weather. This secondary heat source should be downstream of the solar heating system to maximize the solar thermal system's efficiency. Less efficient solar thermal installations use domestic storage tank(s) heated by both solar thermal and a secondary source, such as a boiler or a heating element integral to the tank.

CANNONDESIGN EXPERTS

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Codes

New construction and major renovations of federal buildings in the United States are required by EISA 2007 to generate at least 30% of hot water from SHW systems.

SYSTEM TYPES

Active vs. Passive Systems

Active solar heating systems use circulating pumps and controls, are most efficient, and thus most typical. Passive solar heating systems do not use a pump, relying solely on natural convection for circulation of the heating transfer fluid, and are not recommended.

Drain Back vs. Closed Loop

Drain-back system

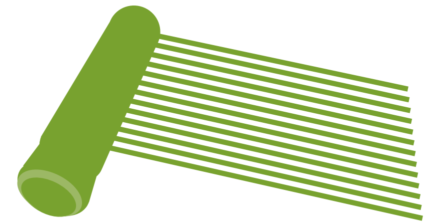
- Piping and collectors installed with a slight pitch
- When the circulation pump(s) turn off, the heating transfer fluid drains down out of the collector(s), into an open reservoir
- Avoids both freezing and/or over heating of the heating transfer fluid
- Use distilled water to avoid scaling
- More costly as each collector must be individually piped (in a parallel configuration)
- Drawback in colder climates: short cycle transferring little heat to the domestic preheat tank

Closed loop system

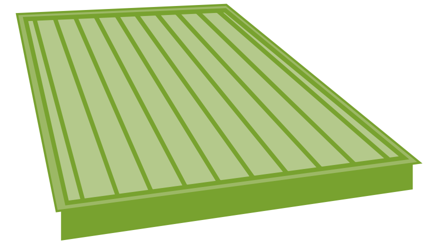
- Pressurized, where the heating transfer fluid is always within the solar piping and collectors
- Up to five collectors together in series, keeping pipe sizing, cost, and heat loss
- Drawback is that the system must be properly sized to avoid overheating

Types of Solar Collectors

- Unglazed collectors are typically used for residential pool heating when the desired temperature is near the ambient temperature. These types of collectors consist of black plastic pipes with pool water used directly as the heat transfer fluid. These collectors become less efficient as the ambient temperature drops and need to be drained along with the pool in colder climates.
- Glazed or flat plate collectors are the most common. The heating fluid runs through a series of copper tubes within the collector. These collectors are typically the most cost effective, and can be mounted either vertically or horizontally, (assuming drain-back installation is not used). These panels can typically melt any snow that covers them, by rejecting heat from heating transfer fluid.
- Evacuated tube collectors are the most expensive type and must be mounted in a vertical fashion. Gases within each evacuated tube are heated by the sun. The heated gas molecules rise to the top of the tub and transfer the heat to a copper header. The collector itself provides for smaller heat losses as compared to the other types, but this is only noticed in colder climate. These panels will not melt snow and require cleaning after a snow storm. These collectors are best suited for systems that require a higher water temperature.



Unglazed collector



Glazed (flat plate) collector

Evacuated tube collector

FINANCIAL CONSIDERATIONS

Cost

Solar hot water economics depend on several variables, including:

- Cost of the fuel replaced/offset by solar thermal heating
- Hot water demand
- Hot water usage patterns
- Incoming water temperature
- Availability of solar energy

Typical costs for all the solar thermal system components can be assumed to range from $6,000 to $8,000 per collector not including any structural supports/reinforcement. Payback varies per project, and should not be assumed less than 12 years. It is possible for certain commercial projects to obtain an accelerated depreciation on the system.

Retrofit

Retrofitting solar hot water systems into existing buildings is possible, but can be complicated by the need to provide access for installing pipes and space for water storage tanks. Structural loads of the solar thermal collectors and additional domestic storage tanks must be considered.

O&M

Solar hot water systems have few moving parts and so are reliable and require little maintenance. The acidity of the heating fluid should be checked annually and replaced as needed. The primary components of systems (collectors, heat transfer systems, heat storage, and controls) require routine, periodic maintenance. From time-to-time, individual components may need repair or replacement. The expected life span of the system is 30 years – care should be taken for design of installations where the life expectancy of the roof is shorter.

SIZE CALCULATIONS

A solar thermal system can overheat if it is oversized, or if there is not enough hot water demand during peak solar months. Size a solar thermal system to provide at most 60% of hot water demand. Beyond that, the efficient of the system dramatically decreases and therefore is not cost effective to cover the full hot water demand load of the building.

ADDITIONAL INFORMATION

GENERAL

www.dsireusa.org
Database of State Incentives for Renewables & Efficiency

www.epa.gov/greenbuilding/tools/funding.htm
Green building funding opportunities

http://apps1.eere.energy.gov/states/
US Department of Energy: Energy Efficiency & Renewable Energy State Activities & Partnerships

www.energysavers.gov/
EERE Energy Savers

PHOTOVOLTAICS

www.nrel.gov/gis/solar.html
Dynamic solar maps, GIS data and analytic tools

www.eere.energy.gov/topics/solar.html
Department of Energy Solar Programs

www1.eere.energy.gov/femp/pdfs/25272.pdf
Case Studies

http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/
Model performance of PV system - angle, ROI and energy cost saved

www.solarabcs.org/solaraccess
Verify local codes and standards for zoning

http://irecusa.org/2010/08/solar-licensing-information/
Solar licensing database

WIND TURBINE

www.designbuild-network.com/projects/bahrain/
Case study on Bahrain World Trade Centre, which is equipped with state-of-the-art wind towers

www.nrel.gov/wind/smallwind/independent_testing.html
Comparison of small wind turbines

GEOTHERMAL

http://geoheat.oit.edu
Geoheat Center

www.eere.energy.gov/topics/geothermal.html
U.S. geothermal resources and projects

www.igshpa.okstate.edu
International ground Source Heat Pump Association

SOLAR THERMAL HEATING

www.nrel.gov/gis/solar.html
Dynamic solar maps, GIS data and analytic tools

www1.eere.energy.gov/femp/pdfs/shw_freezemap.pdf
Resource map showing the probability of frozen pipes

www1.eere.energy.gov/femp/technologies/renewable_shw.html
Solar hot water resources and technologies

www.solar-rating.org/
Solar Rating & Certification Corporation

www.ases.org/
America Solar Energy Society

SIZING CALCULATORS

http://ajdesigner.com/phpwindpower/wind_generator_power.php
Wind turbine power generator equations

www.findsolar.com
Solar calculator provides system size, roof area, estimated cost, incentives, carbon emissions and ROI

www.retscreen.net/ang/home.php
A free sizing tool has been created by the Canadian government