Chapter 3: Applying Solar Technology

3.1 Primary Considerations in Selecting a PV versus Solar Thermal System

The most important consideration in selecting a solar system for a building hinges on the energy needs of the building. For example, if the building uses more electricity than natural gas, then a photovoltaic array is indicated. If the building occupants use considerable domestic hot water (e.g., a dormitory), and/or if the central HVAC system employs hot water for space heating (a so-called central hydronic HVAC system), then a solar thermal system would be the obvious choice. Optimally the available roof space will be partitioned into a PV array and solar thermal array with sizes proportional to the respective energy needs of the building.

Chapter 6 contains descriptions of recommended solar installations that serve as good examples in this discussion. East and West Dorms on the Harvey Mudd campus are equipped with multiple heat pumps that provide both heating and cooling. These systems are driven by electrical power, so the primary needs of these two dorms are for electrical energy. Hence our team is recommending a 139 kW PV array that would be distributed across the roofs of these two buildings. Of course, these dorms also require domestic hot water, so a small solar thermal system would be appropriate if roof space were available. We estimate that East and West Dorms use 2.5 times as much electrical energy as natural gas energy.

A second example in Chapter 6 involves North and South Dorms on the Harvey Mudd campus. These dorms require domestic hot water, but in addition their HVAC systems are central hydronic systems, so these dorms are big users of natural gas and would benefit from a solar thermal system on their available roof space. Our recommended solar thermal system includes an absorption chiller that is driven by extra hot water generated in the summer months. The demand for electricity needed to chill water for air conditioning will be offset partially by the solar thermal – absorption chiller system.

There is one overarching guiding principle in deciding between a solar thermal system and a photovoltaic array. The contribution of electricity consumption to the Colleges' carbon footprint will be reduced as Southern California Edison (SCE) increases its renewable energy portfolio. In principle, the Colleges can pass on the burden to reduce their carbon footprint to SCE, at least that portion of the footprint generated by our electricity needs. But no amount of foot-dragging will reduce our carbon footprint due to the burning of natural gas on our campuses. For this reason, solar thermal systems that displace the burning of natural gas should be given priority over electricity-producing technologies whenever possible.

3.2 Designing and Installing Solar Systems

There are a number of physical requirements that arise when designing and installing a solar system – either a PV array or a solar thermal system. These physical requirements pertain chiefly to sizing and locating the array. When scouting for a location, it is important to keep in mind that the angle of the sun measured from the horizon changes as the seasons change, so areas that may be free of shading in the summer may fall into the shadows of trees or other structures in the winter. Since the earth has an axial tilt of 23.5º, there will be a variation in the sun's position above the horizon from the summer to winter solstice. At 34ºN latitude (Claremont, CA), the sun will be approximately 79.5º above the horizon during the summer solstice, while during the winter solstice the sun will be about 32.5º above the horizon. For some PV systems, shading even part of a cell may decrease the performance of the entire panel by a significant amount and so should be avoided. For solar thermal panels, performance is directly and linearly related to the insolation experienced by the panel.

In addition to finding a location with minimal shading, it is necessary to look at what roofing material is used. While tiled and shingled roofs will not prevent a solar system from being installed, they will increase the system cost due to any support frame or anchoring necessary for the panels. Moreover, these roofing materials often provide significant aesthetic value to the building, from which solar panels may detract. There are, however, solar PV shingles available on the market; the Miller Cottage building on the Pomona College campus utilizes these types of shingles. Ideally though, flat roof spaces should be the most highly utilized space on a building for a solar array. It is also important to note that most solar systems need some sort of anchoring mechanism either with roof penetrations or one that is ballasted; hence a roof that can support these kinds of structures is essential.

A solar system should also be sized and oriented correctly when a location is determined. Solar panels may be tilted to optimize the balance between summer and winter sun positions in the sky, but high tilt angles also lead to shadowing of panels by their neighboring panels. To overcome shadowing, the number of panels accommodated by a given roof area must be reduced, decreasing the maximum generation capacity of the available roof space. Each system must be optimized to increase system performance for the available space while minimizing the cost of the system. There is an inherent optimization battle between costs versus performance versus available space, and if the system is sized and oriented correctly, the winner should be the checkbook.[1]

When sizing PV arrays, there is an interesting and somewhat unfortunate fact to bring into consideration. In what is termed "net energy metering" the utility company will credit a bill with generated electricity (meters run backwards if more electrical power is generated than is being used by the customer). However, unlike much of Europe, U.S. utility companies are not required to compensate customers that produce more energy over the course of a year than they use. Thus, a PV array that could be sized larger to

[1] M. Culligan, J. Botkin. "Impact of Tilt Angle on System Economics for Area Constrained Rooftops." SunPower Corporation. Berkeley, California.

take advantage of additional roof space will not be optimized for financial performance because the excess electrical power produced by the PV array would reap no financial rewards. This point must be considered only for PV arrays on buildings served by the SCE grid directly, rather than the CUC sub-grid.

Sizing a solar thermal system generally involves determining the capacity of a hot water storage tank. For example, the proposed solar thermal system for Sontag Residence Hall on the Harvey Mudd campus (see Chapter 6) requires an additional 1500 gallon tank to provide for domestic hot water needs. If an absorption chiller is included in the system to provide an outlet for excess hot water in the summer and to displace the use of electricity for air conditioning (see North-South Dorms system in Chapter 6), a 3600 gallon tank is required (10' diameter by 6' tall). Thus, a solar thermal system may have an additional space requirement to consider, though the storage tanks do not necessarily need to be next to the solar collectors.

3.3 Manufacturers of Solar Technology

The following is a short and certainly not comprehensive list of companies that manufacture solar panels. The solar industry is highly dynamic, and the reader is advised to search the internet for companies that have recently entered the market. However, the following list includes most of the major players as of the summer 2008, and should serve to jump-start any search for solar systems.

Manufacturers of Photovoltaic Panels:

BP – Produces silicon nitride multicrystalline solar photovoltaic panels. BP offers modules from 5 to 200 watts.
Website: http://www.bp.com/

Conergy – A manufacturer of solar photovoltaic panels as well as solar water pumps and small wind power. Their photovoltaic panels are monocrystalline with a panel efficiency of 13.7%. Conergy also is a distributor of SunEarth solar thermal collectors.
Website: http://conergy.us/

CSI – A Canadian producer of photovoltaic panels that uses both monocrystalline and polycrystalline cells for up to 14.9% module efficiencies.
Website: http://www.csisolar.com/

Day4 Energy – A photovoltaic manufacturer using multicrystalline silicon cells with module efficiencies up to 14.7%
Website: http://www.day4energy.com/

Evergreen Solar – Based in Massachusetts, Evergreen Solar uses a "String-Ribbon" manufacturing process to create polycrystalline silicon cells with module efficiencies up to 13.1%.
Website: http://www.evergreensolar.com/

First Solar – Solar photovoltaic producer of thin film panels. First Solar uses a CdTe semiconductor for their utility grade panels. Currently, First Solar is only selling panels to grid-tied commercial power plants.
Website: http://www.firstsolar.com/

Isofoton – A European producer of solar photovoltaic and solar thermal collectors. Isofoton uses silicon monocrystalline cells to produce modules with up to 12% efficiency.
Website: http://www.isofoton.com/

Jiangsu Huaguang New Energy Tech – A Changzhou-based company producing photovoltaic panels with monocrystalline and polycrystalline modules along with building integrated photovoltaics.
Website: http://www.hg-solar.com/

Lumeta – A manufacturer of building-integrated photovoltaic panels. Lumeta offers flat tiles for both sloping and flat roofs as well as an "S-tile" for clay and concrete tiled roofs.
Website: http://www.lumetasolar.com/

Kyocera – Produces multi-crystalline PV panels with panel efficiencies of up to 16% Kyocera offers both traditional flat panels as well as roofing tiles.
Website: http://global.kyocera.com/prdct/solar/

Mitsubishi Electric – A producer of solar photovoltaic cells using polycrystalline silicon cells with module efficiencies up to 13.7%.
Website: https://www.mitsubishielectricsolar.com/

NanoSolar – A non-silicon thin film manufacturer that utilizes patented CIGS technology. NanoSolar employs a roll-to-roll printing method with CIGS ink, outputting 100 feet of solar panel every minute
Website: http://nanosolar.com/

Photowatt – A solar photovoltaic company that produces both monocrystalline and multicrystalline modules in ranges from 12 to 230 watts with efficiencies around 13%.
Website: http://www.photowatt.com/

Sanyo – Producer of solar panels using hetero-junction panels with thin film layers. Sanyo manufactures standard solar panels, double sided panels, and amorphous silicon panels.
Website: http://us.sanyo.com/solar/

Schott – Among many other products, Schott manufactures concentrated solar power, crystalline and thin film panels, as well as building-integrated photovoltaics.
Website: www.schott.com/solar/

Schüco – Manufactures both solar photovoltaic and solar thermal panels along with architectural insulating glass.
Website: http://www.schueco.com/

Sharp – Manufacturing solar cells since 1959, Sharp claims to produce one quarter of all solar production in the world.
Website: http://solar.sharpusa.com/

Shell Solar – A former manufacturer of silicon wafers, Shell Solar is in the process of becoming a thin film producer using CIS technology. In a joint venture between Shell and Saint-Gobain, Avancis is expected to be producing solar panels in 2008 with a production facility in Germany.
Website: www.shell.com/solar/, http://www.avancis.de/company

Solar-Fabrik – A European manufacturer of solar panels with module efficiencies up to 13.2%.
Website: http://www.solar-fabrik.com/

Solarfun – A Shanghai based photovoltaic producer that uses monocrystalline cells for claimed module efficiencies up to 16.5%.
Website: http://www.solarfun.com.cn/

SolarWorld – Established 1977, SolarWorld produces photovoltaic panels that use monocrystalline silicon cells that yield module efficiencies of up to 13.5%
Website: http://www.solarworld-usa.com/

SunPower – As a manufacturer of solar electric panels, SunPower uses high-efficiency silicon technology. They offer residential, commercial, and utility grade solar panels, including roofing tiles. SunPower also boasts 19.3% panel efficiency on their 315 Solar Panel module.
Website: www.SunPowercorp.com

Sunways – A producer of photovoltaic panels using both monocrystalline and multicrystalline cells for efficiencies up to 13.5%.
Website: http://www.sunways.de/en/

Yingli Solar – One of the largest PV manufacturers in China using multicrystalline polysilicon cells with 200 MW of production capacity.
Website: http://www.yinglisolar.com/

Manufacturers of Solar Thermal Panels:

Alternative Energy Technologies, LLC – A Florida-based manufacturer of Thermafin absorber plates and flat plate solar thermal collectors.
Website: http://www.aetsolar.com/

Apricus – A global company producing evacuated tube solar hot water collectors.
Website: www.apricus.com/

Chromagen – A producer of solar collectors along with whole systems for small to large scale applications in warm and cold climates.
Website: http://chromagen.biz/

Heliodyne – A manufacturer of primarily solar hot water systems. Heliodyne produces packaged systems for warm and cool climates as well as for pool heating.
Website: http://www.heliodyne.com/

Isofoton – A European producer of solar photovoltaic and solar thermal collectors. Isofoton uses silicon monocrystalline cells to produce modules with up to 12% efficiency.
Website: http://www.isofoton.com/

Linuo Paradigma – The largest solar thermal producer in China, Linuo Paradigma offers vacuum tubes, siphoning systems, collectors, and tanks.
Website: http://en.linuo-paradigma.com/

Menova Energy – A Canadian based manufacturer of a hybrid concentrated solar power/solar thermal system. Menova uses a parabolic trough to focus sunlight onto a strip of photovoltaic material and cools the material with a glycol heating fluid to capture the heat energy. The arrays are then placed on a one or two axis tracking mechanism.
Website: http://www.power-spar.com/

Ritter Solar – A manufacturer of solar thermal systems using evacuated tubes with and without compound parabolic concentrator reflectors.
Website: http://www.rittersolar.de/

Schüco – Manufactures both solar photovoltaic and solar thermal panels along with architectural insulating glass.
Website: http://www.schueco.com/

SolarRoofs – A manufacturer of solar water collectors, with their Skyline® models featured on ABC's *Extreme Home Makeover: Home Edition*, the History Channel's *Modern Marvel*, and the Discovery Channel's *Wasted!*.
Website: http://solarroofs.com/index.html

Sunda – Based in Beijing, Sunda offers evacuated tubes, solar collectors, and solar water heaters that package tank and collector into one unit.
Website: http://www.sundasolar.com/

SunEarth – A manufacturer of solar hot water collectors. SunEarth produces four active flat plate collectors for both residential and commercial use as well as two passive collectors that do not require pumping.
Website: http://www.sunearthinc.com/

3.4 Designers/Installers/Vendors

Following is a brief list of installers for solar photovoltaic and solar thermal systems. This list is in no way all-inclusive, offering just a small sample of installers.

Designers/Installers/Vendors of Photovoltaic Panels:

Akeena Solar – A solar electric installer with 6.2 MW installed across California, New York, New Jersey and Connecticut.
Website: http://akeena.net/

EnergyHarvester – Mark and Eric Von Wodtke operate this small company located in Claremont, CA. They will be proposing a PV system, a solar thermal system, and a hybrid concentrated PV – solar thermal system for the roof of Sontag Residence Hall on the Mudd campus.
Website: http://www.energyharvester.com/

HelioPower – An installer of both solar photovoltaic and solar thermal systems for residential and commercial installations.
Website: http://www.heliopower.com/

iPower/Recurrent Energy – iPower is a solar photovoltaic installer. For our estimate on the 103 kWac East Dorm array, they suggested using Sanyo HIT-200 solar panels. In their East/West Dorm 139.8 kW system, they proposed 190 watt Evergreen Solar "Spruce Line" panels. iPower relies on Recurrent Energy for establishing power purchase agreements. Our contact, Tony Papavero, has been helpful in understanding their proposed system and providing feedback to our own ideas.
Website: www.iPowercorp.com, www.RecurrentEnergy.com

Mehr Solar – An installer of PV panels for residential, commercial, and agricultural uses on both the East and West Coasts.
Website: http://www.mehrsolar.com/

Premier Power – A solar electric installer claiming to have installed the most building-integrated solar panel roof tiles in California in 2003.
Website: http://www.premierpower.com/

REC Solar – A California installer of photovoltaic panels with over 8.5 MW installed since entering the market in 1997. REC Solar claims to install more solar power systems than any other installer in the U.S.
Website: http://www.recsolar.com/

Solar City – A photovoltaic installer that also offers customers the ability to "lease" rather than purchase solar systems.
Website: www.SolarCity.com

Southern California Edison -- SCE has recently announced a solar roofs program to install 250 MW of photovoltaic capacity on roofs in southern California.[2] SCE will pay for the solar array, install it and operate it as a miniature power plant for their grid. The company has declared they expect to be able to install the panels for the program at a price of $3.50 per watt, or 20 ¢/kWh.[3] The first installation is a 2 MW array on the roof of a commercial building in Fontana using FirstSolar CdTe thin film panels. The array is expected to begin producing power in September, 2008.
Website: http://www.sce.com/

Designers/Installers/Vendors of Solar Thermal Systems:

Altadena Energy & Solar – Located in Altadena, Ca, Altadena Energy & Solar is an installer of both solar thermal and solar photovoltaic systems operated by Hans Rosenberger.
Website: http://altadenasolar.com/

Dawn Solar Systems – Focusing on architecturally integrated solar energy, Dawn Solar Systems designs their solar thermal systems to be behind the roofing material so as to hide any "ugly" collectors and boost aesthetic value of the entire system.
Website: http://www.dawnsolar.com/

EnergyHarvester – Mark and Eric Von Wodtke operate this small company located in Claremont, CA. They will be proposing a PV system, a solar thermal system, and a hybrid concentrated PV – solar thermal system for the roof of Sontag Residence Hall on the Mudd campus.
Website: http://www.energyharvester.com/

HelioPower – An installer of both solar photovoltaic and solar thermal systems for residential and commercial installations.
Website: http://www.heliopower.com/

SunChiller – An installer of solar thermal arrays and one of the few installers that couple solar thermal panels to an absorption chiller. SunChiller is operated under CEO Serge Adamian, who from our team's experience was very willing to work with us. In general

[2] Southern California Edison. *Southern California Edison Launches Nation's Largest Solar Panel Installation*. March 27, 2008. http://www.edison.com/pressroom/pr.asp?bu=&year=0&id=7002
[3] Southern California Edison. *Southern California Edison Begins Construction of World's Largest Solar Panel Installation Project*. July 16, 2008.
http://www.edison.com/pressroom/pr.asp?bu=&year=0&id=7083

SunChiller specializes in larger systems under power purchase agreements that may also, but not necessarily, include photovoltaic panels.
Website: www.SunChiller.com

SunWater Solar – A "design/build" company specializing in solar thermal installations for both residential and commercial applications.
Website: http://www.sunwatersolar.com/

3.5 Power Purchase Agreement Companies

Our summer 2008 team is aware of several companies that finance "power purchase agreements (PPAs)." In a PPA, a for-profit company installs a PV array (for example) at their expense on the property of a non-profit institution (e.g., HMC). The for-profit company owns and operates the generating equipment and sells the electrical power to the non-profit institution at an agreed-upon rate (e.g., 1% below market rate) for a predetermined period of time (e.g., 20 years). The for-profit company is able to take advantage of tax credits and tax deductions (e.g., equipment depreciation) that are not available to a non-profit institution, while the non-profit is able to enjoy the clean energy generated on their property.

We list below the companies that have caught our attention, though there are many more that have entered this very volatile market. The primary federal tax credit for renewable energy systems expired at the end of 2008, but it was strengthened and renewed for 2009 and beyond. Changes in federal and state legislation could have dramatic effects on the PPA financial industry.

PPA Companies

Recurrent Energy is based in San Francisco and wrote a PPA for the proposed HMC East-West Dorm PV array. They also recently provided a PPA for a 1 MW PV array at the headquarters of The North Face in Visalia, CA.
Website: http://www.recurrentenergy.com/

SunEdison is headquartered in Beltsville, MD, and is perhaps the largest and best known of the PPA companies. We have not yet been able to solicit a proposal from them for a Claremont Colleges installation – they prefer large installations.
Website: http://www.sunedison.com/

GE Energy Financial Services is based in Stamford, CT, and invests in all types of energy. Most recently it has financed projects in wind and solar energy.
Website: http://www.geenergyfinancialservices.com/