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ENERGY SMARTS: PHOTOVOLTAIC SYSTEMS (PV)

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The sun is a source of energy that enters the Earth's atmosphere. It is readily available, but largely underutilized. A photovoltaic system, often called PV or solar panels, can capture the sun's energy and convert it into usable electricity. Photovoltaic literally means sun (photo) power (voltaic). In order for a PV system to be most effective, a home must already be energy efficient. The less energy a home uses, the fewer PV panels will be needed.

HOW DOES PV WORK?

A solar PV system converts the sun's energy into direct electrical current (DC). Some, but not all, appliances are adapted to use DC electricity. Most lighting, appliances, and equipment use alternating electrical current (AC). Therefore, the DC produced by photovoltaic needs to be converted to AC using an inverter.

PV CELLS, MODULES, PANELS AND THE ARRAY

PV cells, also known as solar cells, are made of a thin slice of semiconductive material, such as crystal silicon, specially treated to form an electric field with a positive and a negative side. When light strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material and create electrical current.

Often solar cells are grouped to increase power output. Several PV cells connected in series or parallel circuits to create higher electric output are called a PV *module*. Two or more modules can be pre-wired together to be installed as a single unit called a PV or solar *panel*. Additional PV panels can be added as electricity production needs increase. The entire PV system, consisting of one or more panels, is termed an *array*.

INVERTER

Inverters are used to convert the system's direct electrical current (DC) into alternating electrical current (AC). AC electricity is compatible with conventional electrical systems in most U.S. homes, and is usually necessary for grid-connected systems. Grid connected means that the solar power being generated is connected to the utility grid.

BATTERIES AND CONTROLLER

Batteries can be a method of storing excess electricity produced by the PV system to be used later when there is limited or no sunlight. A charge controller may also be needed to regulate battery charge and prevent power loss. For grid-connected systems, batteries are sometimes used as back up storage when the power grid is unavailable.

LOADS

The appliances which actually use the energy supplied by the PV array are called loads. The load size should be considered because the PV system can only produce a certain amount of energy. Many PV owners schedule appliance use according to the electricity generation capacity of the system and when other loads are in use. For example, if the PV system is the sole source of electrical generation, it may not be possible to run the refrigerator, dishwasher, lights, and the vacuum all at the same time, unless it is a large system or a back-up power source is also used. Table 1 lists of the typical electricity usage of common household appliances.

TYPES OF SYSTEMS

PV owners have several options for using and storing the electricity produced by their systems. PV systems can be grid-connected, grid-independent, or a combination of the two. The particular PV system will depend on preference of the homeowner, size of the system, proximity to a power grid, and need for a reliable supply of energy.

Grid-Connected

Grid-connected PV systems are connected to the utility power grid. Homes using this type of PV system can utilize electricity from the power grid during dark hours, or if the PV system isn't generating enough electricity to run several appliances at once. When the PV system produces more power than it is using, the extra power

flows into the grid. In Utah, utility companies are required to give the customer direct credit for electricity that goes back into the grid. In this "net metering" system, power going into the grid has the same worth as that coming out.

Grid-Independent

Grid-independent systems are often used to power homes in remote locations where it is not physically or economically feasible to connect to the established power grid. It is often less expensive to install a PV system than to pay for electrical lines in a remote location. In most cases, a grid-independent system will require batteries to store electricity for use when the sun is not shining. Since a PV system may be fairly expensive to purchase compared to readily-available electricity, a grid-independent system may not be an economical option for a house located near an existing power grid. However, people who are concerned about the environmental impact of electricity generation and want to use renewable energy are purchasing PV systems regardless of life cycle costs.

A well-designed PV-battery, grid-independent system balances cost and convenience with the user's electrical needs, and it can be expanded if those needs increase. Including more modules and batteries increases system costs, so energy use needs to be studied carefully to determine the best system size for the electrical load.

Hybrid

Hybrid systems receive a portion of their power from one or more sources, including PV. PV modules are often paired with electricity from the grid, a wind generator or a fuel-powered generator. Hybrid systems are different from the standard grid-connected systems because they store excess energy in batteries, thereby insuring that electricity is accessible when utility power is unavailable.

MOUNTING

Photovoltaic arrays can be integrated into roofing materials, mounted on the roof, or mounted on the ground or a pole. Whatever the mounting, it should be made of a stable, durable structure that can support the array, and withstand wind, rain, hail, and other outdoor conditions.

Table 1. Estimated Monthly Kilowatt Hour Consumption

Comfort Central Air Conditioning:

- 2 tons= 1450 kW_{wh}
- 3 tons= 2100 kW_h
- 4 tons= 2750 kW_h

Room Units:

- 1 Ton, EER 6= 2 kW_h
- 8= 1 1/2 kW_h.
- 3/4 Ton, EER 6= 1 1/2 kW_h
- 3/4 ton, EER 8= 1 kW_h
- Dehumidifier= 31kW_h

Fans:

- Whole House= 30 kW_h
- Circulating= 4 kW_h
- Ceiling= 12 kW_h

Water Heating/Supply:

- Water Heater: Typical Use, 2 Persons= 195 kW_h;
4 Persons= 310 kW_h
- Pool Pump (3/4 HP)= 375 kW_h
- Sprinkler System (1 1/2 HP)= 28 kW_h

Kitchen Appliances:

- Baby Food/Bottle Warmer= 2 kW_h
- Broiler/Rotisserie= 7 kW_h
- Coffee Maker= 9 kW_h
- Deep Fat Fryer= 7 kW_h
- Dishwasher= 30 kW_h
- Egg Cooker= 1kW_h
- Frying Pan= 8 kW_h
- Hot Plate= 4 kW_h
- Microwave Oven= 16 kW_h
- Range with Oven= 58 kW_h
- With Self-Clean Oven= 61kW_h
- Roaster= 5 kW_h
- Sandwich Grill= 3 kW_h
- Slow Cooker= 12 kW_h
- Toaster= 3 kW_h
- Trash Compactor= 4 kW_h
- Waffle Iron= 2 kW_h
- Food Mixer= less than 1 kW_h

Food Preservation:

- Refrigerator, Manual 12 cu. ft.= 78 kW_h

Refrigerator-Freezer:

- Manual, 12-14 cu. ft.= 125 kW_h
- Frost-free, 14-17 cu. ft.= 170 kW_h
- Frost free, 17-20 cu. ft.= 205 kW_h

Freezer:

- Manual, 14 1/2-17 1/2 cu. ft.= 135 kW_h
- Frost- Free, 14 1/2- 17 1/2 cu. ft.= 188 kW_h

Laundry Services:

- Dryer= 75 kW_h
- Iron= 5 kW_h
- Washing Machine= 9 kW_h

Lighting:

- 4-5 Room= 50 kW_h
- 6-8 Room= 60 kW_h
- Outdoors, 1 Spotlight, All Night= 45 kW_h

Housewares:

- Clocks= 1 1/2 kW_h
- Floor Polisher= 1 kW_h
- Sewing Machine= 1 kW_h
- Vacuum Cleaner= 4 kW_h

Health and Beauty:

- Hair Dryer= 2 kW_h
- Hair Roller= 1 kW_h
- Heating Pad= 1 kW_h
- Infrared Heat Lamp= 1 kW_h
- Sun Lamp= 1 kW_h
- Curling Iron, Shaver= less than 1/2 kW_h

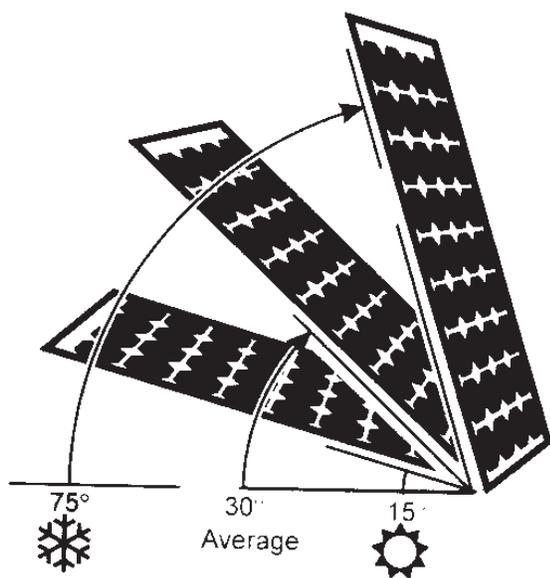
Home Entertainment:

- Radio= 7 kW_h
- Radio/Record Player= 9 kW_h
- Television (color solid state)= 27 kW_h

PV panels should always be mounted facing solar south, which differs from magnetic south as shown on a compass. To determine solar south from the site of your PV system, refer to Appendix A.

On stationary structures, the PV array is mounted at a fixed angle. This angle is determined by the requirements of the load and the availability of sunlight. The rule of thumb for determining the tilt angle is that if the PV system is used mainly in the summer, tilt the panel 15 degrees up from the horizontal plane of the ground (see Figure 1). The tilt is closer to horizontal because of summer's high sun angles. If the PV system is to be used primarily in winter, add 75 degrees to the horizontal plane of the ground. The tilt is closer to vertical because of the low sun angle in winter. Also the 75 degree angle will allow winter snow to easily slide off the array so as not to cover it. To collect solar energy throughout the year, tilt the panel 30 degrees up from the horizontal plane of the ground.

Figure 1. Seasonal PV Solar Angles



Another method for determining tilt angle is based on the degrees latitude of the mounting site. To maximize winter electricity generation, add 15 to the latitude. For example, at the Utah House in Kaysville, the latitude is 41 degrees. The panel should be tilted at 56 degrees ($41^\circ + 15^\circ = 56^\circ$) up from the horizontal plane of the

ground. To maximize electricity generation from the summer sunlight, subtract 15 degrees from the latitude to find the proper tilt angle. At the Utah House, to maximize summer sunlight, the PV array should be tilted at 26 degrees ($41^\circ - 15^\circ = 26^\circ$). Other Utah latitudes are listed in Table 2.

Table 2. Approximate Utah Town Latitudes

Utah Town	Approximate Latitude (in degrees)
St. George	37
Cedar City	38
Price	39
Provo / Vernal	40
Salt Lake City	41
Logan	42

(Adapted: Quest Enterprises, 2003)

Sometimes the mounting structure is designed to track the sun's angle in order to maximize the efficiency of the PV system year-round (see Table 3). The most common type of residential trackers can also follow the sun from east to west in order to gain the most sunlight during daylight hours (U.S. Department of Energy, 2004).

BENEFITS

Sustainability

Operating a PV system has very little negative impact on the environment. Unlike electricity produced from fossil fuels, PV systems produce electricity without air polluting emissions. Because sunlight is free and a constantly renewable source of energy, it cannot be depleted through overuse. Using PV to produce energy can help to reduce the demand for electricity from coal fired power plants, which cause air pollution and other green house gas emissions.

Energy Efficiency

PV systems will produce energy whenever the sun is shining. However, a PV system will produce more energy when the sunlight is more intense and direct, such as during the sunniest periods of the summer. During the summer, electrical demand is very high for air conditioning, and a peak time for utility companies. This means that the demand for electricity from the municipal

power grid is typically at its highest level during the summer. An added benefit of using a PV system is that it can produce the most electricity when the power grid is typically in the highest demand, thus reducing the risk of blackouts or brownouts caused by system overload.

Energy Accessibility

In rural locations where grid power is unavailable, or where extending a power grid connection is costly or physically impossible, installing a PV system can be a simple and cost-effective method to generate power. In urban settings, a PV system eliminates the need to drill additional trenches or to build above-ground power lines to provide additional energy for expanding communities. In such a context, installing a PV system may be a cost-effective alternative.

of power generation equipment. These systems can be ordered so they are portable and require little installation.

Increased Property Values

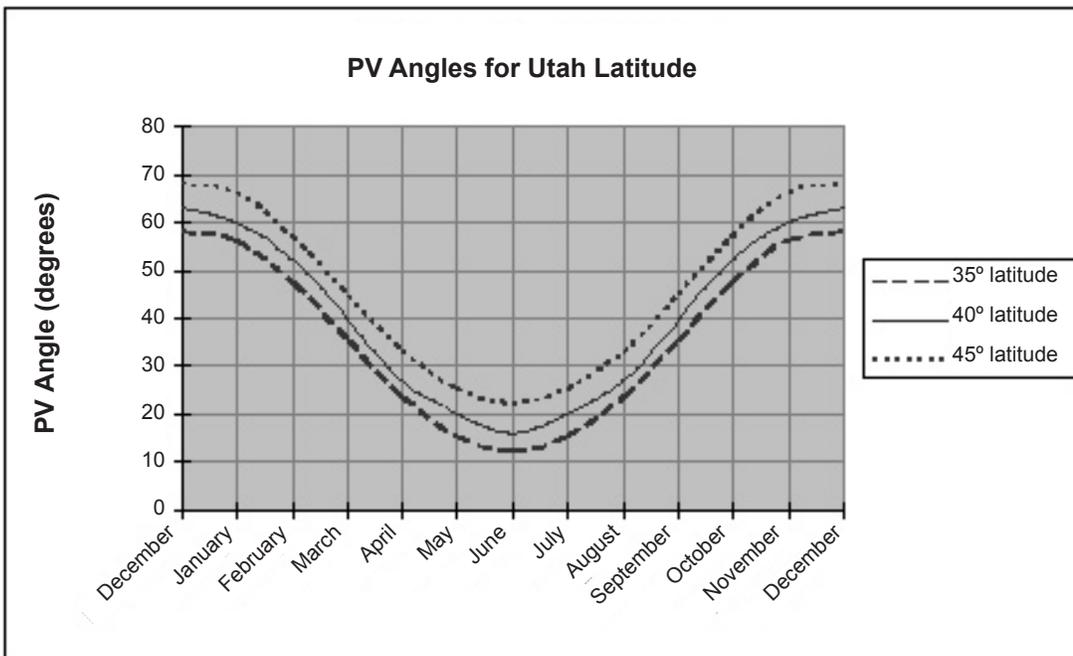
PV systems can significantly increase the property value of your home. A National Appraisal Institute study estimated that for every \$1 reduction in your annual energy bills, your home's value increased by \$20 (SolSource, 2004).

Reduced Energy Costs

PV systems reduce energy costs. Depending on the location, installation and system efficiency, it is possible to pay back the cost of the PV system. This is especially true when the homeowner is able to take advantage of tax credits or other types of incentives. According to our

calculations a 1 kW system at 0.085 cents per kWh will pay for itself in 32 years. These days, many PV systems last up to 40 years (SolSource Energy, 2004).

Table 3. Recommended Solar Panel Tile Angle for Utah Latitudes



(Adapted: Perez and Coleman, 1993)

Flexibility, Comfort and Simplicity

A PV system can be constructed in many sizes depending on the owner's energy needs, and panels can be added as energy needs increase. In addition, many modern PV panels are available in a variety of colors and styles that can be integrated into the home design. PV systems produce electricity without any noise, moving parts, or air pollution emissions that are associated with other kinds

a maximum of \$2,000 per system. Utah application forms can be obtained from Utah Energy Office, 1594 West North Temple, Suite 3610, Box 146480, Salt Lake City, UT 84114-6480, or on line <http://incometax.utah.gov/creditsrenewenergy.html>. Similar tax incentives are available in other states. For information about tax incentives offered in other locations, visit the database of state incentives for renewable energy at www.dsireusa.org.

Tax Incentives

In Utah, tax credits for PV systems and other renewable energy systems are available to pay for up to 25 percent of the cost of components and installation, with

CONCERNS

Cost

Purchasing and installing a PV system can be costly. The total cost of a PV system will depend on many factors, including the size of the system; method used to mount the system, whether or not the system requires batteries, or is connected to the grid. Except for those who live in remote areas where achieving grid connection would require extending the power grid, the price might not be competitive to the price of electricity from a municipal grid (see Table 4). However, the rebates and tax incentives available could help offset the cost of a PV system.

be consistent. Factors such as clouds, shade from trees, or snow collection will affect a PV system's ability to produce energy. For that reason, it is important for PV solar panels to be kept free of debris and placed away from trees, buildings, or other sunlight barriers. For a consistent source of electricity, a PV owner should consider batteries or a grid connection to support the system. With a grid-connected system, when the utility grid has a power loss, the inverter stops working. Therefore, many PV systems that are grid-connected will not work unless the grid is receiving power from the utility company.

Table 4. *When Will PV System Pay For Itself?

When Paying This Amount	**Life of PV	\$kWh	***Nominal Monthly Electricity Savings	\$ Saved Per Year	Yrs to Pay Back Investment
\$20,000	50 years	.085	\$13	\$156	128
\$15,000	50 years	.085	\$13	\$156	96
\$10,000	50 years	.085	\$13	\$156	64
\$5,000	50 years	.085	\$13	\$156	32

* Used PV system installed at Utah House: Grid-Tied - 1-5 kW **Newer units have a life expectancy of 50 years, older units 30 years

***Assumptions power output 5W/ft.5 Watts per foot, average 5 sun hrs/day, 80% of power rated, PV area 200 ft²

Installation

For some applications, installing a PV system requires equipment to be specially engineered, which can be a lengthy and expensive process. Integrated roof systems are usually more expensive and somewhat difficult to install on existing roofs, so it is generally better to install such systems during the initial roof construction. For existing rooftops, a PV system can be mounted on the top of the roof, but not integrated into the roofing material. However, there are PV systems that look like asphalt shingles and can be easily integrated into existing shingles.

Intermittent Energy Production

A PV system produces energy only when the sun is shining, so the production of energy may not

Solar Potential in Utah

Utah has enough solar energy potential to produce up to 69 million megawatt-hours (MWh) per year (The Energy Foundation, 2002). In 1999, Utah's total electricity consumption was 22 million MWh, which means that Utah's total solar potential exceeds power demand. Sunny skies prevail most of the year in Utah (Western Regional Climate Center).

Not only are there excellent solar resources in Utah, but PV installation is now easier than ever and Utah has a number of locations where you can see PV systems in operation, such as the Utah House, owned by Utah State University Extension and located at the Utah Botanical Center in Kaysville, Utah. Just a few years ago, when the Utah House installed its PV system, there were no businesses that offered professional PV installation in Utah. At the time of this publication, there are about 16

such Utah businesses, making locating the PV and installers much easier.

CONCLUSION

Converting the sun's energy into usable electricity for our homes through PV technology offers many opportunities to Utahns. Whether you are building a home in a remote location and concerned about the cost of connecting to the power grid, or live in an urban setting and are concerned about your home's contribution to pollution, PV is a possibility. With excellent solar resources available in Utah, rising fuel costs, and many new businesses selling and installing PV systems, solar energy is likely to become more widely utilized in Utah.

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APPENDIX A. CALCULATE SOLAR NOON AT YOUR HOME'S SITE

1. Determine sunrise and sunset for your site from the local news or an almanac.
2. Count the number of daylight hours and minutes separately.
3. Using a calculator, multiply the number of daylight hours by 60 to convert to minutes.
4. Add the remaining minutes to get total daylight minutes.
5. Divide the total daylight minutes in half to find the mid-point of the total daylight minutes (i.e., solar noon).
6. Divide by 60. The number left of the decimal point is the number of daylight "morning" hours (i.e., before solar noon).
7. Now the leftover fraction of minutes must be converted back to actual minutes. Subtract the number of hours to isolate the leftover fraction of minutes, a decimal between 0.0 and 0.9999...
8. Multiply this number by 60 to figure the remaining minutes. Add these minutes to the number of "morning" hours.
9. Now add the total "morning" daylight hours and minutes to the time of sunrise. The result is the exact time of solar noon.

For example,

1. In Salt Lake City on June 21st, sunrise is at 5:56 a.m. and sunset is at 9:02 p.m.
2. There are 15 total daylight hours, plus 6 additional minutes.
3. (Number of daylight hours) multiplied by (60)
 $15 \times 60 = 900$;
4. (Number of daylight minutes from hours) + (additional daylight minutes)
 $900 + 6 = 906$.
5. (Number of total daylight minutes) divided by (2)
 $906 / 2 = 453$

6. (Midpoint of total daylight minutes) divided by (60)
 $453 / 60 = 7.55$

7. Subtract (number of hours)
 $7.55 - 7 = 0.55$

8. Multiply remaining minute's fraction by 60
 $0.55 \times 60 = 33$

9. Solar noon is 7 hours and 33 minutes later than sunrise:
5:56 am + 7 hours and 33 minutes is 1:29 p.m.

CALCULATE YOUR HOME'S SOLAR NOON:

1. Date: _____ Sunrise: _____ Sunset: _____

2. Hours _____ & Minutes _____ between Sunrise & Sunset

3. (_____ Hours) x (60) = _____

4. (_____ minutes from Hours) + (_____ additional Minutes) = _____

5. (_____ total daylight minutes) / (2) = _____

6. (_____ [answer from step 4]) / (60 = _____ [interger from step 5]) = _____ Hours

7. (_____ [answer from step 5]) - (_____ [interger from step 5]) = _____

8. (_____ [remaining decimal number from step 6]) x (60) = _____ Minutes

9. Sunrise plus _____ Hours and _____ Minutes = _____ Solar Noon

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