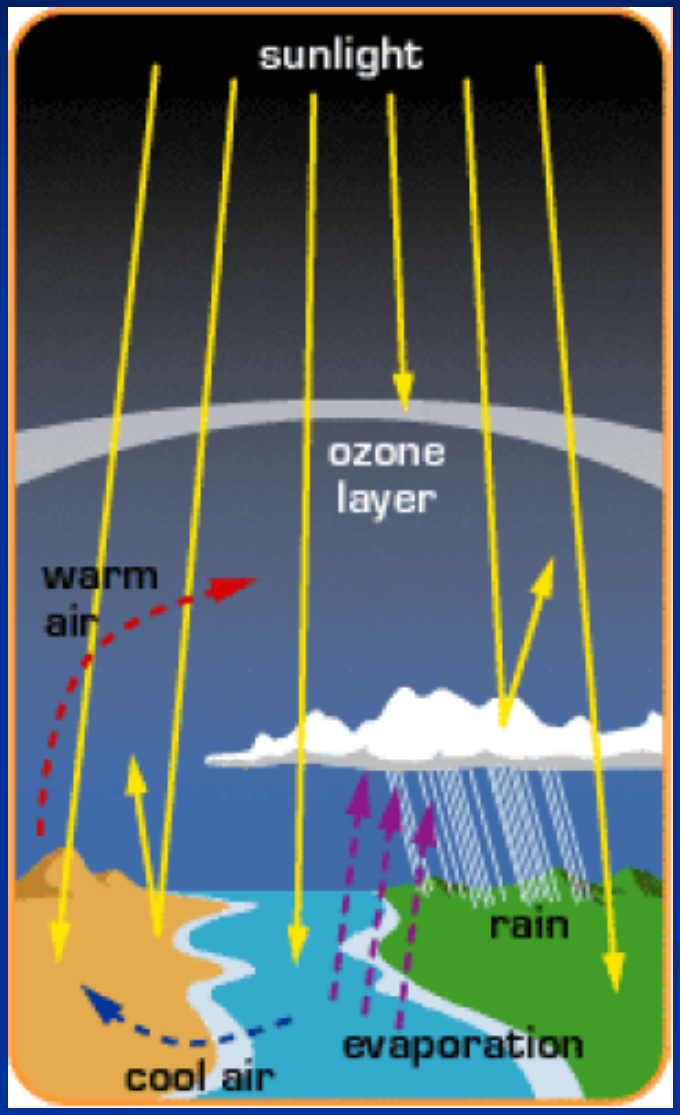
Introduction to Alternative Energy

Solar Energy

What Is Solar Energy?

- Solar energy is the energy that comes from the Sun that supports life on earth as we know it.

- Solar energy can be used as a source of heat and light and can be used to generate electricity



How Was Solar Used In The Past?

- People have been trying to harness the power of the sun for centuries
- In 1877, air blowing over sun-heated iron was used to heat homes
- In 1910, the first patent involving a solar collector was awarded
- The 1930's saw the first widespread use of solar power for heating

Solar Energy Power Plants

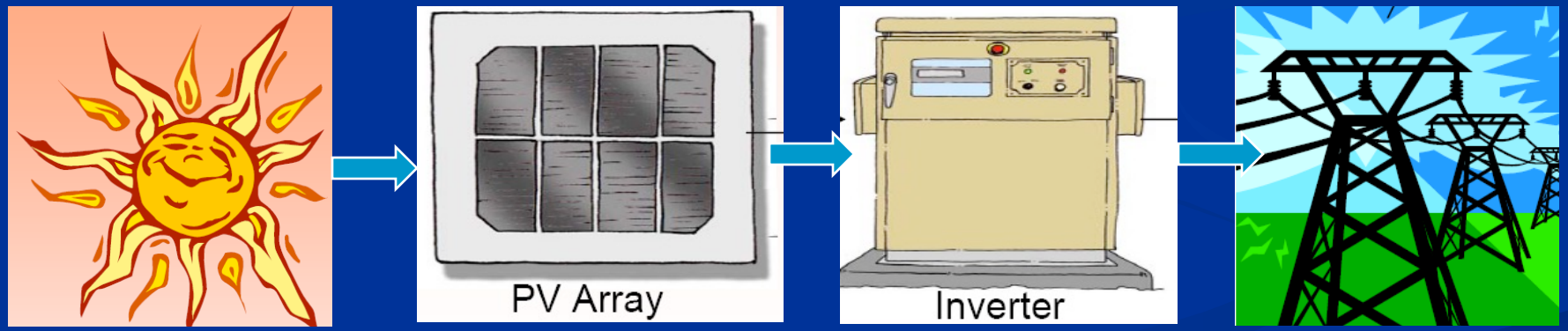
There are two ways to use solar energy to generate electricity:

- Photovoltaic: The direct conversion of sunlight to electricity
  - A Photovoltaic Solar Power Plant contains:
    - Solar Arrays
    - Inverter
    - Transformer
- Thermal: The use of heat to generate electricity
  - A Thermal Solar Power Plant contains:
    - Collector Field
    - Turbine
    - Generator
    - Cooling Tower
    - Transformer

Solar Energy / Photovoltaic

How Does Photovoltaic Solar System Work?

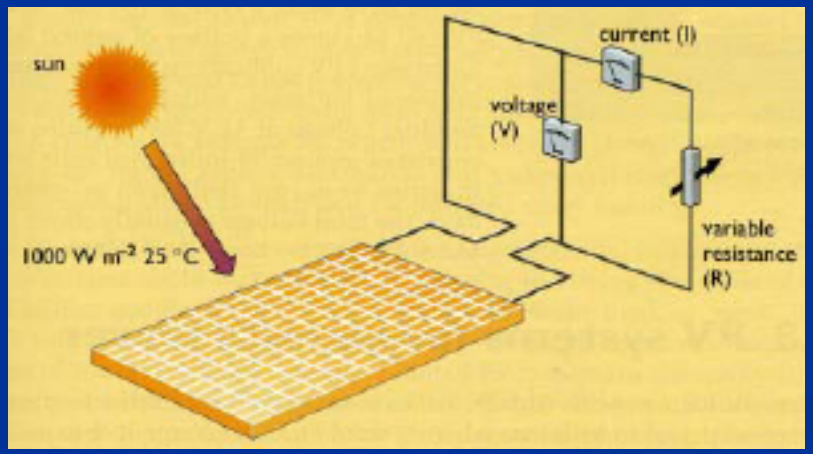
- The sun illuminates the solar cells in the PV Array, which convert the energy in the sunlight into electricity.
- The electricity goes into an inverter and into the power lines to your home.



PV CELLS

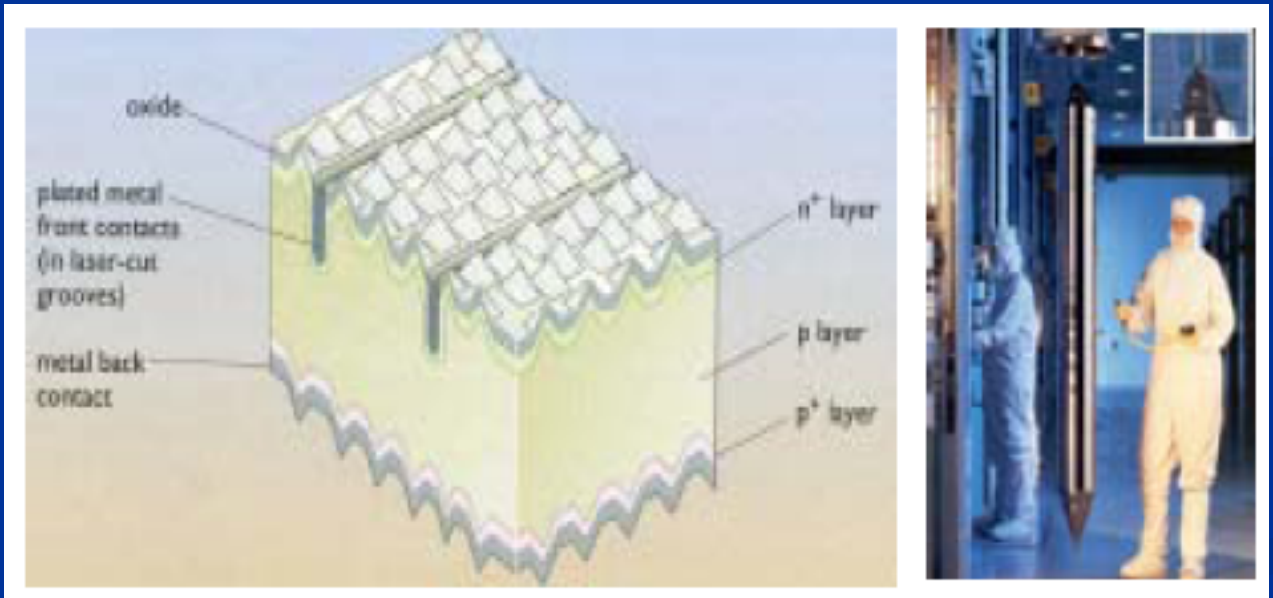
- A typical silicon PV cell of 100cm2 produces a voltage of around 0.5V and a current proportional to the sunlight intensity (3A in full sunlight).

- When the resistance is infinite (i.e., open circuit), the current is at minimum and the voltage at maximum.

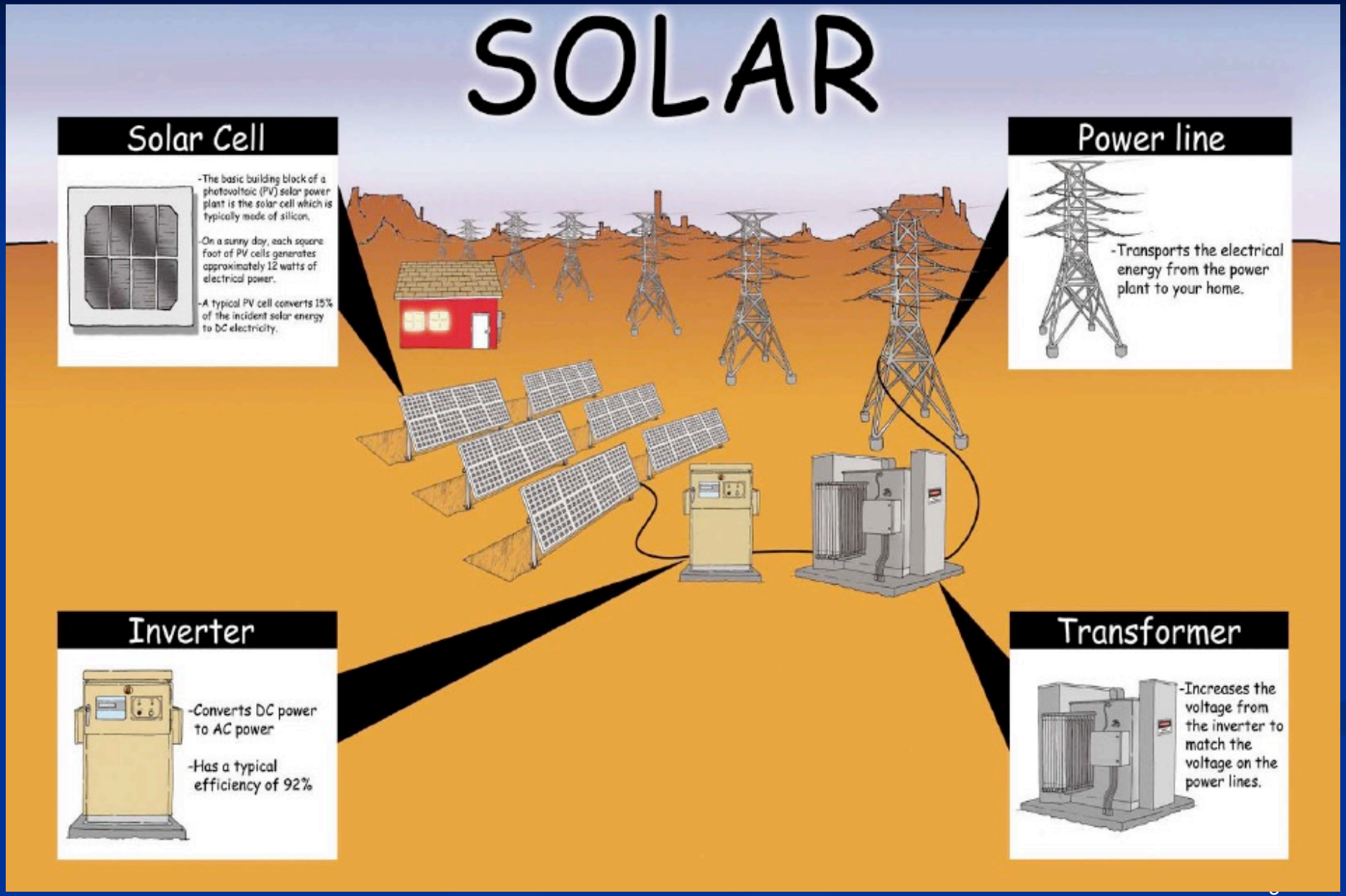


MONOCRYSTALLINE SILICON CELLS

- Until recently, the majority of solar cells were made from extremely pure monocrystaline silicon.
- The process involves growing a crystal from a seed by pulling it out of a molten mass using Czochralski process.



Photovoltaics Power System



Samples of Photovoltaic Power Plants

Glendale Airport, Single Axis and High Concentration Photovoltaic

Prescott Airport, Single Axis, Tilted Tracker Single Axis and High Concentration Photovoltaic

Scottsdale Covered Parking, Fixed Photovoltaic panels

Activity : Solar Photovoltaic

- Form a team of 2
- Your are responsible to locate your IT department to one of the power plants listed in the virtual tour.
- Perform the following tasks:
  - 1. Estimate your energy needs using attached worksheets
  - 2. Visit Solar Photovoltaic Power Plants per attached Virtual Tour
  - 3. Select the smallest power plant that meets your needs with 100% margin (provides 2 x energy estimates)
  - 4. Summarize your result in Power Point for a 5-minutes presentation

Energy Usage Worksheet

Item	Quantity	Power (Watts)	Daily Use (Hours / Day)	Energy (Watt-hours / Day)
Interior lights		75		
Central Air Conditioner				
Central Heating System				
Water Heater				
Personal Computers				
Computer Monitors				
Printer				
Network Servers				
Others				

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Solar Photovoltaic Tour

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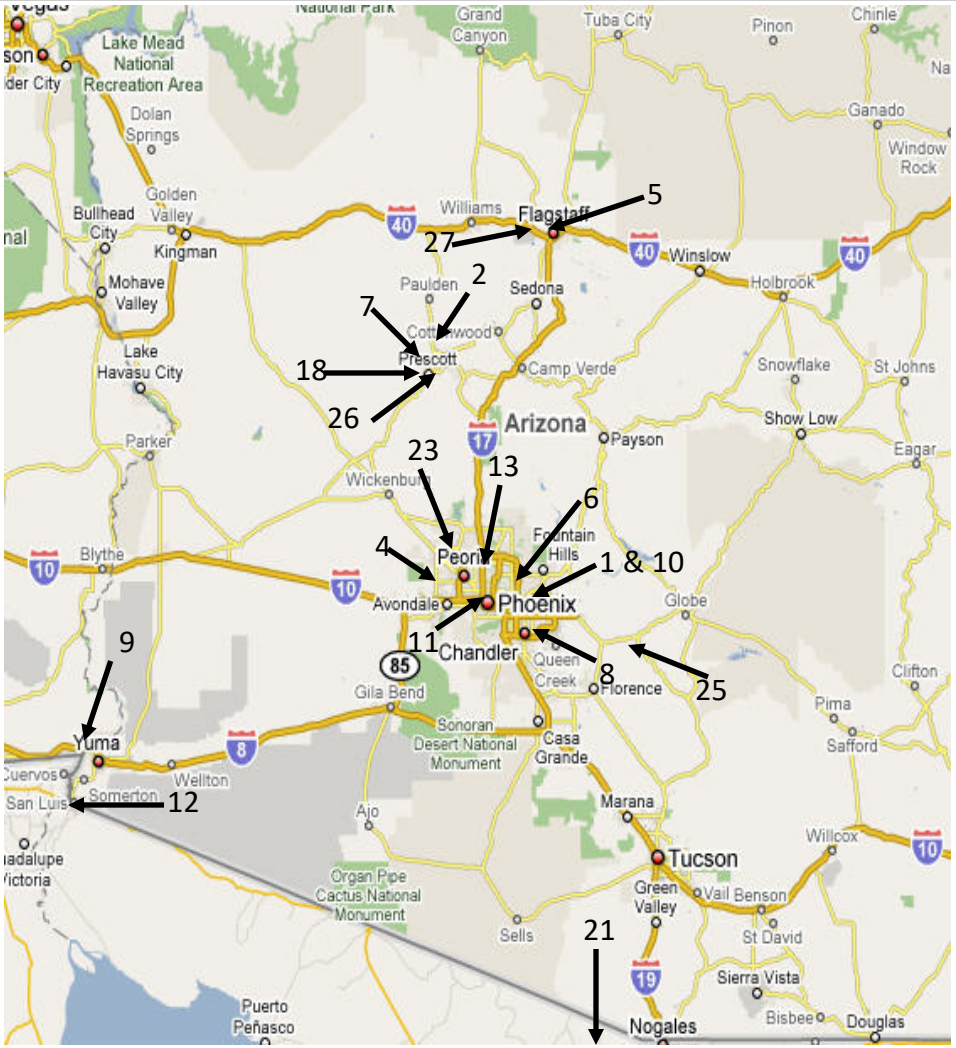
APS Locations

1 Star Center
2 Prescott Airport
4 Glendale Airport
5 Flagstaff
6 Scottsdale Covered Parking
7 Prescott ERAU
8 Gilbert
9 Yucca
10 APS Tempe
11 ADEQ Parking Canopy
12 San Luis Rooftop
13 STMicro
18 Prescott College
21 San Juanico
23 Challenger Learning Center
25 Boyce Thompson Arboretum
26 Sharlot Hall Museum
27 Lowell Observatory



APS Star Center SP001

The APS STAR (Solar Test and Research) Center is one of the most advanced solar testing sites in the world, with virtually all types of photovoltaic technology and the latest in high concentration tracking systems under test or development.

Location: 1500 E. University Dr., Tempe, Arizona

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APS Star Center SP001

- *200 kW Single Axis Tracking PV solar power plant*
- *300 kW High Concentration PV solar plant*
- *60 kW Tilted Tracker PV solar plant*
- *Rooftop PV system demonstrations for residential and commercial use*
- *Numerous examples of solar tracking systems and technologies*
- *Examples of the latest thin film, single crystal, polycrystalline and high concentration PV modules*
- *Boeing Spectrolab Multi-Junction Concentrator System (Space Cells)*
- *Hybrid solar power system test facilities with 600 kWh of battery storage capacity and 150 kW diesel generator*
- *Examples of the latest power conditioning inverter technologies*

MAP

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Prescott Airport SP002

The Prescott Airport Solar Power Plant is a multi-megawatt solar site featuring two types of photovoltaic (PV) technologies –single axis tracking flat plate PV, and two-axis tracking High Concentrating PV (HCPV).

Started in 2002, over 5 MW is planned to cover 55 acres. Over 3.5 MW of one-axis PV is under construction, using conventional PV panels. These systems deliver more energy from the solar panels by rotating them on a horizontal axis throughout the day.

Over 1.5 MW of HCPV system is under construction. These systems use plastic lenses to concentrate the sunlight 250 times onto much smaller, high efficiency solar cells. This reduces the area of PV material by 250 times, which should result in a potentially low cost solar electric generation technology.

Location: Near the Love Field Airport, Prescott, Arizona

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Prescott Airport SP002

- **Plant Output (as of July 2006): 3,387,850 Watts DC**
- **2,879,700 Watts AC**
- **Solar Module Manufacturers: BP Solar, Sharp Electronics, Amonix**
- **Inverter Manufacturer: Xantrex & AES**
- **Inverter Power Ratings: AC 30 37 kW & 125 kW**
- **Type of Tracking: Single Axis and Two Axis High Concentration**
- **Projected Annual Energy Generation: 6,335,340 kWh AC**

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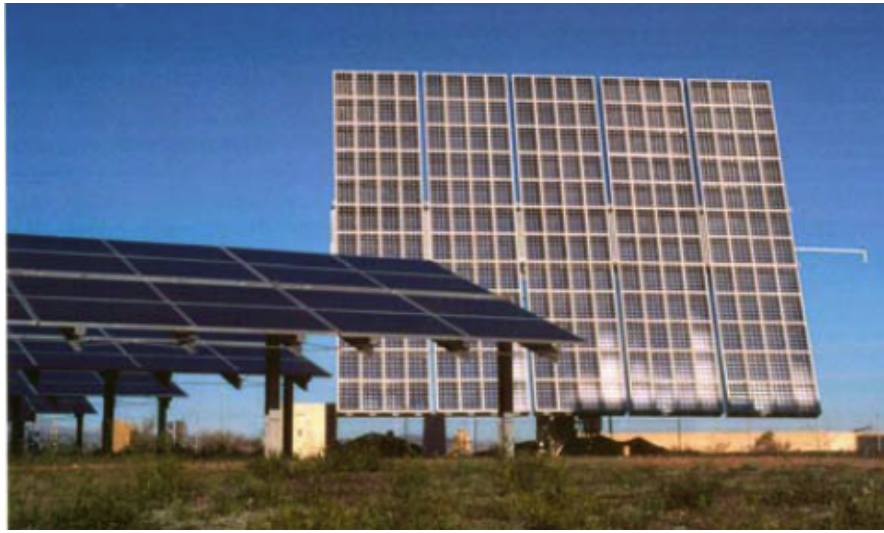
Glendale Airport SP004

Completed in 1999, the Glendale Airport Solar Power Plant was the first commercial installation of a large two-axis tracking, High Concentration PV (HCPV) system. 100 kW of HCPV was installed along with a single axis tracking conventional PV system.

Unlike the flat plate system which collects the energy from the sunlight by covering a large area with high cost PV cells, the HCPV system harvests the sunlight energy using relatively cheap plastic lenses which then concentrate the sunlight 250 times onto much smaller, high efficiency solar cells. This results in a potentially low cost solar electric generating system since only 1/250 of the area of PV material is required to produce the same amount of power as compared with the flat plate, non-concentrating system.

Location: 6801 N. Glen Harbor Blvd. Glendale. Arizona



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Glendale Airport SP004

Plant Output: 204,200 Watts DC 173,500 Watts AC

Flat-Plate Systems	HCPV Systems
Solar Module Manufacturer: ASE Americas	Amonix
Solar Module Power: 280 Watts DC	4800 Watts AC
Quantity of Solar Modules: 320	20
Inverter Manufacturer: UPG	Xantrex
Inverter Power Rating: AC 18,000 Watts	AC 20,000 Watts
Quantity of Inverters: 5	4
Type of Tracking: Single Axis	Dual Axis

Projected Annual Energy Generation: 393,325 kWh

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Flagstaff SP005

This first commercial solar generating plant in Arizona was installed by APS in 1997.

It consists of 6 rows of horizontally mounted photovoltaic (PV) modules that track the sun from East to West each day. This simple tracking system allows the PV modules to generate approximately 25% more energy over the course of a year than if they remained fixed in a Southerly pointing direction.

Location: 2250 E. Huntington Dr., Flagstaff, Arizona

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Flagstaff SP005

Plant Output: 95,000 Watts DC 82,000 Watts AC
Quantity of Modules: 1260
Manufacturer: Siemens
Inverter Manufacturer: Satcon
Quantity of Inverters: 1
Inverter Rating: 100,000 Watts AC
Type of Tracking: Single Axis
Projected Annual Energy Generation: 192,700 kWh AC

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Scottsdale Covered Parking SP006

This APS installation demonstrates the multiple benefits than can be realized by the strategic use of photovoltaic panels. Not only does this plant produce up to 93 kW of electrical power, but it also provides shading for parked vehicles and uses no additional land as it is constructed on top of the covered parking structure.

Location: 9191 E. San Salvador Dr., Scottsdale, Arizona

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Scottsdale Covered Parking SP006

Plant Output: 93,300 Watts DC 79,300 Watts AC
Quantity of Modules: 750 (Triple Junction Thin Film Silicon)
Manufacturer: Bekaert ECD Solar Systems (Uni-Solar)
Inverter Manufacturer: Ominion
Quantity of Inverters: 8
Inverter Manufacturer: Trace/Xantrex
Quantity of Inverters: 2
Inverter Rating: Omnion8,000 Watts
Inverter Rating: Trace/Xantrex25,000 Watts
Type of Tracking: Fixed
Projected Annual Energy Generation: 99,125 kWh AC

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Prescott Embry Riddle Aeronautical University SP007

This is the first large solar plant in Prescott, Arizona. It is a single axis tracking system located on the grounds of the Embry Riddle Aeronautical University near the main entrance to the campus.

The plant consists of 768 PV panels arranged in 16 rows with 48 panels per row. Each row is approximately 160 feet long and five feet high with the solar modules in the horizontal position. They extend to a height of approximately eight feet when the modules are tilted toward their east or west extreme position, about 45 degrees from horizontal.

The system is designed to provide electricity to the grid when the grid is available. Should this section of the grid become disconnected from the rest of the power system, the solar power inverters will shut down and wait until normal grid power is restored, before they restart, which they do automatically.

Location: 3200 Willow Creek Road, Prescott, Arizona

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Prescott Embry Riddle Aeronautical University SP007

Plant Output: 230,000 Watts DC 195,000 Watts AC
Quantity of Modules: 768
Tracking: Single Axis
Manufacturer: ASE Americas
Inverter Manufacturer: Trace Technologies
Inverter Power Rating: 30,000 Watts AC
Quantity of Inverters: 8
Projected Annual Energy Generation: 458,250 kWh AC

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Gilbert SP008

Dedicated in 2001, the APS Gilbert plant was APS' fourth commercial solar power plant in Arizona. It is located adjacent to the Gilbert Riparian Center and demonstrates how well a solar power plant can "blend in" with the environment.

As in most of APS' solar power plants, the Gilbert plant uses single axis tracking technology to maximize the energy output from the solar panels.

Located at the Gilbert Nature Center, 287 N. Cooper Rd., Gilbert, Arizona

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Gilbert SP008

Plant Output: 144,000 Watts DC 122,400 Watts AC
Quantity of Modules: 480
Tracking: Single Axis
Manufacturer: ASE Americas
Inverter Manufacturer: Xantrex
Inverter Rating: 125,000 Watts AC
Quantity of Inverters: 1
Projected Annual Energy Generation: 287,640 kWh AC

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Yucca SP009

This was the first APS solar power plant to be built in the Southwest area of Arizona and is located on the grounds of the APS Yucca natural gas fired power plant.

The APS Yucca solar power plants consists of 18 rows of horizontally mounted photovoltaic panels that track the sun from East to West each day and produces up to 100 kW of AC electrical power.

Location: 7522 S. Somerton Ave., Yuma, Arizona

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Yucca SP009

Plant Output: 120,960 Watts DC 100,000 Watts AC
Modular Manufacturer: BP Solar
Solar Module Power: 140 Watts DC
Quantity of Modules: 864
Inverter Manufacturer: Trace Technologies
Inverter Rating: 30,000 Watts AC
Quantity of Inverters: 4
Type of Tracking: Single Axis
Projected Annual Energy Generation: 235,000 kWh AC

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APS Tempe SP010

Phase I of the APS Tempe Solar Power Plant was dedicated in April, 1998 and was the first commercial solar power plant in the Valley.

Phase II has a MaxTracker®system that has been used at subsequent APS Solar Power Plants. The plant utilizes single-axis tracking to maximize the amount of energy the panels produce over the course of a year. The sun is tracked via computer, positioning the solar panel arrays at the optimum direction for maximum solar exposure.

Location: 1500 E. University, Tempe, Arizona

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APS Tempe SP 010

Plant Output: 204,000 Watts DC 173,000 Watts AC
Phase I Module Mfr.: Siemens SP75-LJ
Phase II Module Mfr.: Various
Phase I Solar Module Power: 94.5 kW DC
Phase II Solar Module Power: 109 kW DC
Quantity of Modules: Phase I 1260
Quantity of Modules: Phase II 578
Inverter Manufacturer: UPG
Inverter Rating: 18,000 Watts AC each
Quantity of Inverters: 6
Type of Tracking: Single Axis
Projected Annual Energy Generation 366,300 kWh AC

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ADEQ Building Parking Canopy SP011

Constructed in 2002, the ADEQ Building Parking Structure is the largest covered parking solar system that APS has built.

This system consists of 900 fixed solar panels on the sixth floor of the parking garage. In addition to generating electrical power, the building integrated photovoltaic array provides shade from the sunny Arizona climate.

Location: 1100 West Washington, Phoenix, Arizona

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ADEQ Building Parking Canopy SP011

Plant Output: 126,000 Watts DC 107,000 Watts AC
Solar Module Manufacturer: BP Solar -BP2140
Solar Module Power: 140 Watts DC
Quantity of Solar Modules: 900
Inverter Manufacturer: Xantrex Inverter
Power Rating, AC: 100 kW
Quantity of Inverters: 1
Type of Tracking: Fixed
Projected Annual Energy Generation: 160,500 kWh AC

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San Luis Rooftop SP012

The San Luis Solar Photovoltaic System is located at the City Hall Building of the City of San Luis, Arizona.

The system consists of two rows of 4 PV modules facing south, mounted on the flat roof on brackets which tilt the panels at approximately 25 degrees from the horizontal. The brackets are fastened to pans which sit on the roof and are secured by roofing cement and ballast material in the pans. There are no roof penetrations.

Location: 23221 1st St., San Luis, Arizona

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San Luis Rooftop SP012

Plant Output: 2,400 Watts DC 2,000 Watts AC
Solar Module Manufacturer: ASE Americas
Solar Module Power: 300 Watts
Quantity of Solar Modules: 8
Inverter Manufacturer: Omnion
Inverter Power Rating, AC: 2,400 watts
Quantity of Inverters: 1
Type of Tracking: Fixed
Projected Annual Energy Generation: 3,260 kWh

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STMicro Rooftop SP013

The STMicro rooftop solar system was the first solar application in Arizona installed for a commercial grid-connected customer.

STMicro purchases all the energy generated by the panels through the APS Solar Partner Program, and gets the rest of it's power from the grid.

The system is a horizontally fixed panel configuration, mounted flat on the roof with synthetic supports which hold the solar panels in place. There are no roof penetrations required for the mounting of the panels

Location: 1010 E. Bell Road, Phoenix, Arizona

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STMicro Rooftop SP013

Plant Output: 26,000 Watts DC 22,100 Watts AC
Solar Module Manufacturer: Astropower
Solar Module Power: 130 Watts
Quantity of Solar Modules: 198
Inverter Manufacturer: Trace
Inverter Power Rating, AC: 2,200 Watts
Quantity of Inverters: 1
Type of Tracking: Fixed
Projected Annual Energy Generation: 27,625 kWh AC

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Prescott College SP018

Completed in 2004, the Prescott College Solar Power Plant was a collaboration between APS and Prescott College to enhance the environmental ideals of the college and add to the APS solar plant family.

There are three rows of 24 panels, fixed at a 10 degree angle which not only generate 10,000 Watts of electricity but also serve as a shade source for the second story.

Location: 215 Garden St. Prescott. Arizona

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Prescott College SP018

Plant Output: 11,500 Watts DC 10,000 Watts AC
Solar Module Manufacturer: Sharp –NT-R5E3H
Solar Module Power per panel: 175 Watts DC
Quantity of Solar Modules: 72
Inverter Manufacturer: Xantrex Model PV10208
Inverter Power Rating, AC: 10,000 Watt
Quantity of Inverters: 1
Type of Tracking: Fixed
Projected Annual Energy Generation: 16,065 kWh AC

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San Juanico SP021

In 1994 APS and Mexico's national electric utility, Comisión Federal de Electricidad (CFE) agreed to upgrade an existing diesel generator-based system in a remote fishing village in Mexico.

Previously, San Juanico, with a population of about 400, had electricity for only three hours per day. The cost of fuel to operate San Juanico's power source, a diesel generator prohibited the villagers from using more electricity to further develop the community's commercial fishing, including ice for preservation of the daily catch, and tourism business ventures.

Using the new power plant with energy derived primarily from wind and solar, the community has power 24 hours a day, allowing preservation of the daily catch, as well as improved food storage in residents' homes.

The plant was designed by APS and built by CFE with assistance from the National Energy Renewable Labs (NREL) of Colorado on behalf of the U.S. Department of Energy. The U.S. Department of Energy, U.S. Agency for International Development, the Municipality of Comondu, and the State of Baja California Sur provided additional financial support for this project.

SP021: San Juanico, Baja Sur, Mexico

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HIGH TECH WORKFORCE INITIATIVE

San Juanico SP021

Plant Output: 100,000 Watts DC Wind 17,000 Watts DC Solar 80,000 Watts Backup Diesel Generator
Solar Module Manufacturer: ASE Americas
Solar Module Power: 285 Watt
Quantity of Solar Modules: 60
Type of Tracking: Fixed
Wind Turbine Generator Manufacturer: Bergey Wind Power
Wind Turbine Power: 10 kW (Bergey Excel)
Quantity of Wind Turbines: 10
Inverter Manufacturer: Trace Technologies (Xantrex)
Inverter Power Rating: AC 70 kW
Quantity of Inverters: 1
Projected Annual Energy Generation: 200,000 kWh AC

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Challenger Learning Center ProjectSol SP023

The Challenger Learning Center is one of five educational establishments chosen by APS to host a 2 kW, grid-tied, photovoltaic solar electric power system as part of the APS ProjectSol (Solar Outreach and Learning) program.

The photovoltaic panels at Challenger are pole mounted, face South and are tilted at an angle of 30 degrees to maximize the energy generated throughout the year.

The electricity generated by the system is used to offset a portion of the energy used by the Center. The system is fitted with Data Acquisition probes which transmit system performance information to the APS ProjectSol website.

Location: 21200 N. 83rd Avenue, Peoria, Arizona

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Challenger Learning Center ProjectSol SP023

Plant Output 2,400 Watt DC 2,000 Watts AC
Solar Module Manufacturer ASE Americas
Solar Module Power 285 Watts DC
Quantity of Modules 8
Inverter Manufacturer Omnion
Inverter Power Rating 2,000 Watts AC
Quantity of Inverters 1
Projected Annual Energy Generation 3,260 kWh AC

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Boyce Thompson Arboretum ProjectSol SP025

The Boyce Thompson Arboretum is one of five educational establishments chosen by APS to host a 2 kW, grid-tied, photovoltaic solar electric power system as part of the APS ProjectSol (Solar Outreach and Learning) program.

The photovoltaic panels at Boyce Thompson are roof mounted, face South and are tilted at an angle of 30 degrees to maximize the energy generated throughout the year. The electricity generated by the system is used to offset a portion of the energy used by the Arboretum.

The system is fitted with Data Acquisition probes which transmit system performance information to the APS ProjectSol website.

Location: 37615 Highway 60, Superior, Arizona

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Boyce Thompson Arboretum ProjectSol SP025

Plant Output: 2,400 Watt DC 2,000 Watts AC

Solar Module Manufacturer: ASE Americas

Solar Module Power: 285 Watts DC

Quantity of Modules: 8

Inverter Manufacturer: Omnion

Inverter Power Rating: 2,000 Watts AC

Quantity of Inverters: 1

Projected Annual Energy Generation: 3,260 kWh

MAP

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Sharlot Hall Museum ProjectSol SP026

The SharlotHall Museum is one of five educational establishments chosen by APS to host a 2 kW, grid-tied, photovoltaic solar electric power system as part of the APS ProjectSol (Solar Outreach and Learning) program.

The photovoltaic panels at Sharlot Hall are roof mounted, face South and are tilted at an angle of 30 degrees to maximize the energy generated throughout the year.

The electricity generated by the system is used to offset a portion of the energy used by the Sharlot Hall.The system is fitted with Data Acquisition probes which transmit system performance information to the APS ProjectSol website.

Location: 415 W. Gurley St.. Prescott, Arizona

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Sharlot Hall Museum ProjectSol SP026

Plant Output: 2,400 Watt DC 2,000 Watts AC
Solar Module Manufacturer: ASE Americas
Solar Module Power: 285 Watts DC
Quantity of Modules: 8
Inverter Manufacturer: Omnion
Inverter Power Rating: 2,000 Watts AC
Quantity of Inverters: 1
Projected Annual Energy Generation: 3,260 kWh AC

MAP

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Lowell Observatory ProjectSol SP027

The Lowell Observatory is one of five educational establishments chosen by APS to host a 2 kW, grid-tied, photovoltaic solar electric power system as part of the APS ProjectSol (Solar Outreach and Learning) program.

The photovoltaic panels at Lowell are pole mounted, face South and are tilted at an angle of 30 degrees to maximize the energy generated throughout the year.

The electricity generated by the system is used to offset a portion of the Lowell Observatory. The system is fitted with Data Acquisition probes which transmit system performance information to the APS ProjectSol website.

Location: 1400 W. Mars Hill Road, Flagstaff, Arizona

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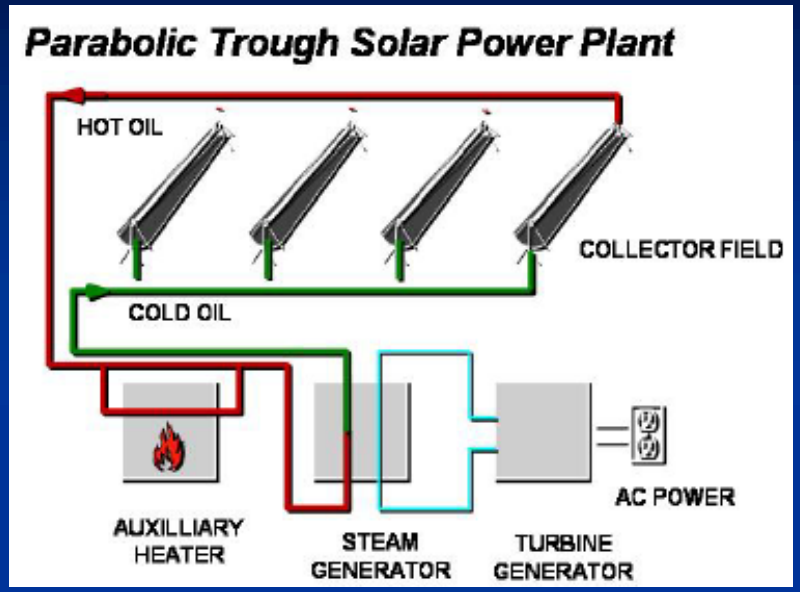
Solar Thermal

How Does Solar Thermal Power Plant Works?

- Parabolic (trough) mirrors can focus the sun at 30 to 60 times its normal intensity on a receiver pipe located along the focal line of the trough.
- Synthetic oil captures this heat as it circulates through the pipe, reaching temperatures as high as 750°F. The hot oil is pumped through a heat exchanger on the power production side of the plant to produce steam.
- Electricity is produced in a conventional steam turbine/generator
- The power cycle is completed with the condensing of the steam through a cooling tower and then pumping it back through the heat exchanger connected to the solar energy collection field.



Power Tower

- Power tower systems consist of a circular array of heliostats (large individually tracking mirrors) to focus sunlight onto a central receiver mounted on top of a tower
- First power tower system was build in 1992 in California and it had a capacity of 10 MW. These systems have a capacity for up to 200 MW

High Temperature Collection

- Solar energy collected as high-temperature heat uses mirrors or lenses that track the motion of the sun and direct the concentrated flux onto a receiver
- Temperatures of up to 1000 K can be generated, enough to produce high-pressure steam used in modern steam turbines to generate electricity

Samples of Solar Thermal Power Plants

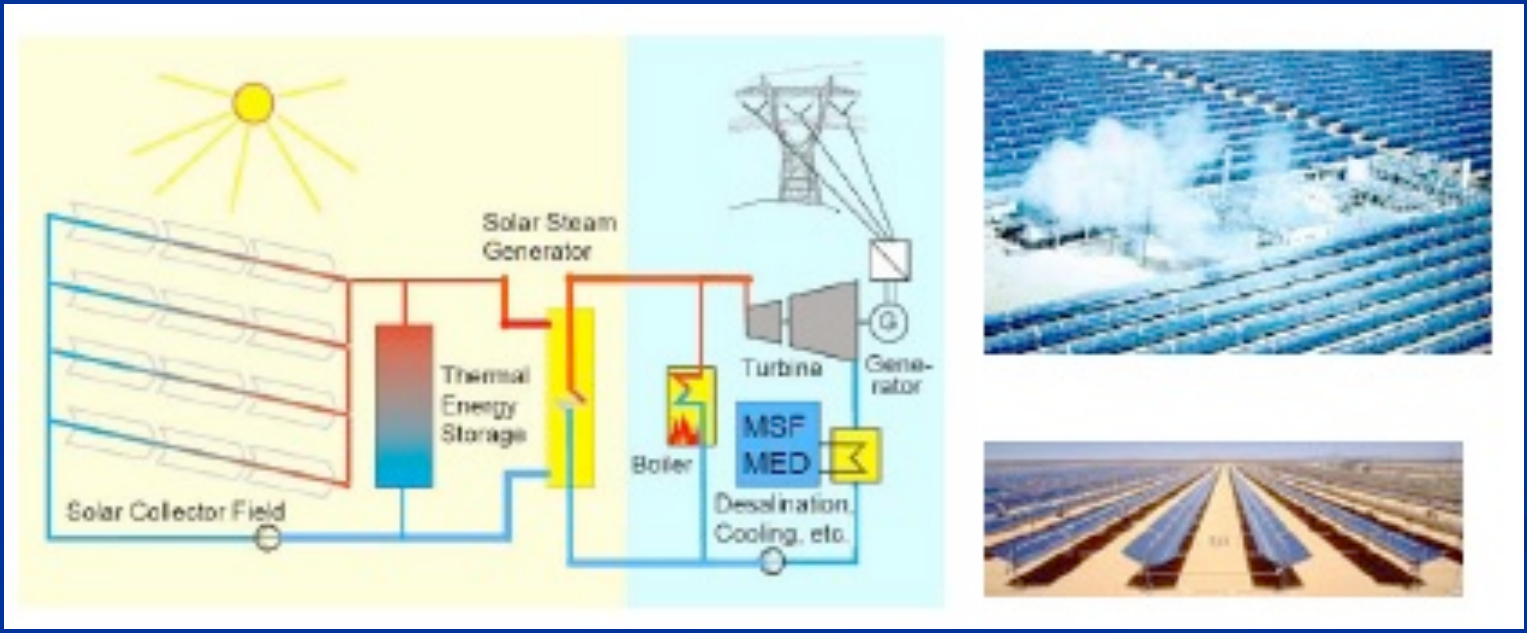
10 MW Solar II Experimental Power Plant, California

350 MW Parabolic Trough Power Plant, California

AZ DEMA Solar AC Project Phoenix, Arizona

Economics and Performance

- Solar to electrical energy conversion efficiency is roughly 10% using Parabolic Trough technology.
- The cost of electricity is 4 – 5 cents/kWh.

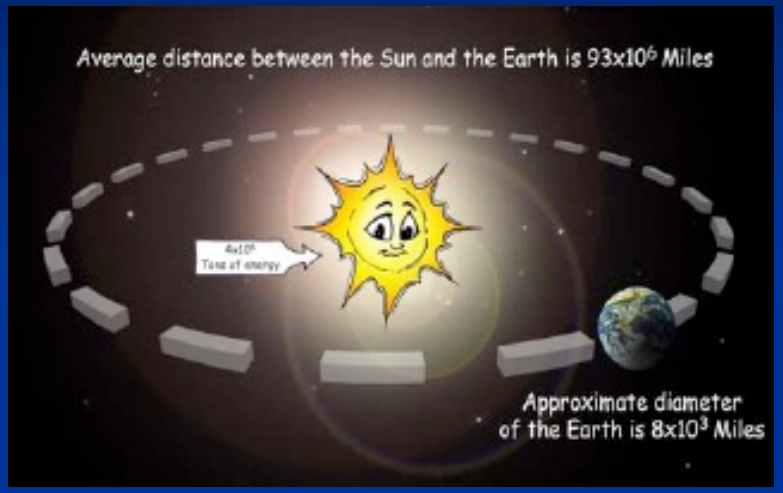


SOLAR TRIVIA

- Every second 657 million tons of hydrogen are converted to 653 million tons of helium in our sun. The missing 4 million tons are converted to light and heat energy via Einstein's $E=MC^2$ equation and radiated into space.

- At an average distance of 93 million miles from the sun, the earth collects approximately 4 lbs. of total energy, which supports life on earth as we know it.

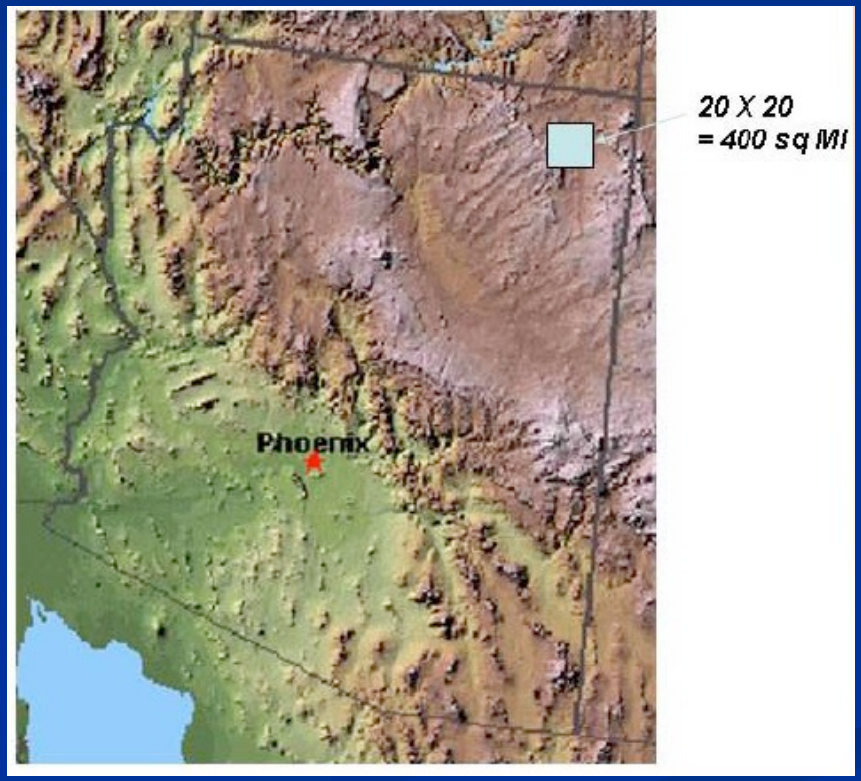
- For every kWh of electricity generated by solar energy, the following emissions are avoided since that kWh need not be generated from a fossil fuel power plant. In one year, the approximate avoided emissions in lbs/year are:



SOLAR POWER PLANT SIZE	CO_2	NO_X	SO_X
1 kW	2,508	6.3	5.2
10 kW	25,800	63	52
100 kW	258,000	630	520
1 MW	2,580,000	6300	6200

How Much Solar Would Be Needed To Power Arizona?

- *In order to power Arizona's electrical energy needs, 400 square miles of land will be required.*
- *We get about 2,400 hours of "productive" sunshine each year.*
- *The state of Arizona consumes about 60,000,000 MWh of electricity each year.*



Energy Units

- 1 Watt is 1 Joule per second.
- 1 KWh is the amount of energy converted in one hour at a rate of one kilowatt.
- 1 kWh = 3.6 MJ

PREFIX	ABREVATION	MEANING	EXAMPLE	MULTIPLICATION
Terra	**T**	**10^{12}**	**1 TW = 1 x 10^{12}W**	**one million million**
Giga	**G**	**10^{9}**	**1 GW = 1 x 10^{9}W**	**one thousand million = one billion**
Mega	**M**	**10^{6}**	**1 MW = 1 x 10^{6}W**	**one million**
Kilo	**k**	**10^{3}**	**1 kW = 1 x 10^{3}W**	**one thousand**

CALCULATION : PER CAPITA CONSUMPTION

- The rate of primary energy consumption worldwide is 13.4 TW (2006 data).
- The current population in the world is 6.1 billion people.
- The average per capita consumption of energy is:
  - 13,400,000 M/ 6,100 M= 2,197 watts or about 2.2 kW
- There are 24 hours in a day, so daily consumption per person is:
  - 2.2 kW x 24 hours = 53 kWh = 190 MJ
- 190 MJ is roughly equal to 5 liters of oil.

ELECTRICAL POWER COST

- **Problem: If the motor (rated 500 W) of a frost-free refrigerator runs 15% of the time, how much does it cost to operate per month if the power company charges 11 c per kilowatt-hour?**

ELECTRICAL POWER COST

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Solution:

- **time: t = (0.15)(24) = 3.60 h**
- **Since P = W/t, the electrical work done is:**
- **W = P x t = (500 W)(3.6 h) = 1.80 Wh = 1.8 kWh**
- **1.80 kWh x $0.11 = $0.198/day**
- **Or 19.8 c per day or $5.94 per month**

Activity : Solar Thermal A/C System

- Form a team of 2
- Perform the following tasks:
  - 1. Review your electricity bill to get your energy usage
  - 2. Visit AZ DEMA Solar AC Power Plant per attached Virtual Tour (AZDEMA-VirtualTour.ppt)
  - 3. Calculations
    - Given:
      - Cooling Capacity of the Solar Thermal A/C System: 120,000 Btu/hr
    - How many homes like yours can be cooled by this Solar Thermal A/C System.
    - Hints:
      - One British Thermal Unit (BTU) equals 1055 Joules (J)
      - 1 Watt (W) = 1 J/s
  - 4. Summarize your result in Power Point for a 5-minutes presentation

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AZ DEMA Solar Thermal AC System

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AZ DEMA System Highlights

- Cooling Capacity : 120,000 Btu/hr
- Collector Array:
  - **Sunda Seido1**
  - **Heat Pipe Vacuum Tube Solar Collector**
  - **Total No. of Tubes: 416**
- Water Fired Chiller:
  - **Yazaki - Aroace**
  - **Model: WFC-SC10**
- Cooling Tower:
  - **Marley 22 Ton**
  - **Model: 492A**
- Est. Energy Savings: ~$1,000 Annual Electricity Saved
- Array Area: 780 Sq. Ft.

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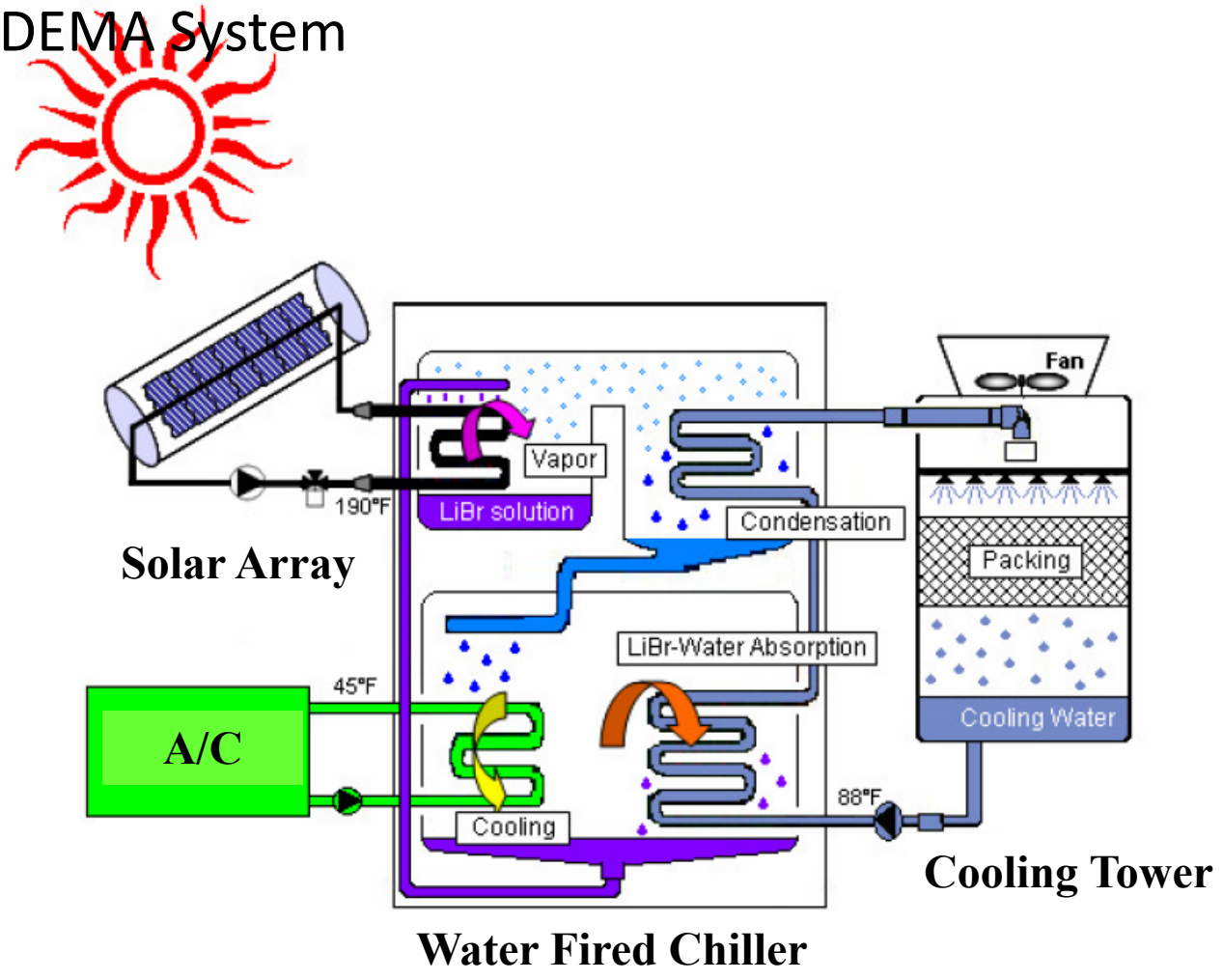
AZ DEMA System



Solar Array

The hot water is produced by a solar array comprised of Sunda Solar vacuum heat pipes, with a gross collector area of 1,100 square feet.

Return to System Overview

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Water Fired Chiller

- The solar thermal cooling system uses hot water produced by solar evacuated tubes.
- The cooling is provided by an absorption process that uses hot water, chemistry, and a vacuum to make cold water.
- Cold water is piped to an air handler where cold air is blown into the Ecobuilding.

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Cooling Tower

The Cooling Tower works in conjuction with the Chiller to provide Cooling Water to the system

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Thermal Controlled Valve

Temperature Sensor is used to control inlet valve to the Chiller.

The water temperature is regulated to provide constant temperature input to the Chiller

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A/C Air Handler

The chilled water is piped to a building mounted air handler and cool air is blown into the building.

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Data Acquisition and Control System

Temperature Sensors are used to monitor Inlet & Output temperatures

Current Sensors are used to monitor System Power usage

Embedded Controller & PLC are used to provide Data Acquisition and Control

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Additional Sources of Information

- http://www.srpnet.com/environment/renewablesolar.aspx
- http://www.aps.com/my_community/Solar/Solar_53.html
- http://science.nasa.gov/ssl/pad/solar/default.htm
- http://www.sandia.gov/
- http://www.nrel.gov/ncpv/pvmenu.cgi?site=ncpv&idx=3&body=infores.html
- http://www.eere.energy.gov/RE/solar.html
- http://rredc.nrel.gov/solar/
- http://www.nrel.gov/clean_energy/solar.html
- http://solarhistory.com/
- http://www.solarenergy.com/info_history.html
- http://www.californiasolarcenter.org/history_solarthermal.html