

Photovoltaic Solar Systems

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Definitions:

Photovoltaic (or PV) systems convert light energy into electricity. The term "photo" is a stem from the Greek "phos," which means "light".

"Volt" is named for Alessandro Volta (1745-1827), a pioneer in the study of electricity.

"Photovoltaics," then, could literally mean "light-electricity."

PV Cell Types

- Selenium
- Silicon
 - single crystalline (c-Si)
 - polycrystalline (p-Si)
- Thin Film
 - amorphous Silicon (a-Si)
 - Copper Indium Gallium diSelenide (CIGS)
 - Cadmium Tellride (CdTel)
 - Gallium Arsenide (Ga-As)
 - Multi-junction

Single Crystalline Silicon

- Silicon - very abundant, although limited quantities of semiconductor grade feedstock
- Comprises great majority of manufactured modules
- Single crystals typically grown into ingots, then processed
- Mature and proven technology
- High efficiencies
- Relatively expensive
- Performance degrades in heat, reverse in cold

Polycrystalline Silicon

- Requires less silicon feed stock
- Crystals typically cast - less waste
- Mature technology
- High efficiencies, although less than c-Si
- Less expensive to produce
- Performance similar to c-Si

Amorphous Silicon

- Non-crystalline form of silicon
- Absorbs solar radiation 40 times more efficiently than c-Si; hence, much thinner (several microns vs. 100+)
- Uses much less silicon in highly automated, fast production
- Less efficient, but cheaper

Amorphous Silicon (cont.)

- Easily deposited on low cost substrates (polymers, thin metal)
- Performs well in heat and dim light
- Well adapted to consumer products and building integration (tinted glass)

aSi Advantages

- can be deposited on low-cost substrates



Advanced Thin Films

(CIGS, CdTe, Ga-As)

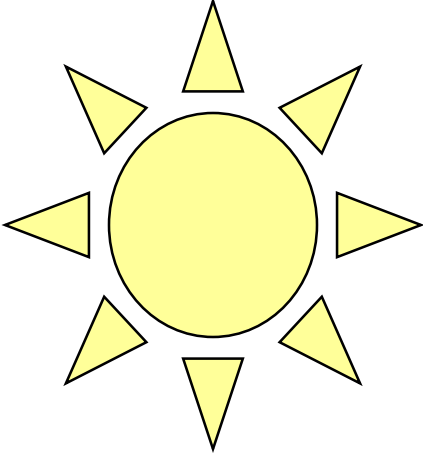
- Similar characteristics as amorphous
- Use more exotic, less common material
- Newer technology
- Efficiencies between a-Si and c-Si
- Multi-junction cells yield much greater efficiencies
 - concentrators: Ga-As
 - space: GaInP₂/Ga-As/Ge

Advanced Thin Film (cont.)

- Potential to be inexpensive to produce
- Fast production rates and low costs could dominate world production in the future

PV Module Performance

<u>Type</u>	<u>Module Efficiency (%)</u>
c-Si	14 - 19
p-Si	12 - 14
a-Si	5 - 8
CIGS	8 - 10
CdTel	9+
Ga-As	25 - 30
Space systems	30+



Fixed Tilt Ground Mount



Fixed Tilt



Single Axis Tracker



Single Axis Tracker



Double Axis Tracker



Double Axis Tracker



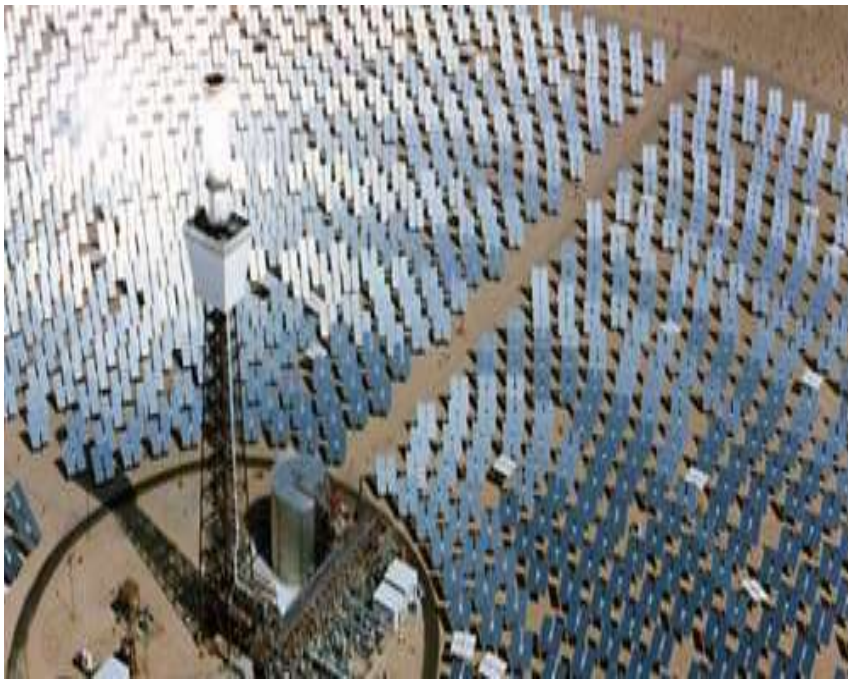
Double Axis Tracker



Parabolic Trough, Concentrated PV

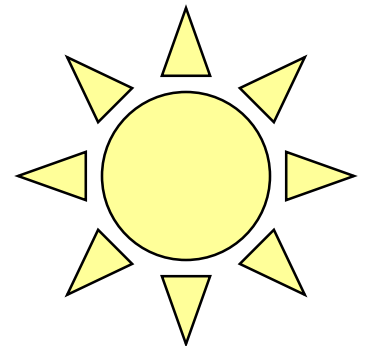


Power Tower, Dish Sterling Engine



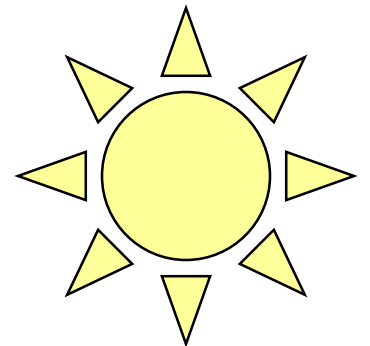
Design Considerations: Matching the User's needs and situation with a solution

- Factors driving design solutions:
 - Lowest cost option?
 - Most energy?
 - Utility rate structure
 - Available area
 - Roof vs. ground
 - Building integrated, carport
 - Shading



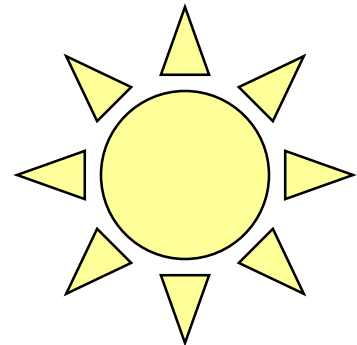
Design Considerations: Matching the User's needs and situation with a solution

- Weather – temperature, insolation
- Environmental or site constraints
- Distance to interconnection
- Aesthetics
- In-house O&M capability



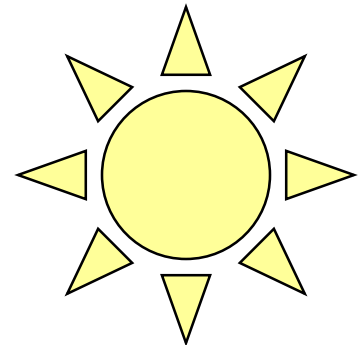
State of the Industry

- Product/system quality
- Costs
- Availability
- O&M
- Monitoring
- Future Technology Prospects



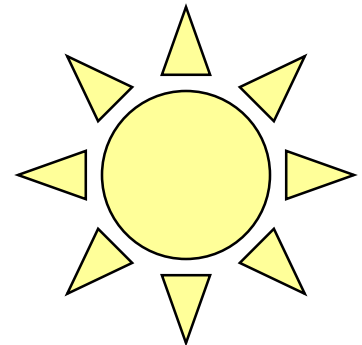
Project Funding Options for Water Agencies

- User funded with internal budget
- Third Party Financing
 - Power Purchase Agreements
 - Leasing
- State and Utility Incentives
- Feed-In-Tariffs
- Renewable Energy Credits



Buying a Solar System

- Buying kW vs. kWh
- Bonding
- Prevailing Wages
- Full Design Docs vs. Performance Specs
 - Most RFBs are very poorly designed and written
 - Good Performance specs often give better results
 - Experienced, independent solar specialists are essential
 - Feasibility studies, economics
 - Technology assessment



Buying a Solar System

- Solar specialists (cont.)
 - Design
 - Document preparation
 - Contractor selection
 - Construction monitoring
 - Commissioning
 - Utility coordination
- O&M: in-house vs. contract
- Monitoring
- Sharing the risk – reduce the unknowns and bid creep
- Performance guarantees

