PV Primer

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Abstract:

PV systems have come a long way in the last two decades. While they may not work for all homes, residential installations are becoming a practical reality under more and more conditions. Here are the nitty-gritty details of photovoltaic systems. The details are meant to "de-mystify" both the technology and its economics.

Building Science Consortium's

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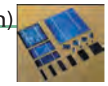
A PV system consists of:

- the PV panels in a modular array, and,
- the Balance-of-System (**BOS**) equipment (the major components are the rack and mounting system for the array, the inverter, the charge controller, and often, a battery bank).

*For even more information on the design and installation of PV systems, see (http://www.eren.doe.gov/erec/factsheets/pvbasics.html.

It used to be that you or a consultant/installer would have to "**build**" the system. And not all of the components had the same level of market readiness, code approval, or availability for residential installations. Now, there are components of each type that are fully developed, widely available, and compatible; and there are many firms that offer residential package systems with all components fully integrated and warrantied (see http://www.eren.doe.gov/pv/pvmenu.cgi?site=pv&idx=2&body=pvdirectory.html).

PV Technology Summary†

Technology	Description	Module Efficiency (Commercial)	Cell Efficiency (Laboratory)	Example Companies Employing Technology
Crystalline Silicon	The original approach; grow silicon crystal structures in variety of ways. In 2001, represented over 90% of total market. Appearance dark blue to black but other colors possible with changes to anti-reflective coatings.			
Single crystal	Grown in cylinders or boules and wire-sliced into circular wafers as thin as 200 microns. Cells are circular and modules are inherently flat black.	14 - 15%	25%	Shell Solar AstroPower Sanyo (Japan) BP Solar (Europe)
Multi-crystalline	Cast in blocks and wire-sliced into rectangular wafers.	12 - 14%	19%	BP Solar Kyocera Solar (Japan)  Sharp
Ribbon	Molten silicon drawn through a die or supported by strings to create a multi-crystalline ribbon (a relatively new technology).	12 - 13%	16%	ASE Americas Evergreen Solar
Film	Crystals grown in a thin film on a supporting substrate (a relatively new technology).	8 - 10%	16%	AstroPower
Thin-Film Materials	A newer approach: Near single-atom, non-crystalline vapor or electro-deposition on low-cost materials such as glass, stainless steel, or plastic. Modules can be flexible. Appearance dark charcoal to near black; can also be semi-transparent.			
Amorphous Silicon (a-Si)	First used in mid-70's, commercial use significant by mid-90's, widely used in consumer products. Cell and module production part of same process. Also applies to next two below.	5 - 7%	13%	BP Solar Uni-Solar TerraSolar
Cadmium Telluride (CdTe)	Alternative semiconductor material under commercialization with research including improved lamination and higher throughput.	7 - 9%	17%	First Solar BP Solar Antec (Europe)
Copper Indium Diseienide (CIS)	Alternative semiconductor under commercialization with research including higher deposition rates of uniform layers.	8 - 10%	19%	Shell Solar Global Solar Wurth Solar (Europe) Honda (Japan)
Concentrators	Lenses or reflectors are used to focus direct sunlight onto cells or modules. Not appropriate for installations under 25kW.	15 - 18%	34%	Amonix SunPower Entech

† Information originally compiled by Environmental Building News; updated by Building Science Corporation with assistance from NREL. Sources included International Energy Agency and NREL reports, PV Power and PV News.

Details from a BSC project in southern California, called Village Green, where it is estimated that more than 60% of the homes' energy will be supplied by the sun. Equipment furnished by BP Solar.

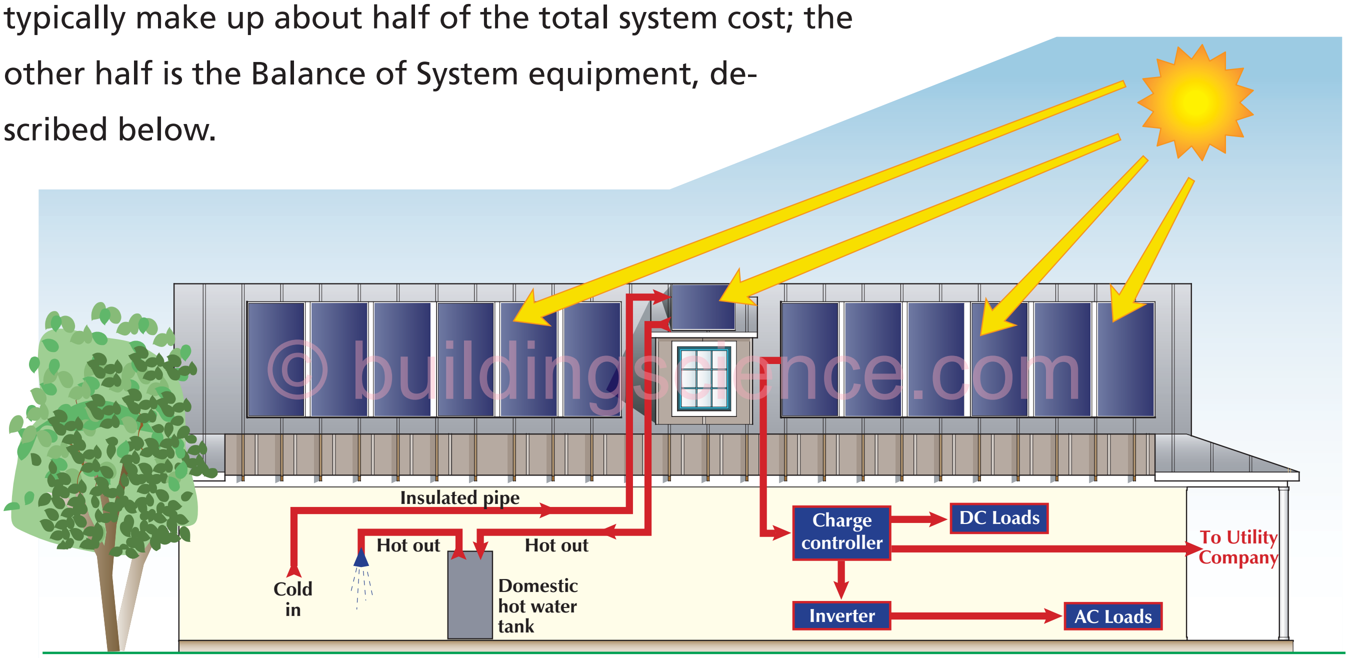
The Modules

There are a lot of different types of PV panels available (see table above). The three main ways PV technologies vary are:

- conversion efficiencies – how much of the **solar energy** they receive they can capture. While there can be correlation between efficiencies and **retail price**, the real impact is on just how much capacity you can fit in a given square area.
- physical properties – **thin-film materials** can be:
  - flexible, making them well-suited to applications such as building-integrated roofing;
  - semi-transparent, making them well-suited to applications such as building-integrated glazing;

  Crystalline materials are by nature rigid and totally opaque, making them well-suited for conventional roof top and stanchion applications and building-integrated commercial wall assemblies.
- historical track record – while there is nothing to suggest that newer PV technologies are inherently less reliable or long-lived, they have quite a reputation to uphold, given the sustained performance of more mature PV technologies. Most manufacturers, regardless of the technology they are employing, are now offering **20 to 25 year warranties**.

All the manufacturers are looking for ways to bring the cost of production down. They have been doing a good job—in the '80s, the **retail price** for a single unit of purchase was over $20/Wp (per peak watt); the industry average is now just over **$4/Wp**. The industry has set a 2010 goal of shaving that price to less than $1.50/Wp, setting up for broadly competitive system offerings in the residential market, without subsidies. The PV panels typically make up about half of the total system cost; the other half is the Balance of System equipment, described below.



Schematic diagram of the energy systems in the **Captain Planet Zero Energy SIPS Cottage** designed by BSC. This shows the south elevation in winter with the porch awnings retracted for maximum solar gain.

BOS Equipment**

Inverter This converts the direct current (DC) power coming off of the panels (or from the battery bank) into alternating current (AC), the convention for household electricity. Inverters vary in terms of their capacity (how much electrical current they can handle) and the "quality" of the AC they produce (some household loads—lights, appliances—can tolerate lower-grade current, while others—printers, computers—have more exacting needs). The inverter generally makes up about **10%** of the total cost of a PV system.

Charge Controller This manages the flow of electrical power from the panels to the battery bank and household loads. It typically makes up about **10% to 15%** of the total system cost, currently at about $5.90 per amp.

Battery Bank PV systems need deep-cycle batteries; this means that they are almost always lead-acid, big, and heavy. The cost of a battery bank depends on its capacity—just how much electricity is needed in storage to deal with night time power needs and cloudy days. Battery banks require proper ventilation for safe operation. PV system battery banks make up about **15%** of the typical system, currently priced at about $1.63 per output Watt. There is little likelihood of this cost changing dramatically based on current and projected battery technology.

Rack and Mounting System This holds the individual panels in place and on the mounting surface, typically the roof (stanchion systems are available for ground mounts). It's important that the system used matches both the cladding and the structural system beneath. There is a wide variety of systems available with wind ratings to 120 mph and more. This part of the PV system is typically about **10%** of the total cost.

Summing It All Up

So, the bottom line is that a 2 kW PV system that can provide a large portion of the electrical needs for a high performance home currently runs about $15,000 to $20,000, or about $8 to $10/Wp. A 5 kW system that handles the entire electrical needs of a conventional home currently runs about $30,000 to $40,000, or about $6 to $8/Wp. Many states have **PV subsidy programs**, and the federal government is working on legislation that would provide tax subsidies for residential PV systems.

For homes that are a quarter of a mile or more from a grid connection, PV is a clear winner. For homes with frequent power interruptions or lacking sufficient electrical "quality," PV can mean a truly functional and reliable home. And for the rest of us, PV systems are inching their way onto our radar screens as the cost, environmental impact, and security issues surrounding conventional power generation increase and the cost of PV systems continues to decline.

** The BOS includes other components such as safety disconnects required by the National Electrical Code.

About this Report

This report was prepared for the US Department of Energy's Building America Program.

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