An Overview of Photovoltaic Equipment and Issues Affecting Its Value

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Introduction

World market demand for photovoltaic equipment is robust with annual growth rates reaching 40%. Reasons for this growth include increased oil and gas prices, improved solar cell and array technologies and renewed government incentives and tax benefits. According to the Photovoltaic (PV) Industry report, Marketbuzz 2006[1], *Solarbuzz* reports a further 1,460 MW of PV were installed worldwide in 2005. This rate of installations is up 34% on the prior year.

The focus of this article is photovoltaic equipment, defined as systems that use semiconducting materials to convert sunlight directly into electricity. PV technology should not be confused with solar thermal equipment that concentrates sunlight to heat a fluid (water, oil, molten salt or other) to generate electricity. Solar thermal equipment is also used to produce heat from sunlight to passively heat buildings, swimming pools and water heaters.

Overview of Photovoltaic Installations

According to *A Guide to Photovoltaic System Design and Installation*[2], there are two general types of electrical designs:

1) Systems that interact with the utility power grid and have no battery backup capability,
2) Systems that interact and include battery backup.

A third type of system, not discussed in the previous source, is a system with no interaction with the electrical grid at all. This "off-grid" system is common in remote homes and remote locations, such as ocean buoys and mountaintop radio repeater installations.

Typical system components include:

- <u>A PV Array</u>. A PV Array is composed of PV modules, which are environmentally-sealed collections of PV cells.
- <u>Additional System Equipment</u>. This equipment includes mounting systems and wiring systems used to integrate the solar modules into the structural and electrical systems of the home.

  Most systems also include a combiner board of some kind since most modules require fusings for each module source circuit.
- <u>DC/AC Inverter</u>. This device takes dc power from the PV Array and converts it into standard ac power used by the home appliances.
- <u>Metering</u>. Metering includes meters to provide indication of system performance and meters to indicate home energy usage.
- <u>Battery Backup</u>. In systems with battery backup, an energy storage device is included.

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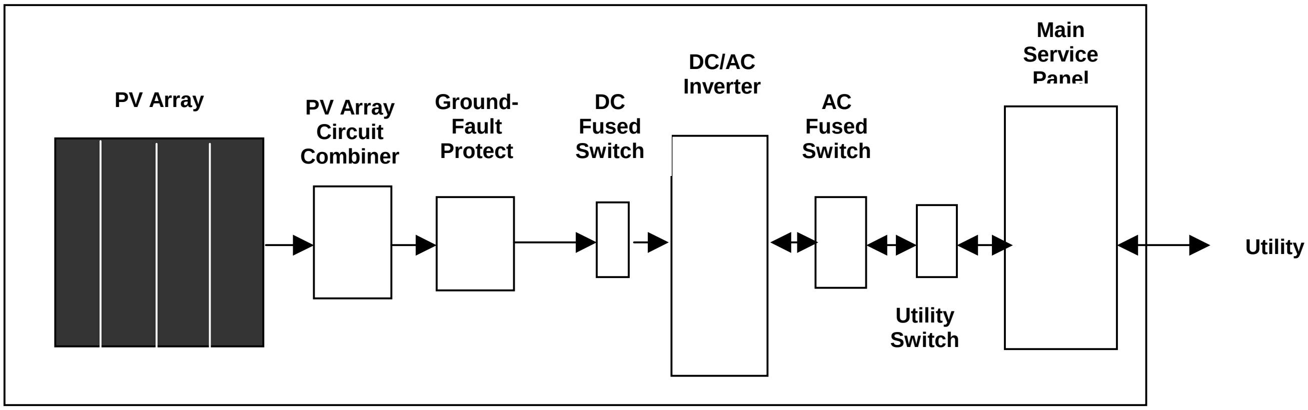
[1] Solarbuzz.com, April 25, 2006.
[2] "A Guide to Photovoltaic System Design and Installation." Prepared by: Endecon Engineering for California Energy Commission. June, 2001. http://www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

Diagram of Grid-Interactive PV System w/o Battery Backup



Source: A Guide to Photovoltaic System Design and Installation

Types of Panels

PV panels are composed of solar cells. The solar cell has three key elements, the semiconductor, which absorbs light and converts it into electron-hole pairs, the semiconductor junction, which separates the photo-generated carriers (electronics and holes), and third, the contacts on the front and back of the cell that allow the current to flow to the external circuit. There are two main choices of semiconductor, either crystalline silicon (93% market share) in a wafer form, or thin films of other materials (7% market share).[3]

Manufacturers

According to *Solarbuzz*, around 50% of the world's solar cell production was manufactured in Japan in 2003. The United States accounted for 12%. Four companies account for over 50% of solar cell production: *Sharp, Kyocera, BP Solar* and *Shell Solar.*

Company	North America Headquarters	Manufacturing Locations	Technologies
Sharp	Ventura, California	Memphis, Tennessee	Polycrystalline
BP Solar	Frederick, Maryland	Madrid, Spain; Sydney, Australia; Frederick, Maryland; Bangalore, India	Polycrystalline, Standard monocrystalline, SATURN monocrystalline
Kyocera	San Diego, California	Hokkaido, Japan	Polycrystalline
Shell Solar	Camarillo, California	U.S., Germany, Portugal	Polycrystalline monocrystalline

Source: Company websites

Additional Manufacturers of Solar Cells and Modules

Canrom	Evergreen Solar	GE Energy	Helios Technology
ICP Global Technologies	Isofoton	Kaneka Corporation	Mitsubishi Electric
Mitsubishi Heavy	Matrix Photowatt	RWE Schott Solar	Sanyo Solar
SolarWorld	SunPower Corporation	Solmec	Uni-Solar

Source: Solarbuzz

[3] Solarbuzz.com, April 27, 2006

Inverter Manufacturers

Advanced Energy Systems	Advanced Electronic Supply	Beacon Power	Cherokee Electronics
Exeltech	Fronius	Go Power Electric	Magnum Energy
Omnion	Outback	PowerPro	PowerSine
PV Powered	Sharp Electronics	Solarix	Solsum
Soltek	Statpower	Studer	Xantrex Technology

Source: Solarbuzz

Batteries

Batteries are used in the substantial off-grid solar markets, but also in on-grid markets, where the customer requires power when the electricity grid is down. According to *Solarbuzz*, batteries can account for around 15% of the cost of an installed solar energy system.

Lead acid batteries can be categorized in different ways, either by form of construction of the electrode plates or by whether the battery is vented or valve-regulated. In the form of construction categorization, electrode plates are either flat plates or tubes. Tubular plates offer larger capacities. The lead used to make the plates is generally alloyed with elements like antimony, selenium, arsenic, calcium or tin to optimize battery characteristics.

In the vented or valve-regulated categorization, a vented battery allows gas produced during over-charging to escape, but lost water has to be replaced.

Valve regulated lead acid cells are sealed and the gas produced during over-charging at the positive electrode is re-converted to water at the negative electrode. A valve regulates excessive pressure build up.

Battery Manufacturers

C&D Batteries	Concorde	Crown Battery	Deka
Douglas	Dyno	Exide	GBC
GNB	Industrial Battery Eng	MK Batteries	Optima
Rolls Battery Engineering	Solar Electric Specialties	Surrette Battery	Trojan Batter
US Battery	Yusasa		

Source: Solarbuzz

Photos courtesy: Getty Images

Markets and End Use
The following table from the *Energy Information Administration (EIA)* breaks out the shipments of PV cells and modules by market sector and solar cell technology.

Shipments of Photovoltaic Cells and Modules by Market Sector and Type, 2003 & 2004
(Peak Kilowatts)

Sector	Crystalline Silicon	Thin-Film Silicon	Concentrator Silicon	Other	2004 Total	2003 Total
Market						
Industrial	29,935	558	0	0	30,493	27,951
Residential	53,538	391	0	0	53,900	23,389
Commercial	53,755	13,996	0	0	67,751	32,604
Transportation	1,376	4	0	0	1,380	11,089
Utility	3,233	6,758	0	0	9,991	8,474
Government	3,140	117	0	0	3,257	5,538
Other	14,162	154	0	0	14,316	313
Total	**159,138**	**21,978**	**0**	**0**	**181,116**	**109,357**

Source: EIA

Recent large U.S. commercial installation announcements include:

- *Microsoft*, Mountain View, California campus, 480kWp, April, 2006
  (Manufactured by *SunPower Corp.*, designed and installed by *PowerLight Corp.)*

- *Timberland*, Ontario, California, 400kWp, April, 2006
  (Manufactured by *Sharp*, designed and installed by *Northern Power*)

- *V. Sattui Winery*, St. Helena, California, 34 kW, March, 2006
  *(*Designed and installed by *Akeena Solar)*

- *Walgreens, 100+ stores*, California & New Jersey, January, 2006

Recent U.S. government installation announcements include:

- City of Brockton, New Jersey, 425 kW, March 2006
  (Modules by *Schott Solar*, installed by *Global Solar Energy*)

- Whitehall Ferry Terminal, New York City, New York, 40 kW, March 2006
  (Commissioned by *Atlantis Energy Systems*)

- Department of Energy & Social Security Administration, Chicago, Illinois, 100kW, November, 2005
  (*Sanyo* cells, designed and installed by *PowerLight Corp.*)

Recent U.S. residential project announcements include:

- 3,000 Army homes, Hawaii, December, 2005
- City of Roseville, California, 20% of all new homes, November, 2005

PV Applications
The following table from the *Energy Information Administration (EIA)* breaks out the shipments of PV cells and modules by end use application and solar cell technology.

Shipments of Photovoltaic Cells and Modules by End Use and Type, 2003 & 2004
(Peak Kilowatts)

End Use	Crystalline Silicon	Thin-Film Silicon	Concentrator Silicon	Other	2004 Total	2003 Total
End Use						
Electricity Generation						
Grid Interactive	114,400	14,865	0	0	129,265	42,485
Remote	17,838	534	0	0	18,371	15,025
Communication	11,235	113	0	0	11,348	14,185
Consumer Goods	6,442	1	0	0	6,444	2,995
Transportation	1,376	4	0	0	1,380	14,143
Water Pumping	1,028	295	0	0	1,322	6,073
Cells/Modules to OEM	441	6,011	0	0	6,452	11,334
Health	341	0	0	0	341	2,924
Other	6,037	156	0	0	6,193	194
Total	**159,138**	**21,978**	**0**	**0**	**181,116**	**109,357**

Source: EIA

PV Pricing
Installed cost of standard PV systems runs in the range of $8-$10/Watt, so a 1kW system will run upwards of $8,000 to install. This price is before any federal, state or local rebates or tax credits. The system price breaks down to approximately 50% for the PV array and 50% for the balance of system components.

With raw material supply extremely tight and worldwide demand for solar cells continuing to increase, solar module prices are on the rise. *Solarbuzz* reports average solar module pricing at $5.37/Watt in April, up from $5.12/Watt a year ago.

Inverter pricing is somewhat more stable at $0.83/Continuous Watt and battery pricing is reported at $1.63/Output Watt Hour.

Factors Affecting Value
The lack of moving parts in PV panels makes them extremely reliable and largely maintenance free. This also accounts for their high value in used condition.

<u>Conditions affecting PV valuation:</u>
Physical damage from large hail, gunshot or failure of frame or mount in high winds resulting in broken cover glass and damage to the solar cell. This type of damage is not repairable and the panel is worthless.

In the case that one broken panel has taken an entire series string of panels off-line, the series can function again properly after the broken panel has been replaced.

Browning of the substrate. This is seen in older panels with significant sun exposure, newer technology panels do not brown. Minor browning results in slightly reduced power output.

Major browning indicates that the panel was used with concentrators, and their power output is significantly reduced, along with their value.

Conditions affecting Balance of System components:
PV Controllers
The most common causes of controller failure are using an undersized controller for the PV array output and lightning.

Inverters
The most common causes of inverter failure are lightning and incorrect sizing. Most inverters are designed to shut down and are undamaged if the load is too big, so lightning is the predominant source of failure here.

Lead-Acid Battery Banks
Batteries lose value faster than of any of the other PV installation components. Prone to installation problems, some systems need battery replacement within 2 years, others within 10-15 years. Most used systems need to have the battery replaced before the system returns to operation. The most common cause of battery problems is repeated overdischarge.

Overcharging a flooded lead-acid battery will also ruin it if the electrolyte level has dropped below the top of the plates. Non-flooded gel cell batteries are damaged if any overcharging has occurred.

Temperatures below freezing can also damage a battery, if discharged. Batteries with a full charge are good to -50ºF.

Conclusion
While the percentage of PV-produced energy in the United States is small relative to other traditional forms of energy, the industry is rapidly growing. Increased installations will ultimately increase the need for appraisal and valuation in this industry.

According to *Solarbuzz*, the United States increased its installed base of photovoltaic capacity to 105MW in 2005. Germany, meanwhile, increased its installed capacity to 837MW in 2005 and Japan grew to 292MW.

About the Authors
Catherine J. Rein, MBA, ASA Candidate Member, is president of Sandalwood Valuation & Consulting based in Louisville, Colorado, www.sandalwoodvaluation.com. She earned her Bachelor of Science degree in Chemical Engineering from the Colorado School of Mines and her Master of Business Administration degree from the University of Houston. She has over ten years of experience in financial analysis and strategic planning in the energy, chemicals and semiconductor industries.

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