International Energy Agency

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1
Exchange and Dissemination of Information on PV Power Systems

NATIONAL SURVEY REPORT OF PV POWER APPLICATIONS IN THE UNITED STATES 2004

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1 EXECUTIVE SUMMARY

1.1 Photovoltaic Activities in the United States

The United States Department of Energy's (DOE) Solar Energy Technologies Program made progress in photovoltaics (PV) on several fronts in 2004. The following is a summary of that progress as categorized by PV production, installed PV power, cost and prices, and budgets for PV.

1.1.1 PV Production in 2004

The United States (US) PV business increased its production of PV cells and modules growing 30% (2003 production was 103 MW, 2004 production was 138.7 MW). Shell Solar led the industry with over 62 MW produced. General Electric in their first full year since the purchase of AstroPower, produced 25 MW. Thin films from United Solar (14 MW of amorphous silicon in 2004) and First Solar (6 MW of cadmium telluride in 2004) had the highest percentage growth. Installations of systems sized greater than 40 watts grew 37 percent (63 MW in 2003 to 86 MW in 2004). The state incentive programs led to the installation of 57 MW of grid-connected PV systems. California led the way with 43 MW installed. No federal incentives were initiated. All assistance was state-centered. Prices for modules increased from a low of $2.60 per watt in 2003 to $3.25-3.50 per watt in 2004. Installed prices remained essentially flat.

United States PV cell/module production totaled 138.7 MW in 2004, which was a 35% increase from the previous year. The growth was driven by increases by all producers. General Electric (GE), after acquiring the assets of AstroPower, produced 25 MW in 2004. Shell Solar increased production to 62 MW. The BP Solar U.S. plant production stayed constant (14.2 MW) while a new plant was constructed. The BP cast-ingot polycrystalline silicon slice production rose to over 40 MW with 25 MW exported. RWE Schott increased its production from 4MW to 10MW in 2004. United Solar Systems Corporation (USSC) doubled its production of amorphous silicon on steel to 14 MW. First Solar increased production of cadmium-telluride modules from 3 MW to 6 MW. Evergreen Solar also doubled its production of string ribbon cells and modules to 6 MW.

Table 1-1: U.S. PV Cell/Module Production (MW)

Company/Year	1998	1999	2000	2001	2002	2003	2004
Shell Solar	**20.0**	**22.2**	**28.0**	**39.0**	**46.5**	**52.0**	**62.0**
BP Solar	**15.9**	**18.0**	**20.5**	**25.2**	**31.0**	**13.4**	**14.2**
General Electric (GE)							**25.0**
AstroPower	**7.0**	**12.0**	**18.0**	**26.0**	**29.7**	**17.0**	**See GE**
USSC	**2.2**	**3.0**	**3.0**	**3.8**	**4.0**	**7.0**	**14.0**
RWE Schott (ASE)	**4.0**	**4.0**	**4.0**	**5.0**	**5.0**	**4.0**	**10.0**
Evergreen Solar					**1.9**	**2.8**	**6.0**
Global Solar						**2.0**	**1.0**
First Solar						**3.0**	**6.0**
Other*	**0.6**	**1.0**	**1.5**	**1.3**	**2.5**	**1.8**	**0.5**
Total	**49.7**	**60.2**	**75.0**	**100.3**	**120.6**	**103.0**	**138.7**

*** Amonix, Iowa Thin Films, others**
Source: PV News, Vol 24, No 4, April 2005

1.1.2 Progress in Thin-Film Commercialization

In 2004, thin-film production in the United States increased 75% to 21 MW. The USSC 30-MW roll-to-roll amorphous silicon plant produced 14 MW in 2004. USSC also announced plans to build a second 30-MW plant in Michigan. Shell Solar Industries shipped 2 MW of copper-indium-diselenide (CIS) modules. First Solar, LLC shipped 6 MW of cadmium-telluride (CdTe) modules and announced plans to produce 20 MW in 2005. Global Solar Energy, Inc. produced nearly 2 MW of CIS-on-steel modules. Iowa Thin Film Technologies, Inc. produced about 100 kW for specialty small power applications.

1.2 Installed PV Power

The PV installations in the United States increased 36.5% from 63 MW (not counting systems sized at less than 40 W) in 2003 to 86 MW (dc) in 2004. Most of the growth was in the grid-connected sector-from 37 MW in 2003 to 62 MW (dc) in 2004. This represented a 67.6% increase in the grid-connected sector.

Table 1-2: PV Applications by Market Sector in the United States (MW)

Application	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Grid-Connected Distributed	1.2	1.5	2.0	2.0	2.2	3.7	5.5	12.0	22.0	32.0	57.0
Off-Grid Consumer	3.0	3.5	4.0	4.2	4.5	5.5	6.0	7.0	8.4	9.0	10.0
Government Projects	0.6	0.8	1.2	1.5	1.5	2.5	2.5	1.0	1.0	1.0	1.0
Off-Grid Industrial /Commercial	3.3	4.0	4.4	4.8	5.2	6.5	7.5	9.0	13.0	16.0	18.0
Consumer (<40 W)*	1.7	2.0	2.2	2.2	2.4	2.4	2.5	3.0	4.0	4.0	4.0
Central Station	—	—	—	—	—	—	—	—	—	5.0	4.0
Total Installed in U.S.	9.8	11.8	13.8	14.7	15.8	20.6	24.0	32.0	48.4	67.0	94.0
Imports						2.0	4.0	5.0	9.0	18.0	40
Exports	16.2	24.0	25.1	36.3	37.9	39.8	55.0	73.3	81.2	54.0	88.0
Total	26.0	35.8	38.9	51.0	53.7	62.4	83.0	110.3	138.6	139.0	222.0

Highlights from California: Installation of PV Systems Nearly Doubled To 36.5 MW
The California PV program involved several key State players and unique assistance. The California PV "buy down" program resulted in the installation of 19 MW of grid-connected residential and commercial PV systems.

The Sacramento Municipal Utility District (SMUD) completed phase two of its "PV Pioneer" program by offering subsidized PV systems to its customers at reduced prices. In all, SMUD installed about 1.1 MW of PV systems in 2004, bringing its total to more than 9 MW installed in the last ten years. The Los Angeles Department of Water and Power (LADWP) PV program resulted in 2 MW of newly installed PV systems in 2004. Cumulative installations by LADWP reached 9.6 MW. Additionally, The California Public Utilities' Renewable Portfolio Standard (RPS) program with Pacific Gas & Electric, Southern California Edison, San Diego Gas and Electric, and Southern California Gas Co. installed 18.8 MW in 2004. Other California utilities and cities installed nearly 200 kW.

1.3 Costs & Prices

The installed cost of grid-connected PV systems remained nearly constant as the cash subsidies, especially in California, decreased from $4.50/Wac installed to $3.20/Wac. In this competitive environment, the installed prices remained nearly constant at $6.50/Wac–$8.00/Wac despite increased module prices. Some volume systems, primarily to builders, were sold at lower prices of $.6.50/W. These price reductions were made possible by continued low wholesale module prices for volume purchases (see Table 1-3) and reduced labor costs owing to increased volume of installations.

Table 1-3: Typical Prices in the U.S. of Single- and Multi-Crystalline Silicon Modules*-

Year	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Price ($U.S.)/W	**4.25**	**4.25**	**4.00**	**3.75**	**4.00**	**4.15**	**4.00**	**3.50**	**3.75**	**3.50**	**3.25**	**3.00**	**3.25**

***Estimated by PV Energy Systems**

Table 1-4: National Trends pf Residential System Prices in the U.S.

Year	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Price ($U.S./W)	**12.00**	**11.00-12.00**	**10.00-12.00**	**10.00-12.00**	**10.00-11.00**	**9.00-11.00**	**8.00-10.00**	**7.00-9.00**	**6.50-9.00**	**6.50-8.00**	**6.50-8.00**

1.4 Budgets for PV

The federal budget for PV research and development (R&D) was essentially level. Table 1-5 shows that the total funds for Fiscal Year (FY) 2004 were $76.5 M. The DOE-approved $72.5 M was for research and engineering, and market-support programs totaled $4 M. The emphasis was placed on R&D with minimal funds for market stimulation. Nearly one-half of the funds for market were grants ($100 k each) in support of state Million Solar Roofs programs. The Federal 15% tax incentive for grid-connected residential systems was not funded by Congress.

State tax credits for PV systems totaled more than $150 M, and the funds are expected to increase for next year. Nearly 60% of the state support came from California, which installed nearly 70% of the grid-connected systems in 2004.

Table1-5: Public Budgets for R&D, Demonstration/Field Test Programs, and Market Incentives ($U.S.)

FY 2004	R&D ($k)	Demo/Field Test ($k)	Market ($k)
National/Federal	**72,500**	**4,000**	**0**
State/Regional	**10,000**	**1,000**	**150,000**
Total	**82,500**	**5,000**	**150,000**

Table 1-6: U.S. Funding Schedule for PV ($M)

Program Element	FY 2001	FY 2002	FY 2003	FY 2004
Fundamental Research	**17.560**	**21.700**	**30.400**	**29.409**
Advanced Materials & Devices	**37.000**	**26.900**	**29.793**	**29.408**
Technology Development	**19.700**	**17.555**	**13.500**	**17.638**
Total	**74.260**	**66.155**	**73.693**	**76.455**

1.5 Value of U.S. PV Industry

The value of business for the U.S. PV industry is shown in Table 1-7. The values include the solar grade silicon that was exported, the value of the modules exported, the domestic R&D, and the value of installed systems. This estimate is the first attempt at valuation. The total value of the U.S. PV industry is estimated to be $1.2 billion for 2004.

Table 1-7: Value of PV Business (2004)

Sub-Market	Capacity Installed in 2004 (kW)	Price ($/W)		VALUE ($U.S. Million)
Off-Grid Domestic	**10,000**	**15**		**150**
Off-Grid Non-Domestic	**18,000**	**15**		**270**
Grid-Connected Distributed	**30,000 (Residential)** **27,000 (Commercial)**	**7** **6**		**210** **162**
Grid-Connected Centralized	**4,000**	**7**		**28**
Total U.S. Installed PV				**820**
Export of PV Modules	88 MW	$3.25/W		**286**
Change in stocks held (not available)				**---**
Import of PV Modules	40 MW	$3.25/W		**130**
Export PV Silicon	5000 TON	$50,000/Ton		**250**
Value of U.S. PV Business				**1486**

2 THE IMPLEMENTATION OF PV SYSTEMS

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a capacity of 40 W or more. A PV system consists of modules, inverters, batteries, and all installation and control components for modules, inverters, and batteries.

2.1 PV System Applications in the United States

PV applications over 40 W in size in the United States grew 37%, from 63 MW in 2003 to 86 MW (dc) in 2004. The U.S. applications for PV cover virtually all uses. Table 2.1 summarizes the development of the applications sectors. The grid-connected sector started its high growth rate in 1999 with the state-subsidized applications.

<u>The Off-Grid Consumer Sector:</u>

This sector includes applications in mostly remote locations, including applications for remote residences, boats, motor homes, travel trailers, vacation cottages, and farms. The systems provide electricity for all types of loads used for modern habitat. Most systems are rated less than 1 kW, have several days of battery storage, and

usually serve dc loads. Some larger systems use stand-alone inverters to power ac loads and may have a diesel generator as backup. More than 10 MW was installed in the off-grid consumer sector in the United States in 2004.

The Off-Grid Commercial/Industrial Sector:

This sector is the second largest sector of the U.S. PV market (18.0 MW in 2004). Telecommunication applications encompass a wide range of applications, from remote repeaters and amplifiers for all modes of communication (including fiber optics, satellite links, and cable links) to small data link stations via phone, TV, and secure communications throughout the country. Remote PV power systems also serve as sensor power sources and data communication power for a broad range of applications, including weather, storm warning, seismic, radiation and pollution monitors, security phones on highways and in parking lots, and traffic monitors. Remote lighting and signals are proliferating; applications include bus stops, remote shelters, parking-lot lights, billboards, highway information/construction signs (replacing small engine generators), inter-coastal navigation aides, and lighting for environmentally friendly corporate headquarters.

The Government Sector:

PV serves a broad array of applications in this sector, and many applications are considered "emerging markets." These include PV/diesel hybrid power stations that can ultimately serve remote sites or are transportable for emergency power. The Department of Defense funds the installation of about 0.5 MW per year that has resulted in installed PV systems totaling more than 5 MW. These PV systems included applications ranging from remote sensors to large, off-grid PV-diesel hybrid systems where utility power is not available or reliable.

The Utility Photovoltaic Group (UPVG) program directed thousands of utility installations amounting to more than 9 MW in the past five years. Several thousand applications have been installed that are "nearly economic" applications. The U.S. Department of Energy has subsidized these early applications with an average of 25% of federal funds. No UPVG systems were installed in 2003/2004. Another important government program is "PV for Schools," where federal and state programs funded the installation of small grid-connected systems in schools for education and emergency power.

The On-Grid Distributed Sector:

Prior to 1999, this sector involved a few "early adopters" that installed residential and commercial systems connected to the utility grid and amounted to less than 2 MW/year. In 2004, this sector nearly doubled over the 2003 installations, to 57 MW of new installed power. PV installation growth was primarily in the on-grid residential sector and was primarily the result of the tax credits implemented by the states. California led the way with over 38.5 MW of grid-connected PV systems installed in 2004.

Other Sectors

Other important programs included but were not limited to the following:

- ✓ **The U.S. "PV for Schools" program, which installed PV systems on schools with a goal of increasing awareness of PV applications among youngsters.**

- ✓ **The state programs for renewable energy set-asides resulting from restructuring.**

Other forms of marketing incentives included:

- ✓ **Standard PV systems for new homes offered through homebuilders by General Electric, BP Solar and Shell Solar.**
- ✓ **Expanded in-store sales of packaged retrofit, grid-connected, BP Solar PV systems through Home Depot stores.**

Table 2-1: PV Applications by Market Sector in the United State

Application	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Grid-Connected Distributed	**1.2**	**1.5**	**2.0**	**2.0**	**2.2**	**3.7**	**5.5**	**12.0**	**22.0**	**32.0**	**57.0**
Off-Grid Consumer	**3.0**	**3.5**	**4.0**	**4.2**	**4.5**	**5.5**	**6.0**	**7.0**	**8.4**	**9.0**	**10.0**
Government Projects	**0.6**	**0.8**	**1.2**	**1.5**	**1.5**	**2.5**	**2.5**	**1.0**	**1.0**	**1.0**	**1.0**
Off-Grid Industrial/ Commercial	**3.3**	**4.0**	**4.4**	**4.8**	**5.2**	**6.5**	**7.5**	**9.0**	**13.0**	**16.0**	**18.0**
Consumer (<40 W)*	**1.7**	**2.0**	**2.2**	**2.2**	**2.4**	**2.4**	**2.5**	**3.0**	**4.0**	**4.0**	**4.0**
Central Station	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**—**	**5.0**	**4.0**
Total Installed in U.S.	**9.8**	**11.8**	**13.8**	**14.7**	**15.8**	**20.6**	**24.0**	**32.0**	**48.4**	**67.0**	**94.0**
Imports						**2.0**	**4.0**	**5.0**	**9.0**	**18.0**	**40.0**
Exports	**16.2**	**24.0**	**25.1**	**36.3**	**37.9**	**39.8**	**55.0**	**73.3**	**81.2**	**54.0**	**88.0**
Total	**26.0**	**35.8**	**38.9**	**51.0**	**53.7**	**62.4**	**83.0**	**110.3**	**138.6**	**139.0**	**222.0**

2.2 Total PV Power Installed

Table 2-2: The Cumulative Installed PV Power in the United States by IEA-defined Sub-markets.**

Sub-market/ Application	31/12/ 1994 MWp	31/12 / 1995 MWp	31/12/ 1996 MWp	31/12/ 1997 MWp	31/12/ 1998 MWp	31/12/ 1999 MWp	31/12/ 2000 MWp	31/12/ 2001 MW p	31/12 / 2002 MWp	31/12 / 2003 MWp	31/12/ 2004 MWp
Off-grid (Domestic)	**15.8**	**19.3**	**23.3**	**27.5**	**32.0**	**37.5**	**43.5**	**50.5**	**58.9**	**67.9**	**77.9**
Off-grid non-Dom.	**21.8**	**25.8**	**30.2**	**35.0**	**40.2**	**46.7**	**55.2**	**64.7**	**77.7**	**93.7**	**111.7**
On-grid Distributed	**8.2**	**9.7**	**11.0**	**13.7**	**15.9**	**21.1**	**28.1**	**40.6**	**63.6**	**95.6**	**153.6**
On-grid Centralised	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**12.0**	**18.0**	**22.0**
TOTAL	**57.8**	**66.8**	**76.5**	**88.2**	**100.1**	**117.3**	**138.8**	**167.8**	**212.2**	**275.2**	**365.2**

**** IEA sub-markets are categorized for PV power applications above 40 W.**

2.3 Major Projects, Demonstration, and Field Test Programs

The major PV projects in the United States consisted of the continuation of projects started in the 1995-1999 timeframe. These included the following:

The completion of Pioneer II, where SMUD offered PV systems for sale to customers at subsidized prices (as low as $3.50/W installed), The Pioneer II program called for 5 MW of PV to be installed in 1999-2004. SMUD installed 0.2 MW in 1999, 0.4 MW in 2000, 1.3 MW in 2001, 1.6 MW in 2002, 0.4 MW in 2003, and 1.1 MW IN 2004. The program is essentially complete with over 10 MW (Pioneer I and II).

The program initiated by the State of California, where cash rebates of $4.50/W were offered to residential and commercial customers that installed grid-connected PV systems on investor-owned utility grids (1.4-1.6 MW in 2001, 8.1 MW in 2002, 12.3 MW in 2003, and 18.8 MW in 2004. Cumulative installations of nearly 45 MW have been made. California has a program of renewable power set-asides administered by the California Public Utilities Commission. More than 14.2 MW were installed by the four key utilities: Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, and Southern California Gas Company. Ten cities in California installed 0.4 MW of PV. The total PV installed by California was 38.5 MW (ac) with cumulative installations of 93.1 MW.

State PV Assistance Programs: Although detailed figures are not available for most state programs, several states have renewable energy subsidies. These are funds for research leading to new PV industry within the state, assistance for PV school programs, tax rebates, Renewable Portfolio Standards, and "Green Pricing" programs. States with major programs include the following:

Arizona: More than 10 MW of PV power systems have been installed during the last ten years. More than 5 MW of PV systems were installed in 2002-2004.

California: More than $350 M has been invested in grid-connected PV electricity generation systems. (See #2 above for summary).

Illinois: Illinois is led by the "Brightfields" program in Chicago, where abandoned factories called "Brownfields" are converted to PV manufacturing plants (owned and operated by Spire Corporation) or installed PV systems. The state of Illinois passed the largest subsidy in the United States for PV systems, $6/$W_p$. More than 1.5 MW of PV generation was installed in Illinois in 2003/2004.

New Jersey: New Jersey is implementing one of the most aggressive PV support programs in the United States. More than $100 million has been appropriated for the program, and nearly 2 MW of PV was installed in 2004.

New York: New York has legislated more than $150 M to support new industry, new installations, and studies to accelerate commercialization. Recently, New York increased the PV subsidy to $5/Wp for grid-connected systems.

North Carolina: North Carolina provides a 35% tax credit for PV system installations. Owing to the fact that net metering is not law in North Carolina, the subsidy has not been aggressively sought.

2.4 Highlights of R&D

The U.S. Department of Energy (DOE) is the principal source of funding for PV research and development in the United States. The primary purpose of the U.S. DOE PV subprogram, part of the Solar Energy Technologies Program, is to accelerate the development of PV as a national and global energy option. The PV subprogram budget summarizes PV R&D as follows:

"Research is focused on increasing domestic capacity by lowering the cost of delivered electricity and improving the efficiency of modules and systems. Fundamental research at universities was increased to develop non-conventional, breakthrough technologies. Laboratory and university researchers work with industry on large-volume, low-cost manufacturing, such as increasing deposition rates to grow thin-film layers faster, improving materials utilization to reduce cost, and improving in-line monitoring to increase yield and performance.

Specific goals by 2006 follow:

- ✓ **Reduce the direct manufacturing cost of PV modules by more than 30% from the current average manufacturing cost of $2.50/W to $1.75/W**
- ✓ **Identify and begin prototype development of two new leapfrog technologies that have the potential for dramatic cost reduction**
- ✓ **Establish greater than 20-year lifetimes for PV systems by improving the reliability of balance-of-system components and reduce recurring costs by 40%**
- ✓ **Work with the U.S. PV industry to facilitate achievement of its roadmap goals of 1-GW cumulative U.S. sales (export and domestic) by 2006, and 30 GW by 2020.**

Installed price goals for a grid-connected PV system paid by an end user (including operation and maintenance costs) are as follows: Price goals are to reduce from a minimum value of $6.25/W$_p$ in 2003 to $4.50/W$_p$ in 2006 (equivalent to reducing the cost of energy produced from $0.25/kWh to $0.18/kWh.

2.5. Public Budgets for Market Stimulation, Demonstration/Field Test Programs and R&D

The federal budget for PV was essentially level from 2003 to 2004. Table 2-3 shows the total funds for FY 2004 were $76.5 million. About $72.5 million was approved for research, development and engineering. Market support programs totaled $4.0 million. The emphasis was placed on R&D with minimal funds for market stimulation. Nearly one-half of the funds for market were grants ($100,000 each in support of state Million Solar Roofs program). The federal 15% tax incentive for grid-connected residential systems was not funded by the Congress (for the fifth year in a row).

State tax credits for PV systems totaled more than $150 million, and the funds are expected to increase. Nearly 60% of the state support came from California, which installed nearly 80% of the grid-connected systems in 2004.

Table 2-3: Public Budgets for R&D, Demonstration, and Market Incentives ($U.S.)

PUBLIC BUDGET: R&D, DEMOS, TESTS, MKT INCENTIVES; 2004	R & D U.S. $M	Demonstration & Field Test U.S. $M	Market U.S. $M	Total U.S. $M
National/Federal	**76**	**0.5**	**000**	**76.5**
State/Regional	**10**	**10**	**180**	**200**
Total	**80**	**10**	**180 M**	**276.5**

Table 2-4: U.S. DOE Federal Funding Schedule for PV ($M,U.S.)

Program Element	FY 2002 ($M)	FY 2003 ($M)	FY 2004 ($M)
Fundamental Research	**$17.56**	**$21.70**	**29.41**
Advanced Materials & Devices	**$37.00**	**$26.90**	**29.41**
Technology Development	**$19.70**	**$17.56**	**17.68**
Navajo Electrification Project	**0**	**$2.31**	**Transferred to Reliablity and Infrasture Program in 2004**
Total	**74.26**	**68.96**	**76.50**

3 INDUSTRY AND GROWTH

3.1 Production of Feedstocks and Wafers

Table 3-1 shows the U.S. production of feedstocks (poly-crystalline and single-crystalline silicon), edge-defined film-fed growth (EFG) wafers, and solar-grade silicon feedstock. Prior to 2004, most of the solar-grade silicon feedstock (90%) was purchased from the semiconductor industry as scrap. In 2004, the purchase of solar-grade silicon increased as scrap supplies were diminished. Yield and efficiency are increased as scrap is replaced with solar-grade silicon.

Table 3-1: Production and Production Capacity Information for 2004 for Feedstock Producers and Wafer Manufacturers

	Solar-Grade Si Production (Metric tons)	Total Silicon Production (Metric tons)	Solar Grade Si Product, Destination (Metric tons)
Hemlock Semiconductor Corp	**2000**	**6800**	**500 U.S. 1500 Export**
Advanced Silicon Materials	**000**	**2,700**	**000**
Solar Grade Silicon	**2100**	**2,100**	**800 U.S. 1300 Export**
MEMC	**400**	**1,700**	**400 U.S.**
Mitsubishi Polysilicon America	**100**	**1,200**	**100 U.S.**
TOTAL SILICON	**4600**	**13,700**	**1000 U.S. 1000 Export**
Solar grade scrap	**500**		**500 U.S.**
Total silicon USED BY PV in U.S.	**5,100**		**2100 U.S. 5000 Export**
U.S. Silicon Wafer Production	MW	MW	MW
Reject Wafers from I.C. Industry (GE)	**25**		**7 MW U.S. 18 MW Export**
Shell Solar	**60**		**20 MW U.S. 40 MW Export**
BP Solar	**40**		**15 MW US 25 MW Export**
Evergreen Solar	**6**		**6 MW**
SOLEC International	**20**		**0 U.S. 20 MW Export**
Total Wafers	126		

Production of PV Cells and Modules

Total U.S. production of cells and modules increased by 30% from 2003 to 2004.

Table 3-2: 2004 Production and Production Capacity Information for PV module manufacturers in the United States

Module Manufacturer	Cell Type	2004 Production (MWp)		2004 Max Capacity (MWp)	
		Cells	Modules	Cells	Modules
Shell Solar	**Single-crystalline silicon**	**60.0**	**60.0**	**60.0**	**60.0**
BP Solar	**Multi-crystalline silicon**	**14.2**	**14.2**	**15.0**	**20.0**
General Electric	**Single-crystalline silicon (from reject IC wafers)**	**25.0**	**25.0**	**30.0**	**30.0**
RWE Schott Solar	**EFG ribbon silicon**	**10.0**	**10.0**	**15.0**	**15.0**
Evergreen Solar	**String ribbon**	**6.0**	**6.0**	**8.0**	**8.0**
Total Crystalline		115.2	115.2	128.0	133.0
Thin-Film Manufacturers					
Shell Solar	**Copper-Indium-Diselenide (CIS)**	**2.0**	**2.0**	**3.0**	**3.0**
USSC	**Amorphous Silicon**	**14.0**	**14.0**	**30.0**	**30.0**
First Solar	**Cadmium Telluride**	**6.0**	**6.0**	**8.0**	**8.0**
Global Solar	**CIS**	**1.0**	**1.0**	**2.0**	**2.0**
Total Thin Films		23.0	23.0	43.0	43.0
Other (Concentrator)	**Concentrator**	**0.5**	**0.5**	**1.0**	**1.0**
Total U.S. Production		161.7	161.7	215.0	220.0

3.2.1 Shell Solar Industries:

Founded in 1978, Shell Solar Industries is located in Camarillo, California. Formerly Siemens Solar Industries, Shell Solar Industries specializes in engineering and manufacturing copper-indium-gallium-selenide (CIGS) thin-film and mono-crystalline modules. Shell Solar's U.S. crystalline PV production is fully integrated: Shell purchases solar-grade polycrystalline silicon to be used in a melt from which single-crystalline silicon ingots are pulled using the latest 6- to 8-inch diameter pullers. Shell Solar then slices the ingots into 300-micron thick wafers using wire saws. The

crystal and wafer production is in its plant in the state of Washington. The wafers are processed into cells and modules in an automated plant in Camarillo, CA. Shell Solar modules are certified to all standards including the Institute of Electrical and Electronic Engineers (IEEE), ISPRA, and Underwriters Laboratories (UL). The Shell Solar package is tempered glass/cells/EVA encapsulation/back cover of Tedlar® or aluminum. Shell Solar offers a warranty of 25 years on its crystalline modules. In 2004, Shell Solar produced 62 MW of cells and modules. Single-crystalline silicon accounted for 60MW and copper indium diselenide (CIS) thin-film modules accounted for 2 MW.

Shell Solar has performed research, pilot production, and testing on CIS solar modules for more than fifteen years, and has produced CIS modules with efficiencies greater than 12%. The CIS product was produced in pilot quantities in 1998–2000. Shell Solar shipped 2 MW of CIS modules in 2004.

3.2.2 BP Solar International, Inc.:

BP Solar International, Inc., founded in 1983, is incorporated in the United States and is headquartered in Linthicum, Maryland, with manufacturing facilities in Maryland, Australia, Spain, and India. Formerly known as Solarex, then as BP Solarex, the company specializes in manufacturing, design, and marketing of multi-crystalline and polycrystalline silicon modules for the residential and commercial building industry. BP Solar is the world's third largest producer of cast-ingot, multi-crystalline silicon cells and modules (Kyocera of Japan is first and Sharp of Japan is second). Production in 2004 was essentially flat in the United States. According to BP Solar, this static performance can be attributed to production changes to a new antireflection coating manufacturing line and development of a larger (15 cm by 15 cm) cell. The U.S. capacity is being doubled, owing to the increase in the U.S. market. BP Solar purchases solar-grade polycrystalline silicon, and casts the silicon into rectangular parallelepiped ingots. The ingots are sawed into smaller ingots (15 cm by 15 cm), which are then sliced, using wire saws and inside diameter saws. The slices are processed into solar cells and then integrated into glass/EVA/Cells/EVA/Tedlar modules. BP Solar offers power modules with outputs of 33-300 W with a standard 25-year warranty.

3.2.3 General Electric Company (formerly AstroPower):

General Electric Company's GE Energy Solar Energy Division purchased Delaware-based AstroPower in the summer of 2004 to expand its solar energy business. GE Solar produces single-crystalline cells and modules from purchased reject wafers from the semiconductor industry. GE Solar processes the wafers and produces solar cells using standard processing. Much of the product is sold as cells, primarily for European building-integrated PV products, and standard power modules are also produced. All modules are UL listed and certified by ISPRA or the Arizona State University Photovoltaic Testing Laboratory (PTL). GE Solar produced 25 MW of single-crystalline silicon cells and modules in 2004. GE Solar also implemented a major new product program, "zero energy homes," primarily in California. GE has formulated strategic business relationships with the buildings industry to incorporate the most efficient General Electric appliances, heat pumps, and PV in residential and commercial construction.

3.2.4 RWE Schott Solar, Inc.:

RWE Schott Solar, Inc., formerly Schott Applied Power Corporation, was founded in 2000 and has facilities in Massachusetts and California. Formerly Ascension Technology, Inc., RWE Schott specializes in PV system integration. Schott Solar (formerly ASE GmbH), in Germany, purchased the assets and technology of Mobil Solar in 1993 and established ASE Americas. The edge-defined film-fed growth (EFG) process was refined, and new pullers were installed. RWE Schott purchases polycrystalline silicon that is melted. Sheet silicon is pulled from the melt in the form of an octagon. The octagon is cut into 15cm x 15cm slices. Cells and modules are produced in a semi-automated plant. The RWE Schott crystalline-silicon modules use a glass/proprietary dielectric/cells/dielectric/glass configuration. RWE Schott sells sliced silicon wafers, cells and modules. RWE also sells large, 300-W modules and Offers 25-year warrantees. In 2004, Schott Solar produced and shipped 10 MW of cells and modules. RWE Schott (U.S.) also produced 20 MW of silicon wafers, which were shipped to its facilities in Germany for cell processing and manufacturing.

3.2.5 Solec International, Inc.:

Solec International, Inc., a subsidiary of Sumitoma Corporation of America (SCOA), is in partnership with Sanyo Electronics and specializes in solar system manufacturing. In 2000, Solec International terminated its cell and module production to produce nearly 5 million n-type wafers for its owner Sanyo. The wafers are used to produce Sanyo's new Heterojunction with Intrinsic Thin layer (HIT) solar cell consisting of an amorphous silicon layer on a crystalline silicon heterojunction cell. Sanyo has obtained large area (>100 cm^2) efficiencies of 21%, with production efficiencies reaching 17.5% with this cell.

3.2.6 United Solar Systems Corporation (USSC):

United Solar Systems Corporation (USSC) started production in its new 5-MW, triple-junction amorphous-silicon plant in Troy, Michigan in 1997. Over 4 MW of modules were shipped in 2002. In addition to its marine modules and framed power modules, USSC manufactured two unique products. They include a PV roof shingle that can be used with normal shingle roofing materials and a standing-seam metal roofing material that can be used with metal roofing. The building-integrated products are listed by UL and have been certified by the Arizona State University Photovoltaic Testing Laboratory. In 2000, Energy Conversion Devices, USSC's owner, signed an $84 M joint venture agreement with Bekaert (Belgium). Bekaert is a 50% owner of Bekaert/USSC and funded construction of a 25-MW amorphous production line in Michigan. Production from the new plant commenced in late 2002. In 2003, Bekaert discontinued its interest in the United Solar plant and sold its ownership to United Solar's parent company, Energy Conversion Devices. This 25-30 MW plant is the world's largest thin-film plant, and in 2003 United Solar shipped 14 MW from the plant. Unite Solar's production in 2004 was 14 MW.

3.2.7 Evergreen Solar, Inc.:

Evergreen Solar, Inc., founded in 1994, is incorporated in the United States and is located in Marlboro, Massachusetts. The company specializes in developing and manufacturing modules made with crystalline silicon string-ribbon solar cells. Evergreen has taken Dr. Sachs (MIT) string-ribbon process into production. Pilot production started in late 1997. The modules have been certified by the Arizona PV

Testing laboratory and are UL listed. About 400 kW of string-ribbon modules were shipped in 2001. In 2000, Evergreen made a successful initial public offering on the U.S. stock market. The proceeds were used to build a 10-MW string-ribbon plant in Massachusetts. Pilot production on the new plant was achieved in the 2nd half of 2002. The new plant was dedicated in June 2002. Evergreen produced 6 MW of ribbon modules in 2004.

3.2.8 First Solar, LLC:

First Solar, LLC, established in 1999, is located in Perrysburg, Ohio. Formerly Solar Cells, Inc., First Solar specializes in developing and manufacturing cadmium telluride (CdTe) thin-film solar modules and PV module products used by electric utilities and commercial, distributed-generation power plant projects. First Solar continues pilot production of CdTe modules using a continuous closed-space sublimation process to deposit the CdTe on glass coated with a transparent conducting oxide. Modules measuring 24 inches by 48 inches have been produced with efficiencies of over 8%. First Solar is in the final stages of completing its 100-MW CdTe coating line and a 25-MW cell and module production line. The coating line and the first stage of the cell and module line (about 10 MW) were to be completed in late 2000. After over a year of "fine tuning," production from the new plant was delayed until 2003. Nearly 3 MW of CdTe modules were produced by First Solar in 2003. In 2004, the company produced 6 MW.

3.2.9 Amonix, Inc.:

Amonix, Inc. integrates high-concentration photovoltaic (IHCPV) systems. Since the early 1990s, Amonix has field-tested several IHCPV generating systems throughout the United States. The company focuses on utility-scale applications for solar generating systems. Amonix has advanced the "point contact" cell into a production-model, 24%-efficient, concentrator cell at 250-350 times concentration. During 2004, Amonix produced about 500 kW of its 20-kW system using its design for all components. The systems operated with installed efficiency over 18%, which was a record for PV.

Table 3-3 shows typical factory module prices for large customers in the United States. Included are modules imported mostly from Japan. Module prices to end-users are much higher, depending on the position in the distribution chain. A $3.00 factory price to a large distributor can be as high as $5/W to a retail customer or a small dealer.

Table 3-3: Typical Module Prices of Single-Crystal and Multi-crystalline Silicon

Year	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04
Price $/W	**4.25**	**4.25**	**4.00**	**3.75**	**4.00**	**4.15**	**4.00**	**3.50**	**3.75**	**3.50**	**3.25**	**3.00**	**3.25**

Modules ($U.S./W)

***Estimated by PV Energy Systems**

3.2 Manufacturers and suppliers of other components: Balance of Systems

Typically, the balance-of-systems (BOS) components for a PV system cost as much, if not more, than the retail price of the PV module. About one-half of the installed PV systems involve stand-alone systems that have storage (usually deep-cycle lead-acid

batteries) and charge controllers that control the charging of the battery to extend the service life by optimum charging and preventing the load from exceeding the design discharge levels. Most stand-alone systems have dc loads and use 12- and 24-V battery banks. When ac loads are used, the stand-alone system will have an inverter. Some stand-alone systems are designed as hybrids with diesel or gasoline generators as an integral part of the system.

In the United States, about 37 MW of PV systems were grid-connected in 2003. The magnitude of grid-connected systems increased to greater than 62 MW in 2004. The grid-connected systems use all technologies of PV modules and are typically connected to an inverter that permits the PV system to first serve the building's load and then send excess power to the utility grid. When the grid power is not available, some inverters may be designed to switch to "standby" and power the local load from energy stored in a battery bank and the numbers of systems utilizing the standby option is minimal.

3.2.1 Inverter Manufacturers:

There were several small domestic inverter manufacturers serving the U.S. market in 2004, but the majority of inverters used in 2004 installations were imported, in part because the PV program has not supported development of advanced inverters for nearly the last decade due to lack of funding, and in part because the infrastructure for a large grid-connected market is just emerging. New domestic producers of inverters did emerge in 2004 and additional imports appeared on the market. Domestic producers included Xantrex, Outback Power, Beacon, Ballard Power, SatCon, and PV Powered. Imported models were available from SMA America (claiming the majority of the residential market), Fronius USA, Alpha Technologies, Sharp Electronics and a new introduction by Magnetek. Several new domestic manufacturers including General Electric and are planning to introduce inverter models in the next year.

SMA (Germany) opened a sales office in the United States in 2000 to sell its UL-listed grid-connected residential inverters. The SMA market share for 2004 was reported to be greater than 80% for numbers of residential-size grid-interactive inverters. Xantrex follows SMA with the number of inverters sold in the U.S. in 2004. The dramatic increase in the market for grid-connected residential PV systems in 2002-2004 greatly increased the sales of small inverters. Sharp, which installed more than 60,000 inverters in Japan, entered the U.S. market in 2003 with a majority of its sales coupled to complete Sharp systems. At least eight companies now have UL-listed inverters for the U.S. grid-connected markets.

The U.S. Solar Program recently increased its support for inverter development focusing on improving the reliability of inverters. Three contractors were developing high reliability inverters in 2004 with prototypes being delivered for characterization and analysis. The Phase III (commercialization prototype) of the high-reliability inverter is continuing.

The prices of inverters for grid-connected applications vary with the number being purchased and with the size of the inverter. Many other variables enter the price making a price comparison a complex task. For instance some inverters offer the full range of necessary disconnects along with data acquisition, displays, and options such as outdoor rated. The residential size inverters ranging from 600 W through 10kW ranged in price from $0.75/W through $1.05/W in single quantity purchases.

Large quantity purchases can reduce the cost of some inverters by as much as 40%. The larger inverters ranged in price from $0.45/W through $0.80/W. Other major cost factors include service contracts and warrantees. Factors that are expected to influence inverter prices in the near future include the possibilities of installing ungrounded systems with associated transformerless inverters according to the new 2005 National Electrical Code.

3.2.3 Battery Charge Controllers:

Battery charge controllers are an essential component for the PV systems that store the energy in batteries. The charge controller charges the battery and controls the discharge of the battery to the load. The charge controller is designed to optimize the charge and discharge of the battery so as to obtain maximum battery life and provide the highest charge and discharge efficiency. The United States has several producers of charge controllers. Based on a phone survey of most suppliers, the number-one U.S. producer was Morningstar Corporation with production of more than 75,000 charge controllers.

Other producers in the 10,000 units/year range included Xantrex, Specialty Concepts, Sun Selector, and Outback Power, RV Power Products. Sales by several producers were available, including ETA Engineering, Orion, PICO, ICP Global Tech, and DYNAGE POWER. Total production is estimated at 130,000-150,000 units/year. More than 60% of the battery charge controller products produced in the U.S. was exported.

3.2.4 Systems Designers and Installers:

There are about 30 companies in the United States primarily dedicated to the design, sales, and installation of PV systems. When the market was primarily off-grid, stand-alone systems (prior to 1996), about 10 large distributors had a system designer/installer who served most of the larger commercial systems (telecommunications, water pumping, remote military, etc.). These include Atlantic Solar, Home Depot, Hutton Communications, and SunWize. When the state tax credits for grid-connected systems (residential and commercial) were established, several of the distributors became full-service system installers. Many new or expanded companies were formed to deal exclusively with grid-connected systems. The most notable of these companies is PowerLight, which installs more than 20% of the U.S. grid-connected systems. PowerLight combines PV with foam insulation to form building-integrated flat roofs. In 2004, several PowerLight systems were larger than 1 MW.

3.3 System Prices

The increased volume for grid-connected PV systems has caused intense competition, more effective use of installation labor, packaged systems, and purchasing power. These changes have led to price reductions of installed systems.

Table 3-4: Turnkey Prices of Typical Applications

Category (Size)	Typical Applications with Brief Details	Price ($U.S./Wdc)*
Off-Grid (up to 1 kW_p)	**Stand-alone dc with 4-10 days storage**	**$12.00-$25.00**
Off-Grid (> 1 kW_p)	**Stand-alone dc or ac with 4-10 days storage**	**$12.00-$20.00**
On-Grid (up to 10kW_p)	**Roof-mounted/inverter/no storage**	**$7.00-$10.00**

On-Grid (> 10 kW_p)	**Roof or ground-mounted/inverter/no storage**	**$6.25-$8.50**

***Prices do not reflect add-on costs for warrantees, service contracts and training. Additional energy storage for uninterruptible power will also increase costs.**

Table 3-5: National Trends in System Prices for Grid-Connected Residential Systems

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Price /W:	**12**	**11-12**	**10-12**	**10-12**	**10-11**	**9-11**	**8-10**	**7-9**	**6.50-9**	**6.50-8**	**6.00-9**

3.4 Labor Places

The number of labor places rose dramatically in 2004 in the United States. Table 3-7 shows the dollar values, approximate average labor rates and the number of laborers

Table 3-6: 2004 Analysis of the PV Industry Labor Force and Costs in the United States

Category	(MW)	Total Value ($M)	Labor $/W	$ For Labor ($M)	Labor Dollars/ Person	Number of Laborers
Cell/Module Production	**138.7**	**$450**	**1.25**	**$173.4**	**40,000**	**4335 Factory**
Factory Marketing	**138.7**	**$450**	**0.30**	**41.6**	**100,000**	**416 Marketing**
Management	**138.7**	**$450**	**0.30**	**41.6**	**150,000**	**277 Management**
Research/Eng Industry	**138.7**	**$450**	**0.30**	**41.6**	**130,000**	**320 Research**
University/Lab Research/Eng.				**40.0**	**130,000**	**308 Research**
BOS Production	**88**	**$264**	**0.50**	**44.0**	**40,000**	**1100 Factory**
BOS Marketing	**88**	**$264**	**0.25**	**22.0**	**60,000**	**370 Marketing**
BOS Management	**88**	**$264**	**0.25**	**22.0**	**80,000**	**275 Management**
Installation Labor	**88**	**$264**	**1.00**	**88.0**	**40,000**	**2200 Installers**
Install Management	**88**	**$704**	**0.50**	**44.0**	**60,000**	**733 Managers.**
Total Labor For Modules BOS and Installation						**10,334 Total Workers** **5435 Factory** **628 Research/Eng.** **786 Marketing** **1285 Management** **2200 Installers** **10,334 TOTAL**
SOLAR SILICON PRODUCTIOM	**Metric Tons**	**Price/ kG**	**Value $M**	**$ Labor/ kG**	**Labor Value M $/ Person**	**Labor Number**
	4600	**$50**	**230 M**	**$10.00/ KG**	**$46M 80,000**	**575**
TOTAL U.S. PV LABOR						**10,909**

3.5 Business Value

The value of the PV product and services in the United States can be estimated by adding the total value of the product installed, the product exported and the R&D costs in the in government labs and universities.

4. FRAMEWORK FOR DEPLOYMENT

4.1. Non-technical Factors

The U.S. PV industry continues to address the grid-connected power market through programs such as the Sacramento Municipal Utility District (SMUD) PV Pioneer Program moving into customer purchase of PV home systems, the California subsidy for PV systems, the Los Angeles Department of Water and Power PV subsidy program, several new state subsidy programs and other market-centered programs. All are combining in forming the base for the expanding U.S. grid-connected PV market.

4.2 Indirect Policy Issues

The United States has completed virtually no indirect policy initiatives that affect the deployment of PV. The international policies that affect the use of PV power systems are few. In the general aegis of "free trade", the NAFTA (North America Free Trade Agreement) with Mexico and Canada permit the sale of PV systems to these markets without duty or trade restrictions, while there are duties for modules imported into Mexico from other countries. The United State's trade with all of the Americas leads to more open markets for PV industry.

The United States has not introduced environmental regulations that have affected the deployment of PV. Neither the global warming treaty (Kyoto Accord) nor any part of the treaty has been approved by the U.S. Congress. Some analysts have reported that PV credits would be less than one cent per kilowatt-hour if there were serious efforts to credit PV for mitigation of CO_2 (the carbon tax). Although there was some analysis of the externalities and hidden costs of conventional energy generation compared to renewable energy in the 1990-1995 timeframe, most of these studies have been stored in files and no policy action has resulted.

4.2.1 Deregulation of the Electric Utility Industry

The U.S. PV industry is benefiting from the federal government's deregulation of the electric utility industry. Utilities have been regulated monopolies in each of the 50 states, but the Federal government has now required the states to deregulate utilities and permit the free trade of electricity generation, distribution and service across the country.
The deregulation process has resulted in several programs being proposed and legislated that affect PV. These include "Green pricing", set-asides for PV, net metering, interconnection requirements, etc. Owing to the fact that the regulation of the production and distribution of electricity has been relegated to the states, the initiatives related to promotion of PV are individually created and adopted by each of the 50 states. The state programs are so diverse that it is virtually impossible to provide a summary.

In order to provide a detailed overview, U.S. DOE has funded project DSIRE (Database of State Renewable Energy) at the North Carolina Solar Energy Center and managed by the Interstate Renewable Energy Council. The DSIRE project has issued a report "National Summary Report on State Programs & Regulatory Policies for Renewable Energy" that summarizes over 120 regulatory incentives in 45 states. The report and the latest updates can be found at the web site, DSIRE on line at http:/www.ncsu.edu/dsire.htm. Owing to the fact that the 50 states are responsible for

implementing the Federal utility restructuring mandate, this report has been invaluable for state advocacy groups and energy planners and regulators.

Because there are over 3000 private and public electrical utilities in the United States, and all are regulated in detail by the 50 states in which they reside under a Federal policy umbrella, a coherent picture is difficult to construct. The two main federal rules affecting PV are the Public Utilities Regulatory Policy Act (1978) (PURPA) and the Utility Restructuring Law (1996). The UPVG program was (now complete) also an important development process for the utilities to identify and gain experience with early applications for PV.

PURPA established the independent power industry in the United States by requiring that the utilities permit on-line third party generation of electricity and that the utility allows on-line interface with grid back up of the system. Not only was the utility required to permit interconnection, it must pay for excess electricity at "avoided cost". This law, approved by the U.S. Supreme Court established a large and growing independent power industry.

All generation options were allowed. Wind energy and PV benefited some from the law. However PV, with its high installed costs, despite a 10% investment tax credit, and some state tax-credits, was too expensive to compete with natural gas powered turbines. With the Million Solar Roofs Initiative, state and federal tax credits, utility leadership, and reduced prices, coupled with restructuring initiatives, the PURPA regulations are vital to deployment of PV and other renewable energy sources.

4.2.3 Restructuring

Since the federal government passed a law designed to deregulate the utility industry, some of the state monopolies have been replaced with competition and the market is being broken up into generation, transmission and distribution, power sales, and service. This means that new companies offering lower rates, improved quality and better service may directly contact the customer. This has opened the door for the sale of "green energy", on-site energy generation and other services that favor the intrinsically distributable PV option. The renewable energy industry has worked with the states that are leading the deregulation process to be sure that such options as net metering, green pricing, and set-asides for environmentally benign renewables are included in the restructuring regulations. At the end on 2003, twelve states had enacted restructuring legislation. Seven of the states have provisions for renewables through the legislation of systems-benefits charges and/or renewable portfolio standards. With the election of President Bush and the Republican-controlled Congress, there is now more emphasis on drilling for oil, so-called "clean coal", and "safe nuclear" and decreased emphasis on renewable energy developments.

4.3 Standards and Codes

The electrical safety, interconnect requirements, and personnel safety codes and standards have undergone continuous updates and thorough examinations by designers, installers, inspectors and users in the United States over the years. The vital safety and interconnect issues associated with codes and standards are some of the most important activities within the PV infrastructure and program. The U.S. DOE Solar program funds and supports a large portion of the standards, codes and certification activities. It has provided quality consensus of utility- and industry-inputs into the *National Electrical Code® (NEC®)*, new and revised equipment listing

standards, certification standards, interconnect standards, and related standards in the international arena.

The "Industry Forum", headed by Sandia National Laboratories submitted 23 proposed changes for Article 690 – Solar Photovoltaic Systems, for the 2005 edition of the NEC and a majority was accepted. Additional proposals came from other sources through a public input process. The 2005 edition of the NEC is published in 2004 but becomes effective only upon legislated actions by each of the states. One major change in Article 690 came was an allowance for ungrounded PV systems in the United States. Additional infrastructure is still being implemented to make the allowance economical but it is seen by the inverter manufacturers as a means to improve performance and lower costs.

The Institute of Electrical and Electronic Engineers Standards Coordinating Committee (SCC21) obtained approval of the IEEE Std 929-2000 "utility interconnect guideline for PV systems" in 2000 and continued progress on a new interconnect standard, labeled IEEE Std 1547. The new standard addresses interconnection of all distributed generation. This activity has a tremendous representation by the utilities and is supported by the national laboratories. Personnel from Sandia National Laboratories and NREL headed up other IEEE standards and other certification activities.

Underwriters Laboratories continued to evolve the UL1741 "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems", but was rewriting to include inverters and charge controllers for all distributed generation to match the requirements of the new IEEE 1547 standard. The first UL1741 was published in May 1999 and was last amended in 2001 and work continued throughout 2004 to coordinate it with the new *NEC* and IEEE1547. Coordination with both the *NEC* and the IEEE interconnect guidelines remains a valuable activity for finalizing the new UL1741 standard.

The IEEE 1547 (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems is a standard for interconnecting distributed resources with electric power systems. Supplementing IEEE 1547 are IEEE 1547.1, a Draft Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems; IEEE 1547.2 Draft Application Guide for IEEE 1547 Draft Standard for Interconnecting Distributed Resources with Electric Power Systems; IEEE 1547.3, the Draft Guide for Monitoring, Information Exchange and Control of DR Interconnected with Electric Power Systems; and IEEE 1547.4, Draft Guide for Design, Operation and Integration of Distributed Resource Island Systems with Electric Power Systems.

The U.S. actively participated in the International Electrotechnical Commission activities for PV-related standards.

PowerMark Corporation continued as a non-profit certification body for the U.S. PV industry. PowerMark recognized the Arizona State University PV Testing Laboratory (PTL) and approved it for performing module certification tests based on the accreditation certificate they received from the American Association of Laboratory Accreditation. The PTL regularly performs tests on all types of PV modules according to IEEE 1262, IEC 1215, and PV-3 for crystalline silicon and IEEE 1262, IEC 1646, and PV-3) for amorphous silicon. Testing also includes UL 1703 requirements for PV module safety. Most of the modules qualified meet reciprocity requirements with

European standards. The Arizona PTL tests are accepted throughout the world through reciprocity agreements for international applications.

4.4 Certification of Installers and Hardware

Both hardware and practitioner certification programs are being developed in the United States. A certification program for PV inverters was initiated by Sandia National Laboratories to better characterize the operation of inverters and to certify the performance relative to power throughput. A draft of the testing protocol was supplied to the California Energy Commission in 2004 to be considered for inclusion in California's new Emerging Renewables incentive program.

The national voluntary practitioner certification program is being spear led by the North American Board of Certified Energy Practitioners (NABCEP). NABCEP board members are volunteers representing PV and solar thermal manufacturers and installers, federal, state and local government, policymakers, labor, contractors, and training organizations. Much of the technical input to develop the task analysis, applicant study guide, tests, and general requirements evolved from component and system monitoring and evaluation tasks within the U.S. DOE National Solar Program. Sandia National Laboratories, along with its strategic team members and partners that include the National Renewable Energy Laboratory, the Solar Energy Industries Association (SEIA), the Florida Solar Energy Center (FSEC), the Southwest Technology Development Institute (SWTDI), the Institute for Sustainable Power (ISP), and the Interstate Renewable Energy Council (IREC) spurred practitioner certification efforts by focusing on the initial goal of establishing a voluntary practitioner certification program that could be adopted by all states for installers of PV systems.

Tests are conducted two times per year for the certification program. Certificants were added to the roles in 2004 with over 150 total certified installers. Several states already have or plan to develop state-level licensure for solar installers. The "National Voluntary Practitioner Certification Program" began in 2003.

5. FUTURE TRENDS

It is anticipated that the U.S. PV production will continue to expand at least 20% per year, both in applications and total production.

Plant Expansion: **Most plant expansion will be dedicated to; 1) production at the ECD- United Solar 30-MW amorphous silicon plant (2003/2004); 2) full operation of the Shell Solar CIS plant 3) operation of the First Solar 20-MW cadmium-telluride plant; a 25-MW expansion of the BP SOLAR cast ingot poly-silicon plant and 4) completion of the Evergreen 10-MW string-ribbon plant. United Solar announced a new 30-MW amorphous silicon plant to be commissioned in 2006.**

The Market: **The U.S. PV market will experience major sales increases primarily due to the state subsidies. California, New Jersey, Illinois, Arizona, and New York and others have or are initiating incentive programs to help meet requirements for the use of renewable energy being included in legislated goals. Major changes in the U.S. market (growth greater than 30% per year) are expected once profitable factory prices of \$2.00/W_{ac} or less for PV modules and installed costs of \$4.00/W_{ac} are offered.**

Technology: **The production of thin films (copper indium diselenide, and cadmium telluride) from new facilities in the United States will provide a market test for new,**

lower manufacturing cost, module options. Experience with thin-film performance, stability and reduced costs will compete with the dominant sliced single- and poly-crystalline silicon product, and the creation of new markets for flexible light-weight, thin-film products will assure further market growth and penetration.

Continued progress in the cast-ingot poly-silicon technology with increased cell efficiency (in production), volume production (with its reduced material costs), and automation (with its reduced labor costs) will maintain a robust market for the workhorse of the market and build a base for even future expansion.

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ANNEX A: METHOD AND ACCURACY OF DATA

The data in this report are primarily the result of the annual survey of PV industry shipments performed by PV Energy Systems, Inc., and published in *PV NEWS*. All U.S. PV manufacturers formally responded to the survey. The U.S. results are crosschecked with the U.S. DOE Energy Information Reports. The 2004 data could not be crosschecked because the EIA report has not yet been issued. There is some uncertainty in the base data in that details on inventories are not tracked. These data are believed to be accurate to ±10%. The installation data for the United States is a result of an extensive phone survey by the author with key manufacturers, distributors, and systems integrators. The accuracy of the U.S. installation data is estimated to be in the ±10 % range. The currency used in this report is U.S. Dollars ($).