THE 2002 NATIONAL SURVEY REPORT OF PHOTOVOLTAIC POWER APPLICATIONS IN THE UNITED STATES*

For
The International Energy Agency
Co-Operative Program on Photovoltaic Power Systems
Task I - Exchange and Dissemination of Information on Photovoltaic Power Systems

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Table of Contents

i. Forward

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD), which carries out a comprehensive program of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Program (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The twenty participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), the United Kingdom (GBR) and the United States of America (USA). The European Commission is also a member.

An "Executive Committee" leads the program. It is composed of one representative from each participating country, while the management of individual Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org.

ii. Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Program is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual International Survey Report on photovoltaic power applications. This report gives information on trends in photovoltaic power applications in the twenty member countries and is based on the information provided in the National Survey Reports, which are produced annually by each Task 1 participant. The public PVPS website also plays an important role in disseminating information arising from the program, including national information.

iii. Definitions

For the purposes of this National Survey Report, the following definitions apply:

Photovoltaic (PV) Power System Market: The market for all nationally installed (terrestrial) photovoltaic applications with a photovoltaic power capacity of 40 W_p or more.

Installed Photovoltaic (PV) Power: Power delivered by a photovoltaic module or a photovoltaic array under standard test conditions (STC) – irradiance of 1000 W/m^2, cell junction temperature of 25^{o}C, AM 1.5 solar spectrum – (also see 'Peak power').

Peak Power: Amount of power produced by a photovoltaic module or array under STC, written as W_p.

Photovoltaic (PV) System: Set of interconnected elements such as photovoltaic modules, inverters that convert dc current of the modules into ac current, storage batteries and all installation and control components with a photovoltaic power capacity of 40 W_p or more.

Module Manufacturer: An organization carrying out the encapsulation in the process of the production of photovoltaic modules.

Off-grid Domestic Photovoltaic (PV) Power System: System installed in households and villages that are not connected to the utility grid. Usually a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone photovoltaic power system'.

Off-grid Non-domestic Photovoltaic (PV) Power System: System used for a variety of applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'Stand-alone Photovoltaic (PV) Power System'.

Grid-connected Distributed Photovoltaic (PV) Power System: System installed on consumers' premises usually on the demand side of the electricity meter. This includes grid-connected domestic photovoltaic systems and other grid-connected photovoltaic systems on commercial buildings, motorway sound barriers, etc. These may be used for support of the utility distribution grid.

Grid-connected Centralized Photovoltaic (PV) Power System: Power production system performing the function of a centralized power station.

Turnkey Price: Price of an installed photovoltaic system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid photovoltaic system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the photovoltaic system, these should be excluded. (E.g. If extra costs are incurred fitting photovoltaic modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication system in a remote area are excluded).

Field Test Program: A program to test the performance of photovoltaic systems/components in real conditions.

Demonstration Program: A program to demonstrate the operation of photovoltaic systems and their application to potential users/owners.

Market Deployment Initiative: Initiatives to encourage the market deployment of photovoltaic through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, utilities etc.

1 EXECUTIVE SUMMARY

1.1 PHOTOVOLTAIC ACTIVITIES IN THE UNITED STATES

The United States photovoltaic program made progress on several fronts in 2002. The following is a summary of that progress as categorized by production, installations, development and commercialization of product.

1.1.1 Photovoltaic Production and Installations Increased in 2002

Cell and module shipments totaled 120.6 MW in 2002, which was a 20 % increase. The module shipments by manufacturers are shown in Figure E1. New photovoltaic installations in the United States that were rated at >40 W increased 53 % to 44.4 MW in 2002.

1.1.2 Progress in Thin-Film Commercialization Was Mixed

The United Solar Systems Corporation (USSC) 30-MW roll-to-roll amorphous silicon plant started pilot production in 2002, while its 5-MW plant stopped production. The BP Solar amorphous silicon factory in Virginia was closed with all production terminated in 2002. After an attempt to sell the plant, it was permanently dismantled. USSC and BP Solar (Solarex) produced nearly 11 MW of amorphous-silicon modules in 2002. Shell Solar (formerly Siemens Solar Industries) shipped nearly 1 MW of copper-indium-diselenide (CIS) photovoltaic modules. BP Solar closed its cadmium-telluride (CdTe) plant in California. AstroPower shipped over 1 MW of its thin-film silicon on low-cost substrate as its Silicon Film^{TM} product. First Solar delayed the opening of its new (CdTe) plant until 2003 or beyond.

1.1.3 Installation of Photovoltaic Systems in California More Than Doubled To 15.3 MW in 2003

The California photovoltaic “buy down” program resulted in installation of 6.0 MW of grid-connected residential systems and nearly 2 MW of commercial grid-connected photovoltaic systems. A list of newly installed systems in California in 2002 includes:

The Sacramento Municipal Utility District (SMUD) continued phase two of its PV Pioneer program by offering subsidized photovoltaic systems to its customers at prices below $3.50/W. SMUD installed about 1.4 MW of photovoltaic systems in 2002.

The Los Angeles Department of Water and Power (LADWP) PV program (with subsidies as high as $5.50/W) resulted in 2.3 MW of newly installed photovoltaic systems.

Pacific Gas & Electric installed 1.9 MW of new systems

Southern California Edison installed 0.9 MW of new systems

Other California municipalities installed over 0.7 MW in 2002.

FIGURE E1: US PHOTOVOLTIAC CELL/MODULE PRODUCTION

Company	1996	1997	1998	1999	2000	2001	2002
Shell Solar	17.00	22.00	20.00	22.20	28.00	39.0	46.5
BP Solar	10.80	14.80	15.90	18.00	20.47	25.22	31
Solec International	3.50	4.00	4.00	0.60	0.00	0.00	0.00
AstroPower	2.85	4.30	7.00	12.00	18.00	26.0	29.7
USSC	0.60	1.70	2.20	3.00	3.00	3.8	4.0
RWE Schott (ASE)	3.00	4.00	4.00	4.00	4.00	5.0	5.0
Evergreen Solar							1.9
Other*	1.10	0.20	0.60	1.00	1.50	1.3	2.5
Total	**38.85**	**51.00**	**53.70**	**60.80**	**74.97**	**100.32**	**120.6**

From PV News, Vol 22, No 3, Mar 2003.
* First Solar, Global Solar, SunPower, Amonix

1.2 PHOTOVOLTAIC PRODUCTION & INSTALLATIONS IN THE UNITED STATES

The photovoltaic module production in the United States reached 120.6 MW in 2002 (PV News, V 22, No. 3). Photovoltaic installations in the United States grew 53% to 44.4 MW for systems larger than 40 W. New photovoltaic applications in the United States in 2002 involved all market sectors except the large central power application. The growth rate exceeded 20% in 2002 and this was the third such year in the past 15 years. This growth was nearly all in the grid-connected sector and was enhanced by the State tax credits and the renewable energy set-asides by some utilities. The proposed (15%) federal tax credit was not approved by the United States Congress in 2002. Key State programs include the California "buy-down" program, the SMUD $3.00/W effective buy-down (to allow <$3.50/W costs to the consumer), the Los Angeles Department of Water & Power renewable energy program, and several other significant state subsidies, including those in Illinois, New York, Arizona, and North Carolina. Note that many of the smaller state subsidy programs are not listed in this report

1.3 COSTS AND PRICES IN THE UNITED STATES

The average photovoltaic module manufacturing costs measured in dollars/W decreased in 2002 as shown in Figure E2. The decreases were the result of improvements in automation, increases in yields, and efficiency gains. Details typically are not available from the manufacturers due to the proprietary nature of the information. The module prices from the manufacturer remained flat or slightly decreased owing to high demand, especially for exports to Europe and Japan. Installed systems prices remained nearly constant, despite the higher volume of installations in the United States.

Figure E2: Estimated Module Prices (United States $, FOB Factory, Single and Multi-crystalline Silicon*

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PRICE	4.25	4.25	4.00	3.75	4.00	4.15	4.00	3.50	3.75	3.50	3.25

*Estimated by PV Energy Systems

1.4 BUDGETS FOR PHOTOVOLTAICS IN THE UNITED STATES

The Federal Budget for the photovoltaic program remained essentially flat when inflation is factored in and was at approximately $73 M. Figure E3 below shows the DOE budgets for photovoltaics for fiscal years 2001, 2002, and 2003.

Figure E3: DOE Federal Funding Schedule for Photovoltaics ($M)

PROGRAM ELEMENT	FY 2001	FY 2002	FY 2003
Fundamental Research	17.560	21.700	30.400
Advanced Materials & Devices	37.000	26.900	29.793
Technology Development	19.700	17.555	13.500
Southwest Resource Opportunity	0	0,489	0
Navajo Electrification Project	0	2.313	3.0
TOTAL FUNDING	74.260	71.551	73.693

2 THE IMPLEMENTATION OF PHOTOVOLTAIC SYSTEMS IN THE UNITED STATES

2.1 Applications for Photovoltaics in the United States

The United States photovoltaic applications over 40 W grew 53% from 29 MW in 2001 to 44.4 MW in 2002. The United States applications for photovoltaics cover virtually all applications. Figure 1 shows a summary of the development of the applications sectors. The grid-connected applications started its high growth rate with the State and United States Government subsidized applications.

The Off-grid Consumer Sector: This sector includes applications in mostly remote habitat. They include photovoltaics 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. Over 8.4 MW was installed in the off-grid consumer sector in the United States in 2002.

The Off-grid Commercial/Industrial Sector: This sector is the second largest sector of the United States photovoltaic market (13.0 MW in 2002). Telecommunication applications encompasses 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 photovoltaic power systems also serve as sensor power sources and data communication power for a broad range of applications, including; weather, storm warning, seismic, radiation monitors, pollution monitors, security phones on highways and parking lots, and traffic monitors. Remote lighting and signals are proliferating with applications ranging from 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: Photovoltaics serves a broad array of applications in this sector and many applications are considered “emerging markets”. These include photovoltaic/diesel hybrid power stations that can ultimately serve remote sites or be transportable power for emergency power. The Department of Defense funds the installation of about 0.5 MW per year that has resulted in installed photovoltaic systems totaling over 3 MW. These photovoltaic systems resided in applications ranging from remote sensors, to large off-grid photovoltaic-diesel hybrid systems where utility power is not available or reliable.

The Utility Photovoltaic Group (UPVG) program has also directed thousands of utility installations amounting to over 9 MW in five years. Several thousand applications have been installed that are “nearly economic” applications. The United States Department of Energy has subsidized these early applications with an average of 25% of federal funds. No UPVG systems were installed in 2002. Another important government program is “Photovoltaics 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 2002 this sector nearly doubled, compared to the 2001 installations, to 22 MW of new installations. Photovoltaic 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 15 MW of grid- connected systems.

California photovoltaic installations more than doubled to 15.3 MW in 2002. The most significant programs in California were:

- The California PV "buy down" program resulted in the installation of 6.0 MW of grid-connected residential systems and nearly 2 MW of commercial grid-connected photovoltaic systems.
- The Sacramento Municipal Utility District (SMUD) continued phase two of its PV Pioneer program by offering subsidized photovoltaic systems to its customers at prices below $3.50/W. SMUD installed about 1.4 MW of photovoltaic systems in 2002. Most of the systems were installed on commercial and institutional buildings.
- The Los Angeles Department of Water and Power PV program with subsidies as high as $5.50/W resulted in 2.3 MW of photovoltaic systems being installed in 2002 in the Los Angeles district.
- Pacific Gas & Electric funded installations amounting to 1.9 MW
- Southern California Edison installed 0.9 MW. 0.7 MW.

Other important programs and in the United States included but were not limited to:

- The United States PV for Schools program installed photovoltaic systems on schools with a goal of increasing awareness of photovoltaic applications among youngsters.
- The State programs for renewable energy set-asides resulting from restructuring.

Other forms of marketing incentives included:

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

Table 1: Photovoltaic Applications by Market Sector in The United States

APPLICATION	1994	1995	1996	1997	1998	1999	2000	2001	2002
Grid-connected Distributed	1.2	1.5	2.0	2.0	2.2	3.7	5.5	12.0	22.0
Off-grid Consumer	3.0	3.5	4.0	4.2	4.5	5.5	6.0	7.0	8.4
Government Projects	0.6	0.8	1.2	1.5	1.5	2.5	2.5	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
Consumer (<40 W)*	1.7	2.0	2.2	2.2	2.4	2.4	2.5	3.0	4.0
Central Station	—	—	—	—	—	—	—	—	—
Total Installed in USA	9.4	10.8	13.8	14.7	15.8	21.0	24.0	32.0	48.4
IMPORTS						2.0	4.0	5.0	9.0
EXPORTS	16.2	24.0	25.1	36.3	37.9	39.8	55.0	73.3	81.2
TOTAL PRODUCED	**25.6**	**34.8**	**38.9**	**51.0**	**53.7**	**60.8**	**75.00**	**100.3**	**120.6**

2.2 Total Photovoltaic Power Installed In The United States

Total United States installations of photovoltaic systems in 2002 with peak power greater than 40 W amounted to about 44 MW. Table 1 shows the cumulative installations by the "Off-grid" and "On-grid" market sectors.

2.3 Major Projects, Demonstration and Field-Test Programs

The major photovoltaic projects in the United States consisted of new initiatives and the continuation of the projects started in the 1995-1999 time frames. These included:

1) The continuation year of Pioneer II, where SMUD offers photovoltaic systems for sale to customers at subsidized prices (as low as $3.50/W installed), The Pioneer II program calls for 5 MW of photovoltaics to be installed in 1999-2004. SMUD installed 1.6 MW in 2001 and 1.4 MW in 2002.
2) 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 photovoltaic systems on investor-owned utility grids (1.4-1.6 MW in 2001, 8.1 MW in 2002
3) State Photovoltaic Assistance Programs:

   Although detailed figures are not available for most State programs, several states have renewable energy set-asides. These are funds for research leading to new photovoltaic industry within the state, assistance for photovoltaic school programs, and "Green Pricing" programs. Two major programs include:

   Arizona: Over 50 MW of photovoltaic systems has been installed during the last ten years. Over 3 MW of photovoltaic Systems have been installed in 2002 and continuing into the first part of 2003.

   California: Over $200 M supported grid-connected renewable energy electricity generation systems. Brown outs, near-bankruptcy of large investor-owned utilities, threats of increased prices started a major increase in photovoltaic uninterruptible (UPS systems). Sacramento Municipal Utility District (SMUD), and Los Angeles Department of Water and Power, along with other municipal utilities have photovoltaic support programs totaling $100 M over 5 years. San Francisco, after passing a bond referendum, is in the early stages of a ten-year, 50 MW photovoltaic program. Its first project is to install a photovoltaic system on its Mosconie Convention Center.

2.3.1 *The SMUD Solar Pioneer Program*

The Sacramento Municipal Utility District (SMUD) completed the PV Pioneer I (PVP I) program where over 400 homes were equipped with SMUD-owned and maintained photovoltaic systems. The PV Pioneer II (PVP II) program offers the sale of subsidized grid-connected photovoltaic systems to customers. Over 5 MW of systems are planned for the next seven years. SMUD has achieved several critical milestones and continued progress in its aggressive program of sustained, orderly development and commercialization of photovoltaic technologies. Key 2002 milestones include:

- In 2002, SMUD installed 1.4 MW of photovoltaic systems in the SMUD district. As of the end of 2002, SMUD has installed over 12 MW of

photovoltaic systems in some 1500 installations. Reported costs of fully installed systems dropped below $4.50/W.

- Under SMUD's Solar Advantage Homes program, production homebuilders offer commercially built homes with photovoltaic systems as a standard feature. The systems are now available in 15 Sacramento new home communities. More than 50 homes were completed in 2002.
- Rancho Seco, the world's largest, single site, photovoltaic power plant is now at 3.9 MW.

2.3.2 The California Photovoltaic Subsidy Program

The California Emerging Renewables Buy down Program was started in April of 1998. The program involves cash rebates for the installation of new renewable energy generation, including photovoltaics, small wind, and fuel cells fueled with renewable sources. It stimulated over 8 MW of photovoltaic system installations in 2002. The photovoltaic systems received a $3.50-4.50/W cash subsidy (up to 50% of the total cost). The California Energy Commission (CEC) has also simplified the rules and tariffs for net metering, and reduced the paperwork (now only four pages) for interconnection requirements for grid-connected photovoltaic systems. Net metering interconnections have become more routine and commonplace in California. A key issue in this program is the limited funds allocated. The first $30 M of photovoltaic funds was over subscribed in four months. The program was expanded to $50 M and all money was spoken for by mid-year.

2.3.3 Other Programs

Other states offered a variety of subsidy programs. Some of the key programs were:

Illinois: Led by the strong "Brightfields" program in Chicago (where abandoned factories (Brownfields) are converted to photovoltaic manufacturing plants (owned and operated by Spire Corporation) or installed photovoltaic systems. The state of Illinois passed the largest subsidy in the United States for photovoltaic systems, $6.00/$W_p$. Over 1 MW of photovoltaic systems was installed in Illinois in 2002.

Ohio: A primary objective in Ohio is support for 50 schools to have photovoltaic systems/training modules installed on public schools.

New York: New York has legislated over $50 M to support new industry, new installations, and studies to accelerate commercialization of photovoltaics. Recently (May 2002) New York increased the photovoltaic subsidy to $5.00/W for grid-connected systems.

Virginia: Virginia offered a $0.75/W cash rebate for installed photovoltaic modules produced in the state. This program is capped at $6 M per year.

North Carolina: North Carolina offered a 35% tax credit for photovoltaic system installations.

Table 2. Summary of New Initiatives Major Projects, Political Environment, Utility Regulation, Tax Incentives, and New Product Strategies

Project Date Plant Start Up	Technical Data/ Economic Data	Objectives	Main Accomplishments Until the End of 2002- Problems and Lessons Learned	Funding	Project Manage-ment	Remarks
Sacramento Municipal Utility District PV Pioneer II (1998-2005) **Residential, Commercial Systems**	Pioneer II: (1-3 kW) PV grid-connected, roof mounted. A $3/W effective subsidy to allow less than $3.50/W cost to the customer.	Provide customers with grid-connected PV systems. Evaluate the performance of the components and the systems. Test the impact of ten years of volume purchase on the installed cost to lead to fully economic PV for homes. Up to 5 MW in 5 years will be installed under Pioneer II.	New models of inverters are much better. A $2.40/W subsidized system price has led to applicants exceeding program plans. Installed nearly 1.4 MW in residences and commercial, municipal buildings in 2002.	SMUD Utility Company @ 100%	SMUD	Minimal monitoring. Issued long term contracts for modules and inverters that reduce installed costs from $6.00/W in 1998 to less than $4.00/W in 2002. SMUD has assisted several other utilities in system designs, procurement, etc.

Table 2. Summary of New Initiatives Major Projects, Political Environment, Utility Regulation, Tax Incentives, and New Product Strategies (Continued)

Project Date Plant Start Up	Technical Data/ Economic Data	Objectives	Main Accomplishments Until the End of 2002- Problems and Lessons Learned	Funding	Project Manage-ment	Remarks
California "Buy-down" Program	Residential: Grid-connected. 1-3 kW size. $4.50/W subsidy. 8 MW in 2002. Over $50 M in 2002. Commercial Grid-connected. 10-100 kW	To expand renewable energy use as a result of utility restructuring.	Codes, permitting, application process streamlined. Improved industry infrastructure, including offers by new home builders have led to improved communication to consumers.	State of California	Mainly private utilities and the PV industry	After-subsidy prices (especially with storage) appeal to affluent "early adopters"

2.4 Highlights of R&D

The United States Department of Energy is the principle source of funding for photovoltaics research and development. The DOE photovoltaic budget summarizes the photovoltaic R&D program 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 are to:

A. Reduce the direct manufacturing cost of photovoltaic modules by 30 percent from the current average manufacturing cost of $ 2.50/W to $1.75/W;

B. Identify and begin prototype development of two new leapfrog technologies that have the potential for dramatic cost reduction

C. Establish greater than 20-year lifetime for photovoltaic systems by improving the reliability of balance-of-system components and reduce recurring costs by 40 percent

D. Work with the U.S. photovoltaic industry to facilitate achievement of its roadmap goals of 1-gigawatt cumulative U.S. sales (Export and Domestic) by 2006 and 30 gigawatts by 2020.

E. Installed price goals for a grid-connected photovoltaic 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 in 2002 to $4.50/$W_p$ in 2006 (equivalent to reducing the cost from $0.25/kWh to $0.18/kWh.

2.5 Budgets for Market Stimulation, Demonstration and R&D

Table 3 shows the budget of the United States for R&D, demonstration, and market incentives for photovoltaic systems at the national/federal level, and at the state and regional level. Total United States DOE budgets for the past few years are shown in Table 3a.

There was only one United States government tax support for photovoltaic systems in 2002. The support is allowed for the installation of commercial grid-connected photovoltaic systems as a 10% investment tax credit. The proposed 15% tax credit for photovoltaics (Million Solar Roofs Initiative) was not passed the Congress.

Table 3. Public Budgets for R&D, Demonstration and Market Incentives ($US)

UNITED STATES FY2003 ($US) October 2002-September 2003	R&D	Demo	Market	Total
National/federal	$35.0 M	--------	$29.6 M	$64.6 M
State/regional	NA	NA	$50-60 M/year estimated	$50-$60 M estimated
Total	**$35.0 M**	**0**	**$29.6 M +** **$50M for states**	**$64.6 M +** **$50 M for states**

Table 3.1 United States DOE Federal Funding Schedule for Photovoltaics

PROGRAM ELEMENT	FY 2001	FY 2002
Fundamental Research	$17.560 M	$21.700 M
Advanced Materials & Devices	$37.000 M	$26.900 M
Technology Development	$19.700 M	$17.555 M
Southwest Resource Opportunity	0	$0.489 M
Navajo Electrification Project	0	$2.313 M

3 INDUSTRY AND GROWTH

3.1 Production of Photovoltaic Cells and Modules

The production numbers for cells and modules in the United States for 2002 is provided in Table 4. There is a listing for each manufacturer under cells and modules to allow counting of each entity. The maximum capacity for each of the manufacturers is also reported in Table 4. There was a net export of cells from the United States in 2002 although some module manufacturers imported some cells to populate the modules.

Table 4. 2002 Production and Production Capacity Information for Each Photovoltaic Module Manufacturer in the United States.

Module Manufacturer	Cell Type	2002 Production (MWp)		2003 Max Capacity MWp)	
		Cells	Modules	Cells	Modules
Shell Solar (formerly Siemens Solar Industries)	Single-crystal silicon Copper-indium-diselenide	43.5 3.00	30.0 3.00	45.0 3.0	40.0 3.0
BP Solar (Solarex)	Multi-crystal silicon Amorphous-silicon	24.0 7.00	15.0 7.00	24 8-10	20 9.0
AstroPower	Single-crystal silicon Silicon-film	28.0 1.7	15.0 1.00	40 2+	20 2-
RWE Schott (ASE)	EFG Ribbon Silicon	5.0	5.0	10.0	10.0
USSC	Amorphous Silicon	4.0	4.0	30.0	30.0
Evergreen Solar	String Ribbon	1.9	0.4	4.0	4.0
Other producers		2.5	0.5	10.0	10.0
Total	All types	120.6	80.4	176	148.0
Thin-Film Manufacturers					
Shell Solar	Copper-Indium-Diselenide (CIS)	3.0	3.0	4.0	4.0
BP Solar / Solarex	Amorphous Silicon	7.0	7.0	0	0
BP Solar (CA)	Cadmium Telluride	0.3	0.3	0	0
USSC	Amorphous Silicon	4.0	4.0	30	30
Total Thin-Films		14.3	14.3	34	34

Module prices

Table 4a shows the factory module prices in the United States for a number of years. It is assumed that the customer (key distributor, systems integrator, or government user) makes an annual purchase order, or has a large project requiring over 50 kW of modules. The prices are derived from an annual survey of top distributors in the United States. The factory prices have been relatively stable since 1985-2000 and within a range of $3.75/W and $4.25/W. In the last four years the prices have generally decreased, primarily caused by the increased demand of Japan and Germany. Factory prices ranged from $2.75 – 3.50/$W_p$ (dc) in 2002.

Table 4a: Typical Module Prices (US$, FOB Factory, Single and Polycrystalline Silicon- Estimated by PV Energy Systems)

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PRICE	4.25	4.25	4.00	3.75	4.00	4.15	4.00	3.50	3.75	3.50	3.25

3.2 Manufacturers and Suppliers of Other Components

3.2.1 Shell Solar (Formerly Siemens Solar Industries):

Shell Solar photovoltaics production is fully integrated. Shell Solar purchases "solar grade" poly-silicon to be used in a melt from which single-crystal silicon ingots are pulled using the latest 6- to 8-inch diameter pullers. Shell Solar then slices the ingots into 300-micron 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 IEEE, ISPRA, and 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. In 2002 Shell Solar produced over 46.5 MW of cells and modules. 43.5 MW was single crystal silicon and 3 MW was copper-indium-diselenide thin-film modules.

Shell Solar has performed research, pilot production and testing on copper-indium-diselenide (CIS) solar modules for over fifteen years. CIS modules with efficiencies greater than 12% have been produced. The CIS product was produced in pilot quantities in 1998,1999 and 2000. Shell Solar shipped 3 MW of CIS modules in 2002.

3.2.2 BP Solar (Solarex in the United States):

BP/Solar (Solarex) is the world's third largest producer of cast-ingot multi-crystal silicon cells and modules (Kyocera of Japan is first and Sharp of Japan is second). BP Solar (Solarex) purchases "solar grade" poly-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 ID saws, into 300-micron slices. The slices are processed into solar cells and then integrated into glass/EVA/Cells/EVA/Tedlar modules. BP Solar offers power modules with power output of 33 - 300 W. A standard 25-year warranty is offered.

BP Solar (Solarex) has researched amorphous silicon for over fifteen years and has produced pilot quantities of 5- and 10-W modules (500 kW) for over ten years. Solarex built a 10-MW double-junction amorphous silicon plant in James City County, Virginia. The

completed plant underwent final pre-production trials in 1997. First product from the new plant was shipped in 1997. Seven MW of amorphous silicon power modules were produced in 2002. BP Solar terminated amorphous silicon production late in 2002. After attempts to find a buyer for the plant, it was permanently dismantled. BP Solar also closed the California CdTe pilot plant in 2002.

3.2.3 AstroPower:

AstroPower has developed its new thin-film silicon on low-cost substrate (SILICON FILM™). AstroPower also produces single-crystal cells and modules from purchased reject wafers from the semiconductor industry. AstroPower processes the wafers and produces solar cells using standard processing. Much of the AstroPower product is sold as cells, primarily for European building-integrated photovoltaic products. Standard power modules are also produced. All modules are UL listed, and certified by ISPRA or the Arizona State University Photovoltaic Testing Laboratory. The new SILICON FILM™ product has been in pilot production for several years. AstroPower shipped 29.7 MW of single crystal silicon cells and modules in 2002. No figures were released on its shipment of SILICON FILM™ product. It is estimated that less than 2 MW were shipped in 2002.

3.2.4 RWE/Schott (Formerly ASE Americas):

RWE Schott (formerly ASE GmbH), in Germany, purchased the assets and technology of Mobil Solar in 1993 and established ASE Americas. The edge-defined film growth (EFG) process was refined and new pullers were installed. RWE purchases poly-crystal silicon that is melted. Sheet silicon is pulled and is then cut into 15-cm x 15-cm slices. Cells and modules are then produced in a semi-automated plant. The RWE Schott crystal-silicon modules use a glass/proprietary dielectric/cells/dielectric/glass configuration. They sell slices, cells and modules. Large 200- to 300-W modules are standard sizes. 25-year warrantees are offered. In 1998-1999, ASE Americas completed a major expansion of its plant. In 2002, RWE Schott produced and shipped 8 MW of cells and 5 MW of modules. RWE Schott also produced 16 MW of slices, which were shipped to RWE Schott GmbH for its cell manufacturing facilities in Germany.

3.2.5 Solec International:

In 2000 Solec International terminated its cell and module production in order to produce nearly 5 million n-type slices for its owner Sanyo. The slices are used to produce Sanyo's new HIT, amorphous silicon on crystal silicon heterojunction cell. (Note Sumitomo and Sony are owners of Solec). Sanyo has obtained large area (>100 square centimeter) efficiencies of 21%, with production efficiencies reaching 17.5 % with the amorphous silicon on single-crystal silicon heterojunction 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 4.0 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 photovoltaic 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 new building-integrated products are listed by Underwriters Laboratories (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 they funded construction of a 25-MW amorphous production line in

Michigan. Production from the new plant commenced in late 2002. This 25-30 MW plant is the world's largest thin-film plant.

3.2.7 Evergreen Solar:

Evergreen has taken Dr. Sachs (MIT) string-ribbon process into production. Pilot production started late in 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 United States 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 ahead of schedule in June 2002. Evergreen produced 1.9 MW of ribbon modules in 2002.

3.2.8 Ebara Solar:

Ebara has taken the Westinghouse dendritic web process into pilot production. Initial production was started in 2001. In 2002, Ebara lost support of its Japanese benefactor. It is not clear what the future holds for Ebara Solar.

3.2.9 First Solar (formerly Solar Cells Inc):

First Solar continues pilot production of cadmium-telluride 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%. In late 1998, Solar Cells Inc. formed a joint venture called First Solar, LLC. 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 has been delayed until 2003.

3.2.10 Energy Photovoltaics (EPV):

Energy Photovoltaics (EPV) produces amorphous-silicon modules and has developed pilot production of copper-indium-diselenide cells. EPV installed an amorphous-silicon production facility at DUNASolar in Hungary and also installed an amorphous silicon line in Sacramento CA (CalSolar). DUNASolar provided nearly 2 MW of modules for the SMUD Pioneer II program. In 2001/2002 EPV announced new plant orders in China and Egypt, with a potential factory in Thailand.

3.2.11 Amonix:

Amonix has advanced the "point contact" cell into a production-model, 24%-efficient, concentrator cell at 250-350 times concentration. During 2002, 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 photovoltaics. Amonix increased production capacity to over 1 MW/year in the first half of 2002.

3.2.12 Entech:

Entech has shipped nearly 500 kW of line-focus, low-concentration (18-22 X) systems. Entech has worked in the field for nearly 20 years and has continuously improved the performance and reduced the cost of its concentrator modules. Entech purchases cells from the cell manufacturers. No shipments were reported in 2002. Entech was awarded a contract from the Department of Energy to develop a concentrator for the very high efficiency, III-V technology, 33% efficient cells for its space cell applications.

3.2.13 SunPower:

SunPower is producing arrays of very high efficiency, single-crystal silicon cells using processes developed by its president, Dr. Richard Swanson. Although SunPower can make excellent concentrator cells, they have not sold or installed concentrators using its cells. In 1997, Honda Motors made an equity investment in SunPower. This investment could lead to the production of concentrators based on Dr. Swanson's "point contact" cell. In 2002, SunPower shipped a few hundred kW of cells. Cyprus Semiconductor purchased a major equity in SunPower. It is believed that production of very high efficiency cells (> 20%) will commence in early 2003.

3.2.14 Balance-of-Systems:

Typically, the balance-of-systems components for a photovoltaic system cost as much, if not more than the retail price of the photovoltaic module. About one-half of the installed photovoltaic 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-volt 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.

The United States installs about 22 MW per year of grid-connected systems. Approximately 14 MW of small, 2- to 4-kW roof-mounted systems are now installed on private residences. The systems use all types of photovoltaic modules and are usually connected to an inverter that permits the photovoltaic system to first serve the building's load and then to send excess power to the utility grid. When the grid power is not available, the inverter may be designed to switch to "standby" and power the local load from energy stored in a battery bank.

Inverter Manufacturers

There are several inverter manufacturers serving the United States market. They all have other markets for inverters other than photovoltaics, and some export a large percentage of its product. In 2000, much of the photovoltaic inverter industry was consolidated under Xantrex in Canada. Xantrex acquired Trace Engineering, Heart Interface, and StatPower. Trace was the largest manufacturer of inverters for photovoltaics with over 30,000 inverters shipped in 2002. Other producers included Advanced Energy Systems Inc., Heliotrope General, and Vanner Weldon. In 2000 SMA (Germany) opened a sales office in the United States to sell its UL-listed grid-connected residential inverters. In 2001, SMA claimed to have sold 30% of the grid-interactive inverters in the United States market. The SMA market share for 2002 was reported to be greater than 75% for numbers of grid-interactive inverters. The dramatic increase in the market for grid-connected residential photovoltaic systems in 2002 greatly increased the sales of small inverters.

The prices of inverters for grid-connected applications are shown in Table 5. The lowest prices are the inverters supplied to Sacramento Municipal Utility District under its long-term contract with Trace (now Xantrex). Prices have not decreased much in the past few years.

Table 5. Price of Inverters for Grid-connected Applications

Size of Inverter	<1 kVA	1-10 kVA	10-100 kVA	>100 kVA
Average price ($) per kVA	$700-1200	$550-950	$550-750	$530-650

Battery Charge Controller Manufacturers
There are several excellent charge controller manufacturers in the United States. Key companies include Morningstar, Specialty Concepts Sun Selector, Connect Energy, RV Power Products, Xantrex, SunAmp, Heliotrope General, and Vanner Weldon. Over 250,000 charge controllers manufactured by United States suppliers were sold in 2002, and over 80% of those were exported.

3.3 System Prices

The system prices for installed photovoltaics are very difficult to quantify owing to the vast array of customer requirements, system reliability (for example in telecommunication and signal applications.), and the low volume of systems of various custom installations. Because of only slightly decreases in the cost of modules, and the increased cost of labor, installed system prices have remained nearly constant in 2002. The price for packaged systems installed on new homes has decreased to less than $7.00/W. The following will discuss the installed prices for representative systems in the IEA PVPS categories**:**

Off-grid 40-1000W: (Typical Prices $12 to $24/W installed). The range of prices in this off-grid market depends primarily on the storage required for the off-grid application and the climate in which it is installed. In the United States Sun Belt, with up to 2500 hours of peak sun, dc systems can be installed with 4 to 5 days of storage. In such a "bare bones" system with photovoltaic arrays purchased from a distributor, mounting hardware, charge controller and a lead-acid deep-cycle battery bank, a local installer can profitably install the system for $12 -$14/ $W_{p(dc)}$. In a moderate climate (1600 hours of peak sun) an ac system with ten days of storage, a stand-alone inverter, and ground-mounted hardware, can be installed for prices in the $14-18 range. High reliability systems in moderate climates with 20 days of storage, all weather remote mounts, battery enclosures, system controllers, etc., can cost as high as $24.00/$W_p$ AC. The stand-alone system can have installed costs from $12/$W_p$ dc to high-reliability telecommunication systems costing over $20/$W_p$ dc installed. Table 6 shows typical installed costs for stand-alone systems in the 1- to 20-kW size. These costs assume that the system installer purchases modules directly from the manufacturer and installs about 200 kW per year.

Off-grid >1000 W: Several large off-grid photovoltaic systems have been installed for the Department of Defense. Bids for these stand-alone ac systems, usually hybrid with diesel electric generators and 1 to 2 days of storage, ranged from $16.00 to $25.00/W ac installed. These systems, built with military use in mind, have advanced system controllers, built-in redundancy, and the highest quality available. Therefore, the cost was higher.

On-grid 40-10,000 W: The grid-connected systems are almost all less than 10 kW. Most systems are 1- to 5-kW roof-mounted systems for residences and commercial buildings. The largest volume-to-date are the 700, 3- to 4-kW residential systems

installed by Sacramento Municipal Utilities District (SMUD). According to SMUD, as a result of competitive bid, with factory-supplied modules, and volume purchases (for the first time ever) of inverters, the installed cost of these systems was in the $4.50-$5.00 range. According to SMUD suppliers, the module suppliers, and the systems installers made little profit, if any. Similar systems are being offered, with profit, outside the SMUD program for $6.00-8.00/W installed.

On-grid (>10 kWp): The larger grid-connected systems have moved from ground mounted to roof mounted, especially the roof-integrated systems installed by PowerLight. Several large roof-mounted systems greater than 500 kW were installed or started in 2002.

Table 6 Turnkey Prices of Typical Applications

CATEGORY/SIZE	Typical Applications Brief Details	Price per DC Watt ($)*
Off-grid (UP to 1 kW_p)	Stand-alone dc with 4-10 days storage.	**$12-$25**
Off-grid (> 1 kW_p)	Stand-alone dc or ac with 4-10 days storage.	**$12-$20**
On-grid (Up to 10 kW_p)	Roof-mounted/inverter/No storage.	**$7-$10**
On-grid (> 10 kW_p)	Roof or ground-mounted/inverter/no storage.	**$6.50-$9.00**

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

System Prices Over Time:
The Table 6a shows a summary of installed systems prices for grid-connected photovoltaic systems with no storage as a function of time. As noted above factory prices for modules have been essentially flat for the period covered. The number of systems installed before 1998 was very small. This resulted in higher costs because each system was custom designed, had to work with local codes, utility intervention, and inexperienced labor. The largest number of installations in 2002 was in California, with SMUD installing systems in Pioneer I and by “buying down” the cost of systems in the Pioneer II program, the Los Angeles Department of Water and Power buy down and the State buy down program.

Table 6a: National Trends in System Prices for Grid-connected Residential Systems.

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PRICE $/W	12	12	12	11-12	10-12	10-12	10-11	9-11	8-10	7-9	6.50-9

Note: SMUD claims that "total installed costs for Pioneer II PV systems were below $4.00/Wp in 2001." (This is believed to be $2.00/W amorphous silicon modules from DUNASolar, $0.50/W inverters from Trace (Xantrex) and fixed price installation.)

Large Systems Cost Analysis

The Solar Electric Power Association performed a detailed analysis of the performance and cost of 70 kW and larger photovoltaic systems installed from 1996 to 2000 by the UPVG TEAM-UP project. (Large Systems Cost Report- 2001 Update, Prepared by the Solar Electric Power Association, Washington, DC, September 2001). The analysis covers 2.87 MW of 23 projects larger than 70 kW. The projects ranged in size from 70 kW to 437 kW. When projects were grouped by installation year (completion) the average total cost declined 35% from $10.93/$W_{(ac)}$ in 1996 to $7.16 in 2000. When grouped by TEAM-UP Round, (time of contract award) average total cost declined markedly from $9.86/$W_{(ac)}$ in Round One to $8.12/$W_{(ac)}$ in Round Two and $7.51/$W_{(ac)}$ in Round Three. This represents a decrease of 23.8% over the course of the program.

3.4 Labor Prices and Labor Breakdown in the Photovoltaic Industry

No analysis of the labor in the United States photovoltaic industry has been published. An estimate for the labor content of the 121 MW of Cells/modules produced in the United States and 44 MW of installed systems could lead to the following estimates of the labor content (No current studies, models, or estimates for the labor involved in the United States photovoltaic industry are available). The author made logical assumptions and calculations for this analysis. This model would indicate the full time equivalent labor content of the cell/module production (120.6 MW) and the installations (44 MW) in United States account for about 1100 labor positions with 705 in factory labor, 88 in installation labor, 127 in marketing, 86 in research/engineering and 94 in management.

Table 7. Analysis of the Photovoltaic Industry Labor Force and Costs in the United States

Category	(MW)	Total Value	Labor$/W	$ For Labor	Labor Dollars/Person	Number of Laborers
Cell/Module Production	120.6	$422 M	1.50	$180.9 M	35,000	517 Factory
Factory Marketing	120.6	$422 M	0.60	72.36 M	100,000	72 Marketing
Management	120.6	$422 M	0.30	36.1 M	150,000	24 Management
Research/Eng Industry	120.6	$422 M	60.00	72.36 M	130,000	56 Research
University/Lab Research/Eng.				40.0 M	130,000	31 Research
BOS Production	50	$150 M	0.50	75 M	40,000	188 Factory
BOS Marketing	50	$150 M	0.25	33 M	60,000	55 Marketing
BOS Management	50	$150 M	0.25	33 M	80,000	42 Management
Installation Labor	44	$440 M	1.00	44 M	50,000	88 Installers
Install Management	44	$440 M	0.50	22 M	80,000	28 Managers.
Total Labor						1100 Total Workers 705 Factory 87 Research/Eng. 127 Marketing 94 Management 88 Installers

4 FRAMEWORK FOR DEPLOYMENT (Non-technical Factors)

The United States photovoltaic industry continues to address the grid-connected power market through programs such as the Sacramento Utility PV Pioneer Program moving into customer purchase of photovoltaic home systems, the California subsidy for photovoltaic 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 United States grid-connected photovoltaic market.

4.1 New Initiatives in Photovoltaic Power Systems

There were no new initiatives started in 2002 in the United States. Initiatives that were in effect and continuing from previous years included:

The SMUD Solar Pioneer Program, Phase II

The Sacramento Municipal Utility District (SMUD) completed the PV Pioneer I (PVP I) program where over 400 homes were equipped with SMUD-owned and maintained photovoltaic systems. The PV Pioneer II (PVP II) program offers the sale of subsidized grid-connected photovoltaic systems to customers. Over 5 MW of systems are planned for the next seven years. SMUD has achieved several critical milestones and continued progress in its aggressive program of sustained, orderly development and commercialization of photovoltaics. Key 2002 milestones include: 1.) in 2002, SMUD installed 1.4 MW of photovoltaic systems in the SMUD district. As of the end of 2002, SMUD has installed over 12 MW of photovoltaic systems in approximately 1500 installations. Costs of fully installed systems dropped below $4.50/W. 2.) Under SMUD's Solar Advantage Homes program, production homebuilders offer commercially built homes with photovoltaic systems as an offered feature. The systems are now available in 15 Sacramento new home communities. More than 50 such homes were completed in 2002. 3.) Rancho Seco, which is the world's largest, single site, photovoltaic power plant with 3.9 MW now installed.

Unlike the PVP I program where SMUD installed and owned photovoltaic systems on customer's roofs, the PVP II customers purchase and own their photovoltaic systems and qualify for net metering. The photovoltaic systems are sold to the customer at reduced prices that reflect the savings of SMUD's large volume purchases (modules and inverters) and the buy down provided though SMUD's Public Goods Funds (PGF).

The California Photovoltaic Subsidy Program

The California Emerging Renewables Buy down Program was started in April of 1998. The program involves cash rebates for the installation of new renewable energy generation, including photovoltaics, small wind, and renewably fueled fuel cells. The 2002 photovoltaic installations totaled over 8.0 MW. The photovoltaic systems received a $4.50/W cash subsidy (up to 50% of the total cost). Two-thirds of the systems were small, less than 5-kW, grid-connected systems, mainly for residences. One-third of the systems, mostly commercial, were over 10 kW in size. The CEC has also simplified the rules and tariffs for net metering, and reduced the paperwork (four pages) for interconnection requirements for

grid-connected photovoltaic systems. Net metering interconnections have become more routine and commonplace in California.

Other State Initiatives

Illinois: Led by the strong "Brightfields" program in Chicago (where abandoned factories (Brownfields) are converted to photovoltaic manufacturing plants (owned and operated by Spire Corporation) or installed photovoltaic systems. The state of Illinois passed the largest subsidy in the United States for photovoltaic systems, $\$6.00/W_p$. Over 1 MW of photovoltaic was installed in Illinois in 2002.

Ohio: A primary objective in Ohio is support for 50 schools to have photovoltaic systems/training modules installed on public schools.

New York: New York has legislated over $50 M to support new industry, new installations, and studies to accelerate commercialization of photovoltaic systems. New York increased the photovoltaic subsidy to $5.00/W in May 2002 for grid-connected systems.

Virginia: Virginia offers a $0.75/W cash rebate for installed photovoltaic modules produced in the state. This program is capped at $6 M per year.

North Carolina: North Carolina offers a 35% tax credit for photovoltaic system installations.

4.2 Indirect Policy Issues

The United States has completed virtually no indirect policy initiatives that affect the deployment of photovoltaics. The international policies that affect the use of photovoltaic 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 photovoltaic 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 United State's photovoltaics.

The United States has not introduced environmental regulations that have affected the deployment of photovoltaics. Neither the global warming treaty (Kyoto Accord) nor any part of the treaty has been approved by the United States Congress. Some analysts have reported that photovoltaic credits would be less than one cent per kilowatt-hour if there were serious efforts to credit photovoltaics 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 time frame, 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 United States photovoltaic 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 photovoltaics. These include “Green pricing”, set-asides for photovoltaics, 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 photovoltaics 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, United States DOE has funded project DSIRE (Database of State Renewable Energy) at the North Carolina Solar Energy Center. The DSIRE project is 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 photovoltaics 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 photovoltaics.

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 interconnect, it must pay for excess electricity at “avoided cost”. This law, approved by the United States Supreme Court established a large and growing independent power industry.

All generation options were allowed. Wind energy and photovoltaics benefited some from the law. However photovoltaics, 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 photovoltaics and other renewable energy sources.

4.2.2 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 photovoltaic 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 2002, 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.

The recent electricity supply and price problems in California did not add momentum to the deregulation progress. The California experience has caused delays in other state deregulation processes but will undoubtedly provide insight for other states as they address deregulation.

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4.3 Standards and Codes

The electrical 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 important activities among the photovoltaic industry. The U.S. DOE National Photovoltaic program funds and supports a large portion of this work. The work has provided a consensus of utility- and industry-input into the National Electrical Code® (NEC®), new and revised listing and certification standards, interconnect standards, and standards activities in the international arena.

An industry forum recently submitted 23 proposed changes in Article 690 – Solar Photovoltaic Systems, for the 2005 edition of the NEC. Additional proposals came from other sources through a public input process. For details on the proposed changes contact Ward Bower at Sandia National Laboratories. (E-mail wibower@sandia.gov.)

The Institute of Electrical and Electronic Engineers (IEEE Std.1374) “Guide for Terrestrial Photovoltaic Power System Safety” was completed and published in 1998 and is being updated. The updates are to make this standard conform to the 2002 NEC. The IEEE Standards Coordinating Committee (SCC21) obtained that was responsible for the IEEE Std 929-20000 utility interconnect guideline for photovoltaic systems is continuing progress on a new interconnect standard, to be labeled IEEE Std 1747, to address 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. The United States actively participated in the International Electrotechnical Commission activities for photovoltaic-related standards. Underwriters Laboratories finalized the UL1741 "Standard for Static Inverters and Charge Controllers for Use In Photovoltaic Power Systems", but is now considering including inverters and charge controllers for all distributed generation to match the requirements of the IEEE 1747 standard. The first UL1741 was published in May 1999 and was last amended in 2001. Coordination with both the NEC and the IEEE interconnect guidelines will remain a valuable activity for finalizing the new UL1741 standard.

PowerMark Corporation continued as a non-profit certification body for the U.S. photovoltaic 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 photovoltaic modules according to IEEE 1262, IEC 1215, and PV-3 for crystalline silicon and IEEE 1262, IEC 1646, and PV-3) for amorphous silicon. Some testing also includes UL 1703 requirements. Most of the modules qualified meet reciprocity requirements with European standards. The Arizona PTL tests are accepted throughout the world for international purchases.

4.4 Certification of Installers and Hardware

Both hardware and practitioner certification programs are being developed in the United States. A certification program for photovoltaic inverters has been initiated by Sandia National Laboratories to better characterize the operation of inverters and to certify the performance relative to power throughput. The framework for a single national voluntary certification program for photovoltaic installers is also being developed. In addition, several states already have or plan to develop state-level mandatory licensure for solar installers. A "National Voluntary Practitioner Certification Program" is scheduled to begin in 2003.

The national voluntary practitioner certification program is being spear headed by the North American Board of Certified Energy Practitioners (NABCEP). NABCEP board members are volunteers representing photovoltaic 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 United States 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 photovoltaic systems.

5 FUTURE TRENDS

It is anticipated that the United States photovoltaic production will continue to expand at least 20 percent per year, both in applications and total production.

Plant Expansion: Most plant expansion will be dedicated to; 1) production at the Bekaert/ECD United Solar 25-MW amorphous silicon plant (2002/2003); 2) completion of the AstroPower Silicon-Film™ plant; 3) full operation of the Shell Solar CIS plant 4) operation of the First Solar 100-MW cadmium-telluride plant; and 5) completion of the Evergreen 10-MW string-ribbon plant. No new PV-cell or module manufacturing plants were announced in 2002 in the United States.

The Market: The United States photovoltaic market will likely experience some sales increases primarily due to the fall out from the California energy crisis. Major changes in the United States market (growth greater than 20% per year) are expected once profitable factory prices of $2.00/W or less for photovoltaic modules are offered. The SMUD Pioneer II project and the California PV subsidy market will continue to be indicators of public interest in reduced-cost photovoltaic grid-connected systems. Systems with energy storage and an inverter to provide a key-load uninterruptible power supply will continue to be a popular installation option.

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 polysilicon 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 photovoltaic industry shipments performed by PV Energy Systems, Inc., and published in *PV NEWS.* All United States photovoltaic manufacturers formally responded to the survey. The United States results are crosschecked with the United States DOE Energy Information Reports. The 2002 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 $\pm$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 United States installation data is estimated to be in the $\pm$10 % range. The currency used in this report is United States Dollars ($).