International Energy Agency

COOPERATIVE 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 2007

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i Foreword

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

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative research and development (R&D) agreements established within the IEA. Since 1993, its participants have conducted a variety of joint projects in the applications of photovoltaic (PV) conversion of solar energy into electricity.

The 21 participating countries are Australia, Austria, Canada, Denmark, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, The United Kingdom, and The United States of America. The European Commission and the European Photovoltaic Industry Association are also members.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (tasks) is the responsibility of Operating Agents. Eleven tasks have been established and seven are currently active. Information about these tasks can be found on the public Web site www.iea-pvps.org.

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental, and social aspects of photovoltaic power systems.

ii Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme (PVPS) 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 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 Web site also plays an important role in disseminating information arising from the programme, including national information.

1 Executive summary

The United States' National Survey Report (NSR) summarizes some of the key indicators of the national photovoltaic (PV) industry's progress. These indicators include manufacturing and installation data, policy developments, and national progress in research and development (R&D). However, the US NSR does not cover the global progress being made in the PV industry. The International Energy Agency (IEA) Photovoltaic Power Systems Programme (PVPS) *Trends in Photovoltaic Applications* provides an overview of applications and markets for PV power systems in the reporting countries at the end of 2007 and analyzes trends in implementing PV power systems. Please visit www.iea-pvps.org to obtain an electronic copy of the report.

In 2007, the United States' PV industry witnessed significant progress on the following fronts:

- Expanded R&D efforts among the US Department of Energy (DOE) Solar Energy Technologies Program (Solar Program), industry, and university partners through the Solar America Initiative (SAI) for fundamental research and development of next-generation, low-cost PV products.
- Expanded efforts by SAI to transform the US PV marketplace by working with federal, state, and city governments to increase public awareness through education and training, provide technical assistance for large-scale PV projects, streamline utility interconnection agreements for solar energy systems, and update codes and standards.
- Increased interest in educational efforts by nongovernmental organizations (NGOs) and for-profit organizations to support the market acceptance of solar technologies.
- Substantial investment in solar energy technologies as part of the clean technology investment movement.
- Expansion of US manufacturing capacity by many PV manufacturers to meet the ongoing global demand for PV.
- Growing political interest in alternative energy sources, such as PV, as a way to hedge against volatile fuel prices, protect the environment, and diversify energy sources.

A summary of 2007 progress follows.

Cell and Module Production
Silicon shortages continued to plague the industry in 2007. Thin-film producers took advantage of the higher silicon prices and ramped up production. As a result, thin-film production accounted for about 11 % of worldwide PV production and more than 30 % of US production during 2007. US PV cell and module production increased by 74 %, with total US PV module shipments reaching 266 megawatts (MW) in 2007.

PV module shipments by large US PV companies in 2007 were:

- First Solar: 120 MW
- Uni-Solar Ovonics: 48 MW
- Solar World (Shell): 35 MW
- Evergreen Solar: 16,4 MW

PV Installations
Total cumulative US PV installations grew by 45 % in 2007. California accounted for 70 % of all PV installations in the United States. PV installations in the United States increased 42 % from 144 MW (not counting systems sized less than 40 W) in 2006 to 205 MW (DC STC rating) in 2007. Most of the growth occurred in the grid-connected sector—from 106 MW (DC STC rating) in 2006 to over 148 MW in 2007. Off-grid installations accounted for about 40 MW. Despite the increase in installations in California, the United States fell behind Spain to become the fourth-largest global market for PV.

Costs and Prices
The installed cost of grid-connected PV systems remained nearly constant as the cash subsidies, especially in California, decreased from 4,50 USD/W_{AC} installed in 2000 to 2 USD/W_{ac} in 2007. The installed prices remained relatively constant at 7 USD–8 USD/W_{ac} despite increased module prices. Some high-volume customers, primarily builders, were sold systems at low prices of 6,50 USD/W_{ac}. Reductions in installed costs to compensate for higher module costs were made possible by volume discounts, reduced labor costs owing to increased volume of installations and module efficiency increases, and reduced profits.

Table ES-1: Typical Single- and Multi-Crystalline Silicon Module Prices USD/W_{ac})

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Price*	4,00	3,75	4,00	4,15	4,00	3,50	3,75	3,50	3,25	3,00	3,50	3,60	3,75	3,75

*Estimated by PV Energy Systems

Budgets for PV R&D and Installations
The DOE Solar Program provides the primary leadership for research in advanced material and devices, device performance and reliability, and deployment of PV. The federal budget for PV R&D was approximately 138,3 million USD (MUSD) for fiscal year (FY) 2007—a 78,3 MUSD increase over FY 2006 research funding. In 2007, state tax credits for PV systems totaled more than 300 MUSD. Unless the federal tax credit for PV purchases is extended in late 2008, it will expire on 31 December 2008. The following sections of the US NSR provide detailed information and data about the progress of the US PV industry, including cumulative installed power, manufacturing and technology data, R&D news, and policy advancements.

2 The implementation of PV systems

The PV power market is defined as the market of all nationally installed (terrestrial) PV applications with a PV 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 Applications for photovoltaics

PV applications are divided into two categories: on-grid and off-grid. On-grid applications feed environmentally friendly power into the US electrical grid. Off-grid applications provide power to remote areas, emergency backup power during power outages, and support for disaster relief efforts. US applications for PV include:

- Stand-alone devices such as solar calculators, parking meters, outdoor lighting, emergency telephones, and temporary traffic signs
- Transportation applications such as auxiliary power in space and for boats and cars
- Building-integrated PV incorporated into new domestic and industrial buildings as a principal or ancillary source of electrical power (typically, a PV array is incorporated into the roof or walls of a building, and roof tiles with integrated PV cells can now be purchased)
- Utility-scale PV power plants, the largest of which produces up to 154 MW of electricity.

The sectors are described below.

Off-Grid Consumer Sector: This sector refers to PV systems that are not connected to a local utility grid and that use batteries to store energy for use during the evening hours. Stand-alone PV systems are often best in places where utility-generated power is unavailable, undesirable (for example, when utility-generated power requires emergency backup power), or too costly (the price of extending power lines costs more than a PV system). Stand-alone systems are also excellent for uses that don't require a lot of power. Off-grid PV applications include PV-powered homes in rural and remote areas, boats, motor homes, travel trailers, vacation cottages, and farms where connecting to the electricity grid is neither feasible nor practical. Most systems are rated at 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 include a diesel generator as backup. Off-grid consumer-sector installations amounted to more than 40 MW in the United States in 2007.

a)  b) 

a) This sailboat uses a 300 watt PV system for remote power. b) PV is often used for water pumping on farms and ranches in the United States.

Off-Grid Commercial / Industrial Sector: This is the second-largest sector of the US PV market. Telecommunications encompass a wide range of applications, from remote repeaters and amplifiers for all modes of communication, including fiber optics, satellite links, and cable links, as well as small data-link stations via telephone, television, 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 warnings; seismic, radiation, and pollution monitors; security phones on highways and in parking lots; and traffic monitors. Remote lighting and signals are ubiquitous, with applications ranging from bus stops, remote shelters, parking-lot lights, billboards, highway information / construction signs (replacing small-engine generators), intercoastal navigation aides, and supplemental lighting sources for environmentally friendly corporate headquarters.

a) Solar electricity used for irrigation control. b) Telecommunications station in Arizona.

Government Sector: PV is used in a variety of applications for city, state, and federal governments. These include large PV / diesel hybrid power stations where grid connections are impractical, as well as smaller systems for the types of applications mentioned above. Notable government PV application activities in 2007 included

- Installing a 14,2 MW PV-powered solar power plant on Nellis Air Force Base, Nevada, by the US Department of Defense
- Installing hundreds of PV systems throughout the country through the DOE Solar America Initiative (SAI), which provided funding and technical assistance to cities, states, and federal agencies for PV applications, including large-scale PV installations more than 100 kW (SAI inaugurated 13 US cities as Solar America Cities dedicated to accelerating the adoption of solar energy at the local government level)
- Reducing market barriers for solar energy technologies through nontechnical activities, including the establishment of the Solar America Board of Codes and Standards (www.solarabcs.org)
- Launching the Renewable Systems Interconnection study in spring 2007 to address the technical and analytical challenges related to high penetration levels of distributed renewable energy technologies on the nation's utility grids.

A 14,2 MW PV power plant at Nellis Air Force Base, Nevada.

On-Grid Distributed Sector:
Most of the PV installations in the United States in 2007 were in California (about 70 %). PV installation growth occurred primarily in both the on-grid residential and commercial sectors. The on-grid sector growth may be the result of the growing popularity of state tax credits and rebates, as well as the federal tax credit.

A 766-kW PV system on the roof of the Rodney Strong Vineyards building in California.

2.2 Total PV power installed

In 2007, the United States fell to the fourth-largest PV market in the world behind Germany, Japan, and Spain. In the United States, grid-tied PV increased 45 % to about 150 MW, largely due to large solar installations by retailers such as Wal-Mart, Best Buy, Safeway, Home Depot and Costco. Also, the largest utility-scale PV system (14,2 MW) was installed at Nellis Air Force base in Nevada and another 8 MW system was installed for Xcel Energy in Colorado.

Table 1: PV power installed in four submarkets during 2007

APPLICATION	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Grid-Connected Distributed	2,0	2,0	2,2	3,7	5,5	12,0	22,0	32,0	57,0	65,0	101,0	143,0
Off-Grid Consumer	4,0	4,2	4,5	5,5	6,0	7,0	8,4	9,0	10,0	12,0	14,0	16,0
Government Projects	1,2	1,5	1,5	2,5	2,5	1,0	1,0	1,0	1,0	1,0	2,0	2,0
Off-Grid Industrial / Commercial	4,4	4,8	5,2	6,5	7,5	9,0	13,0	16,0	18,0	21,0	23,0	35,0
Consumer (<40 W)	2,2	2,2	2,4	2,4	2,5	3,0	4,0	4,0	4,0	4,0	4,0	5,0
Central Station	—	—	—	—	—	—	—	5,0	4,0	5,0	5,0	8,5
TOTAL (Installed in USA)	**13,8**	**14,7**	**15,8**	**20,6**	**24,0**	**32,0**	**48,4**	**67,0**	**94,0**	**108,0**	**149,0**	**209,5**

Table 1a: 2007 US PV Power Production

TOTAL PRODUCED	**39,0**	**51,0**	**54**	**61**	**75**	**100**	**121**	**103**	**138**	**154**	**201,6**	**266,1**
IMPORTS				2,0	4,0	5,0	9,0	18,0	40,0	55,0	65,0	75,0
EXPORTS	25,1	36,3	37,9	39,8	55,0	73,3	81,2	54,0	88,0	100,0	117,6	131,6

Table 2: Cumulative installed PV power for each US submarket*

Submarket/ application	1995 MW	1996 MW	1997 MW	1998 MW	1999 MW	2000 MW	2001 MW	2002 MW	2003 MW	2004 MW	2005 MW	2006 MW	2007 MW
Off-Grid Domestic	19,3	23,3	27,5	32, 0	37,5	43,5	50,5	58,9	67,9	88,0	100,0	114,0	134,0
Off-Grid Non-Domestic	25,8	30,2	35,0	40,2	46,7	55,2	64,7	77,7	93,7	112,0	133,0	156,0	191,0
Grid-Connected Distributed	9,7	11,0	13,7	15,9	21,1	28,1	40,6	63,6	95,6	154,0	219,0	322,0	465,0
Grid-Connected Centralized	12,0	12,0	12,0	12,0	12,0	12,0	12,0	12,0	18,0	22,0	27,0	32,0	40,5
Total	**66,8**	**76,5**	**88,2**	**100,1**	**117,3**	**138,8**	**167,8**	**212,2**	**275,2**	**376,0**	**479,0**	**624,0**	**830,5**

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

KEY POLICY INITIATIVES

Federal Support of Photovoltaics

DOE launched the SAI in 2006 to accelerate manufacturing, cost, and commercialization goals for solar energy technologies. The initiative supports an increase in funding for PV, from about 82 MUSD in FY 2006 to 125 MUSD in FY 2007. A majority of the funding is directed at cost-shared research and commercialization efforts with external partners. 2007 was the first official year for SAI and represented a shift in Solar Program operations, budget, activities, and partnerships that will have a significant effect on the 9-year initiative.

SAI highlights for 2007 include:

- Launching the Technology Pathway Partnerships or TPPs, which are public-private partnerships with industry designed to create fully scalable PV systems that meet SAI cost goals. The TPPs are characterized by rigorous review and down-selection processes as well as ambitious timetables.
- Establishing PV incubator activities, which fund the development of PV system components to shorten their time line to commercialization.
- Initiating a groundbreaking market transformation effort to help commercialize solar energy technologies by eliminating market barriers and promoting deployment opportunities through outreach activities.
- Establishing the Process Development and Integration Laboratory at the National Renewable Energy Laboratory (NREL) for use by both laboratory and private industry researchers and designed to help standardize key aspects of PV research processes.

Federal tax credits for the purchase of PV went into effect in 2006 and include a 30 % investment tax credit for commercial grid-connected systems and a 30 % tax credit for residential grid-connected PV systems, with an annual cap of 2 000 USD per system.
In 2007, the federal tax credit and other investment tax credits were not included in the Energy Independence and Security Act signed in late 2007. The new energy bill also did not require utilities to produce 15 % of their electricity from renewable sources, although roughly half the states have enacted a renewable portfolio standard (RPS). The federal tax credit for installing both residential and commercial PV systems expires 31 December 2008. However, Congress could extend the tax credit in late 2008. Several bills introduced to Congress in 2008 include extensions and, in some cases, improvements to the tax credits: Feb. 27 House-passed bill H.R. 5351, April 10 Senate-passed H.R. 3221 with the Cantwell-Ensign amendment (S.A. 4419), and a Senate-proposed 2008 tax extenders bill reported out of the Senate Finance Committee on April 17.

Meanwhile, interest in utility-scale PV projects increased as states created more incentive programmes for PV installations. Top policy issues at the state level included interconnection agreements, renewable portfolio standards, and net metering.

State Support of Photovoltaics

RPS requiring utilities or electricity providers to supply a certain quantity of their delivered energy from renewable energy sources such as PV were adopted in 25 states and the District of Columbia. These requirements call for as much as 20 % to 30 % of electricity to come from renewable energy sources in the next 15 to 20 years.

In 2007, many states revised their renewable portfolio standards to include solar technologies. Five states established new renewable energy generation requirements, three adopted

voluntary programmes, and seven significantly increased (in many cases doubled) their commitment to renewable energy. Several states established ambitious PV goals, including California: 3 000 MW in 10 years; New Jersey: 2 300 MW by 2020; Maryland: 1 500 MW by 2022; and Massachusetts: 27 MW by 2011.

Currently, no national interconnection standard exists for connecting PV systems to the electrical grid. Only 36 states and the District of Columbia have interconnection policies to govern connection to the grid. In 2007, 42 states had net-metering rules allowing owners of solar energy systems to sell excess electricity back to the grid. However, the programme standards vary widely. To learn more about these varied and complex codes, laws, and incentives, visit www.dsireusa.org.

2.3 PV implementation highlights, major projects, demonstration and field test programmes

States with the highest solar PV installations in 2007 were California (87,1 MW); New Jersey (16,4 MW); Nevada (14,6); Colorado (12,4 MW); and New York (4,4 MW). With the exception of New York, these were also the states with the best net-metering policies. The number of states that are executing subsidy programmes for implementing clean energy technologies is growing annually. State funds are used as incentives (rebates) for the purchase of PV systems, as well as for renewable energy education and outreach, research, and establishing green pricing programmes. Utility green-pricing programmes are one segment of a larger green power marketing industry that counts Fortune 500 companies, government agencies and colleges and universities among its customers, and helps support more than 3 000 MW of new renewable electricity generation capacity. Utility green power programmes allow customers to choose to support additional electricity production from renewable resources such as solar and wind. More than 800 utilities in the United States offer these programmes. In 2007, the utilities with the highest green power sales as a percentage of total utility retail electricity sales were Austin Energy (Texas), Portland General Electric (state?), PacifiCorp (state?), Florida Power & Light, and Xcel Energy (state?). Ranked by customer participation rates, the top utilities in 2007 were City of Palo Alto Utilities (Calif.), Lenox Municipal Utilities (Iowa), Silicon Valley Power (Calif.), Portland General Electric, and Sacramento Municipal Utility District. In 2007, total utility green power sales exceeded 4,5 billion kilowatt-hours (kWh), about a 20 % increase over 2006. Approximately 600 000 customers are participating in utility programmes nationwide.

Utility-Scale PV Projects
Pacific Gas & Electric (PG&E) announced an agreement with two developers of utility-scale PV solar power systems: Cleantech America LLC and GreenVolts, Inc., to deliver up to 7 MW of PV power for its customers throughout northern and central California. The US-based SunEdison and the Canadian company SkyPower Corporation joined forces to develop, build, own, and operate an up to 50 MW PV farm in Ontario, Canada. Xcel Energy began purchasing 8,2 MW of PV from a plant near Alamosa, Colo. Nellis Air Force Base celebrated the completion of North America's and the world's largest utility-scale PV system. The 14 MW PV system, which is a joint effort of the US Air Force, MMA Renewable Ventures LLC, SunPower, and the Nevada Power Company, will supply approximately 25 % of the total power used at the base.

2.4 Highlights of R&D

The US Solar Program's goal is to develop highly reliable PV systems with user-lifetime energy costs competitive with electricity from conventional resources. The national programme attempts to achieve this goal through R&D by 1) increasing the sunlight-to-electricity conversion efficiency and performance of solar cells, modules, and systems; 2) reducing the manufacturing cost of solar cells, modules, and balance of systems; 3) reducing the installation, interconnection, and certification costs for residential, commercial and utility systems; and 4) increasing system operating lifetime and reliability.

National laboratory participation in the Solar Program changed under SAI in 2007. The Thin-Film Partnership programme, PV Manufacturing R&D project, and the University and Exploratory Research programme were phased out in 2007 to address new technology developments and because these programmes will now be supported by the new Technology Pathway Partnerships project, the PV Incubator project, and other SAI solicitations.

In 2007, the PV subprogramme was organized around three major research, development and deployment activities: Fundamental Research, Advanced Materials and Devices, and Market Transformation. A brief overview of 2007 activities and achievements in these three areas follows.

Fundamental Research
This area of R&D conducts cross-cutting research focused on semiconductor material, device, and processing issues that benefit multiple companies and/or technologies. In 2007, there were four main research activities performed under this research area.

University and Exploratory Research—works on cross-cutting research to help solve fundamental scientific problems associated with all PV materials and devices and investigates innovative ideas that may lead to next-generation technologies.

NREL and Boeing Spectrolab were jointly awarded an R&D100 Award in 2007 by *R&D Magazine* for developing the first high-efficiency solar cell to achieve 40,7 % conversion efficiency. The solar cell, called a High-Efficiency Metamorphic Multijunction Concentrator Solar Cell or HEMM solar cell, achieved the highest efficiency level of any photovoltaic device ever, making it twice as efficient as a typical silicon solar cell. The HEMM solar cell is designed for solar power systems that use lenses and mirrors to concentrate sunlight onto small, high-efficiency solar cells, requiring far less semiconductor material than standard flat-plate solar panels. Boeing Spectrolab is planning to commercialize this technology for utility-scale solar power plants, such as those being planned in the southwestern United States.

On 8 November 2007, SAI awarded funds to 25 universities and companies for the research and development of next-generation PV projects:

- Arizona State University, Tempe, AZ—Advanced semiconductor materials for breakthrough photovoltaic applications
- Arizona State University, Tempe, AZ—II-IV-V-based thin-film tandem photovoltaic cell
- California Institute of Technology, Pasadena, CA—Solar cells from Earth-abundant semiconductors with plasmon-enhanced light absorption
- Massachusetts Institute of Technology, Cambridge, MA—All-inorganic, efficient photovoltaic solid-state devices utilizing semiconducting colloidal nanocrystal quantum dots

- Massachusetts Institute of Technology, Cambridge, MA—Thin, high-lifetime silicon wafers with no sawing; recrystallization in a thin-film capsule
- Mayaterials, Ann Arbor, MI—Solar-grade silicon from agricultural by-products
- Pennsylvania State University, University Park, PA—Improved electrodes and electrolytes for dye-based solar cells
- Pennsylvania State University, University Park, PA—High-aspect-ratio semiconductor heterojunction solar cells
- Rochester Institute of Technology, Rochester, NY—High-efficiency nanostructured II-V photovoltaics for solar concentrators application
- Solasta, Inc., Newton, MA—High-efficiency solar power via separated photo and voltaic pathways
- Solexant, Sunnyvale, CA—High-efficiency quantum-dot solar cells based on multiple exciton generation
- Soltaix, Los Altos, CA—Feasibility demonstration and performance optimization of a disruptive ultra-high-efficiency, thin-film, crystalline silicon solar cell for cost-effective, grid-connected electricity
- Stanford University, Stanford, CA—CuIn(Ga)Se_2 (CIGS) nanowires solar cells
- Stanford University, Stanford, CA—Nanostructured material for high-efficiency, low-cost, solution-processed photovoltaics
- University of California, Davis, CA—Functional multi-layer solution processable polymer solar cells
- University of California, Davis, CA—High-efficiency photovoltaics based on semiconductor nanostructures
- University of Colorado, Boulder, CO—Exciton fission for an ultra-high-efficiency, low-cost solar cell
- University of Delaware, Newark, DE—Novel approaches to wide-bandgap $CuInSe_2$-based solar cells
- University of Florida, Gainesville, FL—Very high-efficiency hybrid organic-inorganic photovoltaic cells
- University of Illinois, Urbana, IL—Transfer-printed microcells with micro-optic concentrators for low-cost, high-performance photovoltaic modules
- University of Michigan, Ann Arbor, MI—Crystalline organic photovoltaic cells
- University of South Florida, Tampa, FL—Next-generation CdTe technology substrates foil-based solar cells
- University of Washington, Seattle, WA—Interfacial engineering for highly efficient conjugated polymer-based bulk heterojunction photovoltaic devices
- Voxtel, Inc., Beaverton, OR—Optimization of impact ionization in composite nanocrystal photovoltaic devices
- Wakonda Technologies, Inc., Fairport, NY—Novel manufacturing of flexible III-V thin films.

Electronic Materials and Devices—conducts research in semiconductor materials, device properties, and fabrication processes to improve the efficiency, stability, and cost of photovoltaics. This research supports technology in near, mid- and long-term time frames. Accomplishments in 2007 included:

- Demonstrating record efficiencies of 33,8 % and 30,6 % under one-sun global space conditions for a triple-junction PV concentrator cell (the GaInP top junction and GaAs middle junction are grown inverted and lattice matched on a GaAs substrate then combined with a lattice mismatched GaInAs bottom junction).

- Completing the Process Development and Integration Laboratory (PDIL) at NREL. Located in the laboratory's Science and Technology Facility, the PDIL is a 10 170 ft^2 (945 m^2) laboratory space dedicated to a new class of PV deposition, processing, and characterization tools. One of the exciting capabilities in the PDIL is the ability for researchers to pass 6 inch (15,2 cm) samples between equipment without contamination from the air. Other capabilities of the PDIL include a thorough integration of control systems and databases enabling researchers with various expertise to work together on integrated tools and integrated data.

    - Developed state-of-the-art infrastructure for organic-based, thin-film PV
    - Achieved best-to-date efficiency of 19,1 % heterojunction c-Si solar cell in the wafer silicon field
    - Developed the "cone kinetics" model to guide film-silicon growth.

Measurements and Characterization—conducts research in analytical microscopy, electro-optical characterization, surface analysis, and device performance. In 2007, SAI supported more than 70 PV research partners in industry, academia, and NREL with analytical microscopy, surface analysis, electro-optical characterization, and cell and module performance. SAI also initiated the design of an improved solar simulator that will reduce uncertainty in high-efficiency concentrator measurements and develop a luminescence spectrum-imaging system for characterizing industrial silicon wafers and solar cells.

Resource and Safety Research—conducts solar-resource research to address the needs of designers, modelers, and other resource-assessment personnel and to determine ways to minimize the potential environmental, health, and safety impacts associated with PV manufacturing and applications. In 2007, SAI conducted a life-cycle analysis of buffer options for CIGS PV and completed the 1991-2005 National Solar Radiation Data Base (NSRDB) update and documentation, including the 10-km satellite-derived data grid from the State University of New York.

Advanced Materials and Devices

This area of R&D carries out research in semiconductor material properties, mechanisms, and fabrication processes to improve the efficiency, stability, and cost of PV energy conversion. The effort focuses on thin-film materials and modules that hold promise for major cost reductions in PV, module manufacturing methods, and module reliability. Traditionally, this area of R&D focused on three areas: Thin Film PV Partnership, Advanced Manufacturing R&D, and Module Reliability R&D. In 2007, these activities were realigned to support the new Solar America Initiative. Research conducted under the Thin Film PV Partnership and Advanced Manufacturing R&D was concluded in 2007 and all future work transferred to the new Technology Pathway Partnerships solicitation. Module Reliability R&D research, which solves reliability issues such as degradation mechanisms and intrinsic instabilities of precommercial thin-film modules, was transferred to Fundamental Research.

Achievements in Advanced Materials and Devices in 2007 included the following:

Component Development—uses industry, laboratories and universities to help advance state-of-the-art individual components as opposed to fully integrated systems. There are four project activities under component development: thin-film partnerships; advanced module manufacturing; module packaging; and inverter and balance-of-systems development. In 2007, DOE awarded funds to 10 industry projects that provided proof-of-concept for improvement of

PV modules, including the use of diverse materials and innovative product designs, under its PV Incubator solicitation. The 10 companies awarded funds are

- AVA Solar, Colorado
- Blue Square Energy, Maryland
- CaliSolar, California
- Enfocus Engineering, California
- MicroLink Devices, Inc., Illinois
- PlexTronics, Pennsylvania
- PrimeStar Solar, Colorado
- Solaria, California
- SolFocus, California
- SoloPower, California

Systems Development—features two primary R&D projects: Technology Pathway Partnerships and University Process and Product Support. In 2007, this activity worked primarily through cost-shared contracts with industry to advance the development of PV systems and components. Below is a brief description of each and the 2007 awardees.

Technology Pathway Partnerships (TPPs)—Under the TPPs, industry-led teams are funded to develop photovoltaic technologies that have the greatest potential for cost-competitiveness by 2015. Examples of promising PV technologies include crystalline silicon and thin-film modules and systems. The TTPs will also consider development and testing of balance-of-system component designs that address emerging requirements for modularity, reliability, and decreased installation cost. In 2007, DOE awarded funds to the following 13 US solar manufacturers:

- Amonix, California
- BP Solar, Maryland
- Boeing, California
- Dow Chemical, Michigan
- General Electric, Delaware
- Miasolé, California
- Nanosolar, California
- SunPower, California
- Powerlight, California
- United Solar Ovonic, Michigan
- Konarka, Massachusetts
- GreenRay, Massachusetts
- Practical Instruments, California

University PV Process and Product Development Support—emphasizes direct, near-term improvements in PV products and development processes by universities, which have a fundamental understanding of materials and device physics as well as experience with lab-scale processes and prototype production. The following US universities and their industry partners received funds under this project in 2007:

- Arizona State University with SolFocus, Inc., and Soliant Energy, Inc.

- California Institute of Technology with Spectrolab, Inc.
- Georgia Institute of Technology with SiXtron Advanced Materials, Inc.
- Massachusetts Institute of Technology with CaliSolar, Inc., and BP Solar International, Inc.
- North Carolina State University with Spectrolab, Inc.
- Pennsylvania State University with Honeywell International, Inc.
- University of Delaware Institute of Energy Conversion with Dow Corning
- University of Delaware Institute of Energy Conversion with SunPower Corporation
- University of Florida with Global Solar Energy, Inc.; International Solar Electric Technology, Inc.; Nanosolar, Inc.; and Solyndra, Inc.
- University of Toledo with Calyxo USA, Inc.
- University of Toledo with Xunlight Corporation

Technology Evaluation—focuses on evaluation of technical advances throughout the Solar Program using independent testing and analysis, including the evaluation of ongoing system-level progress of the Technology Pathway Partnerships. Technology Evaluation contains three primary activities: Systems Analysis; Systems Test and Evaluation; and Component Test and Evaluation. Systems Analysis activities continue benchmarking, modeling, and analysis for the systems-driven approach as well as market, value and policy analysis necessary to support the SAI. Systems Test and Evaluation activities focus on the critical need to test and evaluate all the deliverables developed under the TPPs. Under the third activity, Component Test and Evaluation, researchers work in partnership with universities, industry, and the National Laboratories to improve the efficiency of cell materials and devices by investigating their fundamental properties and operating mechanisms.

Systems Analysis—In 2007, this activity focused on analysis of the US electrical grid and the impact of PV on the distribution system as well as market, value, and policy studies. PV system cost and performance analyses were also performed.

- Completed 14 draft reports for the Renewable Systems Interconnection study. These reports address the technical and analytical challenges to enable high penetration levels of distributed renewable energy technologies. See www.eere.energy.gov/solar/solar_america/rsi.html for more information.
- Developed a model and other tools to examine the impacts of high levels of PV penetration on the US electricity generation system.
- Developed a PV-system inverter model for use within the Solar Advisor Model.

Systems Testing and Evaluation—provides technical support to SAI's TPPs in developing commercial PV modules, inverters, and controllers that consistently meet SAI's performance, reliability, and cost goals.

- Determined inverter performance, power quality, and utility-compatibility capabilities for commercial inverters and residential PV inverters.
- Conducted performance tests to support the development of industry solar modules.
- Developed an interfacial measurement technique of layer adhesion inside modules.
- Evaluated the performance of system configurations for PV manufacturing companies and characterized additional modules and arrays.

Component Testing and Evaluation—measures and creates models relating to the levelized cost of electricity, efficiency, dollars per peak watt, and other metrics used for analysis.

- Performed 26 spectral and 405 solar broadband radiometer calibrations for national laboratories, industry, and academia.

PDIL Infrastructure, Engineering, and Integration—The Process Development and Integration Laboratory (PDIL) at the National Renewable Energy Laboratory is a unique collaborative facility where industry and universities can work closely with NREL scientists on integrated equipment to answer pressing questions related to photovoltaics. The integrated equipment includes deposition, processing, and characterization tools. The PDIL works with a wide range of PV materials, from crystalline silicon to thin-films (amorphous, nano- and microcrystalline silicon, copper indium gallium diselenide, and cadmium telluride) to organic PV.

- Developed the design of process-integration-compatible measurement and characterization equipment for use in NREL's PDIL, including resonance-coupled photoconductive decay, photoluminescence imaging, and a special spectroscopic ellipsometry chamber.
- Integrated this equipment into a central robotic transfer chamber along with a sputtering/etching chamber and a chamber for studying plasma-enhanced chemical vapor depositions. For more information, visit www.nrel.gov/pv/pdil.

Market Transformation

In 2007, DOE launched aggressive market transformation activities to accelerate adoption of market-ready solar technologies, including the inauguration of 13 "Solar America Cities" and technical assistance for the installation of large-scale, in excess of 100 kilowatt (kW), PV installations. The national programme awarded funds to several organizations to provide technical assistance to states and utilities interested in pursuing PV installations and policies, including the Interstate Renewable Energy Council (IREC), the Clean Energy Group, the National Association of Regulatory Utility Commissioners (NARUC), and the Solar Electric Power Association (SEPA). SAI is also developing voluntary solar codes and standards for PV modules and established the Solar America Board for Codes and Standards (Solar ABCs). New finance activities will be developed in 2008 pending the results and recommendations of the finance-scoping study conducted in FY 2007. In addition, the Technology Acceptance area funds targeted communications and outreach work that supports the mission of SAI, including showcasing solar technologies and providing information to consumers, industry professionals, government officials, and scientists via exhibits at large conferences throughout the United States and through its Web site at: www.eere.energy.gov/solar/solar_america.

Market transformation achievements in 2007 were:

Codes and Standards—

- Led an industry forum with more than 100 attendees for Article 690 of the National Electric Code that resulted in 46 proposals and follow-up on public comments for inclusion in the 2008 National Electric Code
- Established the Solar America Board for Codes and Standards (www.SolarABCs.org).

Training and Certification—

- Published 52 issues of the Interstate Renewable Energy Council (IREC)/SAI e-newsletter for 1 700 subscribers
- Funded IREC activities including providing training workshops for code officials on solar water heating, developing PV resources for community colleges, and supporting North American Board of Certified Energy Practitioners (NABCEP) in developing new certification programmes

- Funded NABCEP PV installer certification, Entry Level Certificate of Knowledge, and Solar Thermal Installer Certification.

Technology Acceptance—
Technology acceptance research activities included conducting market studies to address key market barriers such as substandard interconnection and net metering practices and providing tools and assistance to federal, state, and city governments; utilities; and the building industry.
- Prepared a report technically defining the solar energy opportunities for federally owned Congressional office buildings in Washington, D.C.

Building Integration—
- Prepared for and conducted a successful 2007 Solar Decathlon university competition on the National Mall in Washington, D.C.
- Conducted building energy monitoring and computer modeling research on past Solar Decathlon houses to improve future contests, quantify the annual performance of the houses, identify areas of technical significance, and extend the education and outreach component of the competition beyond the 10 days on the National Mall
- Completed initial data gathering and analysis on state and local government financing of PV.

Solar America Showcase
In May 2007, DOE selected three projects as Solar America Showcases. Winners received technical assistance from DOE for the installation of large-scale PV projects greater than 100 kW. The three projects selected are

- Forest City Military Communities—DOE helped to determine the feasibility of incorporating residential hybrid solar-electric and solar-thermal systems at a large military base in Oahu, Hawaii.
- Orange County Convention Center—DOE worked in partnership with the Orlando Utilities Commission to plan the installation of a 1 MW PV system on the roof of the Orange County Convention Center, the second-largest convention center in the southeastern United States, located in Orange County, Florida.
- City of San Jose, California—DOE provided technical and cost-benefit analysis in evaluating the potential of placing photovoltaic and solar-thermal systems on multiple large buildings and complexes in San Jose.

Solar America Cities
DOE established strategic partnerships with 13 cities through a competitive funding opportunity and awarded a combined 2,5 MUSD in financial assistance. These Solar America Cities, which are committed to accelerating the adoption of PV at the local level, work with a variety of municipal, county, and state agencies; universities; developers; and nonprofit organizations to power their municipalities with PV. SAI plans to announce 12 more city partners in 2008. In June 2007, DOE named the following as Solar America Cities.

- Ann Arbor, MI
- Austin, TX
- Berkeley, CA
- Boston, MA
- Madison, WI
- New Orleans, LA
- New York City, NY

- Pittsburgh, PA
- Portland, OR
- Salt Lake City, UT
- San Diego, CA
- San Francisco, CA
- Tucson, AZ

Technical Outreach—

- Created a readily accessible database of current and previous years' bills on energy (See Solar State Legislation www.ncsl.org/programs/energy/energypolicy.cfm.)
- Launched a Web site (www.statesadvancingsolar.org) that serves as a resource for state policy makers and decision makers interested in developing a solar programme.
- Released the "Solar Energy Technology and Policy Reference Guide."
- Released "The Peer Matching Online Tool" (www.solarelectricpower.org/peer/) to share information and best practices to help all utilities improve their solar programmes.

2.5 Public budgets for market stimulation, demonstration / field test programmes and R&D

The 2007 federal budget for PV funded the Solar America Initiative. SAI's goal is to accelerate widespread commercialization of clean solar energy technologies across America by 2015, diversifying the nation's electricity supply options, increasing national security, and improving the environment. The federal budget for PV R&D was approximately 138,3 MUSD for FY 2007—a 78,3 MUSD increase over FY 2006 research funding.

Key activities funded by federal public funds included:

- Launching the President's Solar America Initiative, designed to achieve market competitiveness for solar electricity by 2015 through federal partnerships with industry, universities, national laboratories, states, and other government entities
- Continuing R&D work on PV technologies with potential for dramatic cost reductions and performance and reliability improvements
- Concentrating solar power work on next-generation solar concentrators, engines, and receivers and expanding research on thermal storage
- Terminating all solar heating and lighting activities after completing major milestones.

On the state level, more than 20 states have established clean energy funds that will collect more than 6 BUSD (BUSD) in aggregate over the next decade through a small surcharge on retail electricity rates known as a "system benefits charge." Almost all of the state funds currently provide some form of support for customer-sited PV. Many funds have implemented what are commonly known as "buy-down" programmes, where funds are distributed as grants to subsidize or buy down the initial cost of a system. California has committed to a 10-year, 3 BUSD solar programme that reduces rebate levels each year by approximately 10 %, with subsidies zeroing out after 10 years.

Table 3: Public Budgets for R&D, Demonstration/Field Test Programmes, and Market Incentives (in MUSD)

Funding Level	R&D	Demonstration/ Field Test	Market
National	138,3*		52**
State/Regional			400 (approx.)
Total	138,3		452

*US Department of Energy's Budget Office - 2007 appropriation for photovoltaic R&D
**federal tax credits for residential and commercial PV installations

3 Industry and growth

The United States photovoltaic (PV) programme made progress on several fronts in 2007. Module production increased 32 % to 266 MW. Installations increased to 205 MW. State-subsidized PV systems topped 150 MW, and the federal government began funding research called for in the Solar America Initiative. This new legislation implemented two programmes: 1) a federal tax credit of 30 % of installed cost for commercial PV systems (connected to the grid) with 30 % residential grid-connected rebate capped at a maximum rebate of 2 000 USD, and 2) major expansion in the US Department of Energy's FY 2007 budget for photovoltaic research and development and market transformation activities. The following summarizes 2007 progress as categorized by production, installations, development, and commercialization of product.

3.1 Production of feedstocks and wafers

Table 4 shows US production of feedstocks: polycrystalline silicon, single-crystal silicon, EFG (edge-defined film-fed growth) wafers, and solar-grade silicon feedstock.

Table 4: 2007 Production and Production Capacity for Feedstock Producers and Wafer Manufacturers

Source	Solar grade Si Production (Metric tons)	Total Si Production (Metric tons)	Product Destination Solar grade Si (Metric Tons)
Hemlock Semiconductor Corp.	2 000	6 800	(US) 500 (Export) 1 500
Advanced Silicon Materials	0	2 700	0
Solar Grade Silicon	2 100	2 100	(US) 800 (Export) 1 300
MEMC	400	1 700	(US) 400
Mitsubishi Polysilicon America	100	1 200	(US) 100
TOTAL SILICON PRODUCED	4 600	14 500	(US) 1 800 (Export) 2 800
Solar-Grade Scrap from semiconductor industry	500		(US) 500
Total Silicon Used by PV-United States	**5 100**		(US) **2 300** (Export) **2 800**
US WAFER PRODUCTION			
Reject Wafers from IC Industry	18 MW		(US) 18 MW
IN-HOUSE WAFER PRODUCTION			
Solar World America	40 MW/yr		(US) 15 MW (Export) 25 MW
BP Solar	40 MW/yr		(US) 15 MW (Export) 25 MW
Evergreen Solar RIBBON	14 MW		(US) 14 MW
Solec Intl. EXPORT TO SANYO	30 MW		30 MW Japan (Sanyo Modules)
SCHOTT SOLAR RIBBON			
TOTAL WAFERS	**142 MW**		

3.2 Production of PV cells and modules

Table 5 shows the US 2007 production of PV cell/modules. Virtually all of the growth in 2007 came from the expansion of thin film production: First Solar's production of cadmium telluride, which was exported to Europe, and increased production by United Solar Ovonics of amorphous silicon on steel.

Table 5: 2007 US PV Cell/Module Production and Capacity

Module Manufacturer	Technology Type	2007 Production (MW_p)		2007 Max Capacity (MW_p)	
		Cells	Modules	Cells	Modules
CRYSTALLINE					
Solar World (US)	Single-crystal silicon	35	35	45	45
BP Solar (US)	Multi-crystal silicon	27,7	27,7	40	40
GE Energy	Single-crystal silicon	NIL	NIL	NIL	NIL
Schott Solar	EFG ribbon silicon	10	10	15	15
Evergreen Solar	String Ribbon	16,4	16,4	16,5	16,5
Total Crystalline	**CRYSTALLINE**	**89,1**	**89,1**	**116,5**	**116,5**
THIN FILM*					
United Solar	Amorphous silicon	48	48	50	50
First Solar	CdTe	120	120	140	140
Global Solar	CIS	4	4	5	5
Total Thin Films	**THIN FILM**	**172**	**172**	**195**	**195**
OTHER					
	Concentrator	0,5	0,5	1	1
	Amorphous Si	4,5	4,5	5	5
TOTAL PRODUCTION / CAPACITY		**266,1**	**266,1**	**317,5**	**317,5**

*Public information indicates First Solar's manufacturing price is under 1,25/watt USD with retail prices under 2,25 USD per watt. United Solar Ovonics shipped 48 MW in 2007, while Global Solar shipped 4 MW of CIGS in 2007. Over 500 MW of new capacity is being installed in the United States, Germany, and Asia. New plants with nearly 100 MW of capacity are being built for operation in 2008.

3.2.1 PV Module Prices: Average module prices at the factory increased slightly from 3,60/W_p USD in 2005 to 3,75/W_p USD in 2006/2007. These prices are for customers that are on a "scheduled release" contract.

Table 6: Module Prices USD/Wp

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Price*	4,00	3,75	4,00	4,15	4,00	3,50	3,75	3,50	3,25	3,00	3,50	3,60	3,75	3,75

*Estimated by PV Energy Systems, Inc.

3.2.2 Key US PV Industry Companies

SOLAR WORLD (was Shell Solar)
Solar World's US PV production is fully integrated. Solar World purchases "solar-grade" polysilicon to be used in a melt from which single-crystal silicon ingots are pulled using the latest 6-inch to 8-inch (2,54 cm) diameter pullers. Solar World then slices the ingots into 200-µm-thick wafers using wire saws. The ingot and wafer production are in its plant in the state of Washington. The wafers are processed into cells and modules in an automated plant in Camarillo, California. Modules are certified to all standards including IEEE (Institute of Electrical and Electronics Engineers), ISPRA (European standards), and UL (Underwriters Laboratories). The package comprises tempered glass/cells/EVA encapsulation/back cover of Tedlar or aluminum. The company offers a warranty of 25 years. In 2007, Solar World announced plans to build a new plant in Portland, Oregon. The facility will have a 5 000-ton (5 080 kg) silicon purification plant, and ultimately a 1 000-MW crystal pulling operation, a 1 000-MW wafer plant, and a 1 000-MW cell plant.

BP SOLAR
BP Solar (United States) is the world's third-largest producer of cast-ingot multicrystal silicon cells and modules (Kyocera of Japan is first and Sharp of Japan is second). US production in 2007 was 26,5 MW of cells and 25 MW of modules. BP SOLAR starts production by purchasing solar-grade polysilicon scrap and new solar-grade silicon and makes all wafers, cells, and modules. BP Solar offers power modules with power output of 150 W to 300 W. The company offers a standard 25-year warranty.

GENERAL ELECTRIC (GE)
GE Energy shipped 18 MW of silicon cells and modules in 2007. Most of the cells were purchased from outside the United States.

SCHOTT SOLAR
Schott purchased the interest of RWE in 2005. RWE Schott (formerly ASE GmbH in Germany) purchased the assets and technology of Mobil Solar in 1993 and established ASE Americas. The company refined its EFG and installed new pullers. Schott Solar purchases poly-crystalline silicon that is melted. Sheet silicon is pulled from the melt in the form of an octagon. The octagon is cut into 15 cm x 15 cm slices. Cells and modules are produced in a semi-automated plant. The Schott Solar crystalline-silicon modules—in standard 200-MW to 300-MW sizes—use a glass/proprietary dielectric/cells/dielectric/glass configuration. They sell slices, cells, and modules. In 2007, Schott Solar produced and shipped 13 MW of cells and modules in the United States and offered a standard 25-year product warranty.

UNITED SOLAR OVONICS (Uni-Solar)
United Solar Systems Corporation (USSC) started production in its new 5-MW, triple-junction amorphous silicon plant in Troy, Michigan, in 1997. In addition to its marine modules and framed power modules, USSC manufactured three unique products: PV roof shingles that can be used with normal shingle roofing materials; a standing-seam metal roofing material that can be used with metal roofing; and a roofing material that involves laminating USSC amorphous silicon flexible coils on membrane roofing. More than 40 MW of this product have been installed in California. The new building-integrated products are listed by UL and have been certified by the Arizona State University Photovoltaic Testing Laboratory (PTL). In 2001–2002, Uni-Solar, a wholly owned subsidiary of Energy Conversion Devices, Inc. (ECD), built a 25-MW roll-to-roll triple junction amorphous silicon-on-steel plant. Production from the new plant commenced in

late 2002. A second 30-MW plant was completed in Michigan and a third is operating. United Solar Ovonics produced 28 MW in 2007.

EVERGREEN
Evergreen Solar has taken the String-ribbon process invented by Dr. Emanuel Sachs (Massachusetts Institute of Technology) into production. Pilot production started late in 1997. The modules have been certified by the Arizona State University PTL 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 US stock market. The proceeds were used to build a 10-MW String-ribbon plant in Massachusetts. Pilot production from the new plant was achieved in the second half of 2002. The new plant was dedicated ahead of schedule in June 2002. Evergreen produced 14 MW of String-ribbon cells and modules in 2007. Evergreen and Q-Cells (Germany) formed a joint venture, "Ever-Q," in which a large silicon-ribbon sheet plant was built in Germany to serve some of Q-Cells' requirements for wafers. Observers believe the intrinsic 7 grams to 9 grams/watt capability of the Evergreen String-ribbon, coupled with Q-Cells cell processes, will lead to a major (50 %) reduction in the silicon required to make a PV cell.

FIRST SOLAR
First Solar produces CdTe modules using a continuous closed-space sublimation process to deposit the CdTe on glass coated with a transparent conducting oxide. Modules measuring 24 in x 48 in (60,96 cm x 121,92 cm) have been produced with efficiencies over 9 %. The expanded plant produced 60 MW of CdTe modules in 2007. The company announced plans to expand its manufacturing capabilities to 100 MW in the United States, 100 MW in Europe, and 100 MW in Malaysia. The factories will be completed in 2008.

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 above 18 %, which was a record for PV. Amonix increased production capacity to 1 MW/year in the last half of 2002 and shipped 500 kW in 2006. A new joint venture in Spain has proposed a 10-MW annual production starting in 2008.

3.3 Manufacturers and suppliers of other components: balance of systems

The cost for balance-of-systems (BOS) components for a PV system is as much, if not more, than the PV modules. Nearly one-fourth of the installed PV systems involve stand-alone systems that have storage (usually deep-cycle lead-acid batteries) and charge controllers that control charging of the battery to extend the service life through optimum charging and preventing the load from exceeding the design discharge levels. Most stand-alone systems have DC loads and use 12-volt and 24-volt battery banks. When AC loads are used, the stand-alone system has 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 installed about 150 MW of grid-connected systems in 2007. The systems use all types of PV modules and are usually connected to an inverter that permits the PV system to first serve the building's load and then to send excess power to the utility grid. When 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. The utility-interactive market now surpasses all other markets for new installations.

3.3.1 Inverter Manufacturers

More than 15 inverter manufacturers serve the US market, and some inverters are branded to be sold under several different names. A large percentage of the inverters used in the United States are now imported, with manufacturing of inverters primarily an international activity. SMA America Inc.'s inverter market share for 2007 was reported to be greater than 60 % for total numbers of grid-interactive inverters. The dramatic increase in the market for grid-connected residential PV systems greatly increased the numbers of models and sales of small inverters. Sharp, which installed more than 100 000 inverters in Japan, entered the US market in 2003. All utility-interactive inverters installed in the United States must be listed for safety under the UL1741 standard by one of three major, nationally recognized testing laboratories. The CEC list of eligible inverters for its Emerging Renewables programme now exceeds 150 models. Sandia National Laboratories continued to work with Xantrex (Trace) and GE on their high-reliability inverter designs.

3.3.2 Battery Charge Controllers

Battery charge controllers are essential for PV systems that store energy in batteries. The charge controller charges the battery and controls the discharge of the battery to the load. It is designed to optimize the charge and discharge of the battery to obtain maximum battery life and provide the highest charge and discharge efficiency. The United States has several producers of charge controllers. At least 22 brands are available for the US market. Major manufacturers include Morningstar, Xantrex, Specialty Concepts, Sun Selector, and Outback Power. Total production is estimated at 130 000 units to 150 000 units per year. More than 60 % of US charge controllers are exported.

3.3.3 Systems Designers and Installers

About 30 companies in the United States are dedicated primarily to the design, sale, and installation of PV systems. When the market comprised primarily off-grid, stand-alone systems (prior to 1996), large distributors had a systems designer-installer who served most of the larger commercial systems (telecommunications, water pumping, remote military, etc.). These designer-installers included Atlantic Solar, Solar Depot, Hutton Communications and SunWize. When state tax credits for grid-connected systems (residential and commercial) were established, several of the distributors became full-service systems 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 US grid-connected systems. Several 2007 PowerLight systems were larger than 5 MW, primarily in Europe. PowerLight is now a subsidiary of SunPower, which manufactures cells and modules in the Philippines. Sun Edison is another large US systems integrator with several installations over 1 MW.

3.4 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 fairly constant installed system prices, despite the continued high cost of modules.

Table 7: Turnkey Prices of Typical Applications 2007

Category/Size	Typical applications	USD per W*
OFF-GRID Up to 1 Kw	Telecom, signals, lighting, highway signs, navigation aids, irrigation, cottages, etc.	10–20 depending on storage, remoteness
OFF-GRID >1 kW	Telecom, homes, farms, irrigation, signals, government sites, parks	10–20
GRID-CONNECTED Specific case	2-5 kW roof-mounted system	7–9
GRID-CONNECTED Up to 10 kW	Homes, business, schools, parking, irrigation	7–8
GRID-CONNECTED >10 kW	Government buildings, warehouses, renewable power set asides-utilities, commercial buildings	5,5–7,5

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

Table7a: National Trends in Residential System Installed Prices (USD/W_{ac})

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Price*	12	11-12	10-12	10-12	10-11	9-11	8-10	7-9	6,50-9	6,50-8	6,50-8	6,50-8	7-9,00	7-9,00

*Estimated by PV Energy Systems, Inc.

3.5 Labor places

The labor analysis uses the model developed in 2002 and revised in 2005. Labor places accounts for R&D, manufacturing, design and installation, product distribution, and utility and government sectors of the PV industry. The labor places in the US PV industry total about 9 000 persons.

Table 7b: 2007 Analysis of the PV Industry Labor Force and Costs in the United States

Category	MW	Total Value (USD)	Labor USD/ W	USD For Labor	Labor USD/Person	Number of Laborers
Cell/Module Production	201,6	655,2 @3,25/W *	0,60	121M	40 000	3 024 Factory
Factory Marketing	201,6	655,2M	0,10	20,16M	100 000	202 Marketing
Management	201,6	655M	0,10	20,16M	150 000	133 Managers
Research/Eng. Industry	201,6	655M	0,10	20,16M	130 000	155 Research
University/Lab Research/Eng.				40,0 M	130 000	308 Research
BOS Production	149	521,5M	0,20	29,8 M	40 000	525 Factory
BOS Marketing	149		0,10	14,9M	60 000	248 Marketing
BOS Management	149		0,10	14,9M	80 000	175 Managers
Installation Labor	149		0,60	89,4 M	40 000	2 235 Installers
Installation Management	149		0,20	29,8 M	60 000	497 Managers
Total Labor For Modules, BOS and Installation						7 502 Total 3 549 Factory 463 R&D/Eng 450 Marketing 805 Managers 2 235 Installers
Solar Silicon Production	**Tons**	**USD/kg**	**Value MUSD**	**USD/kg Labor**	**Value MUSD and USD/Person**	**Labor Number**
	5 500	60	330	10,00	55M 80 000	688
TOTAL US PV LABOR						**8 190**

3.6 Business value

The value of PV product and services in the United States can be estimated by adding the total value of the products installed, the product exported, and the R&D costs in the government labs and universities. Table 8 lists the key elements of this analysis. The total value of the installation of US PV systems, the export of modules (minus the modules imported) and the export of silicon is about 1,7 BUSD.

Table 8: 2007 Value of the US PV Industry

Submarket	Capacity Installed in 2007	Price (USD/W_{ac} Installed)	Totals (MUSD)
Off-Grid Domestic	14 000 kW	15	210
Off-Grid Nondomestic	23 000 kW	15	345
Grid-Connected Distributed	Res = 55 000 kW Com = 45 000 kW	8 7,50	440 337,5
Grid-Connected Centralized	5,000 Kw	7	35
TOTAL US PV INSTALLED			**1 367,5**
Export Modules	118 000 kW*	3*	354 M
Inventory Change	Not available		
Import Modules	65 000 kW	3,75	-244
Export Silicon	5 000 metric tons	60 000 per metric ton	250 M
TOTAL VALUE			**1 727,5**

*Exports included 55 MW of CdTe at 2,50 USD per watt resulting in 3 USD average price.

4. Framework for deployment (nontechnical factors)

The framework for PV deployment is complex and includes building regulations, codes and standards for buildings and PV systems, and public policy issues. In addition to federal policy issues, the framework varies between states and cities.

Energy policy in the United States is largely determined at the state level. In 2007, four key policy factors influenced deployment of PV: financial incentives available for the purchase of solar systems, implementation and standardization of interconnection standards and net metering, and fair and consistent utility rates for solar customers.

4.1 New Initiatives

The two primary initiatives that support the deployment of PV in the United States are the Solar America Initiative (SAI) and the California Solar Initiative. SAI supports the deployment of PV through R&D and through its Market Transformation activities, which are designed to analyze and remove nontechnical market barriers.

Market transformation deployment projects target federal/state/city buildings as early adopters, activities that facilitate mainstream solar adoption, and activities that provide a model for other PV installations. In addition, SAI's market transformation technical outreach projects in this area are designed to build relationships with legislators, energy offices, public utility commissions, air quality offices, and utilities so they can make informed decisions when enacting policies, programmes, and plans that affect solar technologies. SAI also identifies best practices for insurance and finance options, product certification, codes and standards for PV installations, and net metering and interconnection.

Highlights of major state-level initiatives include the following:

California
The California Solar Initiative has a goal to create 3 000 MW of new, solar-produced electricity by 2017. The initiative budget is 3,3 BUSD over 10 years. In 2007, the initiative targeted three primary audiences:

1) Consumers—provides cash back for solar for existing homes and existing and new commercial, industrial, government, nonprofit, and agricultural properties. This programme component has a budget of 2 167 MUSD over 10 years, and the goal is to reach 1 940 MW by 2016. This goal includes 1 750 MW from the general market programme and 190 MW from the low-income residential incentive programme.
2) Builders—advances solar in new home construction through its New Solar Homes Partnership. This programme component is authorized 400 MUSD over 10 years, with a goal of 360 MW. Included in this component is a requirement for all builders of 50 homes or more to offer PV as an option for homebuyers.
3) Utilities—requires each municipal utility to offer an equivalent incentive programme, an aggregate commitment of 784 MUSD over 10 years, toward a goal of 660 MW.

For more information about the California Solar Initiative, visit www.gosolarcalifornia.ca.gov/

New Jersey
As of 2007, New Jersey had one of the best rebate programmes in the United States, paying for up to half the cost of many residential and commercial systems. The state developed a solar renewable energy credits (REC) market as part of the state's Clean Energy Program. Individuals and businesses can finance their solar installations by trading a solar renewable energy certificate (SREC) once the system generates 1 MW. Utilities can purchase the SRECs to meet the state's renewable portfolio standards. Major projects in the state include a combined effort by the New Jersey Board of Public Utilities and New Jersey-based DT Solar to install a 1 400 kW, roof-mounted solar electric system at Hall' s Warehouse Corp. in South Plainfield, one of the largest corporate solar installations in the United States.

Nevada
The state established plans to deliver 100 MW of solar power from the Solar Enterprise Zone, which includes parts of the former Nevada Test Site. Major projects included the installation of a 14,2 MW PV power plant at Nellis Air Force Base, one of the largest PV-powered solar power plants in the world.

Oregon
In 2007l, Oregon expanded its business energy tax credit to include builders who install PV systems on homes. Homebuilders receive the residential tax credit plus 3 000 USD up to a maximum of 9 000 USD, or 3 USD per watt for PV plus 3 000 USD.

Maryland
Maryland revised its RPS in April 2007 to require electricity suppliers to derive 2 % of sales from solar energy (a solar set-aside) in addition to the 7,5 % renewables drawn from other renewable sources. The solar set-aside begins in 2008 and will increase each year to reach 2 % by 2022.

Delaware
Delaware doubled its RPS requirement from 10 % to 20 % of retail electricity sales from renewable energy generation. The state also added a solar set-aside of 2% of electricity sales from solar energy by 2019.

New Mexico
New Mexico doubled its RPS requirement for retail electricity sales from renewable energy generation from 10 % by 2011 to 20 % by 2020. It also added a solar set-aside of 2 % of electricity sales from solar energy by 2019. The state added a 4 % set-aside for solar energy by 2020.

New Hampshire
This state enacted its RPS in 2007 and added a solar mandate requiring electricity providers to use renewables for 23,8 % of retail electricity by 2025. The new mandate includes a solar set-aside of 0,3 % by 2 014 that continues through 2025.

North Carolina
Enacting its RPS in 2007, North Carolina law now requires all investor-owned utilities to supply 12,5 % of 2020 retail electricity sales in the state from renewable sources by 2021. A solar set-aside begins at 0,02 % by 2010 and increases to 0,2 % by 2018.

Arizona
The state's RPS moved forward in 2007, requiring 15 % of retail electricity sales to be generated by renewable resources by 2025, with 30 % coming from distributed energy technologies such as solar energy.

Utilities
- Pacific Gas & Electric (PG&E)—Created a Solar Schools Program that offers grants to 40 schools each year for the purchase of a 1-kW PV system; connected more than 18 000 PV customers to the grid as of 2007, representing more than 153 MW (the largest ever); provided nearly 200 MUSD in rebates, including 4,5 MUSD to Google, Inc., to install a 1,6 MW PV system at its campus. PG&E also funded California's "Clean Energy Fund," which plans to finance 40 % to 50 % of the cost of solar developments that can be repaid over 15 years with SRECs, at 12,11 % interest.

- Sacramento Municipal Utility District (SMUD)—Launched the Solar Shares Program to meet its solar-generation targets by purchasing bundled solar energy in 1 MW units from developers via a solar Power Purchase Agreement (PPA), a utility service model pioneered by SunEdison. The model allows cities and building owners to purchase solar power with no up-front capital. SMUD will then sell its solar "shares" to its residential and commercial customers.

- NSTAR Utility—Launched the "Evergreen Solar Alliance" to work toward aggressive goals for installed solar-power generating capacity (from 2 MW in 2007 to 250 MW by the end of 2017). The alliance promotes standardized systems installed by preapproved solar contractors.

- Public Service Electric & Gas Company (PSE&G)—Submitted a solar loan programme plan to the New Jersey Board of Public Utilities that includes a 100 MUSD investment to finance PV installations on homes, businesses, and municipal buildings in its service area. The loans would be similar to a 15-year mortgage loan and cover 40 % to 50 % of the cost of a PV installation project. Remaining project costs would be covered by a host customer or equity partner eligible to collect the federal investment tax credit (utilities are prohibited from collecting the tax incentive). PSE&G would be repaid in SRECs.

Industry
- Google, Inc.—Announced a new initiative to develop electricity from renewable sources.
- Sun Run Generation—Launched a programme allowing homeowners to deposit 8 000 USD and then lease solar energy from a "rented" PV system on the home under a 20-year lease contract.
- General Electric—Announced a new consumer loan programme for solar products. Loans are available through Yes! Solar Solutions™ in Sacramento, California.

Table 9: PV support measures

Description	National/State/Local
Feed-in-Tariffs	In 2007, the California Public Utilities Commission worked toward making new feed-in-tariffs available in 2008. California's feed-in tariffs differ from those in Germany and Spain, which include an incentive in the feed-in tariff price, by paying customers based on the "market price referent." The price paid to customers is based on the value of electrical generation, but is not intended to embed a subsidy or rebate in the price offering. (See www.dsireusa.org for more information on incentives in other states.)
Direct capital subsidies	State: California Solar Initiative provides for this in the form of 2,50 USD/watt subsidy for residential and commercial projects and 3,25 USD/watt for systems installed by governments and nonprofits.
Green electricity schemes	More than 1 million homeowners in the United States purchased green certificates (renewable energy certificates) and green tags. There are also many large purchasers of green power, including DOE, federal and state agencies, universities, and businesses. For more information, visit www.eere.energy.gov/greenpower/
PV-specific green electricity schemes	State and regional: 0,2 % of 740 MW renewable energy sales (2006). 2007 data not available.
Renewable portfolio standards (RPS)	State level: 25 states and the District of Columbia adopted renewable portfolio standards in 2007.
PV requirement in RPS	Most of the states revising their RPS in 2007 promoted solar technologies. Among the states that expanded their RPS policies to boost solar deployment and percentage of solar set-aside added are: Maryland (2 %); Delaware (2 %); New Mexico (4 %); New Hampshire (0,3 %); North Carolina (0,2 %); and Arizona (2,25 % from residential applications).
Investment funds for PV	Venture capital investment in solar reached more than 1 BUSD in 2007.
Tax credits	State and National: federal investment tax credit of 30 % for commercial systems and up to 2 000 USD for residential systems. Tax credit is set to expire on 31 December 2008 if not extended by Congress.
Net metering	As of September 2007, 39 states had adopted statewide programmes that established rules for compensating consumers who own grid-tied renewable-energy systems.
Net billing (net billing quantifies net metering on a billing-cycle basis)	Net billing exists in states where net metering is allowed. However, the credit will vary in each state and is not necessarily equivalent to 100 % of kWh.
Commercial bank activities	National: 2-3 pilot programmes.
Electricity utility activities	More than 800 utilities across the United States offer green power programmes. In 2007, Austin Energy (Texas) was first in the nation for renewable energy sales, followed by Portland General Electric (Oregon??), PacifiCorp (state?), Florida Power and Light, and Xcel Energy (state?). Ranked by customer participation rates, the top utilities are City of Palo Alto Utilities (California), Lenox Municipal Utilities (Iowa), Silicon Valley Power (California), Portland General Electric, and Sacramento Municipal Utility District. In 2007, total utility green power sales exceeded 4,5 billion kWh, about a 20 % increase over 2006.

	Approximately 600,000 customers are participating in utility programmes nationwide. For more information, visit DOE's Green Power Network: www.eere.energy.gov/greenpower/resources/tables/topten.shtml The California Public Utilities Commission set a goal to install 3 000 MW of solar energy and provide 2,9 BUSD in consumer incentives by 2017.
Sustainable building requirements	Local and State: no federal codes, but DOE does produce "Best Practices" guides for sustainable building for both residential and commercial builders. Some states and local jurisdictions have sustainable building requirements.

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. Under the general aegis of "free trade," the North America Free Trade Agreement (NAFTA) with Mexico and Canada permits the sale of PV systems to these markets without duty or trade restrictions, whereas there are duties for modules imported into Mexico from other countries. The US trade with all of the Americas leads to more open markets for the US PV industry.

The United States has not introduced environmental regulations that have affected the deployment of PV. The global warming treaty (Kyoto Accord) has not been approved by the US Congress. Some analysts have reported that PV credits would be less than 0,01 USD per kWh if there were serious efforts to credit PV for mitigation of CO_2 (the carbon tax). In addition, the externalities and hidden costs of conventional energy generation were compared to renewable energy in an analysis covering the 1990–1995 time frame.

Deregulation of the Electric Utility Industry

The US PV industry is benefiting from the federal government's deregulation of the electric utility industry. Utilities had been regulated monopolies in each of the 50 states, but the federal government now requires 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 programmes being proposed and legislated that affect PV. These include, but are not limited to, "green pricing," set-asides for PV, net metering, and interconnection requirements. Because 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 programmes are so diverse that it is virtually impossible to provide a summary.

To provide a detailed overview, DOE has funded the DSIRE (Database of State Renewable Energy) project, managed by the North Carolina Solar Energy Center. The DSIRE project has issued a report, "National Summary Report on State Programs & Regulatory Policies for Renewable Energy," which summarizes more than 120 regulatory incentives in 45 states. The report and the latest updates can be found at www.dsireusa.org. Because 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 more than 3 000 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 (PURPA,1978) and the Utility Restructuring Law (1996). The Utility PV Group (UPVG) programme, which is now complete, was 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 online third-party generation of electricity and allow online interface with grid backup of the system. Not only was the utility required to permit interconnection, but it also had to pay for excess electricity at "avoided" cost. This law, approved by the US Supreme Court, established a large and growing independent power industry. All generation options were allowed. Wind energy and PV benefited from the law. However, PV, with its high installed costs, was too expensive (despite a 10 % investment tax credit and some state tax credits) 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 the deployment of PV and other renewable energy sources.

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 fragmented into generation, transmission, and distribution; power sales; and service. This means that new companies offering lower rates, improved quality, and better service may contact the customer directly. This has opened the door for the sale of "green energy," onsite energy generation, and other services that favor the intrinsically distributable PV option. The renewable energy industry worked with the states that are leading the deregulation process to ensure that options—such as net metering, green pricing, and set-asides for environmentally friendly renewable energy—were included in the restructuring regulations. At the end on 2003, 12 states had enacted restructuring legislation. Seven of the states have provisions for renewable energy through the legislation of system-benefits charges and/or renewable portfolio standards. Efforts directed at restructuring that include renewable energy are still in the early stages. Additionally, the 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 these issues.

4.3 Standards and codes

The interconnection issues associated with PV systems are becoming increasingly important in the United States as more utility-interconnected systems result in two-way power flow. There is a need to include standards for communications with utilities and consumers. The interconnect issues now include maintaining the quality of the power delivered by the utility infrastructure, the need to address the intermittency of PV and other renewable resources in a two-way power flow, and the likely need for energy storage to add value for PV systems and building-integrated applications. Codes and standards represent important activities in the national laboratories and throughout the PV industry, with the DOE Solar Program supporting critical portions of the work. Electrical and personnel safety codes and standards undergo continuous updates and thorough examinations by designers, installers, inspectors, and users in the United States.

The Solar Program support and leadership continues to provide a consensus of utility and industry input into the *National Electrical Code® (NEC®)*, new and revised safety standards, utility interconnect standards, international standards, and hardware certification. In 2007, the industry forum, headed by Sandia National Laboratories, successfully submitted 42 changes in Article 690—Solar Photovoltaic Systems—for the 2008 edition of the *NEC*. The industry forum is now assessing new technologies, new components, and has begun its consensus building for changes for the 2011 *NEC*.

The IEEE has many coordinating committees. The IEEE Standards Coordinating Committee (SCC21) is responsible for continued progress on the IEEE Std. 1547 interconnect standard to address interconnection of all distributed generation and several addendums including communications and intentional islanding. This activity has tremendous representation by the utilities and is supported by the national laboratories through the DOE Solar Program.

Personnel from Sandia continue to update a draft test protocol for performance certification of inverters for PV applications to include assessment of maximum-power-point tracking and array utilization. The California Energy Commission adopted most of the protocol to provide inverter certification for its Emerging Renewables programme in 2005.

The United States actively participated in the International Electrotechnical Commission activities for PV-related standards. Underwriters Laboratories continued to revise the UL1741, "Standard for Static Inverters and Charge Controllers for Use In Photovoltaic Power Systems," to include inverters and charge controllers for all distributed generation and to match the requirements of the IEEE 1547 standard.

Coordination with both the NEC and IEEE interconnect guidelines will remain a valuable activity for finalizing the revised UL1741 standard that now integrates with IEEE1547.1 for anti-islanding and other performance requirements. The Arizona State University Photovoltaic Testing Laboratory (PTL) continues to perform 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, IEEE 1262, IEC 61215 (crystalline silicon module qualification tests), 61646 (thin-film qualification), and PV-3 for silicon and amorphous silicon modules. Some testing also includes the UL1703 requirements. Most of the PV modules qualified today meet reciprocity requirements with European standards. The PTL tests are accepted throughout the world.

Certification of installers and hardware

Certification programmes for hardware and practitioners have been developed in the United States. A certification protocol for PV inverters to better characterize the operation of inverters and to certify the performance relative to power throughput is implemented by the California Energy Commission. Certified inverters must be used in installations subsidized by its Emerging Renewables programme. The programme maintains a list of eligible inverters on its Web site, as well as selected testing information. The weighted California efficiencies and characteristics are available to installers and designers.

The framework for a single national voluntary certification programme for PV installers began in 2003 and continues to be applied. Called the North American Board of Certified Energy Practitioners (NABCEP), the national voluntary practitioner certification programme is now

ANSI- (American National Standards Institute) accredited and has been very successful, with over 420 certified PV installers in the United States. Exams are administered twice each year.

5. Highlights and prospects

Among the top issues affecting the US PV industry and consumers in 2007 were extension of the federal tax credit, a surge in venture capital investment, development of new technologies, and progress on nontechnical issues such as codes and standards.

Extension of the PV investment tax credit in the Energy Independence and Security Act signed in late 2007 was a top policy concern in 2007 and continues to be in 2008. Unless the tax is extended in late 2008, the commercial tax credit will decrease from 30 % to 10 % of the value of a PV system and the residential credit will disappear on 1 January 2009.

In 2007, the United States was far ahead of Europe in terms of investment in new PV technology, which could encourage federal policy to come up to speed in 2008. Most of the investment was in nontraditional solar technology companies such as Nanosolar in California and Konarka in Massachusetts. Investments were also made in large-scale PV installation projects, such as the 14,2 MW utility-scale system installed at Nellis Air Force Base. The US Solar Energy Industries Association reports that venture capital investment in solar was more than 1,05 BUSD in 2007.

States saw improvement in their renewable portfolio standards, with five states establishing new renewable energy-generation requirements and three others adopting voluntary programmes, increasing the numbers of states with renewable portfolio standards to 25 and the District of Columbia. In 2007, the states with expanding programmes to support PV were: New Jersey, Florida, Maryland, New York, Nevada, North Carolina, Washington, and New Mexico.

Plant Expansion: First Solar of Arizona expanded its Ohio and Germany manufacturing capacity to over 300 MW in 2007. First Solar plans to reach 1 GW capacity by 2009. Other US plant expansions in 2007 include Solar World, which is striving to reach 500 MW by 2010; Evergeen Solar, which announced plans to expand its plant in Massachusetts to 70 MW; and BP Solar, which is planning to expand plants worldwide.

The Market: US PV market growth continues to increase by 40 % per year. The growth is primarily due to the federal investment tax credit and state subsidies in California, New Jersey, Illinois, Arizona, New Mexico, and New York. In 2007, quite a few well-known retailers announced plans to install PV systems on their commercial buildings, including Safeway, Whole Foods, Staples, Target, Home Depot, Macy's, and Wal-Mart, bringing PV more exposure and credibility with consumers in the United States. In 2007, Wal-Mart installed a 624-kW system on its Palm Desert, CA, store and has plans to install PV systems at 22 stores in California and Hawaii.

Technology: The United States continues to lead the world in the manufacture of thin-film solar technology. The driving force behind thin-film technology development and manufacturing is the polysilicon shortage that began in 2004. US PV manufacturing grew by 74 % in 2007 and US PV installations grew by 45 % to 150 MW (grid-tied).

The efforts of the Solar America Initiative pay tribute to the potential of solar energy in the United States. The US DOE Solar Energy Technologies Program, through concerted R&D efforts via public/private partnerships, is working to reduce the cost of solar energy systems and to maximize solar energy's promise over the next 10 to 25 years. The aggressive goals of the Solar America Initiative will require the involvement of new participants and unprecedented

innovation. Solar energy represents an opportunity to diversify the US energy portfolio using a clean energy source while creating jobs in high-tech manufacturing, installation, and operation of solar power equipment. Ultimately, the hard work and innovation of the PV industry and its collaborators will contribute to the growth of the US economy and the clean energy industry in the 21st century.

Annex A. Method and accuracy of data

The data in this report are taken primarily from data collected by the Energy Information Administration, the US Department of Energy, the Solar Energy Industries Association, the Prometheus Institute and PV Energy Systems, Inc. These data are believed to be accurate to within ±10 %. The data for the United States are the result of an extensive phone survey by one of the authors (Paul Maycock) with key manufacturers, distributors, and systems integrators. The accuracy of the US installation data is estimated to be within ±10 %. The currency used in this report is US dollars.

Sources for more information:

US Department of Energy's Solar Energy Technologies Program
www.eere.energy.gov/solar/

US Solar Energy Industries Association
www.seia.org

Database of State Incentives for Renewable Energy
www.dsireusa.org/

PV Research at the National Renewable Energy Laboratory
www.nrel.gov/pv/

The National Center for Photovoltaics
www.nrel.gov/pv/ncpv.html

PV Research at Sandia National Laboratories
http://photovoltaics.sandia.gov/

PV Research at Brookhaven National Laboratories
www.pv.bnl.gov/

Annex B. Country information

This information gives the reader some background about the national environment in which PV is being deployed. It is neither guaranteed to be 100 % accurate, nor intended for analysis. R eaders should do their own research if they require more detailed data.

Description	Value	Source
Retail electricity prices – household, commercial, public institution (average retail price)	All sectors: 0,877 USD / kWh Residential: 0,1022 USD / kWh Commercial: 0,935 USD / kWh Industrial: 0,616 USD / kWh	US Department of Energy The Energy Information Administration
Typical household electricity consumption (kWh)	In 2006, the average monthly electricity consumption for a typical household was 920 kWh.	US Department of Energy Energy Information Administration
Typical metering arrangements and tariff structures for electricity customers	These rules vary from state to state.	See www.dsireusa.org and www.irecusa.org for more information. The US Department of Energy also publishes information on utility tariffs and pricing Issues at www.eere.energy.gov/de/utility_tariffs_pricing.html
Typical household income (assumes married household)	In 2006, the median annual household income was 48 201 USD. 2007 stats are not yet available.	US Census Bureau www.census.gov
Annual average mortgage interest rate	30-year fixed: 6,34 % 15-year fixed: 6,03 %	Freddie Mac – Historical Rate Tables http://www.freddiemac.com/pmms/pmms30.htm
Voltage (household, typical electricity distribution network)	Approximately 110 volts AC.	
Electricity industry structure and ownership	Diversified and deregulated—separate generation, transmission, and distribution. Utility ownership varies: Shareholder-owned electric companies. Sell power at retail rates to several different classes of customers and at wholesale rates (for resale) to state and local government-owned utilities, public utility districts, and rural electric cooperatives. Provide about 70 % of all power in The United States. Municipally owned electric utilities. Owned by the city or municipality in which they operate and are financed through municipal bonds. They are self-regulated. Approximately 11 % of the nation's power needs are met by about	

	2 000 municipally owned systems. Federally owned utilities. Agencies of the federal government involved in the generation and/or transmission of electricity, usually sold at wholesale prices to local government-owned and cooperatively owned utilities and to shareholder-owned companies. These government agencies are the Army Corps of Engineers and the Bureau of Reclamation, which generate electricity at federally owned hydroelectric projects. The Tennessee Valley Authority transmits electricity to the Tennessee Valley.	
Price of diesel fuel	2,70 USD/per gallon (2007 average price)	US Department of Energy Energy Information Agency
Typical values of kWh / kW for PV systems (national average range)	Household: 0,23 – 0,32 USD / kWh Commercial: 0,16 – 0,22 USD / kWh Public Institution: 0,13–0,22 USD / kWh	US Department of Energy Energy Information Agency

Annex C. Definitions, symbols, and abbreviations

For the purposes of the National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) with irradiance of 1 000 W / m^2, cell junction temperature of 25°C, and AM 1,5 solar spectrum (also see "Rated power").

Rated power: Amount of power produced by a PV module or array under STC, written as W.

PV system: Set of interconnected elements such as PV modules, inverters that convert module DC into AC, storage batteries, and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organization carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed to provide power mainly to a household or village not connected to the (main) utility grid(s). Often a means to store electricity is used (most commonly, lead-acid batteries). Also referred to as "stand-alone PV power system." Can also provide power to domestic and community users (plus some other applications) via a "mini-grid," often as a hybrid with another source of power.

Off-grid non-domestic PV power system: System used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as "stand-alone PV power system."

Grid-connected distributed PV power system: System installed to provide power to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers, rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises, often on the demand side of the electricity meter; on public and commercial buildings; or simply in the built environment, as on motorway sound barriers. These systems may be specifically designed for support of the utility distribution grid. Size is not a determining feature: while a 1-MW PV rooftop system may be large by PV standards, it is not considered large for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

Turnkey price: Price of an installed PV system excluding VAT / TVA / (European sales taxes) operation and maintenance costs, but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance / replacement are excluded. If additional

costs are incurred for reasons not directly related to the PV system, these should be excluded. (For example, if extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Similarly, the additional transport costs of installing a telecommunications system in a remote area are excluded.)

Field Test Programme: A programme to test the performance of PV systems / components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing or rate-based incentives. These may be implemented by the government, finance industry, utilities, or others.

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.