INTERNATIONAL ENERGY AGENCY

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in the United States 2009

Prepared for the U.S. Department of Energy

by the National Renewable Energy Laboratory

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TABLE OF CONTENTS

Definitions, Symbols and Abbreviations

For the purposes of this and all IEA PVPS 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) – irradiance of 1 000 W/m^2, cell junction temperature of 25^{o}C, 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 d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organisation 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, etc. 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 on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case 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/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. (E.g. 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. Equally the additional transport costs of installing a telecommunication systems 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, rate based incentives etc. These may be implemented by government, the finance industry, utilities etc.

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.

Currency: The currency unit used throughout this report is U.S. Dollars.

PV support measures:

Enhanced feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)
PV requirement in RPS	a mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering (United States)	An agreement between a utility and a system owner who receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing (United States)	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given (usually lower) price
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Electricity utility activities	includes 'green power' schemes allowing customers to purchase green electricity, large-scale utility PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

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 member countries. The European Commission also participates in the work of the Agency.

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

The 21 participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Malaysia (MYS), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey (TUR), the United Kingdom (GBR) and the United States of America (USA). The European Commission, the European Photovoltaic Industry Association and the US Solar Electric Power 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 Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website

www.iea-pvps.org

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme 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 Trends in photovoltaic applications report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the United States National Survey Report for the year 2009. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

1 EXECUTIVE SUMMARY

The infusion of significant public funds in 2009 contributed to photovoltaic (PV) manufacturing, deployment, and research in the United States. The American Recovery and Reinvestment Act of 2009 (also known as the Recovery Act or Economic Stimulus Act) became law in February 2009. Under this legislation, the US Department of Energy (DOE) was allocated 36,7 BUSD to spend on initiatives to create jobs and transform energy use. Other Federal agencies, such as the US Department of the Interior and the US Department of Defense, chose to fund PV projects with some of their Recovery Act money.

Grants to states have also been used to support efforts in PV deployment. Photovoltaic manufacturing received a boost with the Recovery Act provision of a new 30 % investment tax credit for projects that establish, re-equip, or expand manufacturing facilities. Because fewer businesses were seeking tax credits during the economic downturn, the Recovery Act established a programme, administered by the US Treasury that allows companies to choose to receive direct payments for renewable energy projects instead of tax credits.

Of the 183 winning projects to receive manufacturing investment tax credits, 60 were factories supplying the solar energy industry, accounting for nearly a third of the selected projects and 46 % of the awarded funds. These tax credits will create thousands of new domestic solar manufacturing jobs.

Residential installations increased 101 % in 2009 in part due to the removal of the 2 000 USD cap on the investment tax credit.

This influx of government funds, coupled with falling prices for PV components, contributed to an increase in PV capacity installed in 2009 compared to 2008, despite the unfavourable economic and financial climate.

Meanwhile, the DOE partnered with Federal, state, and local government agencies, national laboratories, universities, and private industry to advance PV technology and increase markets. Specifically, the DOE increased support to programmes aimed at developing pilot production of innovative cell technologies, bringing cross-cutting PV products to market, and promoting approaches to grid integration to accommodate high capacities of PV generation.

1.1 Installed PV power

The United States added more than 473 MW of PV generating capacity in 2009, bringing installed capacity to over 1,6 GW. This represented a 34 % growth in capacity. More than 33 000 systems were connected in 2009, compared to about 19 000 in 2008, for a 76 % growth in the number of systems installed.

By the end of 2009 there were more than 103 000 distributed, grid-connected solar electric systems installed in the United States. California represented 49 % of the total increase in capacity for 2009 compared with 64 % in 2008, indicating stronger growth in other states.

The largest utility-scale project that came on line in 2009 was a 28 MW crystalline silicon PV installation known as the DeSoto Next Generation Solar Energy Center in Arcadia, Florida. Commissioned by Florida Power and Light, it is the largest PV facility in North America and consists of 90 000 SunPower Corporation PV modules.

Near Blythe, California, 24 MW of First Solar thin-film PV modules were commissioned in December 2009 and began delivering electricity to Southern California Edison. It is under contract to deliver 50 GWh of power per year for the next 20 years.

All other PV plants installed in 2009 were smaller than 4 MW.

1.2 Costs & prices

Makers of solar panels and their suppliers had to slash prices as scarce credit quickly reduced demand. The cost of PV modules fell by up to 50 %, according to industry analysts.

1.3 PV production

Researchers are still counting market numbers for 2009, but preliminary estimates indicate that the United States accounted for about 9 % of the 8,9 GW of worldwide PV module shipments for the year (by technology: 1 019 MW CdTe, 796 MW a-Si, 156 MW CIGS, and 6 975 MW CSi). About 40 % of US shipments were thin-film modules, estimated at 307 MW. On the demand side, the US consumed an estimated 6 % of the global demand for modules in 2009.

More new PV manufacturing plants for the United States were announced in the first half of 2009 than in the previous three years combined, according to GTM Research. Companies based in Europe and Asia showed increasing interest in US-based PV manufacturing. Few equipment manufacturers received Recovery Act funds in 2009. An exception is Solyndra, based in Fremont, California, which received a DOE loan guarantee of 535 MUSD to construct a manufacturing facility for cylindrical PV systems. The company also received a cash grant (in lieu of a tax credit) equal to 30 % of the installed cost of the factory.

On the other hand, a number of companies announced lower profits, layoffs, and delayed plans for expansion. Recession forced some companies to re-evaluate their business plans. Innovalight, based in Sunnyvale, California, decided to license its technology and is selling its silicon ink to solar cell makers rather than manufacturing its own cells. The company 1366 Technologies in Lexington, Massachusetts, put its factory plan on hold and opted to sell factory equipment to solar cell makers. In another response to a contracting market, some manufacturers decided to buy unfinished solar farm projects and complete them with their own products, thereby creating demand for the product. The production of major manufacturers in the United States is estimated as follows:

First Solar – 132 MW

United Solar – 120 MW

Sharp – 118 MW

Evergreen Solar – 105 MW

Solarworld – 88 MW

Rest – 215 MW

1.4 Budgets for PV

The DOE Solar Energy Technologies Program supports the entire development pipeline through its PV Technology, Systems Integration, and Market Transformation sub-programmes. The annual appropriations process for the fiscal year (FY) 2009 (October 2008 through September 2009) is separate from the one-time injection of funds provided by the Recovery Act. The base FY2009 budget was 145 MUSD for the PV Technologies sub-programme. In addition, the Recovery Act included 16,8 BUSD for the DOE Office of Energy Efficiency and Renewable Energy's programmes and initiatives. About 12 BUSD were awarded by the close of calendar year 2009. The DOE invested about 44,5 MUSD in PV activities in 2009, and 128,5 MUSD was allocated for FY 2010 from annual appropriations. Because much of the research funding is cost-shared with industry, the amount invested in

R&D for 2009 was much greater than this number would indicate. The publicly financed R&D budget for PV increased in 2009 from 136,7 MUSD in 2008. The request for FY2010 was 149,5 MUSD.

2 THE IMPLEMENTATION OF PV SYSTEMS

The PV power system market is defined as the market of all nationally installed (terrestrial) PV applications with a 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.

For the purposes of this report, PV installations are included in the 2009 statistics if the PV modules were installed between 1 January and 31 December 2009, although commissioning may have taken place at a later date.

2.1 Applications for photovoltaics

Off-grid: An estimated 40 MW of off-grid capacity was also added in 2009. Off-grid systems 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. Some off-grid systems are designed as hybrids with diesel or gasoline generators as an integral part of the system.

Domestic: Off-grid PV systems are often used where utility-generated power is unavailable, unreliable (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). Off-grid systems are often best when only small amounts of power are needed such as for small homes in rural areas, boats, motor homes, travel trailers, vacation cottages, and farms. Most systems are rated at less than 1 kW, have several days of battery storage, and usually serve direct current (DC) loads. Some larger systems use stand-alone inverters to power alternating current (AC) loads and may include a diesel generator as backup.

Non-Domestic: Off-grid PV is also used in commercial, industrial, agricultural, and government activities. These include large PV / diesel hybrid power stations where grid connections are impractical. Telecommunications are often powered by PV for telephone, television, and secure communications, including remote repeaters and amplifiers for fibre optics, satellite links, cable links, and small data-link stations. Remote PV systems provide power for sensors and data communication for weather and storm warnings, for monitors of seismic, radiation, and pollution levels, for security phones on highways and in parking lots, and for traffic monitors. PV-powered lighting and signals are numerous along highways and in cities. They are used at bus stops, shelters, and on billboards. They illuminate highway information / construction signs (replacing small-engine generators), serve as inter-coastal navigation aids, and provide supplemental lighting for environmentally friendly corporate headquarters. Off-grid PV is also being used for pumping water into stock ponds and for irrigation control.

Figure 1. Off-grid PV systems are used for telecommunications, water pumping, and homes. (Photos courtesy of [left to right] Shell Solar, NREL, Lange Twins Winery, NREL)

Grid-Connected: The United States installed 433 MW of grid-connected systems in 2009. 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 AC load and then to send excess power to the utility grid. The grid-connected market now surpasses all other markets for new installations. By the end of 2009, there were more than 103 000 distributed solar electric systems interconnected across the United States.

Centralized: Utility-scale PV power plants, the largest of which produce up to 28 MW of DC electricity, generate electricity used by utilities, IPPs, city, state, and federal governments. This sector expanded from 22 MW installed in 2008 to 66 MW in 2009.

Figure 2. DeSoto Next Generation Solar Energy Center in Arcadia, Florida (Photo courtesy of Florida Power and Light)

Distributed: Distributed generation is connected to the grid on the consumer side of the meter, usually at a facility or building that uses electricity and owns or leases the PV generation. The PV systems can be mounted on the ground near the facility, on the building roof, or integrated into the building roof, walls, or windows.

PV can be 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). In 2009, 367 MW of grid-connected, distributed PV systems (158 MW residential, 209 MW non-residential) were installed.

Figure 3. A new 2-MW solar garden powers Mars candy factory, PSEG Solar Source's first project. (Photo courtesy of Mars Incorporated)

Figure 4. A 766 kW PV system on the roof of the Rodney Strong Vineyards building in California (Photos courtesy of Rodney Strong Vineyards)

2.2 Total photovoltaic power installed

States that led in new grid-tied PV installations were California (212 MW), New Jersey (57 MW), Florida (36 MW), Colorado (23 MW), and Arizona (21 MW).

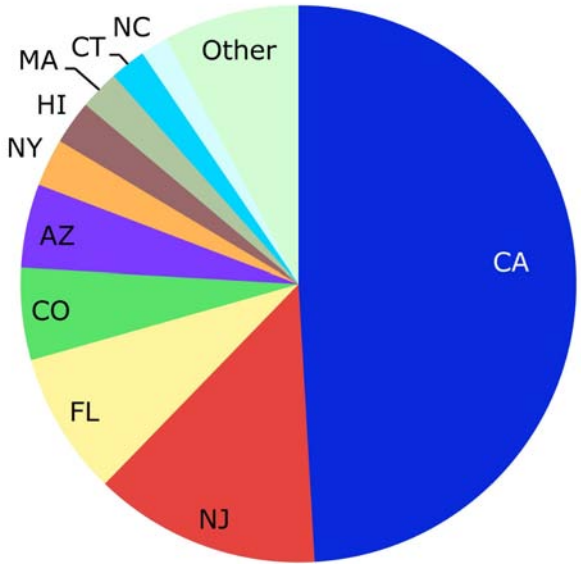


Figure 5. Share of grid-connected installations by state, 2009

Table 1. PV power installed during calendar year 2009 in four sub-markets

Sub-market/ application	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	Total

PV power installed in 2009 (kW)	No data	40 000	366 600	66 500	473 100

A summary of the cumulative installed PV power from 1992-2009, broken down into four sub-markets, is shown in Table 2.

Table 2. The cumulative installed PV power in 4 sub-markets (MW).

Sub-market	1992	1993	1994	1995	1996								2009
Stand-alone domestic													154,0+
Stand-alone non-domestic													256,0
Grid-connected distributed													1 101,6
Grid-connected centralised													130,0
TOTAL (kW)													1 641,6

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

Although the US economy was in turmoil and state legislatures faced severe budget crises in 2009, Federal and state leaders adopted policies to develop cleaner and more diverse energy sources as tools for economic revitalization.

2.3.1 Federal initiatives

The Recovery Act, with its emphasis on clean energy as a way to stimulate the economy, prompted initiatives in nearly every agency of the Federal government. In 2009, the US Department of the Interior and DOE collaborated on a study to identify 24 tracts of land administered by the Bureau of Land Management that are most suitable for large-scale solar energy development. The lands are located in Arizona, California, Colorado, Nevada, New Mexico, and Utah. The Bureau of Land Management has applications for about 470 renewable energy projects representing a combined power capacity of up to 97 GW.

Executive Order 13423, which mandates amounts of renewable energy for Federal agencies, has encouraged some managers of Federal buildings to install PV systems in 2009. For example, the General Services Administration, which administers many public buildings, applied Recovery Act funds to install solar panels on the roof of the Philadelphia Veterans Affairs Regional Office and Insurance Center in Pennsylvania.

The US Commerce Department Patent and Trademark Office began a year-long pilot programme to accelerate the examination of certain "green" technology patent applications by as much as one year. Earlier patenting of these technologies enables inventors to secure funding, create businesses, and bring vital green technologies into use much sooner.

2.3.2 State and local Initiatives

Between September 2008 and September 2009, approximately 40 new solar incentive programmes were created in 19 states, according to the DSIRE incentives database, which is maintained with support from DOE (www.dsireusa.org). Programme incentive levels in 10 states were reduced.

The number of *performance-based incentives* offered by states and utilities increased in 2009. The DSIRE database tallied 39 production incentives in 28 states, with 14 production incentives for solar (excluding feed-in tariffs), 11 feed-in tariffs, and 14 renewable energy credit (REC)-purchase programmes (through which RECs are purchased separately from electricity). California established a law, effective in 2011, that qualifies utilities purchasing electricity through the state's feed-in tariff as eligible for credits under the state's renewable portfolio standards (RPS).

Tradable renewable energy credits (TRECs) were finalized in March 2010 by the California Public Utilities Commission to help utilities comply with the state's RPS. Unbundled REC contracts were also allowed. TRECs will give California's utilities added flexibility to meet the state's RPS and stimulate the development and installation of renewable energy projects in California. Allowing TRECs will also stimulate development outside of California because the RECs do not have to be generated by systems located in the state.

At the close of 2009, *renewable portfolio standards* in 29 states (and in Washington, D.C.) required utilities to procure increasing amounts of renewable electricity and/or RECs. Sixteen of these states (and Washington, D.C.) have specified the amount of solar electricity and/or distributed generation that must be provided.

Net metering policies were in place in 42 states (and Washington, D.C.) at the close of 2009. These policies, which vary widely among states, are an important incentive promoting customer-sited PV and other renewables. Often, system owners in the United State receive less than the retail rate.

New financing options evolved rapidly at the city and county level. Through property-assessed clean energy (PACE) programmes, several local governments offered loans to property owners to help pay for PV systems. These loans are usually repaid via a special assessment on the property, which becomes a lien on the property until the amount is paid in full, usually over many years. Local governments issue bonds or tap existing accounts to fund the loans. Several such programmes sprang from DOE's Solar America Cities efforts. At the close of 2009, 18 states had authorized and approximately 30 municipalities had established PACE programmes.

As of December 2009, 20 US states offered *manufacturing incentives* (mostly in the form of tax credits) to attract construction of PV manufacturing facilities to their areas.

2.3.3 New utility and industry programmes

About 100 MW of utility-driven projects were operating at the end of 2009, but US utilities have announced more than 4,9 GW of large projects for the near future, according to a study from Emerging Energy Research. By December 2009, the United States had roughly 2,4 GW in power purchase agreements for PV, according to an article in Public Utilities Fortnightly. Not all of this capacity can be installed. California utilities PG&E and SCE each announced plans to build, own, and operate about 250 MW of PV plants over the next five years.

Yet to be demonstrated, space-based PV gained its first potential customer when PG&E agreed to buy 200 MW of power over 15 years. The energy from orbiting solar panels would be converted to radio-frequency energy and transmitted to a receiving station in California, where it would be converted to electricity and added to the power grid.

In October 2009, the Interstate Renewable Energy Council (IREC) released updates for its influential rules and procedures for interconnecting and net metering distributed generation. IREC's updates incorporate evolved best practices and compile them into a template regulators and utilities can use as a starting point when drafting local rules.

PV gardens, parks, and plants sized at 1 MW and larger were installed by companies at their sites— including beverage plants, a candy factory, department stores, grocery stores, movie theaters, office towers, and pharmaceuticals plants. Universities are also taking advantage of state incentive programmes to install PV generation systems.

2.3.4 Utility-scale PV projects

The biggest utility-scale project that came on line in 2009 was the 28-MW (DC) PV installation called the DeSoto Next Generation Solar Energy Center in Arcadia, Florida. Commissioned by Florida Power and Light, it is the largest PV facility in North America (90 000 PV modules) and was constructed ahead of schedule and under budget. The DeSoto plant uses SunPower Corporation PV modules and SunPower's proprietary tracking system to increase energy production.

Utility investments were also stimulated in 2009 by the ITC, which was not available to utilities in prior years. According to Solar Electric Power Association (SEPA), innovative utility business models are emerging that include leasing rooftops from customers and mounting PV systems on poles in parking lots. Placing PV modules on power poles has allowed some utilities to monitor power quality while also adding generation on the distribution lines. These PV systems with micro-inverters and advanced wireless communications systems monitor voltage levels and signal power outages.

2.3.5 Market drivers

Third-party financing and Power Purchase Agreements (PPAs) are involved in most grid-connected PV installations. With PPA financing, commercial customers supply a rooftop or other property to host the PV system and agree to purchase the electricity generated at a specified rate (usually at or below current retail electricity rates) for a long term (20 years). The energy company covers all aspects of the PV installation: finance, design, purchase, maintenance, and monitoring. With this arrangement, the customer can buy solar electricity with no up-front investment, and the energy company and investors can apply available tax credits and incentives to the project.

Residential installations also benefited from third-party and PPA financing. Companies offering residential leasing programmes for solar power systems in 2009 helped reduce the homeowner's up-front costs for a PV system.

Community group purchases negotiated up to 48 % off the market price of PV systems for participants. Partnerships between PV suppliers and large employers are offering as an employee benefit the option to buy discounted residential solar systems.

2.4 Highlights of R&D

DOE awarded Recovery Act funds in 2009 to six national laboratories—Argonne National Laboratory, Los Alamos National Laboratory, the National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory, the Pacific Northwest National Laboratory, and Sandia National Laboratories (SNL)—for research and development of PV technologies. Through partnerships with industry and universities, these laboratories worked to carry out the national programme.

2.4.1 Research

Key to advancing PV technology is making DOE research and test facilities available to industry. In 2009, NREL installed an Atmospheric Processing Platform to work with industry to test novel thin-film cells from inks and other solutions. The PV manufacturing industry can also work with NREL to use the Rutherford Backscattering System, which came on line in 2009. The Rutherford measurement system rapidly identifies trace impurities introduced during manufacturing processes that can limit the yield and conversion efficiencies of PV cells. Upgrades are planned for the Distributed Energy Technologies Lab at SNL that will support evaluation of smart inverters and control products developed by industry under the Solar Energy Grid Integration Systems project.

Designing PV products for long life is facilitated by the new Ultra-Accelerated Weathering System at NREL. This solar concentrator provides test results 12 times faster than other accelerated weathering systems and can replicate years of sun damage in just a few weeks. Another channel of Recovery Act funds to PV research and development was the Advanced Research Projects Agency-Energy (ARPA-E), which supports high-risk, high-reward research. PV projects funded under ARPA-E include work on "Direct Wafer" technology to form high-efficiency "monocrystalline-equivalent" silicon wafers directly from molten silicon; a new class of high-efficiency thermoelectric devices and materials powered by waste heat from power plants, industrial processes, and vehicles; and a novel thermoelectric waste heat harvesting device based on large-area arrays of 1-D concentric silicon nanotubes.

2.4.2 Development

Based on the results of the DOE Renewable Systems Interconnection study published in 2008, 12 activities were initiated to develop advanced PV inverters, controllers for components and systems, and energy management systems for distributed PV systems. In 2009, five of these Solar Energy Grid Integration Systems (SEGIS) contractors were selected for additional funding (11,8 MUSD) to develop advanced hardware with communications and intelligence through to the prototype stage. Additional system integration work will include up to 37,5 MUSD for seven projects that will model, test, and evaluate the impact of large amounts of PV power on the reliability and stability of the grid.

Research supported by DOE helped SunPower Corporation to develop a full-size prototype solar panel with minimum cell efficiency of 23 % and a total area efficiency of 20,4 % (confirmed by NREL). Another technology developed at NREL, the inverted metamorphic multijunction (IMM) solar cell, is being commercialized by Emcore Photovoltaics and Spectrolab. The cell's efficiency was demonstrated in 2008 to be 40,8 % under concentrated sunlight.

2.4.3 Demonstration

Strategies for increasing solar energy use are being explored through the DOE Solar America Cities partnership with 25 US cities. Solar experts work with decision makers such as city councils, tax boards, and planning commissions to develop innovative solar financing options, streamline permitting processes, update building codes, and educate residents and businesses about solar energy. In 2009, DOE announced Recovery Act funding for 16 cities to implement 40 promising new projects. Another activity, the Solar America Board for Codes and Standards (Solar ABCs) is ensuring the responsiveness, effectiveness, and accessibility of PV codes and standards.

A sufficient number of trained installation contractors, system designers, engineers, technical salespeople, and code officials is important to successful expansion of PV generating capacity; however, qualified instructors are in short supply. In 2009, DOE awarded nearly 10 MUSD in Recovery Act funds to nine regional solar training centres,

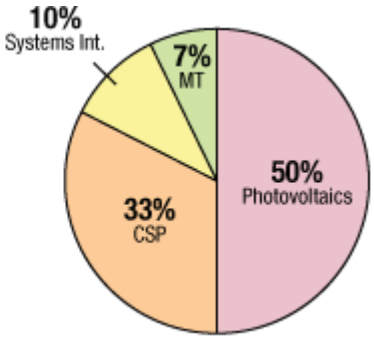
starting a 5-year programme to increase the quality and availability of instruction in solar heating and PV.

The U.S. Department of Energy Solar Decathlon 2009 challenged 20 university teams from four countries to design and exhibit energy-efficient houses powered by the sun. Conducted on the National Mall in Washington, D.C., the competition demonstrated innovative clean-energy technologies, showed consumers the potential of solar-powered living, and helped cultivate a well-trained workforce of future engineers, architects, and entrepreneurs uniquely prepared for jobs in the clean-energy economy.

Figure 6. U.S. Department of Energy Solar Decathlon 2009 all-team photo on the National Mall in Washington, D.C. (Photo by Stefano Paltera/U.S. Department of Energy Solar Decathlon)

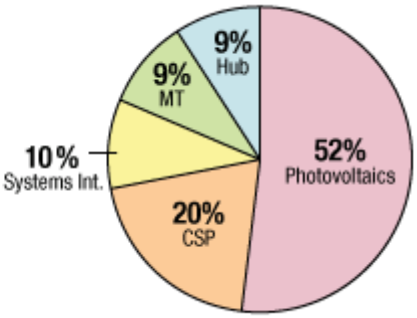
2.5 Public budgets for market stimulation, demonstration / field test programmes and R&D

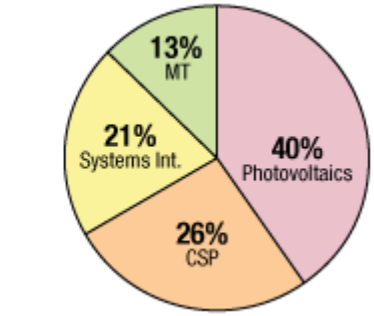
Solar Program	FY 2011 Request
Photovoltaics	$152,000,000
Concentrating Solar Power	$98,200,000
Systems Integration	$30,698,000
Market Transformation	$21,500,000
Total	$302,398,000



Solar Program	FY 2010
Photovoltaics	$128,490,000
Concentrating Solar Power	$49,720,000
Systems Integration	$23,250,000
Market Transformation	$23,540,000
Fuels from Sunlight Hub	$22,000,000
Total	$247,000,000

Solar Program	FY 2009 Recovery
Photovoltaics	$47,600,000
Concentrating Solar Power	$31,000,000
Systems Integration	$24,200,000
Market Transformation	$14,800,000
Total	$117,600,000





Solar Program	FY 2009
Photovoltaics	$124,540,000
Concentrating Solar Power	$24,310,000
Systems Integration	$12,120,000
Market Transformation	$14,030,000
Total	$175,000,000

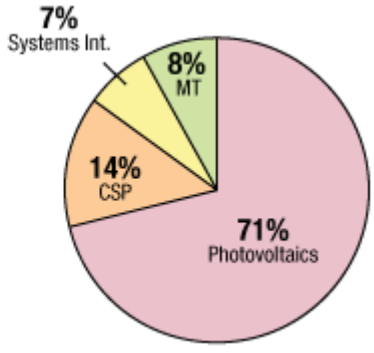


Figure 7. The DOE Solar Energy Technologies Program Budget (all amounts in USD). Source: http://www1.eere.energy.gov/solar/budget.html

Table 3: Public budgets for R&D, demonstration/field test programmes, and market incentives

	R & D	Demo/Field test	Market incentives

National/federal	DOE: 145 MUSD*	44,5 MUSD**	
State/regional			>505,50 MUSD
Total			

* [FY 2010 Congressional Budget Request, May 2009, DOE EERE PV Subprogram p161]
** http://www.energy.gov/recovery/

3 INDUSTRY AND GROWTH

3.1 Production of feedstocks, ingots and wafers

Table 4: Production and production capacity information for 2008 for silicon feedstock, ingot and wafer producers

Manufacturers	Process & Technology	Total Production	Maximum Production Capacity	Product Destination	Price (USD/ kg)
Hemlock Semiconductor Corp.	Silicon feedstock	12 320 tonnes	14 630 tonnes/year	15 % US, 85 % export	70
Renewable Energy Corp.	Silicon feedstock	6 667 tonnes	7 500 tonnes/year	15 % US, 85 % export	70
Solar Recycling Services	Silicon feedstock	2 000 tonnes	2 000 tonnes/year	15 % US, 85 % export	70
MEMC	Silicon feedstock	4 800 tonnes	6 000 tonnes/year	15 % US, 85 % export	70
Total Silicon Used by PV – United States		25 787 tonnes	30 130 tonnes/year		
IN-HOUSE WAFER PRODUCTION					
SolarWorld USA	Wafers	78 MW	100 MW/year	70 % US, 30 % Export	
BP Solar	Wafers	28 MW	40 MW/year	80 % US, 20 % Export	
Evergreen Solar	Wafers	27 MW	59 MW/year	90 % US, 10 % Export	
Solec International (export to SANYO)	Wafers	30 MW	30 MW/year	100 % Export	
SCHOTT Solar	Wafers	11 MW	15 MW/year	70 % US, 30 % Export	
Total Wafers		174 MW	244 MW/year		

All US polysilicon/wafer/ingot companies have overseas presence – Hemlock, MEMC, SolarWorld USA, etc.

3.2 Production of photovoltaic cells and modules

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes, etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

According to Solar Energy Industries Association (SEIA), the United States already has enough manufacturing capacity to meet all domestic demand for solar equipment. Many of the leading solar companies in the world are headquartered in the United States, many have major existing manufacturing operations and many more have plans to set up new facilities in the states to meet growing demand.

Total global PV cell and module manufacture, together with production capacity information, are summarised in Table 5 below. Preliminary estimates indicate that the United States accounted for about 9 % of the worldwide PV module shipments for the year. About 40 % of US shipments were thin-film modules, estimated at 307 MW. On the demand side, the US consumed an estimated 6 % of the global demand for modules in 2009.

Table 5. Global production and production capacity information for 2009

Technology Type	2009 Production (MWp)		2009 Max Capacity (MWp)	
	Cells	Modules	Cells	Modules
CRYSTALLINE				
Standard Crystalline Si	8 082	6 317	13 170	11 065
"Super" Monocrystalline Si	658	658	914	949
Total Crystalline	**8 740**	**6 975**	**14 084**	**12 014**
THIN FILM				
Amorphous silicon	788	796	2 202	2 202
CdTe	1 019	1 019	1 331	1 331
CIS	166	156	660	539
Total Thin Film	**1 973**	**1 971**	**4 193**	**4 072**
TOTAL PRODUCTION / CAPACITY	**10 713**	**8 946**	**18 277**	**16 086**

3.3 Module prices

Table 6. Typical module prices for a number of years

Year	1992						2009
Standard module price(s): Typical							2,20 USD per watt*
Best price							1,85 USD per watt
PV module price for concentration							No data

* Average crystalline Si module price mid-year 2009.

3.4 Manufacturers and suppliers of other components

The market for PV inverters is reported to be 2,4 BUSD in 2009. For the small and medium-size inverter market, SMA represents more than 45 % of that market followed by Ingeteam, Fronius, Kaco, Siemens, and 164 others.

Microinverters are gaining acceptance in residential, commercial and utility-scale applications. Enphase Energy leads the market, shipping more than 100 000 units. Suppliers include: SMA, Satcon, Petra Solar, Tigo Energy, Solar Edge, and NSC.

At the end of 2009, GE introduced a 600-kW inverter that applies GE's expertise and experience from the wind power industry in which it is a leader.

Smart Grid pilot projects are under way in several cities across the United States. Satcon announced a third-generation product that combines the inverter with sophisticated monitoring and communications ability. The new product allows the PV plant and the interconnection to be controlled remotely, even shutting down individual panels if needed. The utility can monitor output to aid in grid management. Other inverter and storage firms adding communication functions to their products include: Apollo Solar, Enphase Energy, Petra Solar, Premium Power, Princeton Power, PV Powered, and SolarBridge.

3.5 System prices

With module prices accounting for up to half of the installed cost of a PV system, these prices are beginning to put downward pressure on system prices. Average installed cost fell roughly 10 % from 2008 to 2009. A summary of typical system prices is provided in the following tables.

Table 7. Turnkey prices of typical applications

Category/Size	Typical applications and brief details	Current prices per W (USD)
OFF-GRID Up to 1 kW	Telecon, signals, lighting, highway signs, navigation aids, irrigation, cottages, boats, RVs, etc.	No data

OFF-GRID >1 kW	Telecom, homes, farms, irrigation, signals, government sites, parks	No data
ON-GRID Specific case	2-5-KW roof-mounted system	7,50–8,50
ON-GRID distributed	Government buildings, warehouses, renewable power set asides for utilities, commercial buildings, factories	5,50–7,50
GRID – CONNECTED (centralized, if relevant)	Power purchase agreements	3,50–5,00

Table 7a. National trends in system prices

YEAR	1992					2007	2008	2009
Price per watt in USD						7,00–9,00	6,50–9,00	6,90

3.6 Labour places

Table 8. Estimated PV-related labour places in 2009

Research and development (not including companies)	
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	
Distributors of PV products	
System and installation companies	
Utilities and government	
Other	
Total	46 000

According to SEIA, overall employment in the solar industry increased by 10 000 people from 2008 to 2009. In addition, the growth in economic activity from the industry and its employees supported an additional 7 000 induced jobs for a total economic impact of 17 000 new jobs in 2009. In total, the solar industry and its supply chain now support roughly 46 000 jobs in the US. With growth expected to continue, that number is likely to surpass 60 000 by the end of 2010.

4 FRAMEWORK FOR DEPLOYMENT (NON-TECHNICAL FACTORS)

Table 10 lists the main support measures (see definitions at start of chapter) for PV during 2009. Further details on these are provided in section 2.2 and 2.3. See www.dsireusa.org for more information on incentives in states.

Table 9. PV support measures

	On-going measures
Enhanced feed-in tariffs (gross/net)	11 states and many municipal utilities considering legislation State: California feed-in tariffs for renewable energy systems increased from 1,5 MW to 2,5 MW in 2009. Vermont initiated a state FIT in 2010. Local: Gainesville, Florida, approved an enhanced feed-in tariff that took effect in 2009.
Capital subsidies for equipment or total cost	Federal: A 30 % tax credit for commercial installations can be taken in lieu of the investment tax credit through 2010. Under the Recovery Act, companies can choose to receive direct payments for renewable energy production projects instead of tax credits. State: California Solar Initiative provides for this in the form of 2,50 USD/W subsidy for residential and commercial projects and 3,25 USD/W for systems installed by governments and nonprofits.
Renewable Energy Credit (REC) purchase programmes purchased separately from electricity	14 states have programmes California adopted Tradable RECs (TRECs) in March 2010 to help utilities meet RPS quotas.
Green electricity schemes	More than 1 million homeowners purchased green certificates (renewable energy certificates). Large purchasers of green power include DOE, federal and state agencies, universities, and businesses. Several dozen companies actively market RECs to residential or business customers. For more information, visit www.eere.energy.gov/greenpower/.
PV-specific green electricity schemes	data not available
Renewable portfolio standards (RPS)	29 states and Washington, D.C.
PV requirement in RPS	State: all states with RPS promoted solar technologies; 13 states and Washington, D.C., included a PV requirement.
Investment funds for PV	Venture capital investment in solar reached more than 3 BUSD in 2008 (no data for 2009).
Income tax credits	Federal: federal investment tax credit of 30 % for commercial and residential systems extended to 2016 and adds provision for utilities to use it. Recovery Act provides a new 30 % investment tax credit for projects that establish, re-equip, or expand manufacturing facilities (about 1 BUSD awarded early 2010).
Net metering	State: available in 42 states and Washington, D.C.

Commercial bank activities, e.g., green mortgages promoting PV	Federal: subsidized commercial loan programme through September 2011. 18 states have authorized and around 30 municipalities have adopted property-assessed clean energy programmes (PACE).
Electricity utility activities	More than 850 utilities (about 25 % of the total) offer green power programmes in 47 of the 50 states. For more information, visit DOE's Green Power Network at www.eere.energy.gov/greenpower/. 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	Federal: no federal codes but DOE does produce Best Practices guides for sustainable building for both residential and commercial builders. State and Local: some states and local jurisdictions have sustainable building requirements.

Feed-in Tariffs:

In March 2009 the Gainesville FIT programme was officially launched with these primary objectives:

- To transform the regional utility's capacity-based incentives to performance-based incentives
- To provide much greater incentive for commercial participation in the utility's solar programme
- To assure a ready supply of renewable energy for the near and far future
- To create both jobs and a strong, renewable energy marketplace.

In the months since the programme's inception, 30 MW of solar capacity has been successfully applied for and reserved through 2017. The utility more than doubled the amount of solar capacity that had ever been installed in the city. Two solar "farms" designed to produce nearly 2 400 MWh of energy each year were under construction and a 2-MW system will operate on the roof of Gainesville's largest shopping center.

4.1 Indirect policy issues

DOE technology acceptance activities, designed to remove barriers to the acceptance of new solar technologies in the marketplace, often make use of experts in the DOE R&D programmes at NREL, Oakridge National Laboratory, Sandia National Laboratories, the Southeast and Southwest Regional Experiment Stations, and private firms. Under this effort, DOE selected 25 Solar America Cities to receive shares of 5 MUSD and important technical assistance from programme experts to help create sustainable solar market infrastructures in their areas. Technical assistance to states and utilities is also provided by other organizations, including the Interstate Renewable Energy Council, the Clean Energy Group, the National Association of Regulatory Utility Commissioners, and the Solar Electric Power Association. The Solar Energy Industry Association in the United States represents solar companies, provides policy and other analysis and information to the industry, and lobbies Congress on behalf of the industry.

Recognizing that technology acceptance is affected by issues of interconnection to the grid, DOE sponsored the Renewable Systems Interconnection (RSI) study, which resulted in 14 published reports. Following recommendations from the RSI study, DOE began to invest up to 24 MUSD (plus company cost share) in Solar Energy Grid Integration Systems projects.

A study was completed to determine the land required for photovoltaics (PV) to provide 100 % of the electricity for each state. While this scenario is extreme, it does provide insight into the potential scale of land-use impacts associated with meeting a large fraction of the nation's electricity requirements from PV.

The US Department of Labor awarded 100 MUSD in Energy Training Partnership Grants under the Recovery Act. Private non-profits applied under one of two categories: national labour management organizations with local networks; or state-wide or local non-profit partnerships. Austin's Electrical Joint Apprenticeship Training Committee (AEJATC), in partnership with Workforce Solutions/Capital Area and ImagineSolar, received 4,8 MUSD to combine utility-scale and commercial solar installation training with immediate employment opportunities in the Austin and San Antonio regions. Up to 1 000 workers will receive electrical and specialized solar installer training within the first 12 months of the contract.

4.2 Standards and codes

The largest of several new testing laboratories opened by national laboratories in 2008, Underwriters Laboratories (UL) announced the opening of its 1 858-m^2 PV Technology Center of Excellence certification facility in San Jose, California. It is the largest commercial laboratory for PV testing and certification in the United States, with 14 test chambers and two solar simulators. Underwriters Laboratories is working to conform the UL1741, "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems," to International Electro-Technical Commission (IEC) standards. It will include inverters and charge controllers for all distributed generation and will 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. 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.

Technology acceptance activities of the DOE PV programme included the creation of the Solar America Board of Codes and Standards (Solar ABCs), which is designed to improve the development of codes and standards that facilitate the installation of safe, high-quality PV systems.

The United States actively participated in the International Electrotechnical Commission activities for PV-related standards. In related work, programme experts also contributed to the first international concentrator qualification document, the International Electro-technical Commission standard 62108: Concentrator Photovoltaic Modules and Assemblies—Design Qualification and Type Approval.

The Arizona State University Photovoltaic Testing Laboratory (PTL) has been converted to a for-profit company. The new company, TÜV Rheinland PTL (TUV-PTL) is a partnership between the TÜVRheinland® (a $1.5 billion USD provider of independent testing, assessment, and certification services for industry) and Arizona State University.

TUV-PTL continues to perform module certification tests based on the accreditation certificate they received from the American Association of Laboratory Accreditation. The TUV-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), IEC 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 TUV-PTL tests are accepted throughout the world.

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 accredited by the American National Standards Institute and has over 420 certified PV installers in the United States. Exams are administered twice each year. Certification of training programmes through ISPQ accreditation of Renewable Energy Training Programs received 45 applications in 2009 and awarded 20 certifications. Audits of 27 applications were being conducted in 2010.

The California Energy Commission implemented a certification protocol for PV inverters to better characterize their operation and to certify the performance relative to power throughput. Certified inverters must be used in installations subsidized by the Commission's Emerging Renewables programme, which maintains a list of eligible inverters as well as selected testing information on its Web site. The weighted California efficiencies and characteristics are available to installers and designers.

5 HIGHLIGHTS AND PROSPECTS

Manufacturers of PV modules and components claimed about 40 % of the 2,3 BUSD of tax credits announced at the end of 2009. The investment tax credits are worth up to 30 % of each planned project, including more than 400 MUSD for materials and component manufacturers. While projects selected for this tax credit generally must be placed in service by 2014, some of the selected projects were completed in 2009, and about a third will be completed in 2010.

According to consultants Black and Veatch, about 2 400 MW of PV power purchase agreements were active in 2009. Connection applications for 14 000 MW of PV have been submitted to the Southwest Power Pool Interconnection, and applications for rights-of-way for 46 000 MW of PV have been submitted to the US Bureau of Land Management. PG&E and SCE plan to build and own 250 MW of PV over the next five years. More than 300 MW of this planned utility-scale construction could come on line in 2010.

ANNEX A: COUNTRY INFORMATION

This information is simply to give the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100 % accurate nor intended for analysis, and the readers should do their own research if they require more detailed data.

1) Retail electricity prices: All sectors: 0,094 4 USD/kWh

Household: 0,104 USD/kWh

Commercial: 0,097 3 USD/kWh

Industrial: 0,066 7 USD/kWh

Transportation: 0,110 1 USD/kWh

Source: US Department of Energy, Energy Information Administration
http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

2) Typical household electricity consumption (kWh): In 2008, the latest year with information available, the average monthly electricity consumption was 920 kWh.
Source: US Department of Energy, Energy Information Administration,
http://www.eia.doe.gov/cneaf/electricity/epa/epaxlfilees1.pdf

3) Metering arrangements and tariff structures for electricity customers vary from state to state.

See www.dsireusa.org and www.irecusa.org for more information.

4) Typical household income: In the third quarter of 2008, the latest year with data available, median annual household income was 46 380 USD.

Source: http://www.census.gov/prod/2010pubs/p70-119.pdf

5) Typical mortgage interest rate in 2009:

30-year fixed ranged from 4,71 % to 5,59 %

15-year fixed ranged from 4,27 % to 5,06 %

Source: Freddie Mac – Historical Rate Tables

http://www.freddiemac.com/pmms/index.html?year=2009

6) Voltage (household, typical electricity distribution network): Approximately 110 volts AC.

7) 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.

Electric cooperatives. Private, independent electric utilities that are owned by the members they serve. Democratically governed businesses, electric cooperatives are organized under the Cooperative or Rochdale Principles, anchoring them firmly in the communities they serve and ensuring that they are closely regulated by their consumers.

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.

8) Price of diesel fuel: 2,46 USD per gallon

Source: http://www.eia.doe.gov/steo