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3.1 OBJECTIVES, STRATEGIES AND INCENTIVES CONTAINED IN NATIONAL AND INTERNATIONAL PROGRAMMES AND ACTIONS

3.1.1 General considerations

The U.S. is accelerating the transfer of PV technology[1] from laboratory level to commercial production and use. Since the federal program is not funded to subsidise every aspect of PV market development, and in order to get the maximum impact from available funds, the U.S. government has instituted a number of partnerships to stimulate the market. These include key players in the process like: government, utilities, industry, end-users, regulators, financiers and the international community. This collaboration is often demonstrated through cost-shared activities which ensure that each participant has a stake in the effort and is dedicated to common objectives. The U.S. national PV program comprises collaborative and innovative efforts addressing a range of research, development, demonstration, and technology delivery issues.

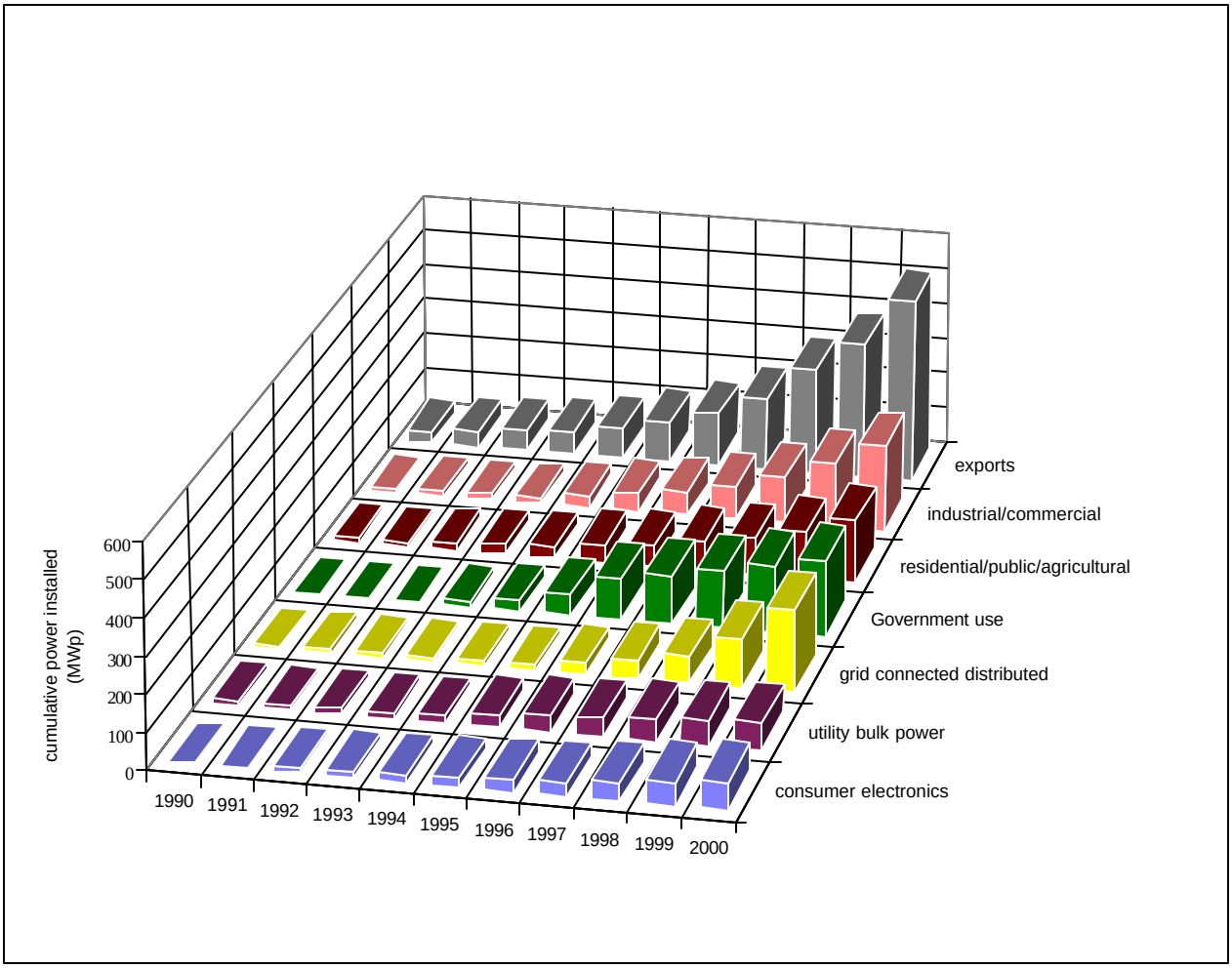
Table 3.1 - Actual and forecasted PV market applications in USA (DOE data)

	PV Market Applications (cumulative capacity installed in MWp)							
year	*consumer electronics*	*utility bulk power*	*grid connected distributed*	*US government*	*residential/ agricultural*	*industrial/ commercial*	*exports*	*TOTAL*
1990	2	12	8	0	12	8	33	75
1991	3	12	10	3	12	15	46	101
1992	12	15	12	3	20	16	58	136
1993	16	16	12	16	28	18	66	172
1994	20	20	15	29	33	33	86	236
1995	25	33	16	58	49	49	115	345
1996	33	44	31	113	58	66	150	495
1997	36	49	49	132	81	90	201	638
1998	49	58	74	156	99	130	296	862
1999	62	66	132	181	130	179	377	1.127
2000	74	74	222	206	173	238	510	1.497

In 1991, the U.S. Department of Energy (DOE), Office of Solar Energy Conversion (OSEC), announced **SOLAR 2000**, its aggressive strategy to accelerate the adoption of biomass electric, photovoltaic and solar thermal electric technologies.

The heart of this strategy is the development of partnerships with key stakeholders in the solar electric field. In the case of PV, this includes the U.S. PV industry, utilities, regulators, international organisations, and federal and state agencies. The SOLAR 2000 collaborative strategy involves coordinated action at each phase of the development cycle, namely: technology development and validation, market conditioning and joint-venture project development. Table 3.1 and figure 3.1 summarise the DOE projections for PV market development under the SOLAR 2000 actions.

Figure 3.1 - Market trends for PV application in USA (DOE projections)



3.1.1.1 Objectives

The main objective of the National Photovoltaic Program[2] is to help the US industry develop photovoltaic technology for large-scale generation of economically competitive electric power in the USA, allowing PV technology to become a significant part of the national energy mix.

The goal is to achieve a profitable and growing industry, reaching 1.000 MW of domestic market and a 500 MW overseas market by the year 2000. To meet this goal the PVUSA Program is working to reduce the price of delivered electricity to 5-6 ç/kWh, raise lifetime to 30 years and increase module efficiencies to 15% for flat plate and 25% for concentrator technologies.

Past effort have emphasised material and cell research to achieve this goals. Today's program follows a balanced plan, which gives equal attention to cost reduction through improved manufacturing, scale-up, expanded markets and technology transfer to industry.

This new approach recognises that PV technology is maturing and has set up therefore the following program priorities:

- more **emphasis on market stimulation** and joint ventures to bring the present technologies into the marketplace,
  - continuation of R&D on the next generation of products,
  - use of feedback from the **marketplace to improve research**.

Much of the recent success can be attributed to the unprecedented co-operation between DOE (Department of Energy), industry, the research community, state and federal agencies, utilities and the financing community. This co-operative activity has emerged from a consultative process involving each of these groups.

3.1.1.2 Strategies

The SOLAR 2000 strategy is multi-faceted, including technology development and R&D, improvements in manufacturing processes, and the accelerated development of commercial markets. This collaborative strategy is aimed to mitigate technical and market barriers to PV commercialisation. Working together participants have made extraordinary progress in laboratory, in manufacturing industry and in marketplace enhanced by positive changes in the federal environment.

For PV, the plan calls for deployment of 1,400 MW of U.S. made PV systems world-wide, with about 900 MW installed in the U.S. and 500 MW installed overseas by the year 2000.

3.1.1.3 Funding and Incentives

A) Industry progress - PVMat PV Manufacturing Initiative:

During the 5 year life of the PVMaT program, more than $100 mioUS$ have been invested, 55 million from the government and an equal amount from industry. Since the program's inception in 1990, significant progress has been made.

In 1991 PVMaT provided 22 US companies the opportunity and resources to identify manufacturing process barriers and approaches to overcome these barriers. In Phase II-A of PVMaT, seven of those companies under cost-shared contracts have improved their manufacturing techniques.

Four other firms joined this group in late 1993 in a second competition (Phase II-B) among US manufacturers. These advancements are not merely staying in the laboratories. Rather the private sector is investing in taking these recent developments into production. Recent announcements of **manufacturing scale-up will more than double US capacity in the next two years**.

B) PVUSA Photovoltaic for Utility Scale Application Program (Utility related initiatives)

The National Utility PV Group (UPVG, now up to 79 utility members) is proceeding with a 50 MW, 4 year, utility PV purchase program with DOE shared-risk to get the process moving.

This program, Project TEAM-UP, would provide the initial part of sustained orderly development process with a target of 50 MW of utility purchases over a four year period.

Under this proposal the USDOE would provide only about 30% of the estimated 513 million US$ program

C) PV-BONUS - Building opportunities in the USA for Photovoltaics

PV-BONUS began in 1992 as a $40 million, cost-shared five year program to develop a market for PV technology in the building sector.

D) Climate Change Action Plan - Item 26

To overcome future obstacles collaborative actions seek a new level of co-ordination and responsibility for both consumer and supplier interests, with a long-term, substantial and reliable commitment of financial and technical support from DOE that will provide $65 million in 1995 and an additional $423 million planned through 2000.

In the frame of strategic actions hereafter illustrated, a more detailed description of the strategic actions is reported:

3.1.2 PV manufacturing and improvement of cell and module efficiencies

Collaborative work has resulted in important technical progress that is accelerating the development of a viable PV industry. Government and industry are co-operating to bring PV technology from the laboratory to prototype production. Through competitive procurements, the PV Program selects the most promising companies and development teams for support. The federal research program[3] has also made a major investment in building a foundation for future technical achievements.

For example the United Solar Systems Corporation is building a 10 MW amorphous silicon triple-junction manufacturing plant in Virginia. A strong factor in siting this facility was the unique economic enhancement package offered by the state of Virginia ($0,75 Watt for modules manufactured in Virginia from 1995 through 1999). Golden Photon one of the PVMaT II-B participants, is building a facility in Colorado capable of manufacturing 2 MW of cadmium telluride power modules annually. Advanced Photovoltaic Systems, another Phase II-A participant recently opened a new 10 MW facility designed for amorphous silicon modules in Fairfield, California, Siemens Solar installed a new automated manufacturing system in California that increases capacity and improves yield.

Several other companies are producing prototype modules using new technologies and are expected to gear up production in the near term. Solar Cells Inc. in Toledo OH recently demonstrated 8% efficient prototypes of 8 sq ft cadmium telluride and completed their first 1 kWp system. Astropower based in Newark, Delaware delivered their first 20 kWp of silicon film modules to Virginia Power. ENTECH improved their concentrator module manufacturing process by fully automating their lens and cell assembly line. In recent months DOE and NREL have announced a major new joint industry/federal laboratory effort in thin film technology development called the Thin Film PV Partnership Program. To be funded with US$120 million during 1995-1999 (plus industry cost-sharing) it represents a sustained focus on thin films.

Over the last several years, the DOE has provided support through a number of initiatives. These include the amorphous silicon research program, the thin film polycrystalline research program,

and in 1990, the most innovative and comprehensive co-operative program devoted to PV ever developed at DOE the PV Manufacturing Technology (PVMaT) program.

3.1.2.1 PV Manufacturing Technology (PVMaT) program.

The PVMaT project is organised as a co-operative activity between DOE (through its Photovoltaic Energy Technology Division) and the U.S. PV industry (through the Solar Energy Industries Association whose membership includes most U.S. PV companies).

This project's focus is on research and development (R&D) assistance to U.S. industry to improve module performance and reliability, and generally lay the groundwork for substantially scaling up U.S.-based production facilities. Each manufacturer faces unique problems in attempting to achieve commercial success.

PVMaT is therefore providing US companies with the opportunity and resources to identify manufacturing process barriers and identify and develop solutions to these barriers.

To achieve the goals of PVMaT, the PV industry and the federal government are investing 100 US$ million and possibly more. The government's share, $55 million has been awarded in a series of contracts aimed at specific needs within the industry. PVMaT is co-ordinated by two committees. The oversight committee is made up of four individuals: one each from DOE, the National Renewable Energy Laboratory (NREL), and Sandia National Laboratories, and a representative of the PV industry.

This committee is responsible for the project's direction and organisation. The implementation committee, composed of representatives from the same organisations, is responsible for the project's day-to-day operations. The National Renewable Energy Laboratory (NREL) is the contracting agency for the project.

The DOE Office of Energy Conservation and Renewable Energies are convinced that PV technology is poised to enter a number of important new markets. After securing its current market foundation in stand-alone applications such as communications, water pumping, lighting, cathodic protection, and off-grid residences, PV systems are entering new markets both in the United States and abroad. For example, new interest has arisen within utilities for shaving peak daytime loads.

To satisfy this growing demand, the PV industry must invest in new large-scale production facilities. **PVMaT ensures that they will be investing in state-of-the-art production technology and capacity increases**. The R&D under the project is broken down into three phases. Phase I has been completed, and Phase 2 and Phase 3 subcontracts will continue over a five-year period beginning in 1992. These phases are outlined below.

Phase 1 - Problem identification

Problem identification Phase 1 of the project was completed in early 1991. The 22 subcontracts awarded under this phase were worth up to 50,000 US$ each. This problem identification phase was designed to single out and order by priority those areas in U.S. manufacturing processes

where R&D was needed to achieve cost reductions in PV module production. Table 3.2 lists the Phase I participants, all of whom were considered for Phase 2 contracts.

Table 3.2 - PVMaT Phase 1 Participants

Company	*Location*
Alpha Solarco, Inc.	Cincinnati, OH
AstroPower, Inc.	Newark, DE
Boeing Aerospace & Electronics	Seattle, WA
Chronar Corp.	Lawrenceville, NJ
Crystal Systems, Inc.	Salem, MA
Energy Conversion Devices	Troy, MI
Entech, Inc.	Dallas/Ft.Worth, TX
Glasstech Solar, Inc.	Golden, CO
Global Photovoltaics Specialists, Inc.	Canoga Park, CA
Iowa Thin Film Technologies	Ames, IA
Kopin Corporation	Taunton, MA
Mobil Solar Energy Corp.	Billerica, MA
Photon Energy, Inc.	El Paso, TX
Siemens Solar Industries	Camarillo, CA
Solar Cells, Inc.	Toledo, OH
Solar Engineering Applications Corp.	San Jose, CA
Solarex Corp.	Rockville, MD
Solar Kinetics, Inc.	Dallas, IX
Spectrolab	Sylmar, CA
Spire Corporation	Bedford, MA
Utility Power Group	Chatsworth, CA
Westinghouse Electric Corp.	Pittsburgh, PA

Phase 2 - solutions

Phase 2 is the solution phase of the PVMaT project and primarily addresses the solution of process-specific problems of U.S. manufacturers. Subcontracted R&D projects under this phase involve U.S. based companies and last for up to three years.

Phase 2 subcontracts were limited by the procurement to up to US$ 55 million over a three-year period, with industry participants contributing a similar amount of money. The initial competition for Phase 2 subcontracts, Phase II-A, was only open to Phase I subcontractors.

A second solicitation for additional process-specific R&D, Phase II-B, was opened to all U.S. companies. Table 3.3 shows the winners of the Phase II-A competition.

Table 3.3 - PV Mat Phase II-A Participants

Company	*Location*	*Technology*
ENTECH Inc.	Dallas Texas	Improvements for Concentrator Module
Mobil Solar Energy Corp.	Billerica, Massachusetts	Thin Edge-Defined Film-Fed Growth (EFG)-Octagons
Siemens Solar Industries	Camarillo, California	Single Crystal Silicon
Energy Conversion Devices	Troy, Michigan	Continuous Roll-to-Roll - Amorphous Silicon
Utility Power Group	Chatsworth, California	Amorphous Silicon - Manufacturing Technology
Solarex Corporation	Newtown, Pennsylvania	Large-Area, Triple-Junction, a-Si Alloy - Production Scale-Up
AstroPower Inc.	Newark, Delaware	Silicon Film, Manufacturing technology

Phase 3 - Teamed R&D for module related common problems

Many module-related problems in PV manufacturing are common to a number of companies, even the entire PV community. These include advanced module engineering related to materials, manufacturing processes, automated manufacturing lines, and efficient assembly and installation. Phase 3 of the project is designed to address these more generic problems. Under Phase 3, teams of U.S. organisations will work together under subcontracts running for one to three years. The R&D will be carried out by research teams led by U.S. industrial organisations and made up of a combination of U.S. industrial firms, utilities, and universities.

Current PV manufacturing activities focus on three types of technologies:

- flat-plate crystalline silicon modules,
- flat-plate thin-film modules,
- concentrator modules.

Therefore, the R&D performed under the PVMaT project is classified under these technologies. They are outlined below, along with possible research objectives to be addressed by PVMaT Phase 2 participants.

- ***Flat-Plate Crystalline Silicon Modules***

  Crystalline silicon is the most common semiconductor material used for PV module manufacturing. Modules made from crystalline silicon consist of individual cells electrically connected and encapsulated in a weatherproof package. To address the goals of the PVMaT project, proposed improvements to crystalline silicon module production include investigating ways to reduce material usage and cost, improving cell and module efficiencies, and significantly reducing labour costs through automation.

- ***Flat-Plate Thin-Film Modules***

  Recent interest in modules made of thin-film semiconductors is justified by the inherent cost benefits, including simpler and faster material deposition procedures to form the PV cells and modules, and the use of much less semiconductor material than is used in crystalline silicon cells. Materials used as the light absorber in thin-film cells include amorphous silicon, copper indium diselenide, cadmium telluride, gallium arsenide, and thin-film crystalline silicon. To address the goals of the PVMaT project, improvements proposed for thin-film module production include investigating methods to increase production rates; investigation the use of lower cost substrate materials; developing mass-production techniques such as roll-to-roll film deposition; improving module conversion efficiencies; developing new, lower cost deposition techniques- and reducing labour costs through automation.

- ***Concentrator Modules***

  Concentrator modules use special lenses to intensify the sunlight falling on banks of small, highly efficient cells. The idea behind this approach is to cover the module surface area with the cheaper lens materials rather than the more expensive solar cell. To achieve an adequate electrical output using this technique, high efficiency cells must be used. This makes the cost of the electricity generated by concentrators comparable to that of the flat-plate designs. Improvements proposed for concentrator module production to address the goals of the PVMaT project include investigating ways to improve module housing production, developing techniques for mass producing the lenses, and reducing labour costs through automation.

3.1.3 Marketplace initiatives

Eliminating market barriers is a critical component of the DOE's program to accelerate the entrance of the photovoltaic technology into the marketplace.

Over the last few years significant progress has been made in influencing the regulatory and policy environment as it relates to renewable energy.

Public utility commissions in many states are establishing or evaluating changes in traditional procedures so that utilities in their service area have a stronger incentive to include PV as an option.

For example the Arizona Corporation Commission requires electric utilities to consider photovoltaic systems as an alternative to line extensions as part of their integrated resources plans. The Vermont Public Service Board is also considering amending its extension policy to encourage PV options by incorporating environmental costs into resource planning decisions or by giving some preference to renewable energy technologies in supply planning or building schemes.

Making the connection between laboratory and industrial advances to value added services for final customers has long been a major hurdle to PV's expanded use.

To address this barrier DOE has supported conferences, symposia and targeted workshops to stimulate feedback and active involvement from the stakeholders that influence final purchases and applications.

The objective of these efforts is to start a collaborative effort that will provide **feedback to research and development** efforts to improve product design, improve the identification and marketing of high-value applications for end-users and manufacturers and better inform potential users of PV capabilities and value.

3.1.3.1 Utility Partnership - PVUSA Photovoltaic for Utility Scale Application Program

In co-operation with investor-owned and municipal utilities, regulatory agencies, and states, the DOE has decided to support a major initiative to stimulate greater near term deployment of PV in the U.S. utility marketplace. Up to 200 MWp of installed capacity are to be anticipated through the year 2000.

The Department of Energy, in conjunction with a number of interested parties related in the electric utility business, joined forces to form a group called PV4U (PV for Utilities). This group is composed of mainstream utilities, regulators, PV industry, state, local, and federal government, trade associations with the common purpose of attacking the barriers preventing the adoption of PV on a widespread basis. this group first met in Tucson, Arizona in December 1991. The workshop was entitled, PV for Utilities: Developing a National Photovoltaic Strategy for Utilities and intended to stimulate interest in accelerating the commercial availability of photovoltaics for utility applications. Subsequently, given the shorthand of Photovoltaics for Utilities, or PV4U, a key result of the workshop was the recognition of the need to establish a group of potential utility buyers and users of PV systems to help develop implementation strategies for the sharing of risks in initial efforts to commercialise PV system.

In the US four major market sectors provide the electric power to ultimate consumers, namely:

- **Private, or investor-owned utilities**: three-fourths of all ultimate US utility customers are served by 213 of such investor-owned utilities;
- **Public power systems (mostly municipal systems):** about 15% of US customers are served by 2,000 non-profit community-owned public power systems;
- **Rural electric co-operatives:** the remainder of US customers are served by 924 rural co-operatives;
- **Cogenerators/independent power producers:** The 2.800 independent US power producers are not considered utility companies and generally only serve themselves. They represent an important growing sector, accounting for 75% of all new electric capacity additions since 1980. In addition, some 13 federal agencies (such as the Western Area Power Administration) supply power at wholesale to other utilities.

Since the 1991 Tucson meeting, numerous discussions among the Electric Power Research Institute (EPRI), the three electric utility trade associations - American Public Power Association (APPA), Edison Electric Institute (EEI) and National Rural Electric Co-operative Association (NRECA) - resulted in the creation of the **Utility Photovoltaics Group (UPVG)**. The overall

mission of the UPVG is to expedite and facilitate the deployment of cost-effective and emerging high value applications of photovoltaics for the benefit of electric utilities and their customers.

DOE is offering R&D funds, technical expertise, support for developing markets and funds and technical assistance for cost-shared demonstration projects. Industry and regulators may provide various means for support. For utilities, the expectation is that market demand will be created beginning with early, cost-effective niche applications including the capital and support for technology demonstrations and project implementation. It is in these latter roles that the function of the UPVG resides.

Currently the UPVG is composed of 79 members (and growing) representing all sectors of the electric utility industry and over 25% of total US electricity sales. Uniting broad-based utility experience with PV will create the necessary conditions for benefit characterisation, methodology development, regulatory treatment and operational requirements. Completing this effort are state-related initiatives. There are four principal objectives:

- provide technical, informational and other support necessary to maintain and expand state activity through the state working groups;
- develop, reach consensus, finalise and implement the state working groups' action plans;
- integrate and co-ordinate the work of the state working groups with the national program UPVG, DOE and other organisations;
- co-ordinate and support the development of the analytic foundation for a commercialisation path with potential for sustained PV mass-buy programs with states.

The UPVG effort is but one component in a broader commercialisation strategy being supported by DOE.

The utility component of the DOE SOLAR-2000 strategy is the **Photovoltaics for Utilities (PV4U) initiative,** which is supplemented by hardware demonstration by the DOE national laboratories, EPRI, and the utilities themselves, and aims to improve communications with and input to state regulators and other state organisations. DOE foresees this market acceleration occurring through **enhancing market demand, developing appropriate products and improving the market and regulatory environment**.

The UPVG, organised specifically to represent the potential buyers' perspective, is self-managed by the electric utilities themselves and functions autonomously. PV4U, however, has a broader function in outreach and co-ordination with non-utility, supplier and state working group.

Thus while PV4U and the UPVG have different constituencies and organisational structures, they share the broad aim of successful PV commercialisation.

3.1.4 Building Market Sector: opportunities in the USA for Photovoltaics (PV-BONUS)

Approximately two-thirds of the electricity generated in the United States is consumed in residential, commercial, and institutional buildings[4]. Major electricity uses in these buildings include lighting, air handling, air conditioning, pumping, and refrigeration. PV systems can potentially provide power for a variety of functions in a building environment. These functions can be classified as follows:

- **Architectural functions**, where the PV array does double duty as roof, a wall, or a window. Increasing the value of PV by making it look and act like a building material (which happens to generate electricity) is a key to the buildings industry adopting the technology.
- **Demand-side management** (DSM) functions, where the PV system is designed to provide power to partially offset a building's contribution to peak utility loads. Electric utilities are placing increasing emphasis on DSM as an alternative to building new generating, transmission and distribution capacities. PV buildings can provide utilities with yet another DSM option, with a resulting increase in value for the PV system and for the PV-building owner.
- **Control functions**, where the PV system provides the primary energy for air movement (fans), fluid movement (pumps), or power for "active" windows and walls (as in PV-powered electrochromic windows or PV-powered variable insulation systems). Many PV-control-function applications could be direct current eliminating the need for most interface electronics. The match of the solar resource to the load requirements is a key in control-function applications.
- **Hybrid functions**, where the PV system supplies as a portion of the energy in conjunction with "conventional" equipment such as heat pumps, air conditioners, or lights. Advanced, electronically controlled products, such as variable-speed heat pumps and high-efficiency electronic ballasts for fluorescent lights, could be easily modified to directly accept PV power. Other hybrid options that include storage are also possibilities. Cost effectiveness in hybrid applications can come for multiple uses of the electronics and coincidence between PV output and time-of-day rates (additionally assisted by utility DSM incentives). Hybrid systems also provide an opportunity for PV market entry into the existing buildings-supply community by considering PV as an option to an existing product line.

Appropriate product and system designs can open up major markets in the residential, commercial, and institutional buildings sectors. The two keys to unlocking this opportunities are value enhancement, through synergistic product application, and co-operative development and demonstration among industry stakeholders (the team members).

The PV-BONUS initiative is directed at creating these keys, and represents an infrastructure and product development program.

The objective is to develop a U.S. PV buildings industry based on the delivery of reliable, cost effective PV products by PV and building equipment suppliers to informed participating builders for use in residential commercial, and institutional buildings.

This product and infrastructure development will be accomplished through a phased, financial assistance program. The three phases of the initiative are

- ***Concept Development (Phase 1)***
  Task include developing both the proposed product and demonstration building(s); a market assessment of the proposed product, including target selling prices, target market sectors, size estimates for each market sector, planned distribution mechanisms as a function of penetration; a detailed development and testing plan; and projected impacts in terms of load control, direct energy supply, or improved energy efficiency the PV-integrated building system.

- ***Product Development and Testing (Phase 2)***
  Tasks include fabricating prototype components, developing and testing a system-level detailed design, conducting the system-level test in co-operation with NREL, and developing detailed drawings of the PV product integrated into the proposed demonstration building.

- ***Field Demonstration and performance verification (Phase 3)***
  Tasks will implement the new systems and provide for a period of monitoring to verify the technical and economic performance of the product and the building. It is expected that viable products will be offered commercially on the market while field verification continues.

The program was supported by technology validation (testing) activities at NREL and a co-operative government-industry education training program.

The emphasis of the initiative during 1993 was on the details of concept development, since deemed critical to fully develop the foundations of the longer-term program.

Toward that end, several specific tasks were defined intended to lead to sound technology and business decisions in the future. Briefly, those tasks are reviewed as follows:

- *Product Conceptual Design*
  Conceptual design of products in sufficient detail so as to identify all electrical, mechanical, and structural interface requirements with other components and with the proposed building, by identifying all systems-level interface, design, and performance issues.

  Included are also identification of research and product development issues and alternative approaches, as well as near and midterm manufacturing cost estimates;

- *Building Conceptual Design*
  Conceptual building design (or identification of existing building type) in sufficient detail to identify all electrical, mechanical, and structural interface requirements with the proposed PV building product; estimates of building energy performance, with and without the proposed PV building product; evaluation of building-level cost and performance trade-offs involved with integrating the proposed PV-building product; identification of research, product development, and performance verification issues that must be resolved prior to committing to the use of the proposed PV-building product; and develop a monitoring, testing, and performance verification plan for the integrated PV building system.

- *Market Assessment*
  Using the information developed in the product and building conceptual designs, development of a market assessment of the proposed PV building product. Issues that must be addressed in this assessment include an evaluation of the market potential for the product (by building sector and type) as a function of wholesale price, product maturity, and level of manufacturing commitment; an evaluation of the competitive environment facing the introduction of the proposed product; the development of a market entry strategy (how will the product be introduced into the market, assuming a successful development and demonstration program, and what is the planned distribution network); and the identification of education and training needed to help assure successful market entry (installers, building code officials, aftermarket repair, and maintenance).

- *Product Development and Testing Plan*
  Based on the product and building conceptual designs, and the market assessment, development of a detailed product development and testing plan, including the fabrication and testing of preproduction prototype components, the fabrication and testing of a scalable system level design (if appropriate), the development of a manufacturing flow diagram for demonstration and market entry production levels, technical and institutional milestones that must be met to assure market acceptance of the product, and resource requirements to carry out the product development and testing plan.

- *Business Development*
  In parallel with the technology and market activities just outlined, a specific purpose of Phase 1 is to encourage the initial formation of individual and business relationships that are the keys to commercial success. Activities conducted under this task included therefore team development, through the integration of product and end-user elements; the assignment of individual and organisational responsibilities; a conceptual outline of a business strategy; and a conceptual outline of a finance strategy for product and market development, including business relationships among team members.

The establishment of industry teams with the knowledge and capability to pursue the development and marketing of PV building products from the research stage, through the development stage, and into commercial application, is a key element of achieving the goals of PV-BONUS.

Because the PV-buildings products envisioned will have to be integrated into the buildings-product-supply industry if commercialisation is to be successful, a product supply team must, as a minimum, be composed of a PV manufacturer and a building-equipment-product supplier.

To ensure that the products designed and developed can be integrated with actual buildings in a technically viable, cost-effective manner, end user team members should include members that represent building architecture, engineering, construction, development, marketing, and ownership perspectives.

Because the introduction of PV into buildings brings an entirely new perspective to residential, commercial, and institutional buildings that may affect the future policies and planning of the

surrounding communities, local electric utilities and state energy offices will also be involved in the initiative.

3.1.5 US Government and Federal Authority Partnerships

3.1.5.1 Department of Defence

The US Department of Defence (DoD) is the largest consumer of energy in the world. Particularly striking is the widespread use of diesel-burning generators which often is many times more expensive than PV now.

Recently the Federal Government allocated funds specifically designed to address environmental problems that were related to the military. DOE, in co-operation with DoD was recently awarded 4 million US$ from the strategic Environmental Research and Development Program (SERDP).

In addition the DoD is planning to spend as much as 10 million US$ for PV Projects from a separate budget item in the military Construction Program.

The DoD partnership with DOE has instituted a program to bring about 100 MW of PV by 1996. It is anticipated that the bulk of this market will occur through the replacement of diesel generators which are in widespread use. A complementary benefit attributed to PV is the resulting reduction in air emissions. In year 1994 the DoD initiated actions to procure approximately 1,2 MWp of PV, of which most are PV-diesel hybrid systems with one grid supplement project.

3.1.5.2 Power Marketing Administration

There are a number of federally owned power generating and marketing agencies, called Power Marketing Administration PMA, in the U.S. that serve as a wholesale and retail platform for independent power generators.

There are similar opportunities for PV as there are in the non-federal utility sector. DOE is working with these PMAs to minimise the barriers to the utility industry.

3.1.5.3 State Energy Offices

Energy offices in the respective US states are beginning to be more and more influential in determining each respective states' position regarding energy conservation, utility matters, introduction of renewable energy technology, and energy policy.

There is an active program of co-operation with these various state offices that has already served well.

Recently, the state of Florida was the scene of immense destruction from Hurricane Andrew.

The Florida State Energy office, in co-operation with local agencies, and the Department of Defence were able to help in through PV the immediate aftermath with emergency communications in the hurricane ravaged areas.

3.1.6 International Partnerships

Developing markets overseas is an important component of SOLAR 2000's strategy of installing 500 MW of U.S. made PV systems overseas by the year 2000. To further this goal, the DOE is involved in several partnership projects in the international area.

3.1.6.1 FINESSE Project

FINESSE (Financing Energy Services for Small-Scale End-users - see also the chapter 1) brings together the governments of the U.S. and Netherlands, the World Bank, the private sector, host countries and others to overcome financial and institutional constraints to PV in Southeast Asia. To date, over 800 million US$ in PV and other alternative energy opportunities have been identified and are being pursued in the Asian region, and efforts are underway to develop comparable projects in the Latin America and Caribbean region.

Project FINESSE is aimed at enhancing project opportunities for PV and other alternative energy technologies in the developing world by working closely with international financing institutions and host countries. It is specifically dedicated to alleviate arising from traditional lending sources, which typically fund large scale coal and hydro plants, but have not met the needs of the developing world for alternative energy sources and that alternative energy technologies offer a new solution for load reduction and rural electrification. This project has been established in conjunction with the World Bank, the United Nations Development Program, and host countries including Malaysia, Thailand, Philippines and Thailand.

3.1.6.2 America’s 21st Century Program

America's 21st Century Program centralises the various efforts of the DOE, the national laboratories (NREL and Sandia), the Committee on Renewable Energy Commerce and Trade (CORECT), and U.S. industry under one program to enhance co-operation and co-ordination. America's 21st Century is a joint venture program focused on developing a sustainable alternative for meeting the energy needs in Latin America and the Caribbean region (LAC) using renewable energy and energy efficiency. A number of U.S./LAC renewable energy projects were already being supported or planned by DOE. To improve the management and co-ordination of these activities, these programs are being centralised under the America's 21st Century Program Umbrella.

3.1.6.3 The Mexico-U.S. Renewable Energy Co-operation

Program (PROCER), is an informal working level program. through this co-operative program, DOE is providing training and technical assistance to Mexican counterparts, co-operating in resource assessment efforts and financing issues, and promoting involvement of the U.S. renewable energy industry in the country. This co-operative program is intended to support the sustainable use of renewable energy technologies in rural areas, principally through the National Solidarity Program (PRONASOL)- a public works and anti-poverty program with a strong emphasis on providing energy and other services in rural areas. Due in part to PRONASOL, approximately 18.000 PV systems have been installed in Mexico, including solar home systems, health clinics (600), schools (700), telecommunications systems, and cathodic protection.

3.1.6.4 Brazil

Another partnership program is the Brazilian Rural Electrification Project, which resulted from the meetings held simultaneously with the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June of 1992.

The program is linked to longer-term economic development plans for Brazil.

The Brazilian Government hopes to curb the exodus of people from rural areas into the cities by electrifying villages to improve their standard of living. The ultimate goal of the project is to leverage World Bank financing for a project to electrify 500.000 residences, schools, and health clinics.

The first phase of this three-phase project will provide electricity to 1.000 homes in the Brazilian state of Pernambuco, and 1.000 homes and a model village in the state of Ceara using PV and PV-hybrid systems. DOE currently plans to support the project with training and technical assistance and possibly with partial funding for the initial demonstration phase.

Because of its modularity, and short lead time, PV technology has the potential to bring power to millions of people decades ahead of the grid expansion schedule.

3.1.6.5 A new Federal Environment - Action Item 26

The current federal policy environment is much more supportive of accelerated expansion of PV in the mainstream energy market. First the new administration has outlined a technology policy Technology for America's Economic Growth: a New Direction to Build Economic Strength, that puts priority on the accelerated development of environmental technologies.

The Clinton administration is also stressing the relationship between the environment, economic development and international competitiveness. Second the Energy Policy Act of 1992 includes several new incentives for renewables and energy efficiency. These range from export promotion to increased emphasis on manufacturing.

In October 1993 President Clinton released the Climate Change Action Plan which outlined a strategy composed of forty-four action-items, to return US greenhouse gas emissions to 1990 levels by the year 2000.

The Action Items focused on making near-term emission reductions while enhancing prospects for economic growth and job creation. Action Item 26 directly involves the PV program and is an integral part of DOE's strategy to bring PV to commercial readiness.

The program's successful introduction of PV as a viable alternative for many conventional fossil fuel applications has continued and will continue to be achieved through co-operation between DOE, industry, the research community, state and federal agencies, utilities, and the financing community. There are two principal areas of emphasis:

- market stimulation which is direct improving the understanding of the range of benefits of renewable energy options and identifying and mitigating discriminatory factors in the existing policy and regulatory framework;
- Joint Venture Projects which validate new technologies and leverage private-sector resources to help absorb high up-front costs associated with new technologies.

Action Item 26 addresses market conditioning and joint venture projects by promoting the accelerated market acceptance of renewable technologies through DOE collaboration with industry.

Collaboration will take the form of organised groups of stakeholders working with DOE to resolve commercialisation barriers, to participate in cost-shared projects and to co-ordinate large-scale purchases of near-commercial PV systems. These efforts provide industry with assured demand that can justify investments in new manufacturing and technology.

The objective is to increase production and lower costs of PV by stimulating market demand, as well as by taking charge of commercialisation and market barriers.

3.2 OVERVIEW OF THE USA PV INDUSTRY

The following tables and graphs provide an overview over the present situation of PV industries in the USA.

Table 3.4 - Number of US producers and production lines for PV technology

Technology	*Manufacturing Facilities*	
	number	*capacity*
Crystalline silicon	7	28,0
Ribbon	1	1,0
A-Si	5	22,0
CdTe	2	10,0
CIS	4	-
Other	5	0,3
TOTAL PRODUCTION LINES	**24**	**61,3**
Only modules assembly	4	-
TOTAL PRODUCERS	**21**	

Figure 3.2 - Distribution of number of US PV manufacturers per technology (1994)

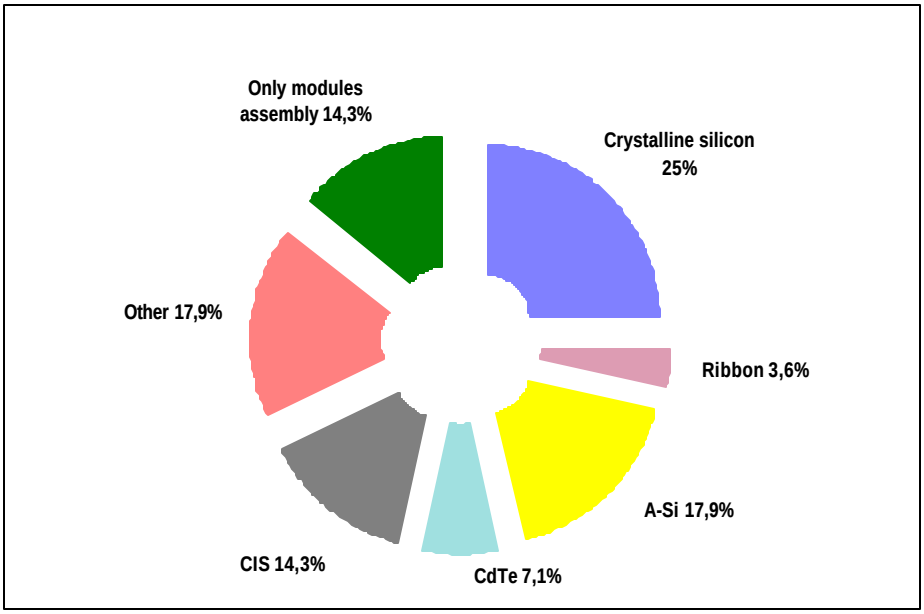


Figure 3.3 - Production capacity distribution of PV manufacturers per technology in the USA (1994)

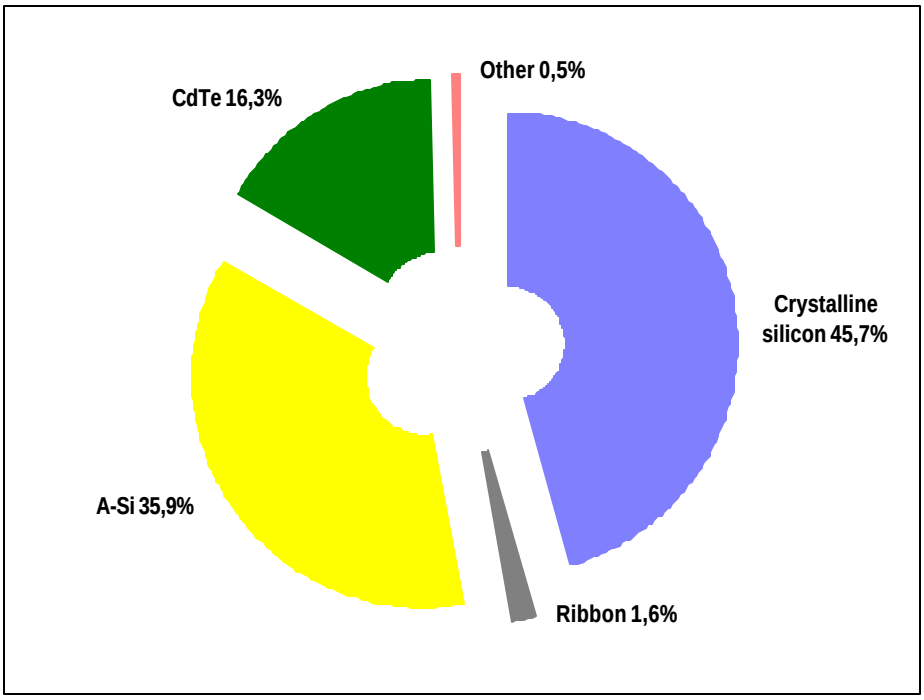
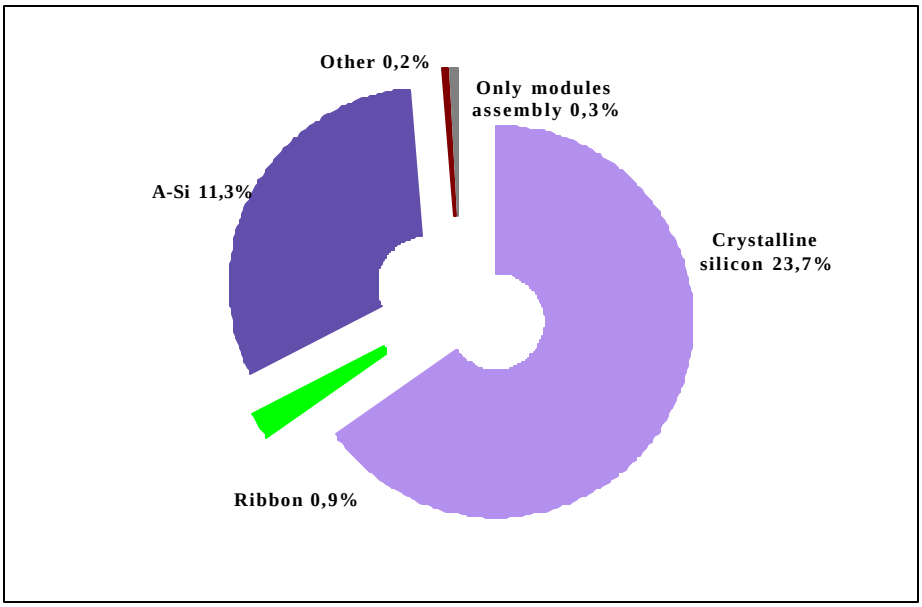


Table 3.5 - US trends of shipments, growth rates and world market share of US PV industry

PERIOD	*SHIPMENTS*			*MARKET SHARE*
	Total	*Annual growth*		%
	kWp	*kWp*	*%*	
1987	9.250			33,3%
1987- 1988	13.000	3.750	40,5%	38,3%
1988- 1989	14.400	1.400	10,8%	35,2%
1989- 1990	16.100	1.700	11,8%	33,5%
1990- 1991	16.980	880	5,5%	31,9%
1991- 1992	18.400	1.420	8,4%	32,5%
1992- 1993	22.330	3.930	21,4%	36,4%
1993- 1994	25.400	3.070	13,7%	36,4%
AVERAGE PERIOD VALUES			**16,4%**	**34,7%**

Figure 3.4 - Distribution of world market shares among USA PV manufacturers per technology (1994)



Note: Given percentages do not sum up to 100% since the world market shares of only US manufacturers are presented

3.2.1 The PV Manufacturing Industry in the USA

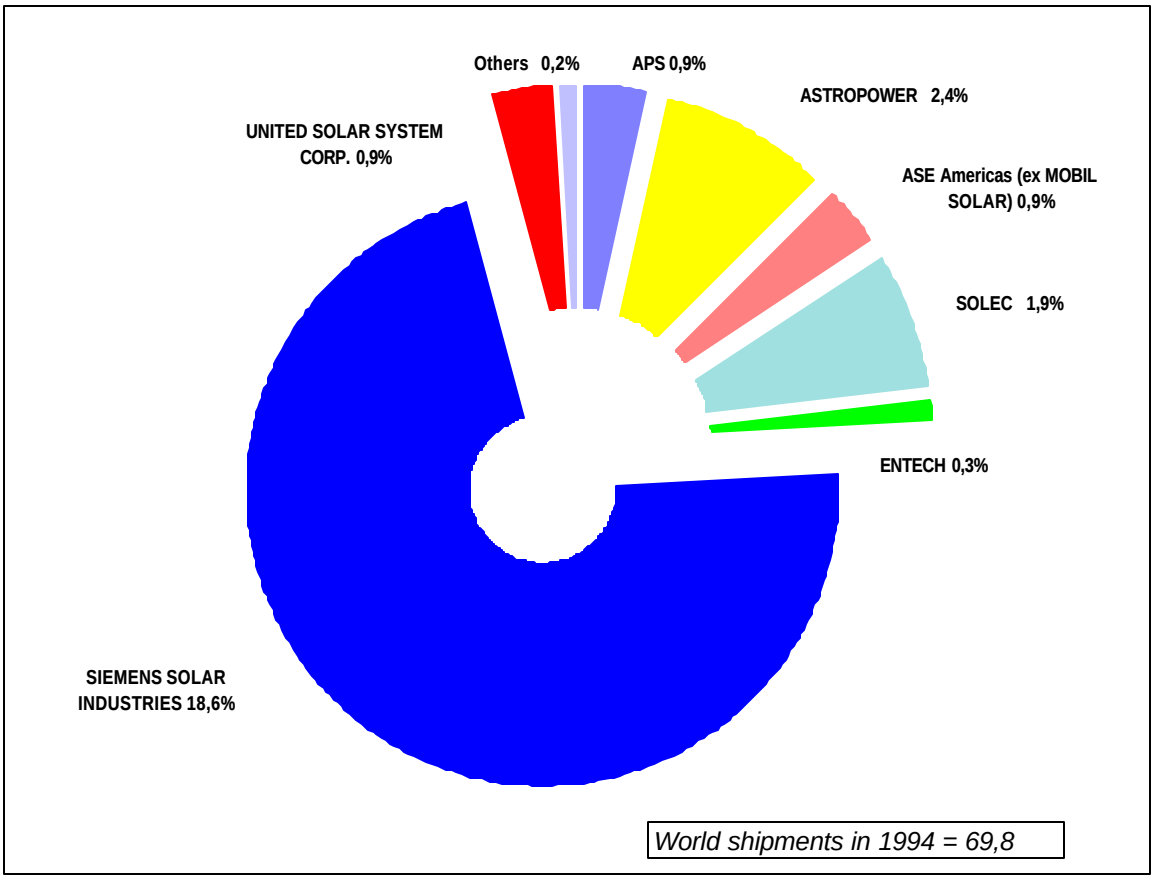
Table 3.6 - Overview of main PV producers per technology in the USA

PRODUCER	*CELLS AND MODULES*						*Only Modules Assemblv*	*Capacity 1994*
	Crystall. silicon	*Ribbon*	*A-Si*	*CdTe*	*CIS*	*Other*		*(in MWp/yr)*
AMONIX							*	
APS			*					10,00
ASEC	*					*		
ASTROPOWER	*							2,00
						*		0,30
ENTECH							*	0,03
EPV					*			
GOLDEN PHOTON				*				
HUGHES-SPECTROLAB	*					*		
ISET					*			
ASE Americas (ex MOBIL SOLAR)		*						1,00
PHOTOCOMM							*	
SIEMENS SOLAR INDUSTRIES	*							18,00
			*					7,00
					*			
SOLAR CELLS				*				10,00
SOLAREX	*							6,00
					*			
			*					2,00
SOLEC	*							2,00
SUN POWER	*							
TEXAS INSTRUMENTS						*		
TIDELAND SIGNAL							*	
UNITED SOLAR SYSTEM CORP.			*					3,00
UTILITY PV POWER GROUP			*					
VARIAN-KOPIN						*		
TOTAL	**7**	**1**	**5**	**2**	**4**	**5**	**4**	**61,33**

Table 3.7 - Estimated market share and trends of main PV producers in the USA

PRODUCER	*ESTIMATED MARKET SHARE*								
	1987	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*TOTAL*
APS	2,9%	8,0%	0,7%	0,6%	0,4%	0,8%	0,4%	0,9%	1,4%
ASTROPOWER		0,3%	0,5%	0,8%	0,8%	1,1%	1,4%	2,4%	1,1%
ENTECH			0,7%	0,1%	0,1%	0,1%	0,2%	0,3%	0,2%
ASE Americas (ex MOBIL SOLAR)	0,2%	0,3%	0,1%	0,1%	0,4%	0,5%	0,3%	0,9%	0,4%
SIEMENS SOLAR INDUSTRIES	17,6%	20,6%	18,3%	16,6%	16,9%	16,8%	20,4%	18,6%	18,2%
SOLAREX	7,2%	6,2%	9,3%	11,4%	9,8%	10,1%	10,3%	10,5%	9,7%
SOLEC	1,4%	1,8%	2,2%	2,3%	2,3%	2,3%	2,5%	1,9%	2,1%
UNITED SOLAR SYSTEM CORP.	0,7%	1,2%	1,7%	0,6%	0,4%	0,7%	0,8%	0,9%	0,8%
Others	3,2%	4,3%	2,3%	1,5%	1,8%	0,4%	0,4%	0,2%	1,0%
TOTAL	**33,2%**	**38,3%**	**35,2%**	**33,5%**	**31,9%**	**32,5%**	**36,5%**	**36,4%**	**34,7%**

Figure 3.5 - Estimated world market shares for major US PV suppliers (1994)



Note: Given percentages do not sum up to 100% since the world market shares of only US manufacturers are presented

3.3 MARKET OVERVIEW FOR MAIN APPLICATION SEGMENTS

3.3.1 Large and medium PV power plants

3.3.1.1 Capacity installed 1980-1994

Table 3.8 - Large-medium PV power plants: capacity started-up per year in USA (1982-1994)

Year	*Cumulative installed peak power (in kWp)*
1982	1.200
1983	
1984	
1985	8.390
1986	600
1987	
1988	15
1989	
1990	2.000
1991	
1992	3.000
1993	1.000
1994	4.000

Table 3.9 - List of main Large-Medium size PV power plants installed in USA (1982-1994)

PLANT	*INSTALLED PEAK POWER (kWp)*	*YEAR*
HESPERIA -LUGO	1.000	1982
Sky Harbor Arizon	200	1982
CARISSA PLAINS	6.100	1985
RANCHO SECHO SMUD	2.100	1985
John F. Long Solar One	190	1985
600 kWp Austin Plant	600	1986
Florida Power Corporation Orlando PV Plant	15	1988
PVUSA - US1	210	1990
Various other plants	1.790	1990
PVUSA DAVIS 400 k	450	1992
Various other plants	2.550	1992
PVUSA - US1	174	1993
PVUSA KERMAN 500	500	1993
Various other plants	326	1993
Various other plants	4.000	1994
TOTAL	**20.205**	

Figure 3.6 - Large-Medium size PV power plant capacity started-up per year in USA, in comparison with same type total world capacity (1982-1994)

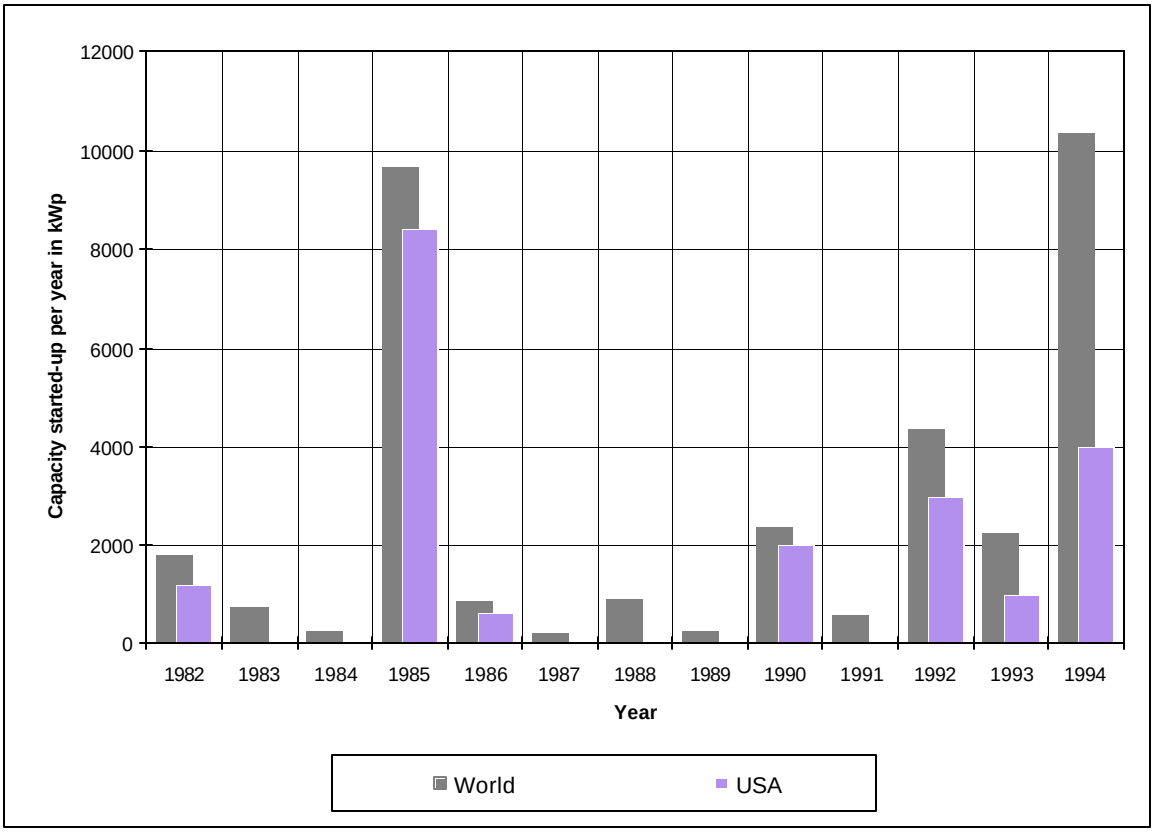


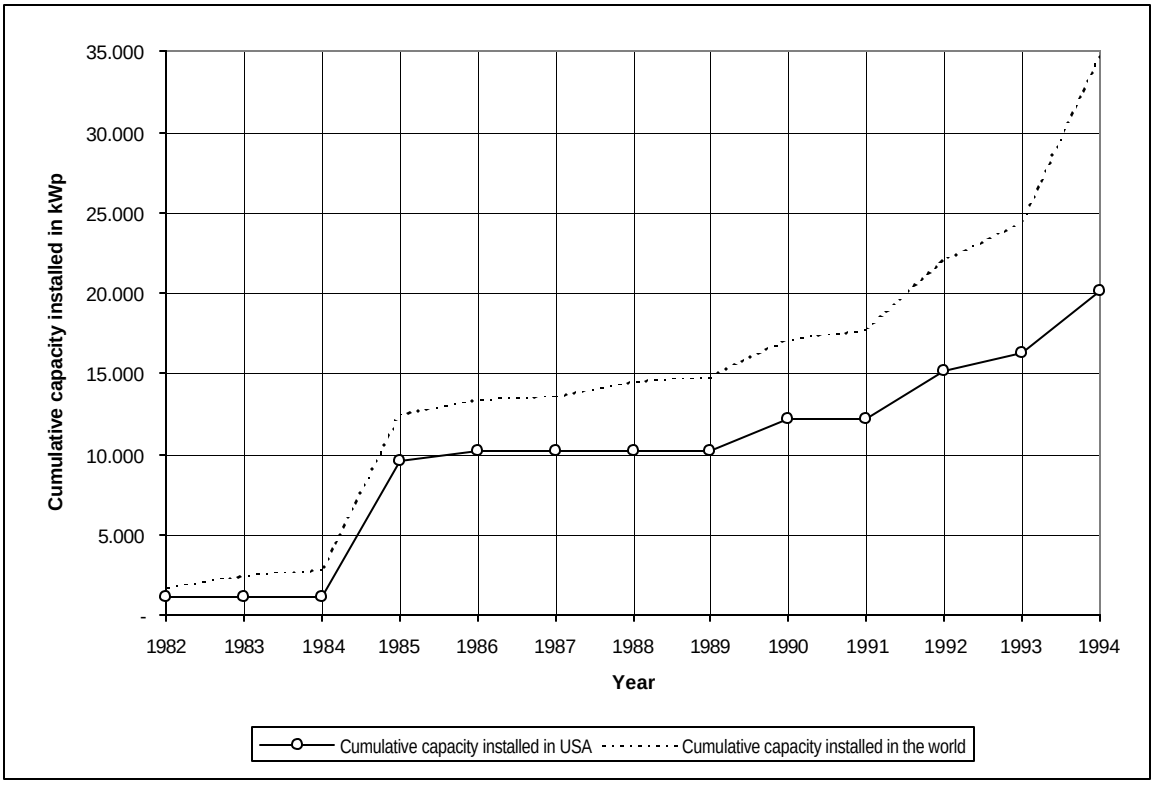
Table 3.10 - Capacity of large-medium size PV power plants installed in USA as share of same type total world capacity

Year	*% of installed world capacity*	
	per year	*cumulative*
1982	67%	67%
1983		47%
1984		42%
1985	87%	77%
1986	67%	76%
1987		75%
1988	2%	70%
1989		69%
1990	84%	71%
1991		69%
1992	69%	69%
1993	45%	67%
1994	39%	58%

Table 3.11- Large-medium PV power plants: installed cumulative capacity per year in USA (1982-1994)

Year	*Cumulative installed peak power (in kWp)*
1982	1.200
1983	1.200
1984	1.200
1985	9.590
1986	10.190
1987	10.190
1988	10.205
1989	10.205
1990	12.205
1991	12.205
1992	15.205
1993	16.205
1994	20.205

Figure 3.7 - Large-Medium size PV power plants cumulative capacity started-up in USA in comparison with same type total world capacity (1982-1994)



3.3.1.2 PV large-medium size power plants: potential demand and market forecast

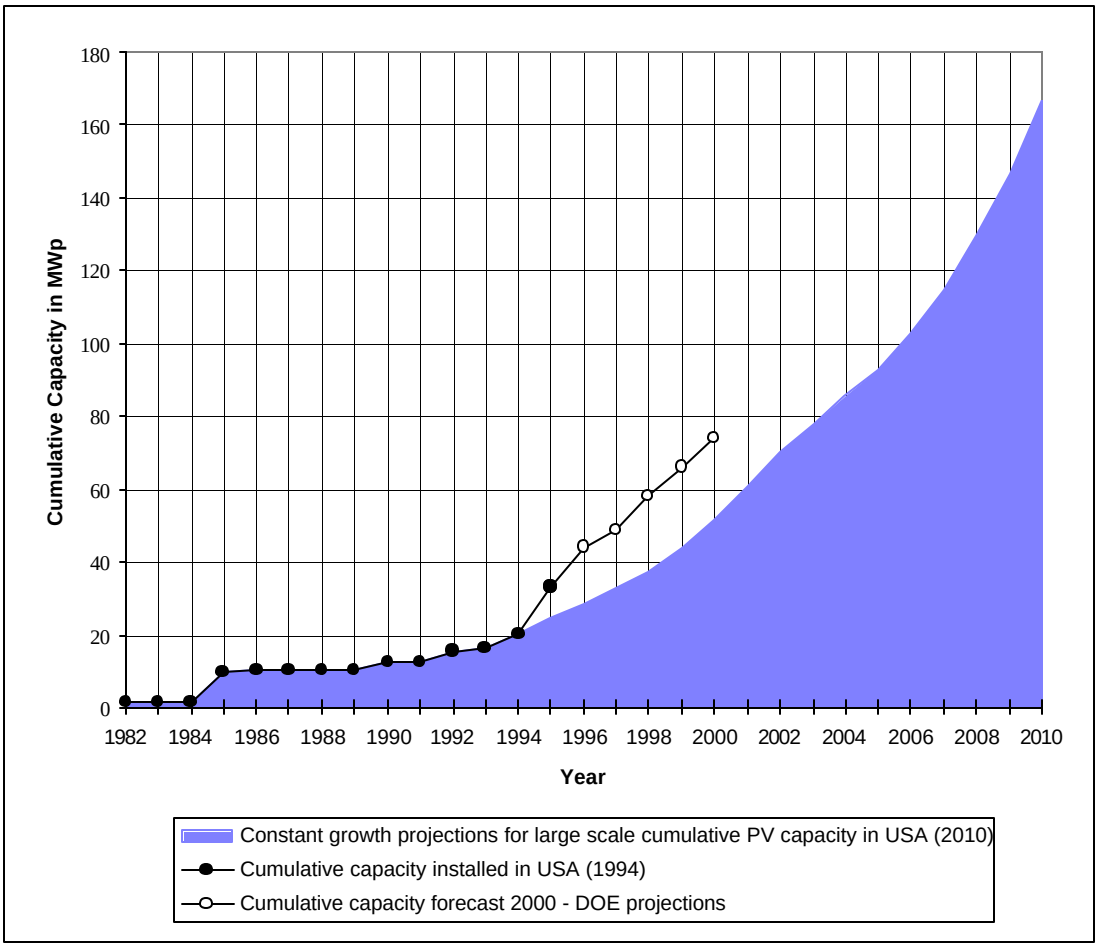
The potential US market demand for medium to large size PV power plants is presented in the following based on the following market projection figures given by the US Department for Energy (DOE) which, through its SOLAR 2000 program, is actively involved in the acceleration and the transfer of PV technology from laboratory level to commercial production and use. The following table 3.12 and related graph 3.8 presents these same DOE market projection figures together with the figures of the actual historic evolution of this market segment until 1994.

Table 3.12 - DOE projections for large-medium size PV power plants in USA

year	*Utility bulk power Cumulative installed capacity MWp*
1990	12
1991	12
1992	15
1993	16
1994	20
1995	33
1996	44
1997	49
1998	58
1999	66
2000	74

The **as usual scenario curve** has been calculated by assuming until year 2010 a constant average annual growth rate of this market segment (19,3%/year) which, apart from the abnormal developments caused by the 6 MWp Carissa Plains plant in 1985, reflects basically the actual evolution of this market segment until 1994.

Figure 3.8 - Large-medium size PV power plants: USA forecast scenarios



3.3.1.3 Large-medium size PV power plant market scenario - Strategic actions of US Utilities

A growing number of US utilities are becoming aware of the important opportunities offered by PV technology for remote stand-alone electrification purposes but, what is more, also applications for grid-connected distributed generation are more and more being taken into consideration.

Since currently cost-effective off-grid (stand-alone) PV applications are at present not sufficient to commercialise and make cost-effective the grid-connected utility PV applications, a need is felt to anticipate the process of grid-connected market development. These grid-connected applications are felt to have value beyond energy and capacity and include residential and commercial customer sited PV for distributed generation and DSM applications and substation/T&D sited PV for grid-support.

The main utility application for large PV bulk power plants has been identified in Transmission and Distribution (T&D) grid support, which may be subdivided into the following two specific types of grid support applications:

- **Area grid support** means that typically 100-500 kWp (or larger) PV capacities are installed near a substation. This application produces advantages to the utility in all those cases, where peak power demand presents a similar behaviour in time as the availability of Solar PV power. Typically, this is the case in all those areas, where a consistent share of power is consumed for air conditioning purposes.
- **Radial line support** is provided by siting typically 50-200 kWp (or more) PV unit capacities along single feeder distribution circuits, allowing thereby to alleviate various problems such as, for example, load growth beyond feeder capacity, voltage drops along the feeder, or simply bad power quality. The economic advantages for the utility arising from this kind of application stem from the consideration that otherwise, without PV support, the utility would have to provide for an increase in capacity of the entire feeder line which, in many cases, may represent a very consistent investment. In the USA the costs of overhead distribution line extensions range typically between 10,000 - 60.000 US$/ mile km (6.000 - 35.000 ECU/km).

Three central concepts have been identified by US utilities as necessary to achieve the production levels and cost reductions required for the accelerated commercialisation of photovoltaics for utility systems:

- sustained orderly development
- commercialisation path life-cycle costing
- proactive leadership to stimulate early adoption

1. Sustained orderly development

The solar industry needs a reliable and long-term market volume to develop and achieve long-term cost reductions required for full commercialisation. Current cost effective utility markets do not provide sufficient market volume to accelerate commercialisation. Demonstration and R&D project alone do not accelerate the commercialisation of new technologies. In fact, **large, one-time purchases tend to dry up supplies** without stimulating the increases in production capacity necessary for manufacturing cost reductions. Furthermore, manufacturers do not rely upon short term subsidies, mandated purchasers, or set-asides in making investment decisions because **these programs create false markets**. A combination of aggressive price reductions and commitments for substantial and sustained capacity acquisition is required for full commercialisation of these technologies. **Sustained orderly development and economies of scale for solar electric systems will result in rapid development of a mature, cost-effective solar industry.**

2. Commercialisation path life-cycle costing

Technology development (or commercialisation path) life-cycle costing, and not just project life-cycling costing, needs to be used. It is important to analyse total expenditures and total

acquired capacity over the entire commercialisation path. Higher costs for early applications can be a good investment if they contribute to accelerating the trend towards lower costs and higher performance. When **solar investments** are selected carefully and in collaboration with other stakeholders in renewable energy development, they can be among the **wisest and, ultimately, the lowest risk** investment that can be made, despite their higher initial capital costs.

3. **Proactive Leadership to stimulate early adoption**

   Sustained orderly development and accelerated commercialisation will not occur early relying just on natural market forces. Accelerated commercialisation won't occur just by demonstration projects and watching cost curve. Utilities and other potential bulk purchasers must commit to an early and sustained series of buys to permit the industry to invest in expanded production and automation. The current thinking among progressive utilities in the diffusion model of PV commercialisation where high value applications are identified and filled, then the next value level developed. This has not resulted in a sufficient aggregation of order commitments to allow the needed expansion of production. Instead of this fairly passive approach, utilities need to take a proactive role in commercialisation of grid-connected applications. **Utilities need to make multi-year commitments for substantial and continuing multi-megawatt per year purchasers.**

SMUD as an example of a utility willing to begin this process, announced in 1992 that it is willing to play a leadership role by beginning a commitment to a multi year, sustained orderly development of PV with a 640 kW purchase of PV system in 1993. In this regard, it is critical to understand that it is not SMUD's belief that this first increment of PV is cost effective of its own, but only that it is the beginning of a cost effective process. SMUD view is that procurement will be relatively small while prices are high, but will become progressively larger as prices decline.

The US utility community is presently taking responsibility to get this process underway now and work with regulators, customers and other stakeholders to make it successful. They are taking account of the non-traditional benefits of distributed PV generation and maximise what they can afford to invest in early systems to accelerated the cost reduction and commercialisation of grid-connected PV. Regulators recognise that the long term best interest of the ratepayer will be served by permitting and encouraging modest early investments in higher cost PV today when these investments will lead to earlier and greater cost reduction of PV for the future. Through DOE the federal government today is willing to share the risk by helping to fill the cost-value gap, a gap declining as commercialisation moves forward.

This process is being developed as a ***sustainable, orderly development of the market in a way that the PV industry can invest with confidence in new processes and manufacturing lines to lower costs and that utilities and their regulators can see accelerated and continuous progress to cost-effectiveness.***

3.3.2 Grid-connected small-scale applications: Rooftops

3.3.2.1 Capacity installed 1980-1994

Table 3.13 - Capacity of grid-connected small-scale PV applications (rooftops) installed in USA (1989-1994)

Country	*INSTALLED PEAK POWER (in kWp) PER YEAR*					
	1989	*1990*	*1991*	*1992*	*1993*	*1994*
USA	6.000	2.000	2.000	2.000		3.000
TOTAL USA						**15.000**

Source: DOE

Figure 3.9 - Capacity of grid-connected small-scale PV applications (rooftops) installed in USA per year in comparison with same type total world capacity (1989-1994)

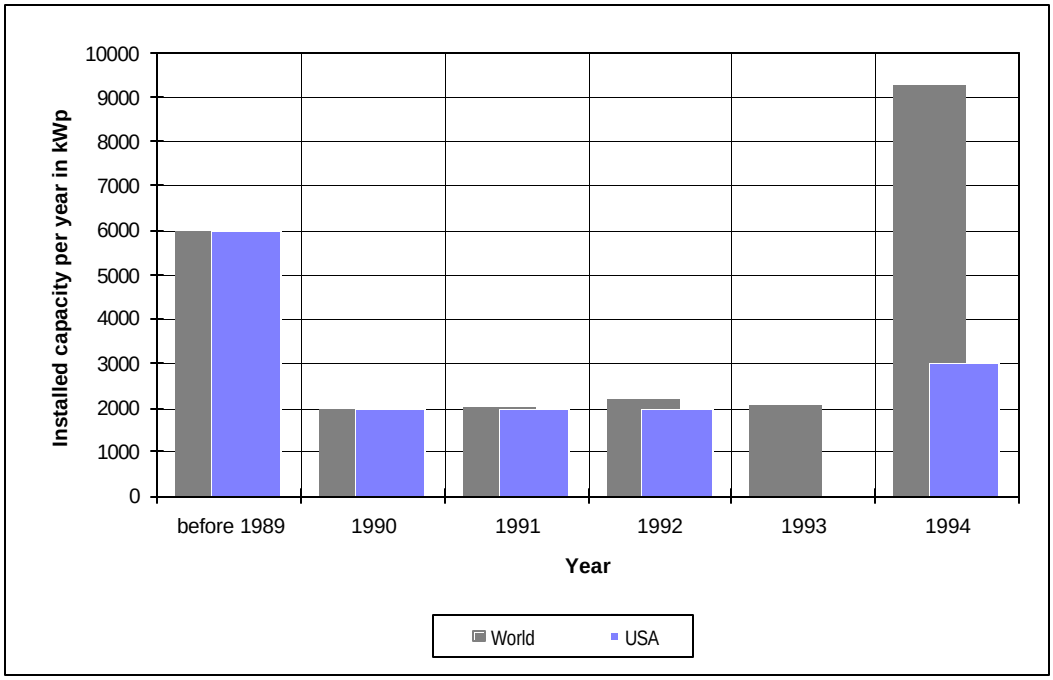
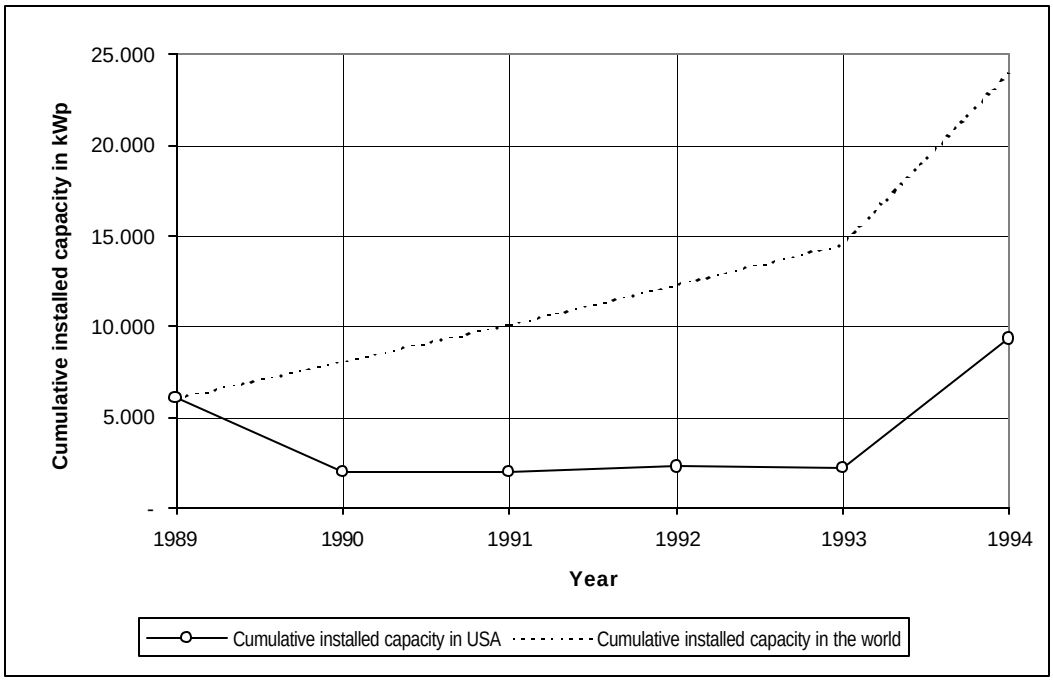


Table 3.14 - Capacity of grid-connected small-scale PV applications (rooftops) installed in USA as share of same type total world capacity

Year	*% of installed world capacity*	
	per year	*cumulative*
1989	100%	100%
1990		25%
1991	20%	20%
1992	17%	18%
1993		15%
1994	13%	39%

Figure 3.10 - Cumulative capacity of grid-connected small-scale PV applications (rooftops) installed in USA in comparison with same type total world capacity (1982-1994)



3.3.2.2 Grid-connected small-scale applications (rooftops): the potential demand today

The market category of grid-connected small-scale PV systems embraces such typical applications as PV rooftops, PV building facades and building integrated PV facilities in general.

Grass-root installations of grid-connected small-scale type are also included in this category, but their market share is considered not significant.

These systems are expected to become the backbone of the **distributed generation utility concept**, where the utility network is expected to provide no more exclusively for the distribution

to consumers of power produced by few concentrated generation facilities, but to collect, at the same time, power from a large number of self-producers distributed over the territory.

As for marked differences in available solar irradiation, the US territory had to be subdivided for analysis into three different geographical zones, assuming within these zones similar climatic conditions[5].

The solar irradiation values used for analysis work are summarised in the following table 3.15.

Table 3.15 - Estimate of Available Net solar rooftop surfaces in the USA (1992)

Countries	*Irradiation*	*Net Available Solar Surface*			
		houses	*offices & services buildings*	*industrial buildings*	*TOTAL 1992*
	kWh/ m2 year	*km2*	*km2*	*km2*	*km2*
Alaska	1.000	5	2	1	8
USA - Rest	1.600	1838	599	395	2832
USA - South West	2.100	491	167	110	768
USA		**2.334**	**768**	**506**	**3.608**

The following table 3.16 gives instead the figures per inhabitant for available solar rooftop surfaces for year 1992 and interpolation results for year 1990 (required for further extrapolation calculations).

It must be emphasised, that **calculations do not take into consideration** that a consistent part of the available solar rooftop surfaces will be used for **concurrent thermal solar applications**, which obviously will have to be subtracted from the quantified rooftop surface potential.

Table 3.16 - Estimate of available net solar rooftop surfaces per inhabitant in 1992 and 1990

Countries	*Available net Solar surface pro capita*					
	houses	*offices & services buildings*	*industrial buildings*	*TOTAL 1992*		*TOTAL 1990*
	m2/ inhabitant	*m2/ inhabitant*	*m2/ inhabitant*	*km2*	*m2/ inhabitant*	*km2*
Alaska	11,1	4,4	2,2	8	17,7	8
USA - Rest	8,9	2,9	1,9	2832	13,8	2.771
USA - South West	10,0	3,4	2,2	768	15,6	752
USA	**9,1**	**3,0**	**2,0**	**3.608**	**14,1**	**3.531**

According to the above mentioned assumptions (see for further details same PV rooftop potential calculation for whole world), the present (1990) [6] potential for grid-connected (distributed) small-scale PV (rooftop) capacities has been calculated **for the total USA** to be roughly **441.000 MWp (~ 1.700 Wp/inhabitant)** of installed PV capacity, whereas the produceable PV energy has resulted to be roughly **526TWh/year (~ 2100 kWh/year per inhabitant)**.

The relevant data for the three considered geographical zones are given by table 3.17.

Table 3.17 - Installable PV Rooftops Capacity in 1990 in USA

Countries	*Installable PV Capacity 1990*		*Producible PV Energy 1990*	
	MWp	*Wp/ inhabitant*	*MWh/year*	*kWh/year inhabitant*
Alaska	979	2.167	684.980	1.550
USA - Rest	346.404	1.684	387.972.912	1.927
USA - South West	93.940	1.907	138.092.053	2.865
USA	**441.323**	**1.728**	**526.749.945**	**2.108**

On the basis of the above results, the produceable PV rooftop electric energy has then been compared with the overall final electricity consumption in the USA, to quantify the share of overall consumption, which can be covered by PV rooftop power.

In the USA, the 1990 potential contribution of PV rooftop power would be roughly 2100 kWh/year per inhabitant equalling more than 17 % of US final electricity consumption.

The following table 3.18 and related figure 3.11 show in addition a comparison with the present **hydropower contribution** to electricity consumption. The purpose of this comparison is to provide a rough quantification means for the maximum Solar PV power contribution, which the utility network would be able to absorb without need for significant changes in present network management techniques (for more details see corresponding chapter for whole world potential calculation).

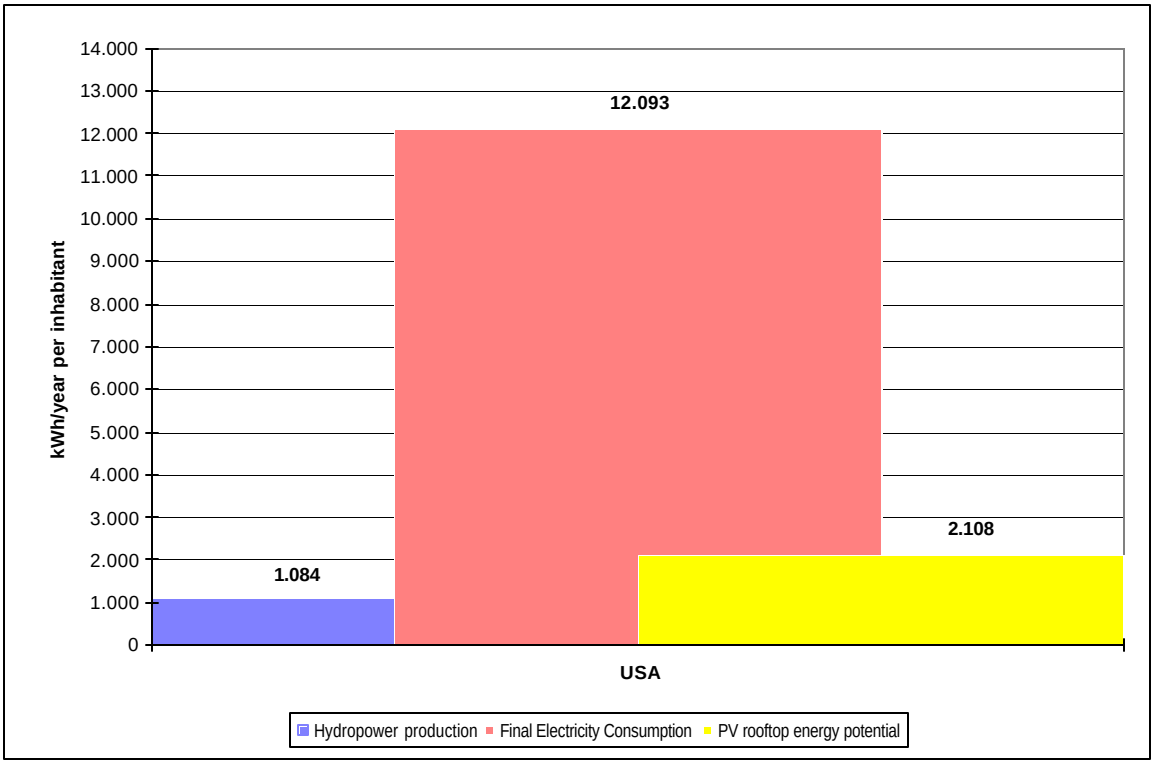
Actually, since the hydropower energy contribution share in the USA is smaller than the corresponding potential PV rooftop share, changes in the present utility network management system might be required to cope with a significant PV contribution. On the other hand, in case that distributed PV generation capacities are installed primarily in areas presenting a large share of air conditioning consumption, this will, to a large extent, allow to compensate this kind of problem, since the resulting daily load profile meets the daily solar energy availability curve.

Table 3.18 - Today's potential PV Rooftop energy contribution share as compared to Final Electricity Consumption in the USA

Countries	*Final Consumption of Electricity* *1990*		*PV Rooftop Potential Energy Share [*]* *1990*	*Actual Hydro Energy Share [*]* *1990*
	MWh/year	*kWh/year inhabitant*	*%*	*%*
USA	**3.022.386.000**	**12.093**	**17,4%**	**9,0%**

[*] as compared to total final electricity consumption

Figure 3.11 - Comparison between PV rooftop potential, final electricity consumption and hydropower share in USA (1990)



3.3.2.3 Grid-connected diffused applications (rooftops) USA market forecast for year 2010

The potential market forecast for year 2010 specifically for grid-connected small-scale PV systems (rooftops and similar) has been extrapolated for the USA following same assumptions and procedures as presented in the corresponding chapter for the whole world potential calculation.

Tables 3.19, 3.20 and 3.21, as well as figure 3.12 produce a synthetic overview of results for the USA.

Table 3.19 - Forecast of available net solar rooftop surfaces in USA for year 2010

Countries	*Available net Solar surface year 2010*	
	TOTAL *km2*	*per capita* *m2/ inhabitant*
Alaska	10	17,7
USA - Rest	3.582	13,8
USA - South West	971	15,6
USA	**4.563**	**14,1**

Table 3.20 - Forecast of Installable PV rooftop Capacity in 2010 in USA

Countries	*Installable PV Capacity* *year 2010*		*Producible PV Energy* *year 2010*	
	MWp	*Wp/ inhabitant*	*MWh/year*	*kWh/year inhabitant*
Alaska	1.679	2.939	1.175.005	2.057
USA - Rest	594.217	2.284	665.523.024	2.558
USA - South West	161.144	2.587	236.881.076	3.803
USA	**757.039**	**2.344**	903.579.106	2.797

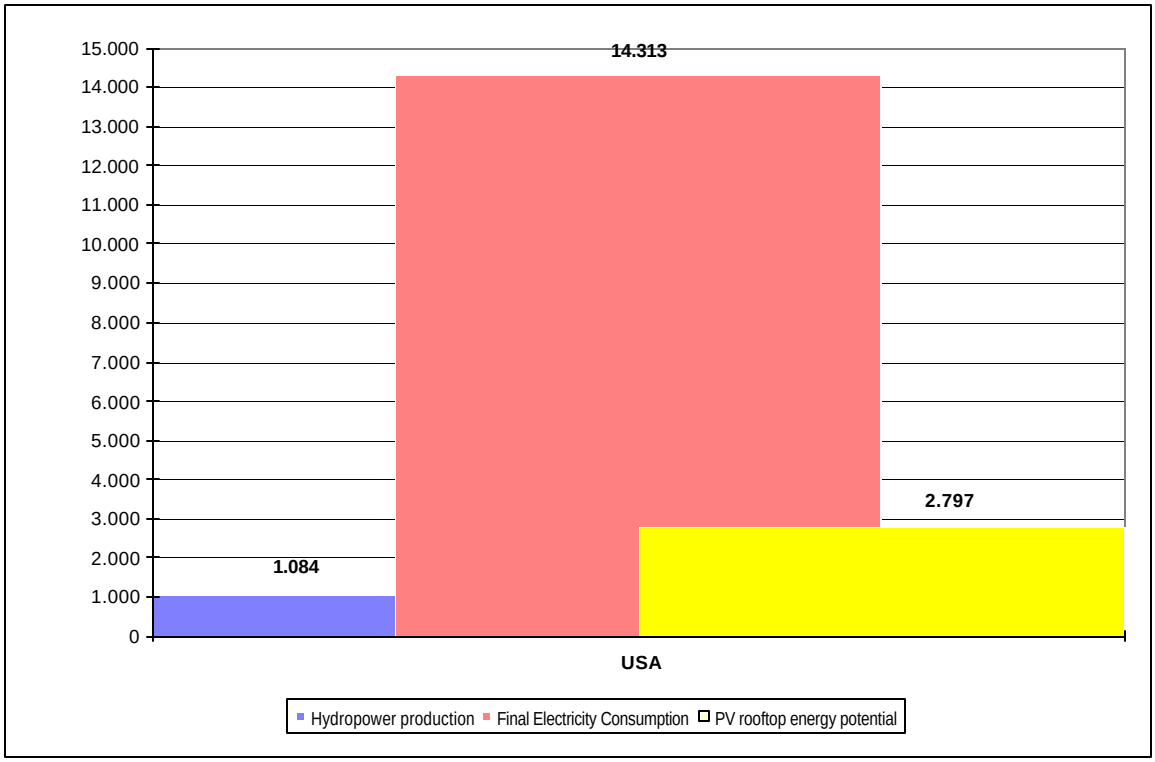
Table 3.21 - Forecast potential PV Rooftop share in USA as compared to Final Electricity Consumption for year 2010

Countries	*Final Consumption of Electricity* *year 2010*		*PV Rooftop Energy Share [*]* *year 2010*	*Hydro Energy Share [*][**]* *year 2010*
	MWh/year	*kWh/year inhabitant*	*%*	*%*
Alaska	8.174.211	14.313	14,4%	3314,5%
USA - Rest	3.723.481.297	14.313	17,9%	0,0%
USA - South West	891.530.559	14.313	26,6%	0,0%
USA	**4.623.186.067**	**14.313**	**19,5%**	**5,9%**

[*] as compared to total final electricity consumption

[**] hydro energy production (in MWh/year) assumed equal to year 1990

Figure 3.12 - Comparison between PV rooftop potential energy contribution, final electricity consumption and hydropower share in USA (year 2010)



CHAPTER 3 - NOTES

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[5] M. Van Brummelen, E.A. Alsema, *Estimation of the PV potential in OECD Countries*, 12th European Photovoltaic Solar Energy Conference, 11-15 April 1994, Amsterdam, Netherlands

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