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Solar Collector Manufacturing Activity 1993

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Energy Information Administration
Office of Coal, Nuclear, Electric and Alternate Fuels
U.S. Department of Energy
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Contacts

Questions regarding the contents of this report may be directed to:

Survey Management Division, EI-52
Office of Coal, Nuclear, Electric and Alternate Fuels
Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Questions of a general nature should be directed to Howard L. Walton (202/254-5500), Director of the Survey Management Division; Noel Balthasar (202/254-5400), Chief, Coal and Uranium Data Systems Branch; or Luther Smith (202/254-5565), Team Leader.

Questions of a technical nature should be directed to Peter Holihan (202/254-5432), Project Manager.

Preface

The "Solar Collector Manufacturing Activity 1993" (SCMA 1993) report prepared by the Energy Information Administration (EIA) presents national and State-level data on the U.S. solar thermal collector and photovoltaic cell and module manufacturing industry. The data are reported to the EIA by U.S.-based manufacturers and importers of solar equipment on the Forms CE-63A, "Annual Solar Thermal Collector Manufacturers Survey," and CE-63B, "Annual Photovoltaic Module and Cell Manufacturers Survey."

Detailed information is presented on 1993 U.S. industry total shipments and shipments by market sector, end-use application, and destination. These data describe the status of the industry at the end of 1993. Historical data for comparison are presented for annual shipments of solar thermal collectors for the years 1974 through 1993 and of photovoltaic cells and modules for the years 1982 through 1993. Two new sections included in 1993 are entitled "Industry Developments" and "Legislation." Throughout the report, the unit of measure for solar thermal collectors is square feet of collector surface and for photovoltaic cells and modules is peak kilowatts.

Appendix A of the report describes the survey methodology. Appendix B contains the 1993 survey forms and instructions. Appendices C and D list the companies that responded to the 1993 CE-63A and CE-63B surveys and also granted permission for their name and address to appear in the report. Appendix E provides selected tables from this report with data converted to the International System of Units (SI) metric units. Appendix F provides an estimate of installed capacity and energy production from solar collectors for 1993.

This report provides annual data necessary for the Department of Energy to execute its responsibilities to (1) monitor activities in the solar collector industry, (2) implement the National Energy Strategy, and (3) provide information on the development and status of the industry to the Congress, Federal and State government agencies, solar energy manufacturers and specialists, universities and research institutes, and the general public.

The EIA and its predecessor organizations began conducting voluntary telephone surveys of the solar thermal collector industry in 1975 to monitor manufacturing activities. The first survey collected data for 1974, and subsequent surveys were conducted semi-annually through 1981. Since 1982, the surveys have been conducted annually, except for 1985, when the Form CE-63A survey was not conducted. The collection of energy data on Forms CE-63/A and CE-63/B is mandated under the Federal Energy Administration Act of 1974, Section 13 (Public Law 93-275).

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Solar Thermal Collectors

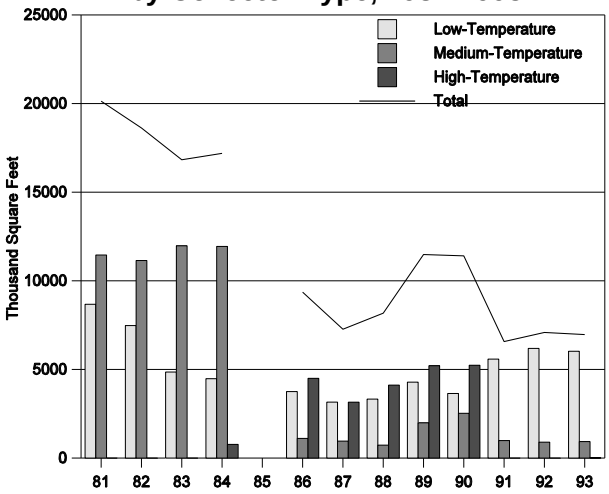
Solar thermal collector shipments totaled 7.0 million square feet in 1993 compared with 7.1 million square feet in 1992. A 3-percent decrease in shipments of low-temperature collectors, used primarily to heat residential swimming pools, was responsible for this decline. Shipments of low-temperature collectors decreased in 1993 to 6.0 million square feet from 6.2 million square feet in 1992. Shipments of medium-temperature collectors remained relatively unchanged at 0.9 million square feet in 1993 (Figure H1). The number of companies that shipped solar thermal collectors declined from 45 in 1992 to 41 in 1993.

The total value of solar thermal collector shipments in 1993 was $27.6 million, 9-percent increase from 1992. This increase was due to increases in the average price per square foot of both low- and medium-temperature collectors. The average price of low-temperature collectors rose 12 percent to $2.79 per square foot in 1993, while the average price of medium-temperature collectors rose 7 percent to $11.73 per square foot.

At the end of 1993, 30 States had legislation providing some financial incentives for investment in the use of solar thermal collectors and photovoltaic (PV) modules and cells, compared with 27 States in 1992. Montana, North Dakota, and South Dakota approved financial incentives during 1993. The legislative actions were passed to encourage the use of an environmentally clean source of energy, to promote energy conservation through the use of renewable energy technologies, and to promote energy efficiency. Among the most common incentives were property tax exemptions and income tax credits for both the residential and business sectors.

California, New York, New Jersey, Florida, and Puerto Rico accounted for 98 percent of the total shipments of solar thermal collectors in 1993. California continued to be the top shipping State, accounting for 42 percent of total solar thermal collector shipments in 1993. The top five domestic destinations for shipments were Florida, California, Arizona, Hawaii, and Puerto Rico. Together, Florida and California received 80 percent of all domestic shipments.

Figure H1. Solar Thermal Collector Shipments by Collector Type, 1981-1993



Note: Data for 1985 are incomplete and are not shown.
Sources: **1981-1984:** Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Photovoltaic Cells

Shipments of photovoltaic (PV) cells and modules (Figure H2) totaled 21.0 peak megawatts in 1993, an increase of 34 percent above the 1992 level. The total value of PV cell and module shipments in 1993 was $110 million, 26 percent higher than in 1992.

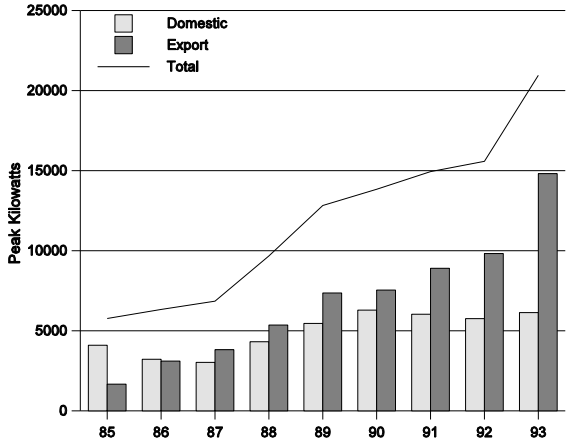
PV exports rose to 14.8 peak megawatts in 1993, a record level, and an increase of 51 percent from 1992 exports. Since 1988, PV exports have exceeded domestic shipments, increasing at an average annual rate of 23 percent. In 1993, exports accounted for 71 percent of total PV shipments.

Total PV shipments to the commercial sector increased 72 percent in 1993 from 1992, after declining 61 percent between 1990 and 1992. Shipments to the residential sector increased 26 percent in 1993 from 1992. From 1990

to 1992, shipments to the residential sector increased 144 percent. The average price of crystalline silicon cells showed a marked increase in 1993 due to customer demand for custom cell orders for specific end-use products. Without the custom cell orders, the average price of PV crystalline silicon cells would have been somewhat lower but still above the 1992 average. The average price for crystalline silicon modules declined from $6.10 per peak watt in 1992 to $5.11 per peak watt in 1993, a 16 percent drop.

The Energy Information Administration estimates that solar thermal collectors and PV modules and cells provided approximately 0.07 quadrillion Btu of energy production in the United States during 1993 (see Appendix F).

Figure H2. Domestic and Export Shipments of Photovoltaic Cells and Modules, 1985-1993



Note: Domestic Shipments equal total shipments minus exports.
Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Cell/Module Manufacturers Survey."

Industry Developments

Breakthrough in Solar Industry

The Department of Energy announced on January 18, 1994, that a 3-year government/industry partnership has produced a new thin-film solar technology that can supply all the daytime power needed for a home at almost half the present cost.[1] The new photovoltaic (PV) solar panels will be manufactured at a new plant site by United Solar Systems Corporation in Newport News, Virginia.

The new thin-film solar panel technology can be made into roofing shingles that could supply daytime electric power needs of a south-facing residential home. This new technology is expected to reduce the cost for PV electricity from 25 to 50 cents per kilowatthour to 12 to 16 cents per kilowatthour.

Photovoltaic Manufacturing Technology

The Photovoltaic Manufacturing Technology (PVMaT) project is an historic government/industry partnership for carrying out research and development (R&D) in the area of photovoltaic (PV) manufacturing. PVMaT consists of joint activities between the U.S. Department of Energy (DOE) and members of the U.S. PV industry.[2] The project's ultimate goal is to ensure that the U.S. industry not only retain but extend its world leadership role in manufacturing and commercial development of PV components and systems. PVMaT, a five-year, three-phase program, is designed to reduce PV manufacturing costs and expand the U.S. production capacity. PVMaT was started in early 1990, and the total DOE funding is expected to be approximately $55 million with a similar amount cost shared by industry.

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[1]"Energy Department Announces Breakthrough in Solar Technology," *Department of Energy News*, U.S. Department of Energy (Washington, DC, R-94-003).

[2]"Four Firms To Negotiate with DOE On Manufacturing Technology Contracts," *The Solar Letter* (Washington, DC, September 3, 1993), p. 182.

Phase 1 PVMaT was completed in early 1991. There were 22 companies in Phase 1, with each company receiving $35,000 to $50,000. Phase 2 of PVMaT, which began in 1992, is expected to continue for 5 years were awarded. In Phase 2B six contracts totalling $46.2 million and in Phase 2B four contracts totalling $40.1 million, were awarded. In Phase 3A, two contracts totalling $2.9 million have been awarded.

New Sacramento Photovoltaic Power Station

The Sacramento Municipal Utility District (SMUD) began operation of a new, low cost PV power station in May 1994. The 200-kilowatt solar generating station at SMUD's Hedge substation is the lowest cost utility-scale sun tracking PV system ever built, constructed at a cost reported by the utility to be 20 percent lower than costs of previous utility PV systems. SMUD attributed the lower costs largely to the simplified design of the solar station's support structure and tracking equipment, which is constructed out of utility poles rather than traditional steel and concrete.

Built next to a primary substation, the Hedge Solar Station is an example of "peak shaving," a new concept where utilities use alternative energy sources to boost output during peak summer periods. PVs fit this need because on hot summer days when energy use is at its highest, PVs are producing the most power.

The Hedge Solar Station is part of SMUD's Solar Program, considered one of the leading utility- run solar programs in the country. Along with PV1 & 2, the world's largest utility- owned PV plant, SMUD operates 108 rooftop PV systems built on customers' homes, and during 1994, another 100 PV "mini-power plants" will be installed. The SMUD program also includes solar water heaters, passive solar design, and commercial air conditioners as well as participation in Solar Two, the solar thermal power demonstration project near Barstow, California.[3]

[3]"California Utility Begins Operations At New Photovoltaic Power Station," *International Solar Energy Intelligence Report* (Washington, DC, May 30, 1994), p. 89.

Utility Photovoltaic Application Survey

More than 1,850 cost-effective PV systems with a total installed capacity of more than 87-peak kilowatts are owned and operated by 74 electric utilities throughout the United States, according to the survey results released in October 1993 by Electric Power Research Institute, Palo Alto, California.

Investor-owned utilities own the greatest number of cost-effective systems (more than 1,500), followed by municipal utilities (more than 170), Federal- or State-owned utilities (more than 100) and rural electric cooperatives (more than 80). In the late 1970's, the utilities started installing the cost-effective PV devices, all of which to date serve small, isolated loads and have a size range of a few peak watts to more than 7-peak kilowatts.

EPRI rates the reliability of these stand-alone PV devices as very high. Some 97 percent of the utilities, with PV systems installed, reported that they were either satisfied or very satisfied with PV system performance. Over 37 percent of the utilities had experienced no downtime with their systems.

The survey identified several applications of PV technology in use by electric utilities today. These systems, reduce a utility's cost and provide a low-risk means to develop a valuable experience base with PV and expand the understanding of the technology.[4]

Photovoltaic BONUS Program

In 1993 the DOE initiated several public/private cost-shared partnerships to commercialize renewable energy technologies. Their initiatives began as part of the Building Opportunities in the United States for PV programs (PV BONUS) and include the following solar program initiatives:

- A $40 million, five-year program cost-shared with industry to develop solar cells that do

[4]"Photovoltaics Cost-Effective for Utilities in Dozens of Applications: EPRI," The Solar Letter (Washington, DC, October 15, 1993), p. 203.

double duty as building components. Five proposals were accepted for negotiation.

- A cooperative agreement valued at $40 million between DOE and a consortium led by Southern California Edison to convert the 10-megawatt central receiver water-steam Solar One facility at Daggett, California, into Solar Two, which will use molten salt in the receiver and as the storage mechanism to allow electricity to be generated when the sun is not shinning resulting in the world's most advanced central receiver plant.

- A collaborative effort between DOE, the Edison Electric Institute, and the American Public Power Association to provide technical assistance to utilities to develop solar water heating programs as part of their services to customers.[5]

DOE Solar Power Task Force

Department of Energy has named the members of the Solar Power Task Force for the Nevada Test Site (NTS). The task force is charged with exploring ways to use NTS for a solar power generating and research facility featuring solar thermal electric and photovoltaic power plants.

The task force will be cochaired by Assistant Secretary for Energy Efficiency and Renewable Energy Christine Ervin and Sen. Richard Bryan (D-Nev..). Other members are Nevada Gov. Bob Miller (D); DOE Nevada Operations Office Manager Nick Aquilina, Pioneer Citizens Savings Bank President and CEO Bill Martin, Nevada State Sen. Dina Titus, Nevada AFL-CIO representative Claude Evans, and Solar Energy Industries Association Executive Director Scott Sklar.

An amendment to the 1992 Defense Authorization Bill, directed DOE to conduct a feasibility study on the potential for solar power at NTS. The nuclear weapons test site, no longer needed for its original purpose, has some of the best insolation in the country.[6] The feasibility study, contracted by DOE, concluded that the 1,350-square-mile site could host an array of solar electricity generating equipment owned by private companies. The study suggested that private industry might be attracted to the site if the federal government provided the land, some power line improvements and other support. Less than seven percent of the area would support 10,000 megawatts of solar electric generating capacity, five times the generating capacity of the Hoover Dam.

Low Income Solar Program

On May 3, 1994 the DOE announced a pilot project to put solar water heaters on the rooftops of 1,000 low-income households in Florida during the next three years. The pilot effort, called the Solar Weatherization Assistance Program (SWAP), will have a budget of $2.3 million, including $800,000 from DOE and $1.5 million from Florida's oil overcharge funds. The initial installations will target low-income households in Citrus, Pinellas, and Suwannee Counties.

The benefits, including the impact on family water heating bills, will be measured as part of the pilot project. Three to five types of systems will be tested for costs, including installation and maintenance.

The Florida Solar Energy Center, which has been involved in solar equipment standards and testing for 15 years, will provide training and technical support for the weatherization crews. The equipment will meet the center's certification requirements.

During the first phase of the pilot program, 150 solar water heaters will be installed by the end of the summer 1994, many of them by the Metropolitan Dade Community Action Agency in the Miami area.[7]

[5]"DOE Announces New Public/Private Partnerships In Renewable Energy Research and Development," *DOE News*, U.S. Department of Energy (Washington, DC, April 29, 1994), R-94-074.

[6]"Solar Power Task Force Named for Nevada Test Site," *DOE News*, U.S. Department of Energy (Washington, DC, April 29, 1994), R-94-074.

[7]"Low-Income Florida Residents to Benefit from Solar Power," *DOE News*, U.S. Department of Energy (Washington, DC, May 3, 1994), R-94-075.

Solar Energy Museum

On April 22, 1993, the Solar Energy Research and Education Foundation dedicated the Center for Renewable Energy and Sustainable Technology (CREST), a unique new museum highlighting solar energy on Capitol Hill in Washington, DC. A rooftop PV panel powers lights and computers running touch-control, visitor-interactive informational software, and a rooftop solar thermal system provides hot water.

CREST will feature interactive displays, examples of several renewable energy sources, including PV, solar thermal, wind, geothermal, hydropower, and biomass, and a unique, rotating "solar orb" created by Southern California Edison Co., for the 1993 Rose Parade, that used 127 state-of-the-art PV cells to power the rotational motor. CREST eventually will also serve as a training center for designers, engineers and users interested in harnessing solar and other forms of renewable energy.[8]

Mobil Terminates Solar Programs

Mobil Corporation announced on November 4, 1993, the termination of its 19-year old PV production operations program at Billerica, Massachusetts.[9] Mobil's Chairman and Chief Executive Allen E. Murray said current PV technology "does not provide an adequate business opportunity either now or the foreseeable future." The Mobil Energy Solar Corporation is being actively sold on the market: it will maintain and support its proprietary technology.

Mobil's departure leaves only one American PV firm owned by an oil company, Solarex Corp., Frederick, Md., a wholly owned subsidiary of Amoco Technology Corp. Previous oil-company dropouts from the U.S. PV industry include Atlantic Richfield, Exxon Corp., and Shell Oil Co.

Delmarva Power and Light Photovoltaic System Evaluation

On July 16, 1993, Delmarva Power and Light Company of Delaware installed a 15-kilowatt PV system at its Northern Division General Offices in Christiania, Delaware.[10] The system was designed to provide electricity to commercial buildings in the area. An array of 40 PV modules is connected to the Delmarva grid through a two-way inverter. The Delmarva Power PV system gathers energy throughout the daylight hours of each day. The energy is first used to charge storage batteries each morning and provide electricity to the building's occupants. As the utility demand for power rises in the afternoon, the stored energy is combined with the PV production and is sent on to the utility's grid to reduce the peak demand for electricity on the utility system.

This initiative is designed to assist in determining how PV systems can help customers reduce their peak electrical demand and to ascertain how Delmarva can reduce its fossil-fueled generating plants to free up electricity for customers during peak demand periods. In distributed generation, a small amount of power carefully matched to a specific need is produced near the point of consumption.

By displacing electricity on the customer's side of the meter, PV systems can allow facility owners to offset electricity normally required from the utility and reduce monthly demand charges. Billed demand charges reflect the peak amount of electricity required from a utility. Development of the PV system initiative for commercial application will be partially funded by the Department of Energy's PV: Bonus Program.

Rooftop Photovoltaics (PV) Program

The Environmental Protection Agency (EPA) is managing a two-phase program to collect field measurements of energy savings and air pollution reductions through rooftop PV systems.[11]

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[8]"Unique Renewable Energy Museum Dedicated on Prominent DC Corner," The SolarLetter, (Washington, DC, April 30, 1993), p. 88.

[9]"Industry News," *Solar Industry Journal (*Washington, DC, Fourth Quarter, 1993).

[10]Chris Whiteley, "Delmarva Power Demonstrates PV on Corporate Office Building," *Solar Industry Journal* (Washington, DC, 1993), p. 14.

[11]"How Many Rooftop PV Systems Does it Take to Save the Planet?," *Solar Industry Journal,* by Ed Kem (Ascension Technology), and Anne Polansky (Solar Energy Industry Association) (Washington, DC, Fourth

Under Phase I begun in 1992, 16 PV systems (eight 4-kilowatt, one 8-kilowatt, and seven 12-kilowatt systems) were installed on residential and commercial rooftops in 11 U.S. cities. In Phase II, 11 additional systems focused on commercial, institutional, and light-industry buildings will be installed. The EPA and 11 electric utilities are sharing Phase I project costs of $1.1 million on a 50/50 basis. In Phase II, 11 utilities, 9 new ones and 2 participating in Phase I, will sponsor installation and monitoring of 18-kilowatt systems to achieve a total capacity of 198 kilowatts. The Electric Power Research Institute is coordinating input of electric utility partners that, collectively, are providing 65 percent of the $2.5-million total cost of Phase II.

Assuming a PV capacity factor of 20 percent and today's electric power generation plant mix, EPA estimates that for each 1,000 megawatts of PV generating capacity about 1.1 million metric tons of CO_2 would be avoided each year. If all U.S. residences were fully equipped with rooftop PV generators, the EPA estimates that CO_2 emissions would be reduced by 170 million metric tons per year.

Low-Cost Solar Power System

The Department of Energy's Sandia National Laboratories and Science Applications International Corporation are developing a 25-kilowatt solar thermal power system for commercial use.[12] The goal of this task is to develop and demonstrate a distributed power system suitable for commercial sale by the year 2000. The system is based on a stretched faceted membrane dish developed by Sandia and a 25-kilowatt solar dish developed by Stirling Thermal Motors, Inc. Potentially, this system will com-pete with conventional power sources to generate electricity at a cost near six cents per kilowatthour, while keeping emissions of pollutants or greenhouse gases to a minimum.

Siemens Solar Training Center

Siemens Solar Industries Inc., of Camarillo, California, has established a fully dedicated PV-powered international solar electric technology and system-design training center.[13] The 1,200-square-foot facility, which opened in the fall of 1993, includes a classroom and a hands-on laboratory where domestic and international customers receive training in the "PV Technology and System Design" course which has been given at Siemens SolarIndustries for the past 11 years.

Legislation

Federal

Energy Policy Act of 1992 (P.L. 102-486)

The National Energy Policy Act (EPACT) of 1992, enacted on October 24, 1992, contains several provisions supporting a broader, more favorable treatment of solar energy. Major sections of EPACT affecting the solar industry are listed below:

(a) Section 1202 created a 5-year cost-share energy efficiency and renewable energy plan including technology demonstration and commercial application programs which authorized expenditure of $50 million in fiscal year (FY) 1994.

(b) Section 1916 extended indefinitely, retroactive to June 30, 1992, the 10-percent investment tax credits for solar equipment. Commercial entities investing in or purchasing qualified solar energy property can take the credit on up to 10 percent of the investment or purchase and installment amount. Solar energy property that qualifies for the credit includes:

- Equipment that uses solar energy to generate electricity, including storage devices, power conditioning equipment, transfer equipment, and related parts, and equipment up to (but not including) the stage that transmits or uses electricity.
- "Dual use equipment" (equipment that uses both solar and non-solar energy, such as pipes and hot

Quarter, 1993).

[12]"Industry News: Contracts and Installations,"*Solar Industry Journal (Washington, DC, Fourth Quarter, 1994), p. 8.*

[13]"Siemens Sets up PV-Powered International Training Center," *The Solar Letter (Washington, DC, January 7, 1994), p. 2.*

water tanks) only if its use of energy from non-solar sources does not exceed 25% of its total energy input in an annual measuring period, and only to the extent of its basis or cost allocable to its use of solar energy.

Energy and Water Development Appropriations Act (P.L. 103-126)

On October 28, 1993, Congress passed a fiscal year (FY) 1994 appropriation for energy and water development that included DOE's Renewable Energy R&D program. In the solar energy area it in-cluded $5 million for the Solar Buildings Program (up from $3 million in FY 1993) $78 million for the Photovoltaic Program (a 20 percent increase above the FY 1993 level of $65 million), and $33 million for the Solar Thermal Program (a 21 percent increase from the FY 1993 level of $27 million).

Rural Electrification Loan Restructuring Act of 1993 (P.L. 103-129)

The Rural Electrification Loan Restructuring Act of 1993 was enacted on November 1, 1993. The Act contains a provision allowing rural electric cooperatives to make low interest (5to7 percent) loans to Rural Electric Cooperatives to assist them in "implementing demand side management, energy conservation programs, and on-grid and off-grid renewable energy systems." Previously, only energy systems that were used in central power applications were eligible for such loans.

State

In 1993, three States, Montana, North Dakota, and South Dakota, passed legislation providing for some financial incentives for investment in the use of solar thermal collectors and photovoltaic cells/modules. At the end of 1993, 30 States had legislation providing such financial incentives. These States are: Arizona, California, Connecticut, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Maine, Massachusetts, Maryland, Minnesota, Montana, Nevada, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Dakota, Texas, Utah, and Virginia.

Solar Thermal Collector Manufacturing Activities

This chapter presents information on the statistics of the solar thermal collector manufacturing industry in 1993. Solar thermal collector shipments, origins and destinations, imports, exports, collector types, values and prices, end uses, and market sectors are presented. Data on solar thermal collector shipments include both imported collectors and collectors manufactured by U.S.-based companies that were shipped for domestic use and for export.

Industry Status

In 1993, 41 companies were active in the solar thermal collector manufacturing industry. They shipped collectors totaling approximately 7.0 million square feet during the year (Table 1). Of the 41 companies active in 1993, 5 were planning to introduce new low-temperature collectors, 11 were planning new medium-temperature collectors, and 4 were planning to intro-duce new high-temperature collectors in 1994 (Tab 2).

From 1984 to 1986, the number of manufacturing companies declined by 127 (Table 1). At the end of 1985, the 40-percent residential energy tax credit and the 15-percent business energy tax credit expired. The decline in industry companies intensified with the drop in oil prices in 1986. The reinstatement of the business energy tax credit at the 15-percent level for 1986, at the 12-percent level for 1987 through 1991, and at the 10-percent level in 1992, plus increasing oil prices after 1986 appear to have had little effect on drawing companies into manufacturing solar thermal collectors.

Table 1. Number of Companies and Annual Shipments of Solar Thermal Collectors, 1974-1993
(Thousand Square Feet)

Year	Number of Companies	Solar Thermal Collector Shipments		
		Total	Import	Export
1974	45	1,274	NA	NA
1975	131	3,743	NA	NA
1976	186	5,801	NA	NA
1977	321	10,312	NA	NA
1978	340	10,860	396	840
1979	349	14,251	290	855
1980[a]	233	19,398	235	1,115
1981[a]	203	20,133	196	771
1982[a]	265	18,621	418	455
1983[a]	203	16,828	511	159
1984	225	17,191	621	348
1985	NA	NA	NA	NA
1986	98	9,360	473	224
1987	59	7,269	691	182
1988	51	8,174	814	158
1989	44	11,482	1,233	461
1990	51	11,409	1,562	245
1991	48	6,574	1,543	332
1992	45	7,086	1,650	316
1993	41	6,968	2,039	411

[a]Includes imputation of shipment data to account for nonrespondent.

NA = Not available. The data reported for 1985 are incomplete.

Note: Total shipments as reported by respondents include all domestic and export shipments and may include imported collectors that subsequently were shipped to domestic or foreign customers.

Sources: **1974-1977** : Federal Energy Administration telephone survey. **1978-1984:** Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993:** Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 2. Number of Companies Expecting to Introduce New Solar Thermal Collector Products in 1994

New Product Type	Number of Companies
Low-Temperature Collectors	5
Medium-Temperature Collectors . . .	11
High-Temperature Collectors	4
Noncollector Components	7

Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey" (1993).

The Energy Policy Act of 1992, Section 1916, extends the 10-percent business tax credits for solar equipment indefinitely, retroactive to June 30, 1992. Investors in or purchasers of qualified solar energy property can take the credit on up to 10 percent of the investment or purchase price and installment amount. Section 1914 established a 1.5-cent per killowatthour electricity production incentive for qualifying facilities.

At the end of 1993, 30 States provided financial incentives for investment in the use of solar thermal collectors and photovoltaic modules and cells, com-pared with 27 States in 1992 and 15 States in 1991. Montana, North Dakota, and South Dakota approved financial incentives during 1993. The legislative actions were passed to encourage the use of an environmentally clean source of energy, to promote energy conservation through the use of renewable energy technologies, and to promote energy efficiency. Among the most common incentives were property tax exemptions and income tax credits for both the residential and business sectors.

Since 1987, the 10 largest U.S. companies that ship-ped solar thermal collectors have supplied not less than 95 percent of all solar thermal collectors manu-factured in or imported into the United States (Table 3). In 1993, 96 percent of the approximately 7.0 million square feet of total shipments were supplied by the 10 largest companies. In the period 1982 to 1984, the average share of the 10 largest companies was 50 percent of total shipments.

Table 3. Percent of Solar Collector Shipments by the Ten Largest Companies, 1982-1993

Year	Company Rank	Shipments (thousand square feet)	Percent of Total Shipments
1982 . . .	1-5	6,320	34
	6-10	2,560	14
	1-10	8,880	48
1983 . . .	1-5	5,919	35
	6-10	2,752	16
	1-10	8,671	52
1984 . . .	1-5	6,092	35
	6-10	2,605	15
	1-10	8,697	51
1985 . . .	NA	NA	NA
1986 . . .	1-5	7,771	83
	6-10	785	8
	1-10	8,556	91
1987 . . .	1-5	6,371	88
	6-10	499	7
	1-10	6,870	95
1988 . . .	1-5	7,585	93
	6-10	335	4
	1-10	7,920	97
1989 . . .	1-5	9,748	85
	6-10	1,321	12
	1-10	11,069	96
1990 . . .	1-5	9,955	87
	6-10	1,029	9
	1-10	10,983	96
1991 . . .	1-5	5,429	83
	6-10	829	13
	1-10	6,258	95
1992 . . .	1-5	6,110	86
	6-10	609	9
	1-10	6,718	95
1993 . . .	1-5	6,135	88
	6-10	551	8
	1-10	6,686	96

NA=Not available. The data reported for 1985 are incomplete.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **1982-1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Manufacturers Survey."

In 1993 employment in solar-thermal-related activities decreased 449 person-years to 392 person-years, a 13 percent drop from the 1992 employment level. Industry employment data for 1990 through 1993 are shown in the following table.

Year	Person Years Expended
1990	850
1991	338
1992	449
1993	392

Most of the 41 reporting companies in 1993 combined manufacturing and related activities with importing of solar thermal collectors:

- A total of 31 companies were involved in design of collectors or systems, 18 were developing prototype collectors, and 16 were developing prototype systems (Table 4).

- There were 24 wholesale companies and 24 retail companies. Of the 41 companies, 20 offered installation of their collectors.

Solar-related sales represented 90 to 100 percent of total company sales for 25 companies in 1993 versus 27 companies in 1992 (Table 5). Solar-related sales made up less than 10 percent of total sales for two companies in 1993, compared with four companies in 1992.

Shipments

Solar thermal collector shipments totaled approximately 7.0 million square feet in 1993, a 2-percent decrease from the 1992 level of approximately 7.1 million square feet (Table 1). Import shipments totaled 2.0 million square feet and export shipments were 0.4 million square feet in 1993 (Figure 1). Shipments of low-temperature solar thermal collectors decreased 3 percent to 6.0 million square feet in 1993 from 6.2 million square feet in 1992 (Table 6). Shipments of medium-temperature collectors in-creased 4 percent to 0.93 million square feet in 1993 from 0.90 million square feet in 1992. Shipments of high-temperature collectors increased from 2,000 square feet in 1992 to 12,000 square feet in 1993.

Table 4. Number of Companies Involved in Solar-Thermal Activities by Type, 1992 and 1993

Type of Activity	Number of Companies	
	1992	1993
Collector or System Design	35	31
Prototype Collector Development	18	18
Prototype System Development	20	16
Wholesale Distribution	24	25
Retail Distribution	24	22
Installation	20	21
Noncollector System Component Manufacture	16	18

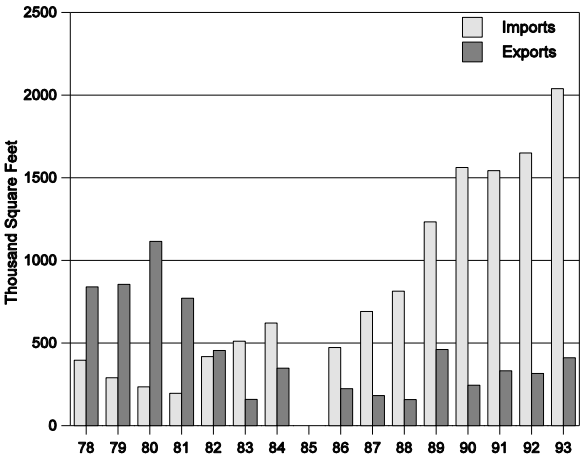
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 5. Solar-Related Sales as a Percentage of Total Sales, 1992 and 1993

Solar-Related Sales as a Percent of Total Sales	Number of Companies	
	1992	1993
90-100	27	25
50-89	7	9
10-49	7	5
Less than 10	4	2
Total	45	41

Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Figure 1. Imports and Exports of Solar Thermal Collectors, 1978-1993



Note: Data for 1985 are incomplete.
Sources: **1978-1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Origins

U.S. manufacturers in California, New York, New Jersey, Florida, and Puerto Rico produced 98 percent of U.S.-manufactured collectors in 1993, the same as in 1992. California continued to lead the Nation in 1993 with 42 percent of total domestic shipments. Shipments of U.S.-manufactured solar thermal collectors in 1993, which totaled 4.9 million square feet, originated from 17 States and Puerto Rico. California shipped 42 percent of U.S.-manufactured solar thermal collectors in 1993 compared with 55 percent in 1992 (Table 7). New York, New Jersey, and Florida shipped a combined 2.6 million square feet in 1993.

Distribution

Of total shipments in 1993, 53 percent were sent directly to wholesale distributors and 35 percent were sent to retail distributors (Table 8). Of export ship-

Table 6. Solar Thermal Collector Shipments by Type, 1980-1993
(Thousand Square Feet)

	Low-Temperature		Medium-Temperature		High-Temperature[a]
Year	Shipments	Average Annual Shipments per Manufacturer	Shipments	Average Annual Shipments per Manufacturer	Shipments
1980[b]	12,233	155	7,165	29	NA
1981[b]	8,677	116	11,456	436	NA
1982[b]	7,476	123	11,145	45	NA
1983[b]	4,853	88	11,975	67	NA
1984	4,479	93	11,939	58	773
1985	NA	NA	NA	NA	NA
1986	3,751	171	1,111	13	4,498
1987	3,157	263	957	19	3,155
1988	3,326	416	732	16	4,116
1989	4,283	428	1,989	55	5,209
1990	3,645	304	2,527	62	5,237
1991	5,585	349	989	24	1
1992	6,187	387	897	26	2
1993	6,025	464	931	28	12

[a]For high-temperature collectors, average annual shipments per manufacturer are not disclosed.
[b]Includes shipment data imputed for nonrespondents.
NA = Not available. The data reported for 1985 are incomplete.
Sources: **1980-1984**:Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 7. Shipments by the Top 5 Solar Thermal Collector Manufacturing States/ Territories 1992 and 1993
(Thousand Square Feet)

Origin	Shipments[a]		Percent	
	1992	1993	1992	1993
California	2,985	2,074	55	42
Florida	208	194	4	4
Other[b]	2,146	2,563	39	52
Subtotal	**5,339**	**4,831**	**98**	**98**
Total U.S.	**5,436**	**4,929**	**100**	**100**

[a]Includes domestic shipments and exports.
[b]Other includes New Jersey, New York, and Puerto Rico.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

ments, 83 percent were sent directly to exporters. Direct shipments to installers, end users, and others accounted for 7 percent of total shipments in 1993.

Table 8. Distribution of Solar Thermal Collector Shipments, 1992 and 1993

Recipient	Shipments (thousand square feet)	
	1992	1993
Wholesale Distributors . . .	3,537	3,710
Retail Distributors	2,709	2,410
Exporters	280	343
Installers	192	313
End Users and Other[a]	367	191
Total	**7,086**	**6,968**

[a]Other includes minimal shipments not explained on Form CE-63A.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Collector Types

Solar thermal collectors are divided into the categories of low-, medium-, and high-temperature collectors. Low-temperature collectors provide heat up to 110º Fahrenheit through either metallic or nonmetallic absorbers and are used in applications such as swimming pool heating and water, space, and process heating. Medium-temperature collectors provide heat greater than 110º Fahrenheit (usually 140 to 180º Fahrenheit) through either glazed flat-plate collectors that use air or liquid as the heat transfer medium or concentrator collectors that concentrate the heat of incident insolation to greater than "one sun." Evacuated-tube collectors are included in this cate-gory. High-temperature collectors are parabolic dish and trough collectors and are used primarily by utilities and nonutility power producers in the generation of electricity for the grid. A high-temperature solar thermal collector operates at temperatures above 180 degrees Fahrenheit.

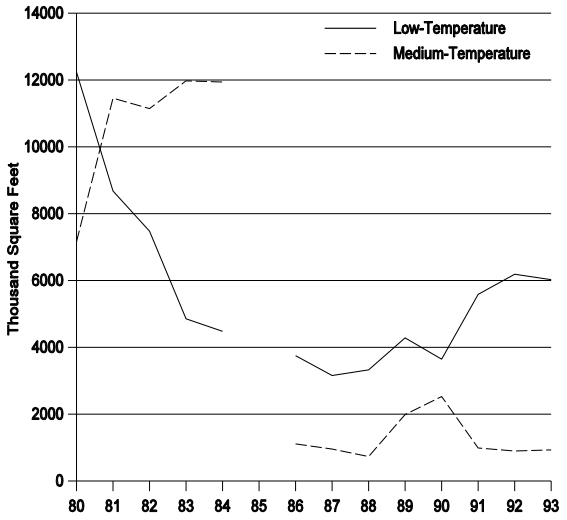
Between 1980 and 1984, annual low-temperature collector shipments decreased from 12.2 million to 4.5 million square feet (Figure 2). From 1986 through 1993, annual shipments of low-temperature collectors ranged between 3.2 and 6.2 million square feet.

In 1983 and 1984, before the expiration of the energy tax credits at the end of 1985, medium-temperature collector manufacturers shipped just under 12 million square feet each year. By the end of 1986, shipments declined to 1.1 million square feet. In 1990, shipments of medium-temperature collectors were 2.6 million square feet, and from 1991 through 1993 shipments have been below 1 million square feet each year.

Low-temperature collectors dominated the solar thermal industry in 1993, accounting for 86 percent of total shipments (Table 9). Medium-temperature col- lectors accounted for 13 percent of total collector shipments in 1993. Flat plate collectors represented 9 percent of total shipments.

Collectors that constituted subunits of thermosiphon systems or integral collector storage systems (ICS) represented 4 percent of total shipments (Table 9). High-temperature collectors, shipped primarily for

Figure 2. Shipments of Low- and Medium-Temperature Solar Thermal Collectors, 1980-1993



Note: Data for 1985 are incomplete.
Sources: **1985-1993**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

research and demonstration projects, represented less than one percent of total shipments in 1993.

Values and Prices

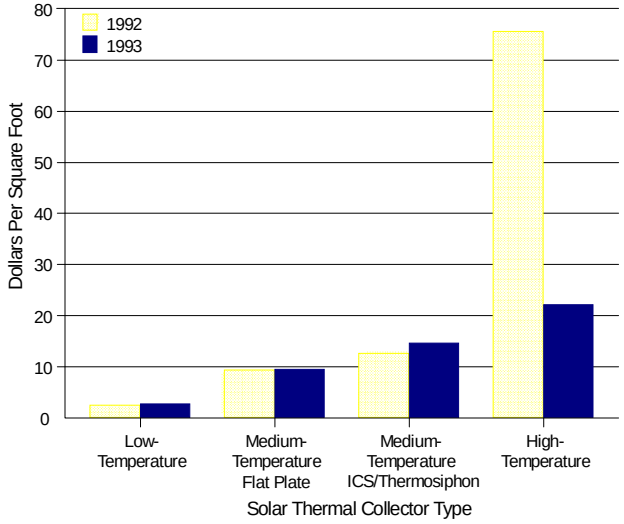
The total value of solar thermal collector shipments was $27.6 million in 1993; a 9-percent increase compared with 1992 (Table 9). The average price of low-temperature collectors increased to $2.79 from $2.49 (dollars per square foot), and the average price of ICS and thermosiphon collectors increased to $14.62 in 1993 from $12.64 in 1992. This increase was due primarily to increased material costs. The average price for flat-plate collectors in 1993 increased to $9.44 from the corresponding 1992 level of $9.32 per square foot (Figure 3). The value of shipments includes charges for advertising and warranties. Excluded are excise taxes and the cost of freight or transportation for the shipments.

Table 9. Solar Thermal Collector Shipment by Type, Quantity, Value, and Average Price, 1992 and 1993

Type	1992			1993		
	Quantity (thousand square feet)	Value (thousand dollars)	Average Price (dollars per square foot)	Quantity (thousand square feet)	Value (thousand dollars)	Average Price (dollars per square foot)
Low-Temperature						
Liquid and Air	6,187	15,403	2.49	6,025	16,819	2.79
Medium-Temperature						
Air	1	8	11.57	1	7	10.19
Liquid						
ICS/Thermosiphon	303	3,825	12.64	304	4,446	14.62
Flat Plate	584	5,441	9.32	623	5,887	9.44
Evacuated Tube	W	W	W	2	174	82.19
Concentrator	W	W	W	1	9	14.40
All Medium Temperature	897	9,831	10.96	931	10,523	11.73
High-Temperature						
Parabolic Dish and Trough	2	148	75.66	12	260	22.11
Total	**7,086**	**25,382**	**--**	**6,968**	**27,602**	**3.96**

W = Data withheld to avoid disclosure.
ICS = Integral collector storage.
-- Not applicable.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Figure 3. Average Price of Solar Thermal Collectors, 1992 and 1993



Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Markets

In 1993, the residential sector was the largest market for solar thermal collectors. Solar thermal collectors shipped to the residential sector in 1993 totaled 6.7 million square feet, 96 percent of total shipments (Table 10). This market sector primarily involves the use of low-temperature solar collectors for heating swimming pools and medium-temperature collectors for water heating in residential buildings. The residential sector was also the largest market in 1992. The second largest market for solar thermal collectors in 1993 was the commercial sector, which accounted for 3 percent of total shipments.

Uses

The largest end use for solar thermal collectors shipped in 1993 was for heating swimming pools, and it represented 87 percent of the total square feet shipped (Table 11). This application usually involved the use of low-temperature collectors. A common low-temperature pool-heating solar collector is a black plastic or rubber-like sheet with tubing through which water is circulated. The heat of the sun is transferred directly from the black absorbing material to the water circulating through the tubing to supply heat to the pool. Shipments for pool heating declined 3 percent in 1993 from the level reported in 1992.

The second largest end use in 1993 was for domestic hot water systems, which accounted for 13 percent of the total square feet shipped. Typical solar water-heating systems feature flat-plate collectors or collectors installed in an ICS or thermosiphon system. Unlike pool-heating systems, domestic solar water-heating systems nearly always have a conventional backup (i.e., gas or electric). Shipments in 1993 for hot water systems increased 10 percent from the 1992 level.

Table 10. Shipments of Solar Thermal Collectors by Market and Type, 1992 and 1993
(Thousand Square Feet)

Market Sector	Low-Temperature	Medium-Temperature					High-Temperature	1993 Total	1992 Total
	Liquid/Air		Liquid						
	Metallic and Nonmetallic	Air	ICS/ Thermo-siphon	Flat-Plate (Pumped)	Evacu-ated Tube	Concen-trator	Parabolic Dish/Trough		
Residential	5,841	1	297	552	2	1	1	**6,694**	**6,832**
Commercial	171	0	3	41	0	0	0	**215**	**204**
Industrial	14	0	2	15	0	0	0	**31**	**27**
Utility	0	0	2	15	(S)	0	11	**28**	**17**
Other[a]	0	0	(S)	0	0	0	(S)	**1**	**6**
Total	**6,025**	**1**	**304**	**623**	**2**	**1**	**12**	**6,968**	**7,086**

[a]Other includes shipments of solar thermal collector s to other sectors such as government, including the military but excluding space applications.
(S) = Less than 500 square feet.
ICS = Integral Collector Storage.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 11. Shipments of Solar Thermal Collectors by End Use and Type, 1992 and 1993
(Thousand Square Feet)

End Use	Low-Temperature	Medium-Temperature					High-Temperature		
	Liquid/Air		Liquid						
	Metallic and Nonmetallic	Air	ICS/ Thermo-siphon	Flat-Plate (Pumped)	Evacu-ated Tube	Concen-trator	Parabolic Dish/Trough	1993 Total	1992 Total
Pool Heating	6,011	0	0	29	0	0	0	**6,040**	**6,210**
Hot Water	0	0	302	575	2	1	1	**880**	**801**
Space Heating	14	1	(S)	0	0	0	0	**15**	**35**
Space Cooling	0	0	0	0	0	0	0	**0**	**1**
Combined Space and Water Heating	0	0	0	4	0	0	0	**4**	**5**
Process Heating	0	0	2	15	0	0	0	**17**	**32**
Electricity Generation	0	0	0	0	0	0	11	**11**	**1**
Other[a]	0	0	0	0	0	(S)	0	**(S)**	**1**
Total	**6,025**	**1**	**304**	**623**	**2**	**1**	**12**	**6,968**	**7,086**

[a]Other includes shipments of solar thermal collectors for other uses such as cooking foods, water pumping, water purification, desalinization, distilling, etc.
(S) = Less than 500 square feet.
ICS = Integral Collector Storage.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Medium-temperature collectors also were shipped for space heating, and for installation into systems that provide both space and water heating and process heating. High-temperature parabolic dish and trough collectors were shipped for electricity generation and hot water in 1993.

Destinations

Domestic

Solar thermal collectors were shipped to 41 States, Puerto Rico, and the U.S. Virgin Islands in 1993. In 1992, 42 States received collector shipments (Table 12). The four States and one U.S. territory that received the largest amounts of solar thermal collectors in 1993 were: Florida (56 percent), California (23 percent), Arizona and Puerto Rico (4 percent each), and Hawaii (3 percent) (Table 13). All of the collectors manufactured in Puerto Rico remained on the island. The U.S. market for solar thermal collectors continued to be highly concentrated in a few States and Puerto Rico. Factors favorable for solar energy use that these States and Puerto Rico have in common are: (1) good solar insolation; (2) high electricity costs; (3) solar-promoting incentives, such as tax credits or exemptions; and (4) a demand for low technology solar pool heaters and solar domestic hot water systems.

Export

Exports accounted for 6 percent of total shipments in 1993. A total of 19 companies exported solar thermal collectors in 1993 compared with 16 companies in 1992. Of total 1993 exports, low-temperature collec-tors accounted for 24 percent and medium-temperature collectors 73 percent. Summed by continents, the largest percentage of shipments were to North America (32 percent), followed by Asia (28 percent) and Europe (23 percent) (Table14). Trading countries that received export shipments were Taiwan (15 percent), Japan (10 percent), Australia (9 percent), Mexico (9 percent), Austria (8 percent), Canada (7 percent), and France (6 percent) (Table 14).

Table 12. Shipments of Solar Thermal Collectors by Destination, 1992 and 1993

(Square Feet)

Destination	Shipments 1992	Shipments 1993	Destination	Shipments 1992	Shipments 1993
Alabama	1,878	1,682	Nebraska	1,749	1,682
Alaska	0	0	**Nevada**	78,417	13,009
Arizona	209,731	285,506	**New Hampshire**	1,956	1,725
Arkansas	2,029	1,682	**New Jersey**	67,217	60,926
California	1,777,328	1,540,145	New Mexico	8,944	10,240
Colorado	44,667	23,611	**New York**	68,266	73,757
Connecticut	11,529	13,908	**North Carolina**	5,609	5,840
Delaware	0	0	**North Dakota**	0	0
District of Columbia	0	0	**Ohio**	11,529	13,908
Florida	3,805,357	3,701,116	**Oklahoma**	92	0
Georgia	27,849	34,505	**Oregon**	82,425	122,534
Hawaii	169,746	196,507	**Pennsylvania**	29,309	17,620
Idaho	93	222	Puerto Rico	202,589	253,379
Illinois	21,309	27,709	**Rhode Island**	4,864	0
Indiana	9,780	12,579	South Carolina	1,951	2,620
Iowa	126	256	**South Dakota**	0	0
Kansas	1,905	2,036	Tennessee	1,749	1,794
Kentucky	0	0	**Texas**	18,837	40,254
Louisiana	1,749	1,682	**Utah**	47	354
Maine	2,570	23,909	Vermont	1,949	1,832
Maryland	11,543	14,236	Virgin Islands (U.S.)	7,435	2,923
Massachusetts	12,098	12,494	**Virginia**	3,378	2,097
Michigan	47	3,382	**Washington**	30,413	12,859
Minnesota	9,087	1,059	West Virginia	161	165
Mississippi	0	0	**Wisconsin**	18,867	15,300
Missouri	1,749	3,374	Wyoming	0	0
Montana	0	111			
Shipments to United States/Territories				**6,769,923**	**6,556,529**
Exports				**315,773**	**411,475**
Total Shipments				**7,085,696**	**6,968,004**

Notes: ● Underlined States sponsored incentives for solar thermal collector purchases during 1992 (Solar Energy Industries Association, *Solar Industry Journal*, First Quarter 1993, pp. 16-21). States in bold face type sponsored incentives during 1993. (Steve Kalland, Solar Energy Industries Association, personal communication to James Holihan, Energy Information Administration, Washington, D.C. June 1, 1994).

Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 13. Shipments Ranked by Top Five Destinations, 1992 and 1993

State or Territory	1992 Shipments: Thousand Square Feet	1992 Shipments: Percent of U.S. Total	1992 Shipments: Rank	1993 Shipments: Thousand Square Feet	1993 Shipments: Percent of U.S. Total	1993 Shipments: Rank
Florida	3,805	56	1	3,701	56	1
California	1,777	26	2	1,540	23	2
Arizona	210	3	3	286	4	3
Puerto Rico	203	3	4	253	4	4
Hawaii	170	3	5	197	3	5
Top Five Total	6,165	91	--	5,977	91	--

-- = Not Applicable

Notes: ● Totals may not equal sum of components due to independent rounding. ● Percentages are based on the total shiiped each year to the United States and Territories shown in Table 12. ● U.S. total includes territories.

Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 14. Distribution of Solar Thermal Collector Exports by Country Within Continent, 1993

Continent	Country	Percent of Exports
Africa	**Total**	**3.4**
	South Africa	2.9
	Other Africa	0.5
Asia	**Total**	**28.2**
	Japan	9.7
	Taiwan	14.6
	Other Asia	3.9
Australia	**Total**	**9.1**
	Australia	9.1
Europe	**Total**	**22.9**
	Austria	8.2
	France	5.8
	Spain	1.0
	Switzerland	2.1
	Other Europe	6.0
North America	**Total**	**32.3**
	Antigua	2.0
	Bahamas	2.7
	Bermuda	2.0
	Canada	6.7
	Costa Rica	0.7
	Haiti	1.9
	Jamaica	1.9
	Mexico	8.9
	Trinidad	1.9
	Other Central America	1.6
	Other North America	1.9
South America	**Total**	**4.1**
	Chile	2.4
	Colombia	0.7
	Other South America	0.9

Notes: Other represents shipments to countries not disaggregated by companies on Form CE-63A and may include shipments to enumerated countries. Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Systems

Of the 41 companies reporting shipments of solar thermal collectors in 1993, 31 reported shipments of 18,809 complete solar thermal collector systems. This was an 18-percent increase compared with 1992 (Table 15). A complete system is a unit with a collector and all the necessary functional components, except for installation materials. Included are thermo-siphon systems, integral collector storage systems, packaged systems, and system kits. The 18,809 complete systems accounted for 3.0 million square feet of collectors, an increase of 8 percent in square feet shipped above the 1992 level. The total value for the systems shipped in 1993 was $20.6 million, compared with $19.4 million in 1992.

Table 15. Shipments of Complete Solar Thermal Collector Systems, 1992 and 1993

	1992	1993
Complete Collector Systems Shipped[a]	15,946	18,809
System Shipments (thousand square feet)	2,763	2,989
System Shipments (percent of total shipments)	39	43
Number of Companies	35	31
Value of Systems (thousand dollars)	19,390	20,631

[a]A complete system is a unit with a collector and all the necessary functional components, except for installation materials.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Photovoltaic Cell and Module Manufacturing Activities

This chapter presents information on the U.S. photovoltaic (PV) cell and module manufacturing industry in 1993. It covers the status of the industry, PV cell and module shipments (expressed in peak kilowatts), manufacturing origins, destinations, imports, exports, cell and module types, values and prices, end uses and markets. PV shipments data in this chapter include cells and modules manufactured by U.S. companies that were shipped for domestic use and for export as well as imported cells and modules.

A PV module is an integrated array of PV cells assembled into a panel. PV cells are the unencapsulated semiconductor components of the module. PV cells convert a portion of the solar energy into electric energy. Cells and modules manufactured and shipped for space and satellite applications are not covered in this report.

Industry Status

PV cell and module shipments totaled 21.0 peak megawatts in 1993 (Table 16). These shipments were reported by 19 companies. Three companies expect to introduce new crystalline-silicon module products, and six companies reported plans to introduce new thin-film products to the industry during 1994 (Table 17). Two companies reported plans to produce new PV concentrator products and five plan new nonmodule system components during 1994.

Employment in PV-related activities totaled 1,431 person-years in 1993 (Table 18), a decrease of 32 person-years from the 1992 level of employment. The average employment per company was 75 person-years in 1993, compared with 70 person-years in 1992.

Table 16. Number of Companies and Total Shipments of Photovoltaic Cells and Modules, 1982-1993
(Peak Kilowatts)

Year	Number of Companies	Photovoltaic Cell and Module Shipments		
		Total	Import	Export
1982	19	6,897	NA	NA
1983	18	12,620	NA	1,903
1984	23	9,912	NA	2,153
1985[a]	15	5,769	285	1,670
1986[a]	17	6,333	678	3,109
1987[a]	17	6,850	921	3,821
1988[a]	14	9,676	1,453	5,358
1989[a]	17	12,825	826	7,363
1990[a]	[b]19	[b]13,837	1,398	7,544
1991[a]	23	14,939	2,059	8,905
1992[a]	21	15,583	1,602	9,823
1993[a]	19	20,951	1,767	14,814

[a]Does not include shipments of cells and modules for space/satellite applications.
[b]Includes imputed data for one nonrespondent, which exited the industry during 1990. See Appendix A for imputation method.
NA = Not available.
Note: Total shipments as reported by respondents includes all domestic and export shipments and may include imports that subsequently were shipped to domestic or to foreign customers.
Sources: 1982-1984: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 17. Companies Expecting to Introduce New Photovoltaic Products in 1994

New Product Type	Number of Companies
Crystalline Silicon	
Single-Crystal Silicon Modules	3
Cast Silicon Modules	3
Ribbon Silicon Modules	1
Thin-Film	
Amorphous Silicon Modules	6
Other[a]	3
Concentrators	2
Nonmodule System Components	5

[a]Other includes various different component materials used in thin film modules.

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey" (1993).

Table 18. Employment in the Photovoltaic Manufacturing Industry, 1990-1993

Year	Number of Companies	Number of Person-Years
1990	19	1,622
1991	23	1,588
1992	21	1,463
1993	19	1,431

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Many companies, engaged in the manufacture and/or importation of PV cells and modules, reported that they also are involved in other PV-related activities. There were 15 companies involved in module or system design, 13 were active in developing module prototypes, and 13 developed PV system prototypes (Table 19). There were 15 companies that sold wholesale and 10 companies sold at retail. Nine companies, two more than in 1992, installed PV cells or modules.

Shipments

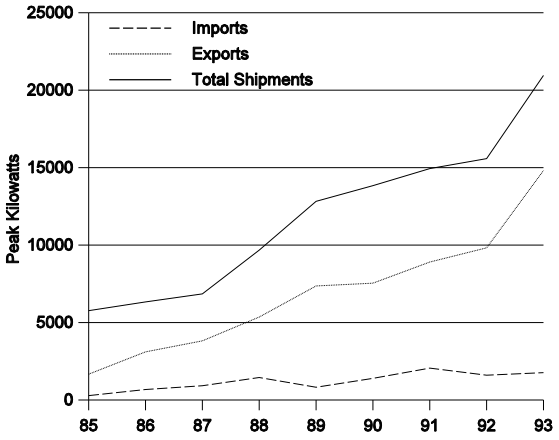
Of the 21.0 peak megawatts in PV cell and module shipments in 1993, module shipments accounted for 14.9 peak megawatts and cell shipments accounted for 6.0 peak megawatts. Total PV shipments in 1993 increased 34 percent above the 1992 level. Total shipments have increased 263 percent since 1985 (Figure 4). Data for PV cells and modules for terrestrial use only (i.e., excluding space applications) have been reported each year since 1985.

Table 19. Number of Companies Involved in Photovoltaic-Related Activities, 1992 and 1993

Type of Activity	Number of Companies	
	1992	1993
Cell Manufacturing	13	10
Module or System Design	18	15
Prototype Module Development	15	13
Prototype Systems Development	12	13
Wholesale Distribution	14	15
Retail Distribution	9	10
Installation	7	9
Noncollector System Component Manufacture	6	10

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Figure 4. Photovoltaic Cell and Module Shipments, 1985-1993



Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Imports

Seven companies reported import shipments of PV cells and modules in 1993 totaling 1.8 peak megawatts, or 8 percent of total shipments (Table 16). The predominant type of imported PV cells and modules was crystalline silicon. These imports originated in Australia, China, and Japan, with Japan accounting for most of the imported PV cells and modules.

Distribution

In 1993, PV cell and module shipments totaling 10.4 peak megawatts (49 percent of total shipments) were sent directly to wholesale distributors (Table 20). Installers and end users combined received 3.6 peak megawatts (17 percent of total shipments).

PV cell manufacturers shipped 5.3 peak megawatts (25 percent of total shipments) to other companies that manufacture (assemble) cells into PV modules.

Table 20. Distribution of Photovoltaic Cells and Modules, 1992 and 1993

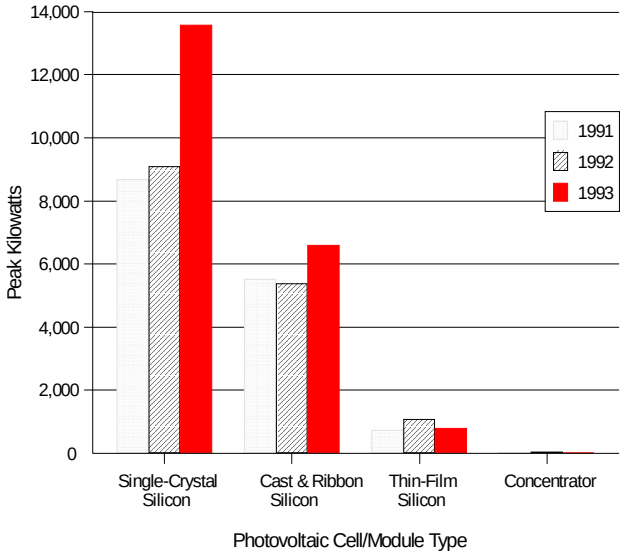
Recipient	Shipments (peak kilowatts)	
	1992	1993
Wholesale Distributors	8,604	10,354
Retail Distributors	592	862
Exporters	591	151
Installers	1,148	1,278
End Users	1,008	2,295
Module Manufacturers	2,511	5,256
Other[a]	1,129	754
Total	**15,583**	**20,951**

[a]Other includes categories not identified by reporting companies.

Note:Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Figure 5. Photovoltaic Cell and Module Shipments by Type, 1991-1993



Cell and Module Types

PV shipments are divided into three categories by product type: (1) crystalline silicon cells and modules (includes single-crystal, cast silicon, and ribbon silicon); (2) thin-film cells and modules (made from a number of layers of photosensitive materials such as amorphous silicon); (3) concentrator cells and modules (in which a lens is used to gather and converge sunlight onto the cell or module surface).

Crystalline silicon cells and modules continued to dominate the PV industry in 1993, accounting for 96 percent of total shipments (Table 21). In particular, single-crystal silicon shipments totaled 13.6 peak megawatts, an increase of 49 percent compared with corresponding 1992 shipments (Figure 5). Together, cast and ribbon silicon shipments totaled 6.6 peak megawatts in 1993, a 22-percent increase from the corresponding 1992 shipments.

From 1992 to 1993, thin-film shipments decreased 27 percent (Table 21). Thin-film shipments represented 4 percent of total shipments in 1993.

Table 21. Shipments by Type of Photovoltaic Cell and Module, 1991-1993

Type	Shipments (peak kilowatts)			Percent of Total Shipments		
	1991	1992	1993	1991	1992	1993
Crystalline Silicon						
Single-Crystal	8,685	9,078	13,560	58	58	65
Cast and Ribbon	5,520	5,379	6,587	37	35	31
Subtotal	14,205	14,457	20,146	95	93	96
Thin-Film Silicon	723	1,075	782	5	7	4
Concentrator Silicon	12	40	21	(*)	(*)	(*)
Other[a]	0	11	2	0	(*)	(*)
Total	**14,939**	**15,583**	**20,951**	**100**	**100**	**100**

[a]Other includes categories not identified by reporting companies.

(*)Represents less than 0.5, rounded to zero.

Note: ●Data do not include shipments of cells and modules for space/satellite applications. ●Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Values and Prices

The total value of photovoltaic cell and module shipments was $110 million in 1993, a 26-percent increase over the 1992 value of $87 million (Table 22). The total value includes charges for advertising and warranties, but does not include excise taxes and the cost of freight or transportation for the shipments.

Table 22. Value and Average Price of Cells and Modules by Type, 1992 and 1993

Type	1992			1993		
	Value (thousand dollars)	Average Price (dollars per peak watt)		Value (thousand dollars)	Average Price (dollars per peak watt)	
		Modules	Cells		Modules	Cells
Crystalline Silicon						
Single-Crystal	47,621	6.14	3.12	63,277	4.41	5.02
Cast and Ribbon	32,339	6.04	4.23	39,216	6.00	5.15
Subtotal	79,960	6.10	3.16	102,493	5.11	5.03
Thin-Film Silicon	6,851	6.31	10.67	6,001	7.64	10.13
Concentrator Silicon	189	4.37	10.08	W	W	W
Other[a]	74	6.00	10.00	W	W	W
Total	**87,074**	**6.11**	**3.21**	**109,797**	**5.24**	**5.23**

[a]Other includes categories not identified by reporting companies.

W = Withheld to avoid disclosure of individual company data.

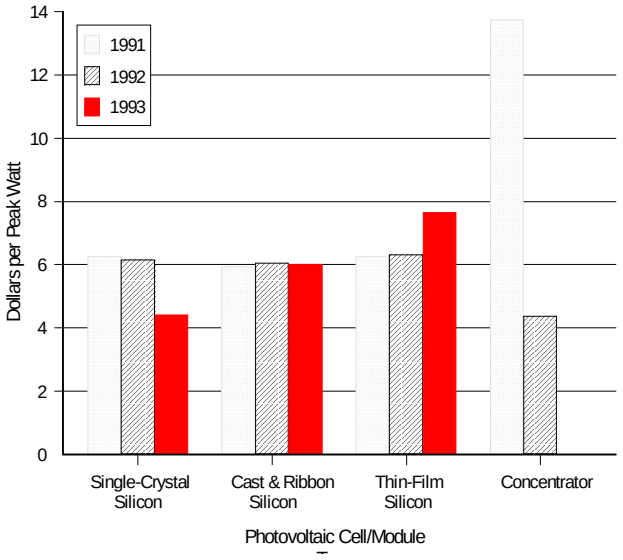
Notes: ●Data do not include shipments of cells and modules for space/satellite applications. ●Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

The total value of crystalline silicone (single-crystal, cast, and ribbon) shipments was $102.5 million in 1993, a 28-percent increase compared with the corre-sponding 1992 value. The value of thin-film shipments in 1993 was $6.0 million, 12 percent less than in 1992.

The average price of crystalline silicon modules in 1993 was $5.11 per peak watt, a decrease of 16 percent from the 1992 price of $6.10 (Figure 6). The average price for thin-film modules was $7.64 per peak watt, 21 percent higher than the 1992 price.

Figure 6. Average Price of Photovoltaic Modules, 1991-1993



Source: Energy Information Administration, CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Uses

The largest end-use application of PV cells and modules in 1993 was for electricity generation (combined grid-interactive and remote). This represented 33 percent of total shipments (Table 23). Of the 6.8 peak megawatts represented by this end use, 99 percent involved crystal-line silicon cells and modules. Grid interactive and remote, i.e., stand-alone, power generation include applications for grid distribution and general remote uses, such as residential power and power for mobile homes.

The second largest PV end use in 1993 was in the transportation sector, which accounted for 4.2 peak megawatts. PV units to power fixed-based com-munications equipment, such as mountain-top signal-repeater stations, totalled 3.8 peak megawatts, or 18 percent of total shipments. In 1992, communications was the second largest PV end-use application.

End uses related to water pumping and original equipment manufacturers accounted for 2.3 peak megawatts and 2.0 peak megawatts, respectively, in 1993 and involved primarily the use of crystalline silicon cells and modules.

Sales for consumer goods accounted for 0.9 peak megawatts in 1993, a decline of 63 percent from 1992. PV cells and modules used for health and medical purposes, such as to power refrigerators, medical equipment, and water purifiers, totaled 0.7 peak mega-watts in 1993, a ninefold increase over the 1992 level. End uses reported as "Other" for 1993 totaled 0.07 peak megawatts, a decline of 86 percent from 1992.

Destinations

Domestic

The industrial sector was the largest market for PV cells and modules in 1993, accounting for 26 percent of total shipments (Table 24). In this market, PV cells and modules are used to produce power for industrial appli-cations including grid and nongrid systems. In 1993, 99.5 percent were crystalline silicon and 0.5 percent were thin-film silicon cells and modules. The industrial sector also represented the largest market for PV ship-ments in 1992.

Use of cells and modules in grid-connected and remote (nongrid) PV systems to provide power for the residen-tial sector was the second largest market for PV in 1993, and accounted for 25 percent of total shipments.

The commercial market was the third largest PV market, accounting for 20 percent of total shipments in 1993. These cells and modules were shipped to pro-vide power for commercial establishments such as office buildings, retail establishments, private hospitals, and schools (publicly owned hospitals and schools are

listed under the government sector). In contrast, the commercial sector accounted for 15 percent of total shipments.

Table 22. Shipments of Photovoltaic Cells and Modules by End Use and Type, 1992 and 1993

Type	Crystalline Silicon	Thin-Film Silicon	Concentrator Silicon	Other	1993 Total	1992 Total
Electricity Generation						
Grid Interactive	1,040	45	11	0	**1,096**	**1,227**
Remote	5,724	30	7	0	**5,761**	**4,238**
Communication	3,824	22	0	0	**3,846**	**3,717**
Consumer Goods	W	W	0	0	**946**	**2,566**
Transportation	3,949	288	1	0	**4,238**	**1,602**
Water Pumping	2,287	6	2	0	**2,294**	**809**
Cells/Modules to OEM[a]	1,753	270	0	0	**2,023**	**828**
Health	664	10	0	0	**674**	**67**
Other[b]	W	W	0	2	**74**	**530**
Total	**20,146**	**782**	**21**	**2**	**20,951**	**15,583**

[a]OEM is riginal equipment manufacturers
[b]Other uses incluse shipments of photovoltaic cells and modules for uses such as coooking food, desalinization, distilling, etc.
W=Data withheld to avoid disclosure.
Note: Total may not equal sum of compondents due to independent rounding.
Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Survey."

Table 24. Shipments of Photovoltaic Cells and Modules by Market and Type, 1992 and 1993

Type	Crystalline Silicon	Thin-Film Silicon	Concentrator Silicon	Other	1993 Total	1992 Total
Industrial	5,327	25	0	0	**5,352**	**4,279**
Residential	5,225	7	5	0	**5,237**	**4,154**
Commercial	3,834	266	14	0	**4,115**	**2,386**
Transportation	2,224	340	0	0	**2,564**	**1,673**
Utility	1,478	25	0	0	**1.503**	**1,553**
Government[a]	1,303	21	2	0	**1,325**	**1,063**
Other[b]	755	99	0	2	**856**	**477**
Total	**20,146**	**782**	**21**	**2**	**20,951**	**15,583**

[a]Includes Federal, State, and local fovernments, excluding military.
[b]Other includes shipmentsthat are manufactured for private contractors for research and development projects.
Note: Total may not equal sum of compondents due to independent rounding.
Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Survey."

PV cells and modules for the transportation sector, which were used to produce power on boats, in cars, in recreational vehicles, and to power transportation support systems, amounted to 2.6 megawatts. The transportation sector accounted for 12 percent of total shipments in 1993 compared with 11 percent in 1992.

Shipments to the utility sector, where cells and modules were used to produce power at utility-owned systems including central stations, decentralized systems, and experimental applications, amounted to 1.5 peak megawatts in 1993, a 3-percent decrease from 1992.

Shipments of PV cells and modules used to produce power at installations of Federal, State, or local governments (excluding military) totaled 1.3 peak megawatts in 1993. This compares with 1.1 peak megawatts shipped to the government sector in 1992. The "Other" sector (Table 24) in 1993 consisted of 0.9 peak megawatts shipped to foreign governments or used for

speciality purposes.

Exports

Export shipments totaled 15 peak megawatts in 1993, an increase of 51 percent from the 1992 level (Table 16). Generally, export shipments since 1990 have paralleled total shipments because of the continured search for new PV markets outside the United States (Figure 4). A total of 17 companies reported exports of PV cells and modules in 1993, and exports accounted for 71 percent of total PV shipments. Of all types of cells and modules exported in 1993, 99 percent were crystalline silicon (Table 25). Destinations of PV exports by continent and by country are shown in Table 27.

Table 25. Export Shipments of Photovoltaic Modules and Celles by Type, 1993
(Peak Kilowatts)

Item	Type			
	Crystaline Silicon	Thin-Film Silicon	Concentrator Silicon	Total
Modules	9,448	152	5	9,605
Cells . .	5,206	2	1	5,209
Total .	14,655	154	6	14,814

Note: Totals may not equal sum of componentsdue to independent rounding.
Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Systems

Of the 25 companies that reported shipments of PV systems in 1993, 12 reported shipments of 447 complete photovoltaic systems, nearly double the number shipped in 1992 (Table 28). A complete photovoltaic system is defined as a power supply unit that satisfies all the power requirements of an application. Such a system is generally made up of one or more modules, a power conditioning unit to process the electricity into the form needed by the application, wires and other electrical connectors, and sometimes batteries for back-up power supply. Some complex, large-scale PV systems use concentrators to focus incident insolation onto small PV cells and tracking systems to track the sun. In this report, installation materials such as the spport frame and concrete foundations are not considered as part of a system. The value of systems reported in Table 28 excludes excise taxes and charges for freight, transportation, and installation. The total value of complete systems shipped in 1993 was $14.1 million. Complete-system shipments in 1993 accounted for 1.4 peak kilowatts, or 9 percent of total module shipments.

Table 26. Destination of Photovoltaic Cell and Module Exports by Continent, 1993

Continent	Percent of Exports
Africa	7.5
Asia	31.8
Australia	.6
Europe	37.7
North America[a]	11.4
South America	11.0
Total	**100.0**

[a]North America consists of Canada, Mexico, United States, Central America, and Caribbean countries.
Note: Total may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturing Survey."

Table 27. Destination of Photovoltaic Cell and Module Exports, 1993

Destination	Peak Kilowatts	Percent of Exports	Destination	Peak Kilowatts	Percent of Exports
Angola	1	(*)	Italy	187	1.3
Argentina	795	5.4	Japan	1,440	9.7
Australia	92	0.6	Kenya	5	(*)
Belgium	4	(*)	Lesotho	4	(*)
Belize	1	(*)	Malaysia	(s)	(*)
Bolivia	145	1.0	Mexico	761	5.1
Botswana	273	1.8	Nepal	3	(*)
Brazil	401	2.7	Netherlands	219	1.5
Burkina Faso	4	(*)	Nigeria	1	(*)
Canada	819	5.5	Norway	8	0.1
Caribbean[a]	46	0.3	Pakistan	(s)	(*)
Chile	96	0.6	Panama	29	0.2
China	421	2.8	Peru	102	0.7
Colombia	1	(*)	Philippines	(s)	(*)
Dominican Republic	17	0.1	Senegal	(s)	(*)
Egypt	(s)	(*)	Singapore	639	4.3
El Salvador	(s)	(*)	South Africa	399	2.7
Ecuador	58	0.4	South Korea	282	1.9
England	20	0.1	Swaziland	(s)	(*)
Ethiopia	4	(*)	Sweden	156	1.1
Finland	11	0.1	Switzerland	4	(*)
France	(s)	(*)	Taiwan	83	0.6
Germany	4,972	33.6	Tanzania	7	(*)
Ghana	14	0.1	Uganda	60	0.4
Haiti	17	0.1	United Kingdom	2	(*)
Hong Kong	1,567	10.5	Venezuela	24	0.2
Hungary	2	(*)	Zaire	(s)	(*)
India	94	0.6	Zambia	(s)	(*)
Indonesia	175	1.2	Zimbabwe	334	2.3
Israel	(s)	(*)			
Total				**14,814**	**100.0**

(*)= Number less than 0.05, rounded to zero.
(s)=Less than 500 peak watts.
[a]Includes all Caribbean countries except the Dominican Republic and Haiti.
Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 28. Shipments of Complete Photovoltaic Module Systems,1991-1993

Category	1991	1992	1993
Complete Photovoltaic Systems Shipped (units)	795	232	447
Modules in Complete Systems (peak kilowatts)	89	781	1,395
Modules in Systems as Percent of Total Module Shipments	1	6	9
Values of Complete Systems (thousand dollars)	5,625	7,4098	14,123

Source: Energy Information Administration, Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Appendix A

Survey Methodology

Appendix A

Survey Methodology

Survey Design

The Energy Information Administration (EIA) uses the Forms CE-63A, "Annual Solar Thermal Collector Manufacturers Survey," and CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey," to collect annual information about the U.S. solar thermal and photovoltaic manufacturing industries. Under these surveys, the EIA obtains data from all U.S.-based manufacturers and importers of solar thermal collectors and photovoltaic devices. The survey forms and instructions are contained in Appendix B.

Respondents to the surveys are required to report data on (1) manufacturing activities, employment, and plans; and (2) total shipments, including imports and exports, type of collectors, shipment value, and shipment origin and destination. Respondents are requested to report their shipments of solar thermal collectors in terms of square feet and shipments of photovoltaic cells and modules in terms of electrical capacity, expressed in peak kilowatts.

The data collected on Forms CE-63A/B are subject to various sources of error. These sources are: (1) coverage (the list of respondents may not be complete or, on the other hand, there may be double counting); (2) nonresponse (all that are surveyed may not respond or may not provide all information requested); (3) respondents (respondents may commit errors in reporting the data); (4) processing (the data collection agency may omit or incorrectly transcribe a submission); (5) concept (the data collection elements may not measure the items they were intended to measure); and (6) adjustments (errors may be made in estimating values for missing data). Because both of the surveys are census surveys, the estimates shown in this report are not subject to sampling error.[14] Although it is not possible to present estimates of nonsampling error, precautionary steps were taken at each stage of the survey design to minimize the possible occurrence of these errors.

Survey Universe and Frame

The universe of the CE-63A/B respondents is a census of those U.S.-based companies involved in manufacturing and/or importing solar collectors. Care has been taken to establish the survey frames accurately. The frames of potential respondents are compiled from previous surveys and from information in the public domain. However, because the solar collector industry is subject to sporadic entry and exit of manufacturers and importers, the frame could possibly exclude some small companies that recently entered or re-entered the industry.

The 1991 survey frames were updated in late 1992. The 1990 survey frames were updated in late 1991 and again in early 1992. Based on results from updates of the survey frames, data for 1990 (published in *Solar Collector Manufacturing Activity 1990*) were revised in the report, *Solar Collector Manufacturing Activity 1991*.

Survey Procedures

The survey forms were sent out via first class mail to ensure their receipt only by the proper respondent organization. If the U.S. Postal Service was unable to deliver a survey form, the corrected address was obtained where possible. In a few instances, businesses that reported in earlier surveys were no longer operating and therefore were

[14]Sampling error is a measure of the variation that occurs by chance because a sample rather than a complete enumeration of units is surveyed.

eliminated from the survey frames. All known companies currently conducting business in the U.S. solar collector industry were contacted before and during this survey.

Approximately half of the respondents replied to the form within the specified initial deadlines. Those that did not were mailed another form specifying a new deadline. Those that had not responded by the second deadline were telephoned to encourage submission of the forms, and those calls resulted in the submission of most of the remaining forms. During the second round of calls, data were taken over the telephone whenever possible. Data received over the phone were entered on a blank survey form. Followup procedures were carried out to reduce the nonresponse rate and possible resulting bias.

Data Editing, Analysis, and Processing

Responses to the surveys were first edited manually to verify the accuracy of the reporting and to ensure reliability of the data. All individual company responses were also compared with the data reported in previous surveys. Wherever manual editing procedures indicated discrepancies or omissions, telephone calls were made to confirm or clarify the data. Data from manually edited forms were then entered into a computer and edited a second time via an automated procedure. After the second edit, a copy of each entry and tabulated computations were reviewed by an analyst familiar with the survey and with the solar collector industry and its companies.

Response Rates

The response rate for both surveys (Forms CE-63A/B) was 100 percent. The status of companies that were mailed CE-63A survey forms for the 1993 survey is shown in Table A. The 1993 survey responses to surveys sent to 66 potential solar thermal collector companies resulted in the following performance statistics:

- Active companies: Forty-one (41) companies are known to have shipped solar thermal collectors during 1993.
- Inactive: Nineteen (19) companies on the mailing list had no shipments in 1993 but were kept on the list because they may have shipments in future years.
- Out of business: Four (4) of the companies were reported to be out of the solar thermal business during 1993, with no plans to reenter the business in a future year.
- Out of scope: Two (2) companies reported that they were not involved in solar thermal collector manufacturing or importing solar thermal collectors.

Table A1. Status of 1993 Survey Respondents

Status	Number of Companies	
	Solar Thermal (Form CE-63A)	Photovoltaic (Form CE-63B)
Active	41	19
Inactive	19	17
Out of Business	4	5
Out of Scope	2	3
Total	**66**	**46**

Sources: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey," and Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

The status of companies that were mailed CE-63B survey forms for the 1993 survey is shown in Table A. The 1993 survey responses to surveys sent to 46 potential photovoltaic cell and module companies resulted in the following performance statistics:

- Active companies: Nineteen (19) companies are known to have shipped photovoltaic cells or modules during 1993.
- Inactive: Seventeen (17) companies on the mailing list had no shipments in 1993 but were kept on the list because they may have shipments in future years.
- Out of business: Five (5) companies were reported to have exited the photovoltaic cell and module business during 1993, with no plans to reenter the business in the future.

- Out of scope: Three (3) companies reported that they were not involved in photovoltaic cell and module manufacturing or importing cells and modules.

Incomplete or Missing Data and Imputation

During the 1990 Form CE-63B survey period, one photovoltaic manufacturer was known to have shipped photovoltaic cells and modules during the first half of 1990. This photovoltaic company had gone out of business in the second half of 1990, and no data were acquired. For this company, one-half of the shipments reported for 1989 was used as the estimate of 1990 shipments.

During 1986 the solar thermal collector manufacturing industry experienced a substantial slowdown in shipments as a result of the expiration of the solar tax credit at the end of 1985 and the reduction in energy prices. Reported shipments declined from 16.4 million square feet in 1984 to 4.9 million square feet in 1986.[15] Many of the 1986 shipments probably occurred during the first quarter, as customers took delivery of materials purchased in late 1985 when solar tax credits were still available. The number of companies reporting and their reported shipments for the years 1984 through 1986 are presented in Table A2.

Although reported shipments for 1985 were only 68 percent of those reported in 1984, it is likely that actual shipments were higher in 1985, which was believed to be a banner year because the energy tax credit expired at the end of the year. The number of companies reporting and, therefore, the reported shipments may have been low because many of the companies had gone out of business, and could not be located to collect the 1985 data when the data collection forms were mailed out more than a year later in early 1987. Shipment data for 80 companies that were in business all 3 years are presented in Table A3.

Table A2. Number of Reporting Companies and Shipments, 1984, 1985, and 1986

Item	1984	1985[a]	1986
Number of Companies	224	116	97
Shipments (million square feet)	16.4	11.1	4.9

[a]Incomplete data.

Sources: **1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1986**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table A3. Shipments of Companies Reporting in 1984, 1985, and 1986

Item	1984	1985[a]	1986
Number of Companies	80	80	80
Shipments (million square feet)	8.7	9.9	4.6

[a]Incomplete data.

Sources: **1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1986**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

For the 80 companies that were in business all 3 of the years, 1984 through 1986, shipments increased 14 percent in 1985 but decreased 54 percent in 1986. Although not conclusive, this is an indication that if all shipments for all companies in business in 1985 were reported, there could have been a substantial increase from 1984 to 1985.

During the 1980 through 1983 survey periods for solar thermal collectors, imputed shipment data for nonespondents were included (Tables 1 and 9). Imputed data are presented in Table A4.

[15]The 1984 and 1986 shipment data stated here are the original survey data. These were revised by the Energy Information Administration (EIA) in *Solar Collector Manufacturing Activity 1989*, DOE/EIA-0174(89) (Washington DC, March 1991). The revised data shipments for 1984 are 17.2 million square feet, and 9.4 million square feet for 1986. The revised data include shipments of parabolic dish/trough collectors to independent power producers to generate electricity for the electric grid. For the purposes of this analysis the original data are provided.

For the survey years 1980 through 1983, imputed solar thermal collector shipment imputed shipment data for nonrespondents were included (Tables 1 and 6).

Data Revisions

The Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration, has adopted the following policy for review and correction (revision) of data it collects and publishes. The policy covers revisions to prior published data. This new policy is initially implemented with the publication of the *Solar Collector Manufacturing Activity 1992*.

1. Annual survey data are published either as *preliminary* or *final* when they first appear in a data report. Data released as *preliminary* will be identified as such. When necessary, preliminary data will be revised and declared to be *final* at the next publication of these data.

2. Monthly and quarterly survey data are published initially as *preliminary* data. They will be revised only after the completion of the data collection cycle for the full 12-month survey period. Revisions will not be made to monthly or quarterly data prior to this time.

3. The magnitude of historical data revisions experienced will be included in each data report to inform the reader about the accuracy of the data presented.

4. Revisions to data published as *final* will be made only in the event that newly available information would result in a change to published data of greater than 1 percent difference at the national level. Revisions for changes of lesser magnitudes will be made at the discretion of the Office Director.

All data from Forms CE63/A and CE-63/B are published as final data. All revised data are indicated by an "R" in front of each revised data cell. No 1992 data were revised in this report.

Nondisclosure of Data

To protect the confidentiality of individual respondents' data, a policy was implemented to ensure that the reporting of survey data in this publication would not associate those data with a particular company. This is in compliance with EIA Standard No. 88-05-06, "Nondisclosure of Company Identifiable Data in Aggregate Cells." In tables where the nonzero value of a cell is composed of data from fewer than three companies or if a single company dominates a table-cell value so that the publication of the value would lead to identification of a company's data, then the EIA classifies the cell value as "sensitive," and the cell value is withheld ("W") from publication. Within a table with a sensitive cell value, selected values in other cells of the table are also withheld, as necessary, so that the sensitive cell value cannot be computed using the values in published cells.

A sensitive table-cell value can be reported, if permission is first obtained from each company (whose data contribute to the sensitivity) to publish the value. This is the only exception to the application of EIA Standard No. 88-05-06 in this report.

Appendix C

Respondents to the 1993 Solar Thermal Collector Manufacturers Survey (Form CE-63A)

Appendix C

Respondents to the 1993 Solar Thermal Collector Manufacturers Survey (Form CE-63A)

Of the companies reporting data on Form CE-63A, 41 gave permission to have their company name and address listed in this publication.

Access Technology Corporation
360 Center Street
Bangor, ME 04401

American Energy Technologies
P.O. Box 1865
Green Cove Spring, FL 32043

American Solar Network, Ltd.
5840 Gibbons Drive, Suite H
Carmichael, CA 95608

Applied Solar Products
4580 Almaden Expressway
San Jose, CA 95118

Aquatherm Industries, Inc.
1985 Rutgers University Blvd.
Lakewood, NJ 08701

Astron Technologies
4001 Atlantic Avenue
Raleigh, NC 27604

BC Solar
South 401 Hodges Road
Greenacres, WA 99016

Bio-Energy Systems, Inc.
P.O. Box 191, 48 Canal Street
Ellenville, NY 12428

BSAR Solar
980 Santa Estella
Solana Beach, CA 92075

Caribe Sol De Puerto Rico
Apartado 190
Mayaguez, PR 00709

Conserval Systems, Inc.
4242 Ridge Lea Road, Suite 1
Buffalo, NY 14226

Cummins Power Generation
P.O. Box #3005 M/C 60125
Columbus, IN 47202-3005

FAFCO, Inc.
2690 Middlefield Road
Redwood City, CA 94063

GS Energy Industries, Inc.
108 Jefferson Avenue
Des Moines, IA 50314

Haleakala Resources, Inc.
P.O. Box 786
Puunene, HI 96784

Hanson Energy Products
P.O. Box 1086
Rockland, ME 04841

Heliocol USA, Inc.
927 Fern St., #200
Altamonte-Springs, FL 32701

Heliodyne, Inc.
4910 Seaport Ave.
Richmond, CA 94804

Industrial Solar Technology
5771 W. 52nd Ave.
Denver, CO 80212

Keenan Solar, Inc.
7000 SW 22nd Ct., 127C
Davie, FL 33317

Professional Solar Products
31125 Via Colinas #904
West Lake Village, CA 91362

Puerto Rico Solar Products
P.O. Box 702
Moca, PR 00716

Radco Products, Inc.
2877 Industrial Parkway
Santa Maria, CA 93455

S & L Solar System Co., Inc.
Box 1535
Carolina, PR 00984

Sage Advance Corporation
P.O. Box 23136
Eugene, OR 97402

Sealed Air Corp.
3433 Arden Road
Hayward, CA 94545

SEMCO
901 21st Street, N.W.
Albuquerque, NM 87104

Solahart USA
155 Mata Way, Suite #109
San Marcos, CA 92069

Solar Alternative, Inc.
P.O. Box 739
Brattleboro, VT 05301

Solar Development, Inc.
3607A Prospect Avenue
Riviera Beach, FL 33404

Solar Energy and Resources, Inc.
P.O. Box 2929
Bayamon, PR 00621

Solar Living, Inc.
P.O. Box 12
Netcong, NJ 07857

SunEarth, Inc.
4315 Santa Ana St.
Ontario, CA 91761

Sun Quest, Inc.
1555 Rankin Ave.
Newton, NC 28658

Sun Ray Solar Heaters
1943-A Friendship Drive
El Cajon, CA 92020

Sun Trapper Solar Systems, Inc.
12118 Radium
San Antonio, TX 78216

Sunwatt Corp
RFD Box 751
Addison, ME 04606

Thermal Conversion Technology, Inc.
P.O. Box 3887
Sarasota, FL 34230

Thermomax USA, LTD
6193 Wooder Run Drive
Columbia, MD 21044

Universal Solar Products
P.O. Box 364027
San Juan, PR 00936-4027

Virginia Solar Components, Inc.
Rt. 4 Highway 29 South
Rustburg, VA 24588

Appendix D

Respondents to the 1993 Photovoltaic Module/Cell Manufacturers Survey (Form CE-63B)

Appendix D

Respondents to the 1993 Photovoltaic Module/Cell Manufacturers Survey (Form CE-63B)

Of the companies reporting data on Form CE-63B, 18 gave permission to have their company name and address listed in this publication.

A Y McDonald Mfg. Co.
Box 508
4800 Chavenelle Rd.
Dubuque, IA 52004-0508

Advanced Photovoltaic Systems, Inc.
P.O. Box 7093
Princeton, NJ 08543

AstroPower, Inc.
Solar Park
Newark, DE 19716-2000

BC Solar
South 401 Hodges Road
Greenacres, WA 99016

EPV - Energy Photovoltaics
P.O. Box 7456
Princeton, NJ 08543

Iowa Thin Film Technologies
ISU Research Park #607
Ames, IA 50010

Kyocera America, Inc.
8611 Balboa Avenue
San Diego, CA 92123

Midway Labs, Inc.
2255 E. 75th Street
Chicago, IL 60649

Mobil Solar Energy Co.
4 Suburban Park Drive
Billerica, MA 01821

Sanyo Energy Corporation
2011 N. Collins
Suite 607
Richardson, TX 75080

Siemens Solar Industries
P.O. Box 6032
4650 Adhor Lane
Camarillo, CA 93010

Solarex Corporation
630 Solarex Court
Frederick, MD 21701

Solec International, Inc.
12533 Chadron Avenue
Hawthorne, CA 90250

Spire Corporation
One Patriots Park
Bedford, MA 01730

SunPower Corporation
435 Indio Way
Sunnyvale, CA 94086

Sunwatt Corporation
RFD Box 751
Addison, ME 04606

Tideland Signal Co.
P.O. Box 52430
Houston, TX 77052

Utility Power Group
9410 Desoto Ave., Unit G.
Chatsworth, CA 91311

Appendix E

U.S. Customary Units of Measurement, International System of Units (SI), and Selected Data Tables in SI Metric Units

Appendix E

U.S. Customary Units of Measurements, International System of Units (SI), and Selected Data Tables in SI Metric Units

The standard factor for conversion from U.S. customary to International System of Units (SI) unit of measure is shown in Table E1.

Table E1. Conversion Factor for U.S. Customary and SI Units of Measurement

To Convert From:	To:	Multiply By:
Area		
Square Feet (ft^2)	Square Meters (m^2)	0.09290304

Note: The conversion factor is exact and all subsequent digits are zero.

Source: Table E1 is patterned after Table 3, "Conversion Factors for SI Metric and U.S. Customary Units of Measurement," in S.M. Lang and A.M. Orellana, "The Metric System," in *"Suggestions to Authors of the Reports of the United States Geological Survey*," Sixth Edition (Washington, DC, 1978), pp. 192-196.

Selected Tables Converted to SI Metric Values

The seven tables listed below contain data converted to equivalent SI units. The crosswalk given below shows the correlation between the tables of SI units and their corresponding tables in U.S. customary units from Chapter 1 of this report. No data tables from the "Photovoltaic Cell and Module Manufacturing Activities" chapter are converted to equivalent SI units.

Appendix E Table Number	Chapter 1 Table Number
E2	Table 1
E3	Table 6
E4	Table 7
E5	Table 9
E6	Table 10
E7	Table 11
E8	Table 12

Table E2. Number of Companies and Annual Shipments of Solar Thermal Collectors, 1974-1993
(Thousand Square Meters)

Year	Number of Companies	Solar Thermal Collector Shipments		
		Total	Import	Export
1974	45	118	NA	NA
1975	131	348	NA	NA
1976	186	539	NA	NA
1977	321	958	NA	NA
1978	340	1,009	37	78
1979	349	1,324	27	79
1980[a]	233	1,802	22	104
1981[a]	203	1,870	18	72
1982[a]	265	1,730	39	42
1983[a]	203	1,563	47	15
1984	225	1,597	58	32
1985	NA	NA	NA	NA
1986	98	870	44	21
1987	59	675	64	17
1988	51	759	76	15
1989	44	1,067	115	43
1990	51	1,060	145	23
1991	48	611	143	31
1992	45	658	153	29
1993	41	647	189	38

[a] Includes imputation of shipment data to account for nonrespondents.
NA= Not available. The data for 1985 are incomplete.
Note: Total Shipments include import and export shipments.
Sources: **1974-1977**: Federal Energy Administration telephone survey. **1978-1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1982-1993** : Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table E3. Solar Thermal Collector Shipments by Type, 1980-1993
(Thousand Square Meters)

Year	Low-Temperature		Medium-Temperature		High-Temperature[a]
	Shipments	Average Annual Shipments per Manufacturer	Shipments	Average Annual Shipments per Manufacturer	Shipments
1980[b]	1,136	14.4	666	2.7	NA
1981[b]	806	10.7	2	4.1	NA
1982[b]	695	11.4	1,035	4.2	NA
1983[b]	451	8.2	1,113	6.2	NA
1984	416	8.7	1,109	5.4	72
1985	NA	--	NA	--	NA
1986	348	15.8	103	1.2	418
1987	293	24.4	89	1.8	293
1988	309	38.6	68	1.5	382
1989	398	39.8	185	5.1	484
1990	339	28.2	235	5.7	787
1991	519	32.4	92	2.2	([s])
1992	575	35.9	83	2.5	([s])
1993	560	43.1	86	2.6	1

[a]For high temperature collectors, average annual shipments per manufacturer are not disclosed
[b]Includes data imputed from nonrespondents
[c]Data for 1985 are incomplete
([s]) = Less than 500 square meters.
-- = Not applicable.
NA = Not available. The data are incomplete.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **1980-1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table E4. Shipments by the Top Five Solar Thermal Collector Manufacturing States/Territories 1992 and 1993
(Thousand Square Meters)

Origin	Shipments[a]		Percentage	
	1992	1993	1992	1993
California .	277	193	55	42
Florida . . .	19	18	4	4
Other[b]	199	238	39	52
Subtotal .	496	449	98	98
Total	505	458	100	100

[a] Includes domestic shipments and exports.
[b] Other includes New York, New Jersey, and Puerto Rico.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table E5. Solar Thermal Collector Shipment by Type, Quantity, Value and Average Price, 1992 and 1993

Type	1992			1993		
	Quantity (thousand square meters)	Value (thousand dollars)	Average Price (dollars per square meter)	Quantity (thousand square meters)	Value (thousand dollars)	Average Price (dollars per square meter)
Low -Temperature						
Liquid and Air	575	15,403	26.80	560	16,819	30.05
Medium-Temperature						
Air	(s)	8	124.59	(s)	7	109.65
Liquid						
ICS/Thermosiphon	28	3,825	136.08	28	4,446	157.42
Flat Plate	54	5,441	100.31	58	5,887	101.66
EvacuatedTube	W	W	W	(s)	174	(s)
Concentrator	W	W	W	(s)	9	(s)
All Medium -Temperature	83	9,831	117.95	86	10,523	121.69
High -Temperature						
Parabolic Dish and Trough	(s)	148	814.95	1	260	237.98
Total	**658**	**25,382**	**--**	**647**	**27,602**	**42.64**

(s) = Less than 500 square meters.
-- = Not applicable.
W = Witheld to avoid disclosure of individual company data.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table E6. Shipments of Solar Thermal Collectors by Market and Type, 1992 and 1993
(Thousand Square Meters)

Market Sector	Low-Temperature	Medium-Temperature					High-Temperature		
	Liquid/Air		Liquid						
	Metallic and Nonmetallic	Air	ICS/ Thermo-siphon	Flat-Plate (Pumped)	Evacu-ated Tube	Concen-trator	Parabolic Dish/Trough	1993 Total	1992 Total
Residential	543	(s)	28	51	(s)	(s)	(s)	**622**	**634**
Commercial	16	0	(s)	4	0	0	0	**20**	**19**
Industrial	1	0	(s)	1	0	0	0	**3**	**3**
Utility	0	0	(s)	1	(s)	0	1	**3**	**2**
Other[a]	0	0	(s)	0	0	0	(s)	**(s)**	**1**
Total	**560**	**(s)**	**28**	**58**	**(s)**	**(s)**	**1**	**647**	**658**

[a]Other includes shipments of solar thermal collectors to other sectors such as government, including the military but excluding space applications.

ICS = Integral Collector Storage.

(s) = Less than 500 square meters.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table E7. Shipments of Solar Thermal Collectors by End Use and Type, 1992 and 1993
(Thousand Square Meters)

End Use	Low-Temperature	Medium-Temperature					High-Temperature	1993 Total	1992 Total
	Liquid/Air		Liquid						
	Metallic and Nonmetallic	Air	ICS/ Thermo-siphon	Flat-Plate (Pumped)	Evacu-ated Tube	Concen-trator	Parabolic Dish/Trough		
Pool Heating	558	0	0	3	0	0	0	**561**	**577**
Hot Water	0	0	28	53	(s)	(s)	(s)	**82**	**74**
Space Heating	1	(s)	(s)	0	0	0	0	**1**	**3**
Space Cooling	0	0	0	0	0	0	0	**0**	**(s)**
Combined Space and Water Heating .	0	0	0	(s)	0	0	0	**(s)**	**(s)**
Process Heating . . .	0	0	(s)	1	0	0	0	**2**	**3**
Electricity Generation	0	0	0	0	0	0	1	**1**	**(s)**
Other[a]	0	0	0	0	0	(s)	0	**(s)**	**(s)**
Total	**560**	**(s)**	**28**	**58**	**(s)**	**(s)**	**1**	**647**	**658**

[a]Other includes shipments of solar thermal collectors for other uses such as cooking foods, water pumping, water purification, desalinization, distilling, etc.
ICS = Integral Collector Storage.
(s) = Less than 500 square meters.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table E8. Shipments of Solar Thermal Collectors by Destination, 1992 and 1993
(Square Meters)

Destination	Shipments 1992	Shipments 1993	Destination	Shipments 1992	Shipments 1993
Alabama	174	156	Nebraska	162	156
Alaska	0	0	**Nevada**	7,285	1,209
Arizona	19,485	26,524	**New Hampshire**	182	171
Arkansas	189	156	**New Jersey**	6,245	5,660
California	165,119	143,084	New Mexico	831	951
Colorado	4,150	2,194	**New York**	6,342	6,852
Connecticut	1,071	1,292	**North Carolina**	521	543
Delaware	0	0	**North Dakota**	0	0
District of Columbia	0	0	**Ohio**	1,071	1,292
Florida	353,529	343,845	**Oklahoma**	9	0
Georgia	2,587	3,206	**Oregon**	7,658	11,384
Hawaii	15,770	18,256	**Pennsylvania**	2,723	1,637
Idaho	9	21	Puerto Rico	18,821	23,540
Illinois	1,980	2,574	**Rhode Island**	452	0
Indiana	909	1,167	South Carolina	181	243
Iowa	12	24	**South Dakota**	0	0
Kansas	177	189	Tennessee	162	167
Kentucky	0	0	**Texas**	1,750	3,740
Louisiana	162	156	**Utah**	4	33
Maine	239	2,221	Vermont	181	170
Maryland	1,072	1,323	Virgin Islands (U.S.)	691	272
Massachusetts	1,124	1,161	**Virginia**	314	195
Michigan	4	314	**Washington**	2,825	1,195
Minnesota	844	98	West Virginia	15	15
Mississippi	0	0	**Wisconsin**	1,753	1,421
Missouri	162	313	Wyoming	0	0
Montana	0	10			
Shipments to U.S. States/Territories				**628,946**	**609,121**
Exports				**29,337**	**38,227**
Total Shipments				**658,283**	**647,348**

Notes: ●Underlined states sponsored incentives for solar thermal collector purchases during 1992 (Solar Energy Industries Association, *Solar Industry Journal,* First Quarter 1993, pp. 16-21). ●States in bold face sponsored incentives during 1993. (Steve Kalland, Solar Energy Industry Association, personal communication to James Holihan, Energy Information Administration, Washington, D.C. (June 1, 1994)).
Source: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Appendix F

Solar Collector Installed Capacity and Energy Production in the United States

Appendix F

Solar Collector Installed Capacity and Energy Production in the United States

Information on the amount of solar collectors, solar thermal, and photovoltaics shipped for installation has been reported in this series of reports, "Solar Collector Manufacturing Activity." Solar thermal collectors are quantified by area (square feet). Photovoltaic cells and modules are quantified by the amount of electrical capacity (peak watts).

Since 1974, approximately 219 million square feet of solar thermal collectors were shipped for eventual installation in the United States (Table F1). Solar thermal collectors are grouped into three categories: low-temperature, medium-temperature, and high-temperature. Presuming an overall efficiency of 50 percent for all three categories and a 1,500 Btu per square foot average daily insolation, the potential thermal energy production from the 219 million square feet of solar thermal collectors is 0.060 quadrillion Btu (quads) in 1992.

An efficiency of 50 percent for solar thermal collectors exposed to 1,500 Btu insolation is a simplified approach for this energy calculation. Low-temperature and high-temperature collectors have been rated at more than 50 percent efficient, and medium-temperature collectors are generally less than 50 percent efficient. A mildly cloudy day produces about 1,500 Btu of insolation onto an area of 1 square foot.

In 1991, U.S. nonutility power producers reported installed capacity of 360 megawatts and gross electricity generation of 746 million kilowatthours (the thermal energy equivalent is 0.008 Quad) from solar thermal collectors.[16] Ninety-eight percent of the installed capacity was SEGS I through IX (nine operating Solar Electric Generating System plants in southern California with an installed capacity of 354 megawatts). A 10th SEGS plant (SEGS X) was never constructed as planned in 1991.

Table F1. Annual Photovoltaic and Solar Thermal Domestic Shipments, 1974-1993

Year	Domestic Shipments[a]	
	Photovoltaic (peak kilowatts)	Solar Thermal (thousand square feet)
Total, 1974-1993	**69,730**	**219,028**
1993	6,137	6,557
1992	5,760	6,770
1991	6,035	6,242
1990	6,293	11,164
1989	5,462	11,021
1988	4,318	8,016
1987	3,029	7,087
1986	3,224	9,136
1985	4,099	E19,166
1984	7,759	16,843
1983	10,717	16,669
1982	6,897	18,166
1981	--	19,362
1980	--	18,283
1979	--	13,396
1978	--	10,020
1977	--	10,312
1976	--	5,801
1975	--	3,743
1974	--	1,274

[a]Total shipments minus export shipments.
E = Estimated data (see Appendix A, pages 24 and 25).
-- = Not applicable.
Sources: **1974-1977**:Federal Energy Administration telephone survey. **1978-1984**: Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1993**: Energy Information Administration, Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey," and Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

[16]Energy Information Administration, *Annual Energy Review* (June 1994), Table 8.12.

Table F2. U.S. Utility Net Electricity Generation from Solar Energy, 1993
(Thousand Kilowatthours)

Utility	Plant (State)	Net Generation
Sacramento Municipal Utility District	Solar (California)	2,680
Austin Electric	Decker Creek (Texas)	366
Pacific Gas & Electric	PVUSA 1 (California)	748
Virginia Electric Power	North Anna (Virginia)	8
Total		**3,802**

Source: Energy Information Administration, *Electric Power Monthly*, April 1994, DOE/EIA-0226(93/04), Table 64.

Since 1982, approximately 70 peak megawatts of photovoltaic cells and modules were shipped for eventual installation in the United States (Table F1). Assuming a 27.5 percent capacity factor,[17] the potential energy production from the 70 peak megawatts is 170 million kilowatthours of electricity. This is equivalent to 0.002 Quad of thermal energy in 1993, using a thermal conversion rate of 10,302 Btu per kilowatthour of electricity generation.[18]

In 1993, U.S. electric utilities reported that net electric generation from photovoltaic modules was 3.8 million kilowatthours (Table F2). Net generation is gross generation minus plant use by all electric utility-owned plants.[19]

Estimated U.S. solar electricity generation was 968.8 million kilowatthours in 1992. Overall, estimated solar energy production was 0.07 quadrillion Btu, and adjusted total energy production in the United States was 65.88 quadrillion Btu (Table F3).

Table F3. Estimated U.S. Solar and Total Energy Production, 1993
(Quadrillion Btu)

Activity, Production Sector, and Solar Energy Source	Energy Production
Production to Generate Electricity	
Electric Utilities	
Photovoltaic	(s)
Nonutility Power Producers	
Solar Thermal-Electric	0.01
End Users	
Photovoltaic	(s)
Production to Generate Thermal Energy	
End Users	
Solar Thermal	.06
Estimated Solar Energy Production	**0.07**
Adjusted Production Estimate	[a]**65.88**

[a]Adjusted total is the sum of EIA's total energy production preliminary data estimate of 65.81 quadrillion Btu (*Annual Energy Review 1993*, Table 1.2) and 0.06 quadrillion Btu estimated for solar energy production.

(s) = Less than 0.005 quadrillion Btu.

Sources: Energy Information Administration (EIA), Form CE-63A, "Annual Solar Thermal Collector Manufacturers Survey," and Form CE-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey." EIA, Form EIA-759, "Monthly Power Plant Report." EIA, *Annual Energy Review 1993* (June 1994), Table 1.2 and Table 8.12.

[17]Department of Energy, "The Potential of Renewable Energy, An Interlaboratory White Paper" (March 1990), p. G-5.

[18]Energy Information Administration, *Annual Energy Review 1993* (June 1994), Table A7.

[19]Energy Information Administration, Form EIA-759, "Monthly Power Plant Report."

Glossary

Glossary

Air Collector: A medium-temperature collector used predominantly in space-heating applications, utilizing pumped air as the heat-transfer medium.

Amorphous Silicon: An alloy of silica and hydrogen, with an irregular internal atomic arrangement, that can be deposited in thin-film layers (a few micrometers in thickness) by means of a number of deposition methods to produce thin-film photovoltaic cells on glass, metal, or plastic substrates.

Btu (British Thermal Unit): A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Cast Silicon: Crystalline silicon obtained by pouring pure molten silicon into a vertical mold and adjusting the temperature gradient along the mold volume during cooling to obtain slow, vertically advancing crystallization of the silicon. The polycrystalline ingot thus formed is composed of large, relatively parallel, interlocking crystals. The cast ingots are sawed into wafers for further fabrication into photovoltaic cells. Cast-silicon wafers and ribbon-silicon sheets fabricated into cells are usually referred to as polycrystalline photovoltaic cells.

Concentrator: A reflective or refractive device that focuses incident insolation onto an area smaller than the reflective or refractive surface, resulting in increased insolation at the point of focus.

Consumer Goods: Goods such as calculators, computers, toys, and watches that are powered by photovoltaic cells and modules.

Evacuated-Tube Collector: A solar thermal collector in which the collector fluid flows through an absorber tube that is contained inside an evacuated glass cylinder.

Export (solar): A shipment of solar thermal collectors and/or photovoltaic devices sent from the United States and any of its territories to a foreign country.

Flat-Plate (pumped): Medium-temperature solar thermal collector, typically with a metal frame, glazing, absorbers (usually metal), and insulation, that uses pumped liquid as the heat-transfer medium; predominately used in water-heating applications.

Generation (electricity): The process of producing electrical energy by transforming other forms of energy; also, the amount of electrical energy produced, expressed in watthours (Wh).

Gross Generation: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.

High-Temperature Collector: A solar thermal collector that generally operates at temperatures above 180 degrees Fahrenheit.

Import (solar): A shipment of solar thermal collectors and/or photovoltaic devices into the United States and any of its territories from foreign countries.

Integral Collector Storage (ICS): A solar thermal collector in which incident solar radiation is absorbed directly by the storage medium.

Kilowatthour (kWh): One thousand watthours.

Liquid Collector: A medium-temperature solar thermal collector, employed predominantly in water heating, which uses pumped liquid as the heat-transfer medium.

Low-Temperature Collector: A solar thermal collector that generally operates at temperatures below 110 degrees Fahrenheit.

Medium-Temperature Collector: A solar-thermal collector that generally operates in the temperature range of 140 degrees Fahrenheit to 180 degrees Fahrenheit but can also operate at temperatures as low as 110 degrees Fahrenheit.

Net Generation: Gross generation less the electric energy consumed at the generating station for station use.

One Sun: Natural solar insolation falling on an object without concentration or diffusion of the solar rays.

Original Equipment Manufacturer (OEM): A non-photovoltaic manufacturer that combines photovoltaic technology into existing or newly developed product lines.

Parabolic Dish: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator, generally bowl-shaped, with two-axis tracking.

Parabolic Trough: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator with the capacity for tracking the sun using one axis of rotation.

Peak Kilowatt: One thousand peak watts.

Peak Megawatt: One million peak watts.

Peak Watt: A manufacturer's unit indicating the amount of power a photovoltaic cell or module will produce at standard test conditions (normally 1,000 watts per square meter and 25 degrees Celsius).

Person Years: The number of hours worked during the year by all persons in the identified type of work divided by the number of hours worked during the year (2080).

Photovoltaic Cell: An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts, and being capable of converting incident light directly into electricity (direct current).

Photovoltaic Module: An integrated assembly of interconnected photovoltaic cells designed to deliver a selected level of working voltage and current at its output terminals, packaged for protection against environmental degradation, and suited for incorporation in photovoltaic power systems.

Ribbon Silicon: Sheets of crystalline silicon fabricated by a variety of solidification (crystallization) methods whereby thin silicon sheets are withdrawn from a pool of relatively pure molten silicon. The methods include: edge-defined, film-fed growth (EFG) and dendritic-web growth.

Single-Crystal Silicon: An extremely pure form of crystalline silicon produced by dipping a single crystal seed into a pool of molten silicon under high vacuum conditions and slowly withdrawing a solidifying single crystal boule (rod) of silicon. The boule is sawed into thin silicon wafers and fabricated into single-crystal photovoltaic cells.

Solar Thermal Collector: A device designed to receive solar insolation and convert it into thermal energy. Normally, a solar thermal collector includes a frame, glazing, and an absorber, together with appropriate insulation. The heat collected by the solar thermal collector may be used immediately or stored for later use.

Special Collector: An evacuated tube collector or a concentrating (focusing) collector. Special collectors operate in the temperature range from just above ambient temperature (low concentration for pool heating) to several hundred degrees Fahrenheit (high concentration for air conditioning and specialized industrial processes).

Survey Frame: The list of companies to which survey forms are sent.

Thermosiphon System: A solar collector system for water heating in which circulation of the collection fluid through the storage loop is provided solely by the temperature and density difference between the hot and cold fluids.

Value (of Shipments): The value received for the complete systems at the company's net billing price, freight- on-board factory, including charges for cooperative advertising and warranties. This does not include excise taxes, freight or transportation charges, or installation charges.

Watthour (Wh): An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.