U.S. Solar Market Trends 2007

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Larry Sherwood
Interstate Renewable Energy Council

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Executive Summary

This report provides data on U.S. solar installations by technology, state, and market sector. Data on solar installations helps industry, government, and non-profit organizations improve their efforts to increase the number of solar installations across the United States. Analysis of multi-year installation trends and state installation data helps these sectors learn more about the state markets and evaluate the effectiveness of marketing, financial incentives and education initiatives. In addition, these data allow better understanding of the environmental and economic impacts of solar installations.

Solar markets are booming in the United States due to rising energy prices, strong consumer demand, and financial incentives from the federal government and many states and utilities. Over 80,000 installations were completed in 2007, but the majority of market share for each solar technology is concentrated in a few states.

The capacity of photovoltaic (PV) installations completed in 2007 grew by 48% compared with 2006, and the average size of PV systems is growing. The two largest U.S. installations, one in Nevada and one in Colorado, were completed in 2007. The PV market is expanding to more states, though California remains the dominant market.

Solar hot water installations (low-temperature thermal) have boomed since the 2006 increase in the federal investment tax credit. In the continental 48 states, installations have quadrupled since 2005. Hawaii continues to be the largest market for solar hot water.

For concentrating solar electricity (high-temperature thermal), the 64 MW Nevada Solar One solar thermal electric plant went on-line June 2007. Other than a smaller 1 MW plant built in Arizona in 2006, this was the first new U.S. solar thermal electric plant constructed in over 15 years.

Over the long-term, the prospect for solar markets is bright. However, the fate of the federal investment tax credits, currently scheduled to expire at the end of 2008, will have a strong influence on the U.S. solar markets in 2009.

About the Interstate Renewable Energy Council

The Interstate Renewable Energy Council (IREC) supports market-oriented services targeted at education, coordination, procurement, the adoption and implementation of uniform guidelines and standards, workforce development, and consumer protection.

1. Introduction

Different solar energy technologies create energy for different end uses. Two technologies—photovoltaics (PV) and high temperature concentrating solar thermal electric—produce electricity. A third technology, low-temperature solar thermal collectors, produce heat for hot water, space heating, pool heating, and process heat.

Photovoltaic cells are semi-conductor devices that generate electricity when exposed to the sun. Manufacturers assemble the cells into modules, which can be installed on buildings or in ground-mounted arrays. PVs were invented in the 1950s and first used to power space satellites. As PV prices declined, PV systems were installed in many off-grid installations—installations with no utility grid power. In the last decade, and especially in the last several years, grid-connected installations have become the largest growth sector for photovoltaics.

High-temperature solar thermal electric systems use concentrating collectors to heat a fluid to a high temperature and then run the heat extracted from the fluid through a turbine power generator. These generating stations produce bulk power on the utility side of the meter rather than generating electricity on the customer side of the meter. Solar thermal electric plants were installed in the United States in the late 1980s and early 1990s, and then installation stopped due to lack of supportive government policies. Installations have now resumed and two plants were completed in 2007 and 2008.

Low-temperature solar thermal collectors can heat hot water, heat and cool buildings, and heat swimming pools. A variety of flat plate and concentrating collector technologies produce the heat needed for these applications. Solar hot water systems were common in southern California in the early 1900s before natural gas was installed and many systems were sold in the late 1970s and early 1980s. In the mid-80s, the loss of federal tax credits and the crash of energy prices led to an industry slowdown, from which it is only now recovering.

This report provides data on U.S. solar installations by technology, state, and market sector. Data on solar installations help industry, government, and non-profit organizations improve their efforts to increase the number of solar installations across the United States. Analysis of multi-year installation trends and state installation data helps these sectors learn more about the state markets and evaluate the effectiveness of marketing, financial incentives and education initiatives. In addition, these data allow better understanding of the environmental and economic impact of solar installations.

For all solar technologies, the United States is only a small part of a robust world solar market and product availability and pricing generally reflect this status. Germany and Spain are the top markets for PV; Spain is the leader for solar thermal electric; and China is the largest market for solar thermal collectors. However, this report does not analyze markets outside the United States.

The data collection methods and the assumptions used in this report are described in detail in Appendices A and B.

2. Photovoltaics

Overall Trends in Installations and Capacity

Annual U.S. PV installed capacity grew by 48% in 2007 over 2006 to more than 205 MW_{DC} including both grid-connected and off-grid markets. Although PV installation growth had been steady and impressive for many years, the annual growth rate doubled when the federal investment tax credits increased in 2006. By 2007, the capacity of PV installed each year was more than double the annual amount installed in 2005. More than 26,000 sites installed PV in 2007, with about half of these sites connected to the grid. Most of these installations are mounted on buildings, but some are ground-mounted installations.

The following factors helped drive the large growth in 2007:

- The federal investment tax credit was increased in 2006 for commercial taxpayers, and a credit for residential taxpayers took effect. For larger systems, especially, it takes time to get the financing, product and other installation details in place. Many of the large systems conceived with the start of the tax credits in 2006 were actually installed in 2007.
- Many states are offering incentives, and system installation growth was especially strong in Colorado, Connecticut, Hawaii, Nevada, and Oregon. Each of these states has a significant incentive program that supports solar.
- Energy prices generally, and electricity prices specifically, continue to increase, and consumer concern about rising energy costs is high.
- Renewable portfolio standards with specific solar requirements had an impact in states that enacted them two or more years previously. Because installations from these standards ramp up over time, states with new requirements in 2007 will not see much installation growth until 2008 or later.

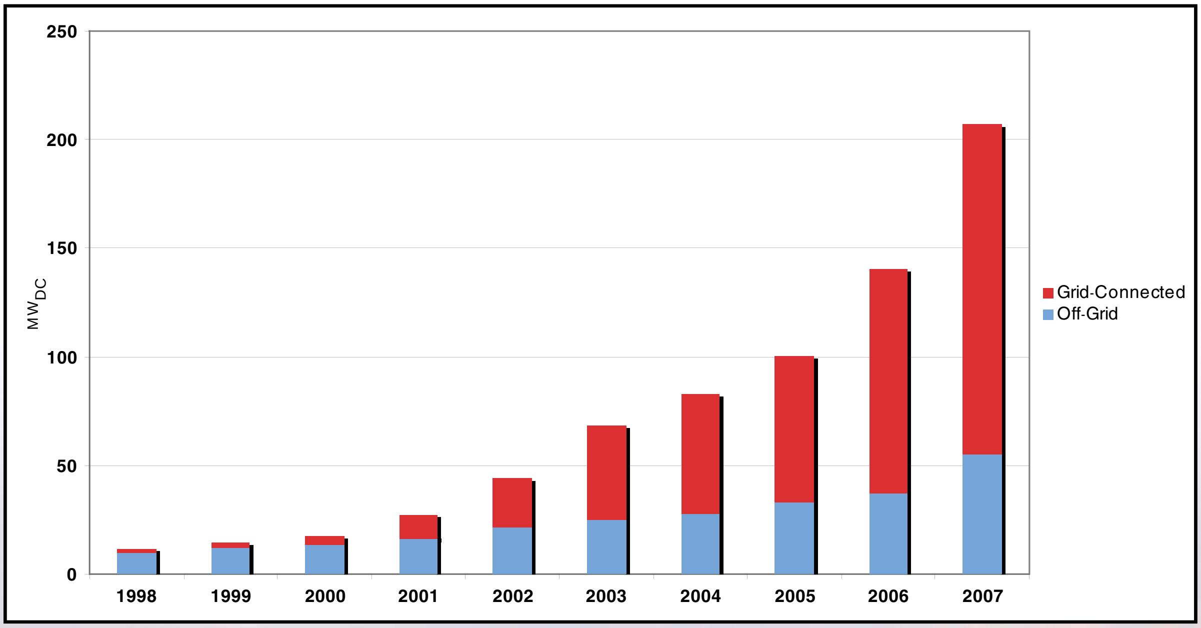
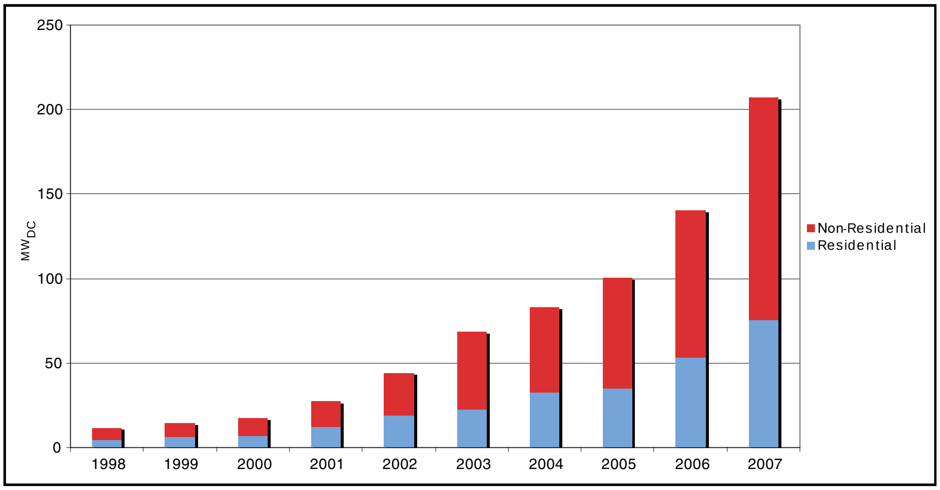


Fig. 1: Capacity of Annual U.S. Photovoltaic Installations (1998-2007)
Off-Grid Data from PV Energy Systems

Photovoltaic Installations by Sector

Residential installations currently account for slightly more than one-third of all grid-connected PV installations by capacity. Over the past three years, these installations have varied from 34% and 38% of the total. Figure 2 shows the annual PV installation capacity data, segmented by residential and non-residential installations. Non-residential installations include such sites as government buildings, retail stores, utility installations, and military installations and their larger average size means a larger aggregated capacity.

Fig. 2: Annual Installed Photovoltaic Capacity by Sector (1998-2007)



The trend toward more non-residential installations should continue, because the federal investment tax credits are more generous for commercial installations. In California, the largest incentive program in the country was (for the most part) converted to a performance-based incentive in 2007. Early reports for 2008 indicate that the commercial market is booming as a result. Detailed data on off-grid PV installations are not available, and so the remainder of the PV section of this report comments only on the U.S. grid-connected PV market.

Photovoltaic Installations by Size

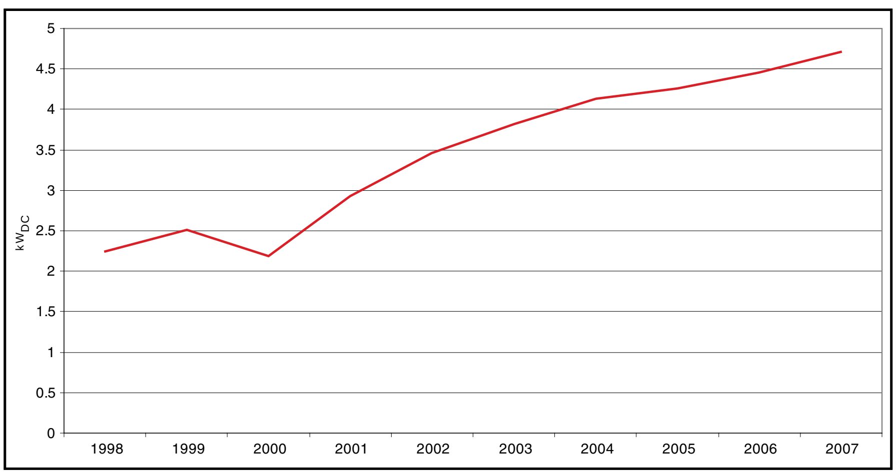


Fig. 3: Average Size of Grid-Connected Residential Photovoltaic Installations (1998-2007)

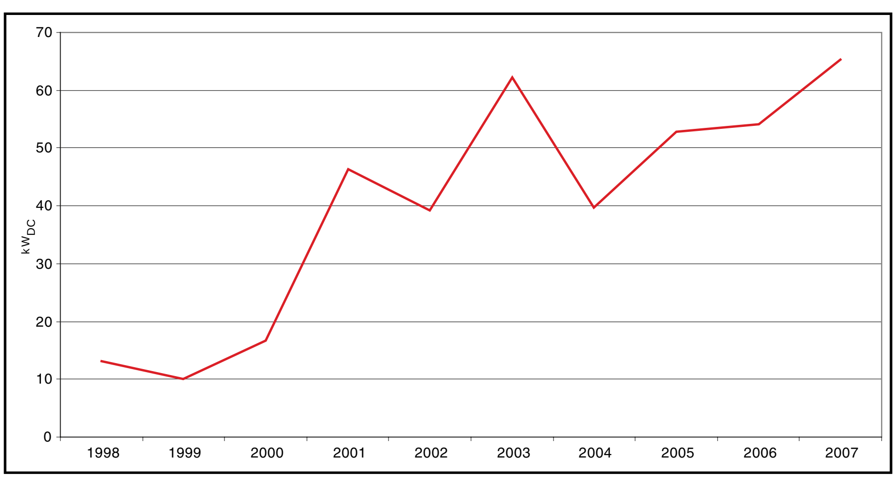
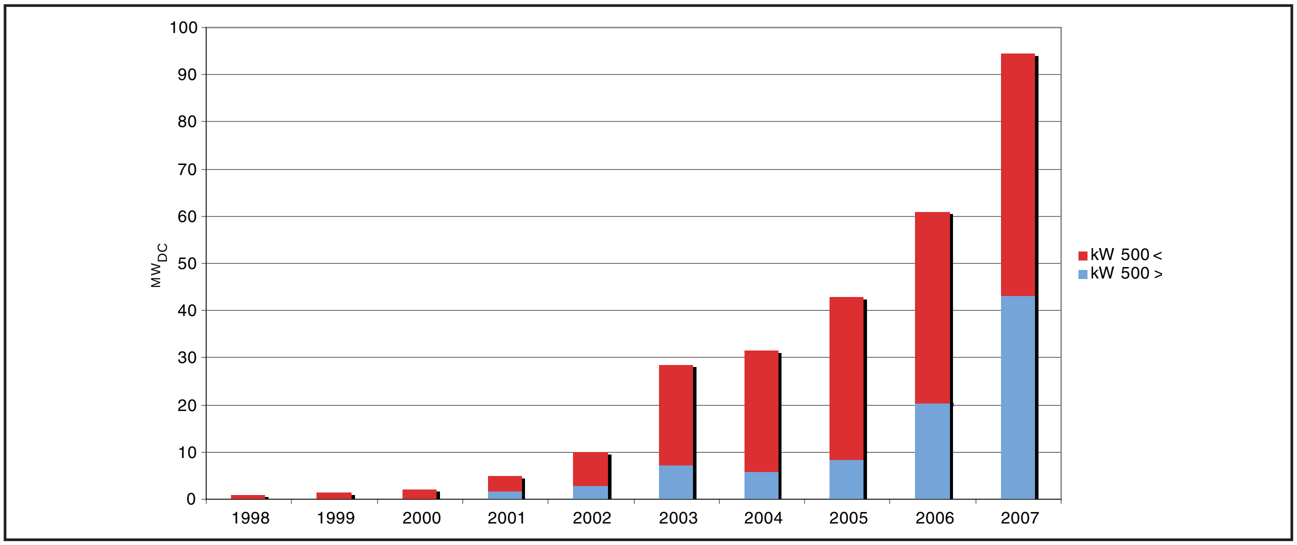


Fig. 4: Average Size of Grid-Connected Non-Residential Photovoltaic Installations (1998-2007)

The average size of a grid-connected PV residential installation has grown steadily from 2.2 kW to over 4.7 kW from 1998 to 2008 (see Figure 3). The average size of a non-residential system has also been growing in recent years and topped 67 kW_{DC} in 2007 (see Figure 4). Because there are far fewer non-residential installations, a few installations can dramatically affect the average, explaining the annual fluctuations in Figure 4. The average size of gird connected PV installations varies from state to state, depending on available incentives, interconnection standards, and net metering availability.

All sectors of PV installations grew in 2007, but installed capacity of large installations grew the fastest. A 14-MW PV installation at Nellis Air Force Base in Nevada and an 8-MW PV installation for Xcel Energy in Alamosa, Colorado were the largest PV systems installed in 2007, and together accounted for 15% of the annual installed capacity. A total of 30 systems larger than 500 kW accounted for 29% of the total 2007 installed capacity. Figure 5 shows the dramatic growth in these larger installations, which in 2007 accounted for 47% of all non-residential installations.

Fig. 5: Non-Residential Grid-Connected Photovoltaic Installations by Size (1998-2007)



Virtually all of the larger installations and many of the medium-sized non-residential installations use power purchase agreements (PPAs). In these agreements, a third party finances and owns the solar installation and receives the available incentives and tax benefits. The third party then leases the system or sells the solar-generated electricity to the building or site owner through a long-term contract.

In several states, regulators are considering defining third-party owners of solar equipment as utilities. If such rulings are made, third-party owners in these states may still be able to lease solar facilities without being classified as utilities, but their ability to use the federal investment tax credit will need to be clarified. If the federal tax credit cannot be used as readily under the leasing model, PPAs will become less viable in these states and the growth of solar installations in these states will be constrained.

The trend toward greater market share for large installations should continue at least through the end of 2008. At the end of 2007 in California, 56% of the California Solar Initiative incentive reservations were for installations 500 kW and larger. The federal investment tax credit is critical to make these deals financially viable, and this credit is currently scheduled to expire at the end of 2008. If Congress renews the federal investment tax credit, the trend toward more PPAs and larger non-residential installations will likely continue.

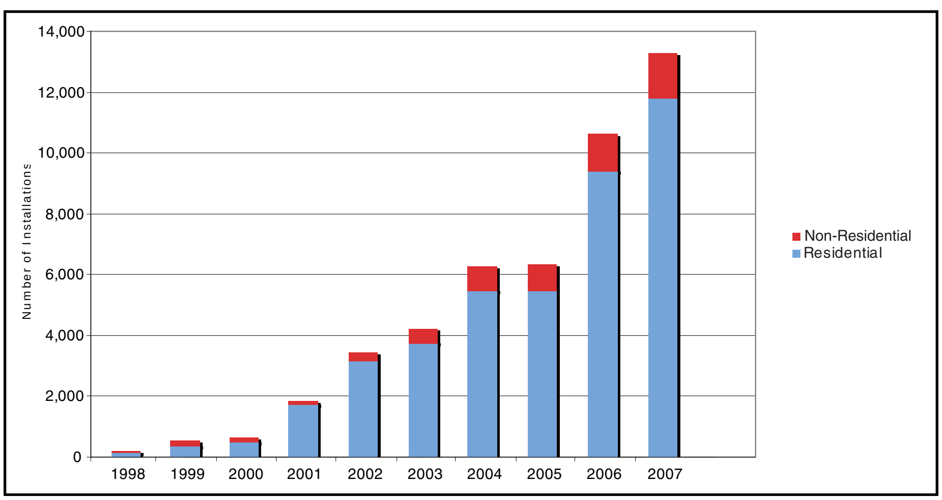


Fig. 6: Number of Annual Grid-Connected Photovoltaic Installations (1998-2007)

Over 13,000 grid-connected PV installations were completed in 2007, with 84% of these at residential locations (see Figure 6). At the end of 2007, 48,000 PV installations were operating on the grid, including 39,000 residential installations. Since the average size of non-residential systems is more than ten times the average size of residential systems, the number of residential installations is much larger than non-residential installations even though the installed capacity of non-residential installations is greater.

Photovoltaic Installations by State

In 2007, installation of grid-connected PV installations was concentrated in California, New Jersey, Nevada, and Colorado, as shown in Table 1. Table 2 shows that 69% of all PV installations have been in California. As noted earlier, no comprehensive data exists for off-grid PV installations by state. A more complete listing of the installed capacity by state is included in Appendix C.

In 2007, California installations increased by 28% to 89 MW_{DC}. The market more than doubled in Nevada, Colorado, Hawaii, Connecticut and Oregon, as well as in many other states with smaller PV markets. Of these top ten states, only two saw a decline in 2007. New Jersey and Massachusetts expect to grow again in 2008.

State	2006 (MW_{DC})	2007 (MW_{DC})	06 - 07 % change	2007 Market Share	2006 Rank
1. California	69.5	88.8	28%	58%	1
2. New Jersey	17.9	16.4	-8%	11%	2
3. Nevada	3.2	14.7	365%	10%	3
4. Colorado	1.0	12.5	1178%	8%	7
5. New York	3.0	4.3	45%	3%	4
6. Arizona	2.1	2.8	30%	2%	5
7. Hawaii	0.7	2.4	236%	2%	9
8. Connecticut	0.7	1.8	174%	1%	10
9. Massachusetts	1.5	1.4	-5%	<1%	6
10. Oregon	0.5	1.1	112%	<1%	11
All Other States	3.2	5.6	75%	4%	
Total	**103.2**	**151.9**	**45%**		

Table 1: TOP TEN STATES
Ranked by Grid-Connected Photovoltaic Capacity Installed in 2007 (MW_{DC}/yr)

State	MW_{DC}	Market Share
1. California	329	69%
2. New Jersey	44	9%
3. Nevada	19	4%
4. Arizona	19	4%
5. New York	15	3%
6. Colorado	15	3%
7. Massachusetts	5	1%
8. Hawaii	4	< 1%
9. Texas	3	<1%
10. Oregon	3	<1%
All Other States	**20**	**4%**

Table 2: TOP TEN STATES
Ranked by Grid-Connected Photovoltaic Cumulative Installed Capacity

State	Cum. Installed Capacity per person (W_{DC}/person)
1. California	9.1
2. Nevada	7.8
3. New Jersey	5.0
4. Arizona	3.1
5. Colorado	3.1
6. Hawaii	3.0
7. Delaware	1.4
8. Vermont	1.2
9. Connecticut	0.8
10. New York	0.8
National Average	**1.6**

Table 3: TOP TEN STATES
Ranked by Cumulative Installed Capacity per Capita (W_{DC}/person)

Although new state markets emerged in 2007, the U.S. PV market remains very concentrated in a few states. Ninety percent of grid-connected installations were in five states.

All of the top states for grid-connected PV installations have financial incentives. The combination of state or local incentives and federal investment tax credits has resulted in most of the installations around the country. There are relatively few installations in locations with no state or local incentives or renewable portfolio standard mandates.

Table 3 shows the cumulative per capita grid-connected PV capacity. Even with California's very large population, it has the highest rate of installations per capita—a rate that is more than five times the national average. No matter how one analyzes the data, California dominates the PV market. Three small states, Hawaii, Delaware, and Vermont show significant solar installations on a per capita basis. The large number of installations in a few states raises the national average, but 44 states have a per-capita PV installation rate that is less than the national average. For reference, the city of Freiburg, Germany, with less sunshine than any of these states, has 41 watts installed per capita.

Photovoltaic Incentives by State

Solar electric market activity has more to do with state incentives and policies than with the amount of solar resource. All states with a large number of grid-connected installations have financial incentives. However, the details of the financial incentives vary greatly from state to state. This section describes the incentives offered in the states with the largest number of installations.

In 2007, **California** began the 10-year $3 billion California Solar Initiative. The largest part of this initiative is a rebate program administered by the California Public Utilities Commission (CPUC) for customers serviced by Pacific Gas & Electric, Southern California Edison, or San Diego Gas and Electric. These rebates are based on actual system performance for larger systems and expected system performance for smaller systems. The rebates decline over time. The CPUC program replaces the CPUC's Self Generation Incentive Program for large systems and the California Energy Commission's (CEC) Emerging Renewables Program for smaller systems.

In addition, the CEC administers the New Solar Home Partnership program for solar installation on new homes. Before 2008, municipal utilities are not included in these programs. A municipal utility program through the CSI began this year. A number of municipal utilities have offered incentives for many years and the larger municipal utilities, in Sacramento and Los Angeles, have installed a large number of PV systems.

As California programs convert to the CSI programs, some program design problems have developed. This has slowed the number of 2007 installations over what might have been expected. By the end of the 2007, the program was operating more smoothly and a large number of rebates are reserved and will likely result in very large installation growth in 2008. CSI has the advantage of being a 10-year program, so the industry in California can now rely on long-term policy stability.

In **New Jersey**, generous state rebates and a renewable portfolio standard (RPS) with a solar carve-out of 2.12% by 2021 have built a strong PV market. Now, the capacity-based rebate program is being converted into an performance-based incentive that involves payments based on the actual energy production of a PV system. Small PV installations will likely continue to receive rebate payments, although rebate funding has been sporadic. In fact, the state's lack of funds to sustain the high demand for New Jersey rebates led to a slight decrease in 2007 installations, compared with 2006. The rebate reservations at the end of 2007 indicate likely growth in 2008. The long-term market remains uncertain, as the performance-based incentive program does not have a long history from which to forecast its market success.

Nevada has an RPS with a solar carve-out equal to 5% of the overall standard. A number of large solar installations have been built, supported by funding from the sale of renewable energy credits (RECs) associated with the electricity generated by these systems. Nevada boasts the largest U.S. PV installation, the 14-MW plant at Nellis Air Force Base. The Nevada RPS has also led to the installation of the Solar One solar thermal electric plant during 2007. In addition, Nevada utilities offer a rebate program for customer-sited PV installations. However, this program is small, and funding has been insufficient. New rules were adopted in January 2008, but as of July 2008, the program was still not accepting applications. The rebate-funded installations accounted for only 5% of the total 2007 installations on a capacity basis. The small size of this program and the one-time nature of the Nellis project indicate that Nevada installations are likely to fall in 2008.

In **Colorado**, voters passed Amendment 37 in 2005, an action that created an RPS with a solar carve-out equal to 4% of the standard. Later, the legislature doubled the overall RPS requirements. Because it is, by far, the largest utility in the state, Xcel Energy's policies are the most important driver to the market in Colorado. Xcel offers capacity-based rebates for smaller, customer-sited PV systems. For these systems, part of the capacity credit is a purchase of the RECs for 20 years and is based on expected performance. For larger PV systems, Xcel purchases the RECs based on actual energy production. In addition, Xcel has contracted for one large, 8.2-MW installation, providing bulk power to its system.

In 2008, Colorado will see large growth in customer-sited installations as all segments of this market remain strong. However, Colorado will not see a 2008 repeat of the utility-side installation, so the overall Colorado capacity installed in 2008 will likely be lower than the 2007 total.

In **New York**, both the New York State Energy Research and Development Authority (NYSERDA) and the Long Island Power Authority (LIPA) provide PV rebates, and most systems have installed through these two programs. The installed PV capacity in New York has been growing steadily each year. Interconnection and net metering restrictions in New York make large installations difficult, though legislation passed in 2008 will improve this situation. Thus, only about 20% of the installations have been non-residential, compared with more than 60% in the rest of the United States.

Arizona is another state where the solar policies are changing. For a number of years, Arizona has had an RPS (known as the Environmental Portfolio Standard), which mandated customer-sited renewable-energy installations. Although no utility ever met the standard, Arizona ranked second for PV installations each year from 1997 through 2004. Arizona has more PV installed on the utility side of the meter than any other state. However, by 2007 Arizona's rank had fallen to sixth among states for PV installations. Recent changes to the Arizona policies have placed more emphasis on customer-sited installations, and all the major Arizona utilities now offer rebates for such installations. Arizona, along with California, Nevada and Colorado, are likely sites for future solar thermal electric plants.

Connecticut, Massachusetts, and **Oregon** all provide rebates administered by non-profit organizations funded with system benefit charges paid by electricity consumers. Each state's PV market has grown in the last few years, and continued growth is likely. With enhanced tax benefits in Oregon, many more large installations are expected. The new Commonwealth Solar initiative in Massachusetts aims to increase the number of installations there.

3. Solar Thermal Electric

The 64-MW Solar One solar thermal electric plant built in Boulder City, Nevada went on-line in June 2007. Other than a smaller 1-MW plant built in Arizona in 2006, this was the first new U.S. solar thermal electric plant constructed in over 15 years. Nine solar thermal electric plants with a capacity of 354 MW were constructed in California from 1985 to 1991 and continue to operate today.

The future prospects for solar thermal electric plants look bright. Several different companies have announced plans for over 3,500 MW of generating capacity, and some have begun to receive required approvals from government agencies for these projects. None of this new capacity will be constructed in 2008, and development of these announced projects will depend on long-term extension of the federal investment tax credit.

4. Solar Hot Water and Space Heating

Solar thermal collectors can heat hot water for domestic use or heat spaces such as houses or commercial offices. More rarely, solar thermal collectors can provide heat for industrial processes or air conditioning.

In 2006, increased federal investment tax credits, together with rising conventional energy prices, caused the solar hot water market to increase dramatically. Prior to 2006, about half of the solar water heaters sold each year in the United States were in Hawaii due to utility rebates, state tax credits, and high energy prices. In 2006, national installations were 2.4 times the number installed in 2005 and installations outside Hawaii quadrupled. In addition to Hawaii, Florida and California lead the states in solar hot water installations.

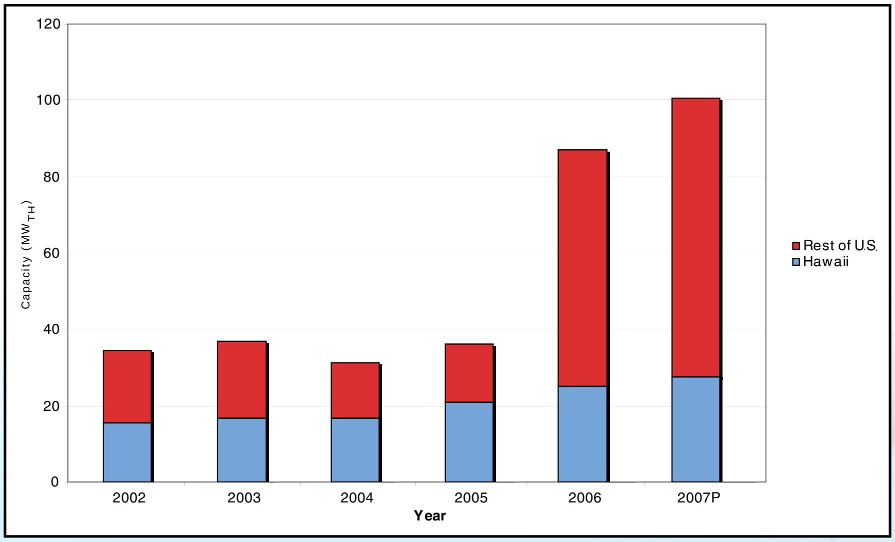


Fig. 7: Annual Installed Capacity for Solar Hot Water and Space Heating (2002-2007)
Based on analysis of collector shipment data from EIA.

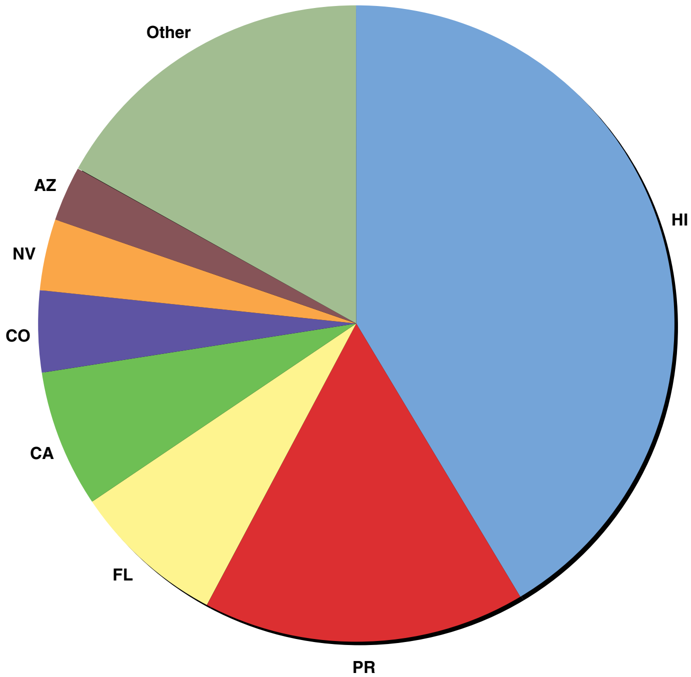


Fig. 8: Installed Solar Hot Water and Space Heating Capacity by State
Based on analysis of EIA data for 2001-2006

Figure 8 shows that, like PV installations, solar water heating and space heating installations are concentrated in a few states and territories. However, the states with the most installed capacity are different for solar hot water than for PV. Hawaii represents almost half of the solar hot water market. High energy prices and supportive government policies have built the solar hot water market in Hawaii. In addition, installation costs are lower in Hawaii than in most other locations in the United States because freezing is not a concern. New policies under development will likely continue Hawaii's status as a market leader for solar hot water.

Solar Pool Heating

Figure 9 shows the annual installed capacity for solar pool heating systems during 1998 to 2007. Installed capacity grew an average of 10% per year through 2006, but decreased 7% in 2007. To a certain extent, the sales of solar pool heating systems follow the sales of pools. The economic decline in the real estate markets in Florida and California likely led to the decrease in pool installations in 2007.

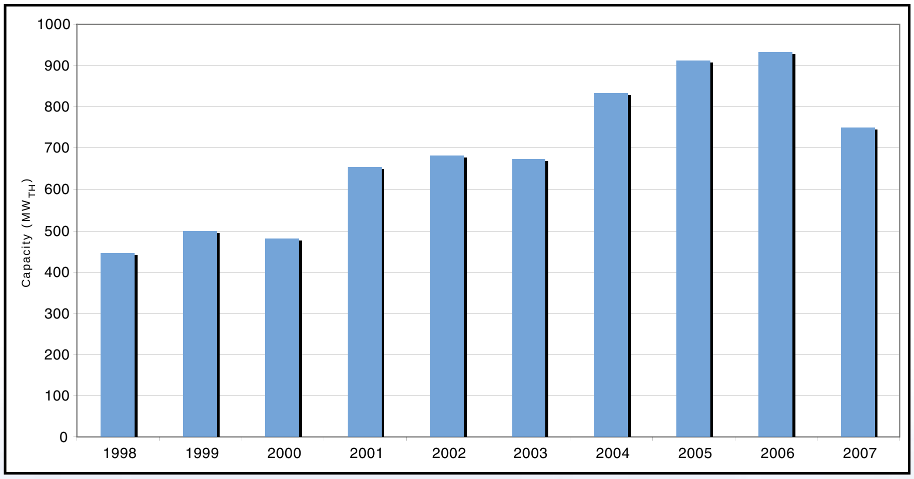
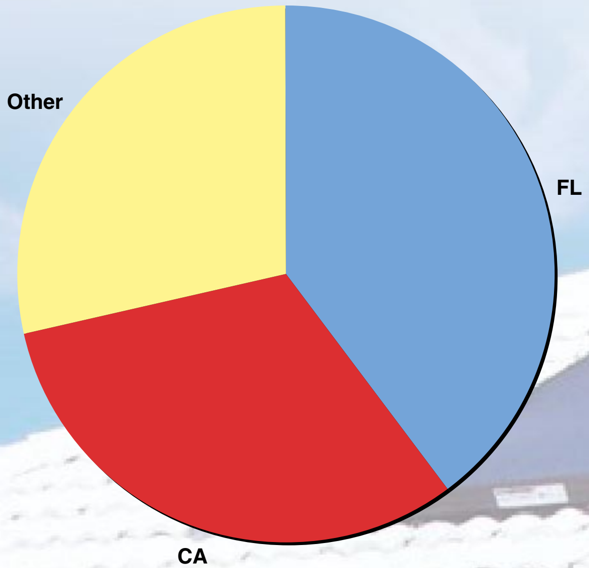


Fig. 9: Annual Installed Capacity for Pool Heating (1998-2007)
Based on collector shipment data from EIA and SEREF.



The trend continues for pool heating systems, with installations concentrated in a few states, notably Florida and California (see Figure 10). Unlike other solar technologies, virtually no incentives exist for solar pool heating systems.

Fig. 10: Installed Pool Heating Capacity by State
Based on EIA Data for 2001-2006

5. Number Of Installations

The number of solar installations from all technologies has grown from nearly 30,000 per year in 1998 to more than 83,000 per year in 2007, as shown in Figure 11. This includes grid connected and off-grid photovoltaics, solar hot water, solar pool heating and solar thermal electric. Through 2005, over half of these installations were for solar pool heating. Because of the federal investment tax credit and the slump in the new pool market, the market shares of the different solar technologies changed significantly in 2006 and 2007. By 2007, roughly one-third of the solar installations were for pool heating, one-third for hot water and one-third PV.

These charts just show the number of installations for each technology, but they do not show the relative energy contribution. Since grid-connected PV installations are larger on average, the energy contribution from PV installations will be larger than the relative number of installations.

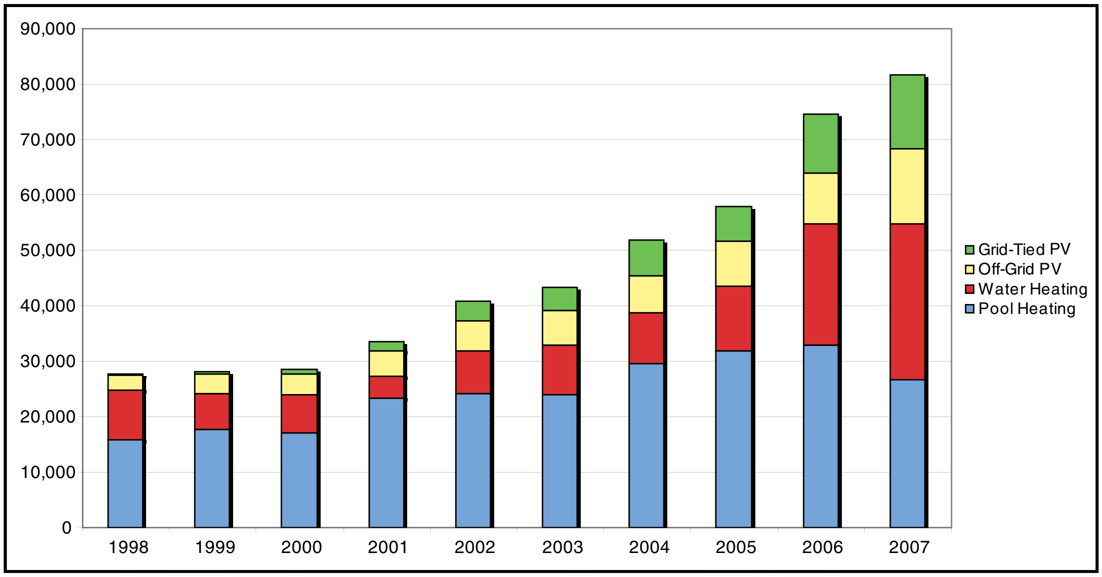


Fig. 11: Number of Annual Solar Installations by Technology

Technology	Number of Installations
Solar Pool Heating	317,000
Solar Hot Water (and Space Heating)	193,000
Off - grid Photovoltaics	73,000
Grid - Connected Photovoltaics	48,000
Total	**631,000**

Table 4: Cummulative Solar Installations By Technology, 1993-2007.

Table 4 shows the cumulative solar installations by technology for 1993-2007. Over 600,000 solar installations currently produce energy in the United States.

6. Prospects For 2008 And 2009

The market growth for 2008 and 2009 will be largely tied to the fate of the federal investment tax credit. As this report goes to press in August 2008, Congress has not renewed the investment tax credit. Uncertainty will increase the number of installations in 2008 as owners rush to install systems in time to quality for the federal credits.

If the investment tax credit is not renewed or if renewal is significantly delayed, the impact on the market in 2009 will be disastrous, with a large drop in installations. When the wind production tax credit expired in 2000, 2002, and 2004, the installation of wind turbines plunged by 74-90% compared with the previous year. This choppy market growth hinders the long-term development of the value-added benefits of renewable energy through manufacturing and installation job development. Even if the investment tax credit is renewed early in 2009, solar installations will be down early next year due to the unwillingness of customers and investors to commit to new solar installations when the investment tax credit's fate is uncertain.

Installations will continue to be concentrated in states with strong financial incentives, and those incentives will remain critical to the market in 2008 and 2009. However, good state incentives will be unable to overcome the market turmoil caused by uncertain federal incentives.

7. Conclusion

Solar markets are booming in the United States due to rising energy prices, strong consumer demand, and financial incentives from the federal government and many states and utilities. Over 80,000 installations were completed in 2007. The markets for each solar technology are concentrated in a few states.

PV installations grew by 48% in 2007 and the average size of PV systems is growing. The two largest U.S. installations, one in Nevada and one in Colorado, were completed in 2007. The PV markets are expanding to more states, though California remains the dominant market.

Solar hot water installations have boomed since the increase in the federal investment tax credit in 2006. In the continental 48 states, installations have quadrupled since 2005. Hawaii is still the largest market for solar hot water.

The 64 MW Solar One solar thermal electric plant built in Nevada went on-line June 2007. Other than a smaller 1 MW plant built in Arizona in 2006, this was the first new solar thermal electric plant in over 15 years.

The fate of the federal investment tax credits, currently scheduled to expire at the end of 2008, will have a strong influence on whether or not the markets continue to grow in 2009.

Acknowledgements

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PHOTOGRAPHY CREDITS

Photovoltaic installation in Colorado (Pg. 2)
Photograph courtesy of Namaste Solar Electric, CO

8.3 MW PV installation in Alamosa, Colorado (Pg. 3, 4)
Photographs courtesy of SunEdison and Zinn Photography

14 MW PV installation at Nellis Air Force Base, Nevada (Pg. 11)
Photo credit: SunPowerCorp.

Solar hot water installations in Florida (Pg. 9, 10)
Photo credit: Florida Solar Energy Center

Appendix A
Data Sources

Grid-Connected Photovoltaics

State data were obtained for grid-connected photovoltaic (PV) installations from the following sources:

- State agencies or organizations administrating state incentive programs (data most commonly available from states with incentives);
- Utility companies (data most commonly available from utilities that manage incentive programs or from interconnection agreements);
- Non-profit organizations (data most commonly collected through surveys or from installations facilitated by local programs); and
- The National Renewable Energy Laboratory's (NREL) Renewable Electric Plant Information System (REPiS) (1) (data available only through 2002 in most cases).

The data quality depends on the source. Certainly, this study misses some installations. Data based on incentives paid are usually the most reliable. Since grid-connected PV is the technology most reliant on incentives, the state-by-state installation data for grid-connected PV are the best.

Off-Grid Photovoltaics

National data for off-grid PV capacity were obtained from PV Energy Systems (2). Other sources provide much less data on off-grid PV installations than grid-connected installations. The best grid-connected data come from incentive programs, which usually do not fund off-grid applications. Therefore, state data are not reported for off-grid PV installations.

Solar Thermal

Some sources report data on state solar thermal applications, but many do not. The U.S. Energy Information Administration (EIA) annually reports the shipments of solar thermal collectors to each state and the shipments by market sector and end use (i.e. shipments to California and total shipments for pool heating use)(3). However, the EIA does not report shipments by state and market sector (i.e. shipments to California for pool heating use). The pool heating market is very different than the hot water and space heating markets, and the goal of this analysis is to learn the distribution of installations for both of these market segments. EIA did not design its survey to provide this information.

Luckily, most pool heating collector manufacturers only ship collectors for that market. EIA provided the author with data titled, *Solar Thermal Collector Shipments by State of Destination for Companies that Shipped only Collectors to be used for Pool Heating*. These shipments account for 95% of the total pool shipments reported elsewhere by EIA.

This study then calculated the difference between the "Total Solar Thermal Collector Shipments by State" and the "Shipments from Companies that Shipped Collectors to be used for Pool Heating." This difference is assumed to be the shipments for hot water and space heating.

This analysis provides a general picture of the state distribution of solar thermal installations, especially for states with the largest number of installations. However, there are problems with these data. Hot water and space heating installations are small compared with the number of pool heating installations, and solar thermal exports are rising. Both these factors make analysis of EIA data difficult. In addition, manufacturers report to EIA where they shipped the collectors. Most shipments go to wholesale and retail distributors. The final destination and installation of the collectors may be in a different state and is not reported to the EIA.

The resulting state analysis was compared with state installation data obtained from other sources. While not a perfect match, the general trends are confirmed (i.e., the top states and the general proportion of collectors sold there). In general, this analysis shows a higher use of thermal collectors for solar hot water than other state sources show.

EIA data for 2007 will not be available until the fall of 2008. Pool data from the Solar Energy Research and Education Foundation (SEREF) was used for 2007 (4). For solar hot water, this study made projections based on partial data available.

REFERENCES

(1) Renewable Electric Plant Information System is available on-line at http://www.nrel.gov/analysis/repis/

(2) Paul Maycock, PV Energy Systems, Inc., June 2008

(3) Energy Information Administration, *Renewable Energy Annual*, 1997-2006 editions

(4) Solar Energy Research and Education Foundation (SEREF), *Solar Collector Production Report*, Fourth Quarter 2007.

Appendix B
Assumptions

Solar Capacity

Capacity measures the maximum power that a system can produce. For a solar energy system, the capacity is the output under "ideal" full sun conditions. Capacity is typically measured in watts (W) or kilowatts (kW). A kilowatt of one technology usually does not produce the same amount of energy, commonly measured in kilowatt-hours (kWh) for electricity, as a kilowatt of another technology. Thus, capacity for one energy technology is not directly comparable to the capacity for another technology.

Occasionally data are only reported in terms of capacity or the number of installations, but not both. In these cases, typical data from other sources are used to obtain both pieces of data.

Photovoltaics

This study reports PV capacity in direct current (DC) watts under Standard Test Conditions ($W_{DC\text{-}STC}$). This is the capacity number that manufacturers and others typically report and is the basis for rebates in many states.

The notable exception to reporting DC watts is the California Energy Commission (CEC), which reports alternating current (AC) watts. CEC calculates AC watts by multiplying DC watts under PVUSA Test Conditions by the inverter efficiency at 75% of load. The resulting capacity ($W_{AC\text{-}PTC}$) is a more accurate measure of the maximum power output under real world conditions.

Based on an analysis of California systems installed in 2003:

$W_{AC\text{-}PTC} = W_{DC\text{-}STC} \times .83.$

This study converted data reported in AC watts to DC watts using this formula.

Solar Thermal

Data sources usually report solar thermal capacity in area (square feet). Representatives from the International Energy Agency's Solar Heating and Cooling Programme and several major solar thermal trade organizations developed a factor to convert aperture area of solar thermal collector to capacity (W_{TH}) (*Recommendation: Converting solar thermal collector area into installed capacity*, IEA, 2004). The factor is 0.7 kW_{TH}/m^2 (.065 kW_{TH}/ft^2). This study uses the IEA factor to convert EIA data reported in square feet to MW_{TH}.

Number of Installations

Many data sources report installed capacity rather than the number of installations. This is especially true for solar thermal systems. So, a factor is needed to convert capacity to installations.

This study uses the following average installation sizes:

Off-Grid Residential PV: 2 $kW_{DC\text{-}STC}$
Off-Grid Non-Residential PV: 10 $kW_{DC\text{-}STC}$
Solar Hot Water: 50 ft^2 (4.6 m^2)
Solar Space Heating: 250 ft^2 (23 m^2)
Solar Pool Heating: 350 ft^2 (33 m^2)

For grid-connected PV installations, this study uses actual data on number of installations. For the data, which shows residential and non-residential installations, real data are used whenever possible. For data sources which only report the size of the installations, this study assumes all installations less than 10 kW_{DC} are residential installations. Analysis of data from the Los Angeles Department of Water and Power (LADWP), which do include both residential and commercial data, indicates that the 10 kW_{DC} assumption is reasonable.

The results for cumulative installations include all installations for the past 15 years. Some older installations still operate today, but no data exists on how many older systems are still operational. This assumption means the cumulative results are likely conservative, especially for solar hot water and pool heating installations.

Appendix C
Grid-Connected Photovoltaic Installations By State

State	Capacity Installed in 2006 (MW_{DC})	Capacity Installed in 2007 (MW_{DC})	Cumulative Installed Capacity (MW_{DC})
Alabama	*	*	*
Alaska	*	*	*
Arizona	2.1	2.8	18.9
Arkansas	*	*	*
California	69.5	88.8	328.8
Colorado	1.0	12.5	14.6
Connecticut	0.7	1.8	2.8
Delaware	0.3	0.4	1.2
District of Columbia	*	*	0.5
Florida	0.2	1.0	2.0
Georgia	*	*	*
Hawaii	0.7	2.4	4.5
Idaho	*	*	*
Illinois	0.1	0.2	2.2
Indiana	*	*	*
Iowa	*	*	0.1
Kansas	*	*	*
Kentucky	*	*	*
Louisiana	*	*	*
Maine	0.1	*	0.2
Maryland	0.1	0.1	0.7
Massachusetts	1.5	1.4	4.6
Michigan	*	*	0.4
Minnesota	0.1	0.1	0.5
Mississippi	*	*	0.1
Missouri	*	*	*
Montana	*	0.2	0.5
Nebraska	*	*	*
Nevada	3.2	14.7	18.8
New Hampshire	*	*	0.1
New Jersey	17.9	16.4	43.6
New Mexico	0.2	0.2	0.5
New York	3.0	4.3	15.4
North Carolina	0.1	0.4	0.7
North Dakota	*	*	*
Ohio	0.1	0.1	1.0
Oklahoma	*	*	*
Oregon	0.5	1.1	2.8
Pennsylvania	0.2	0.1	0.9
Rhode Island	0.2	0.1	0.6
South Carolina	*	*	*
South Dakota	*	*	*
Tennessee	0.1	*	0.4
Texas	0.7	0.6	3.2
Utah	*	*	0.2
Vermont	0.1	0.2	0.7
Virginia	*	*	0.2
Washington	0.4	0.9	1.9
West Virginia	*	*	*
Wisconsin	0.3	0.6	1.4
Wyoming	*	*	*

* = less than 100 kW_{dc} or data not available