# Assessment of Solar Facility Siting in New Jersey and Implications for Land Use and Smart Growth

By Jedediah Drolet
Prepared for New Jersey Future

NEW JERSEY FUTURE

May 2011

# Contents

**Executive Summary**........................................2

**Introduction**........................................4

**The Role of Solar in the Energy System**........................................6

**Types of Solar Installations**........................................9

Net-Metered Installations

Utility-Scale Installations

**Magnitude of Solar Installations**........................................11

Installed Capacity in New Jersey

**Solar Land Use**........................................20

**Solar Footprint**........................................22

**Solar Energy Goals and Land-Use Implications**........................................26

**Impacts of Solar Development**........................................28

Direct Impacts

Impacts on Surrounding Uses

Opportunity Cost

**Incentives**........................................30

State

Federal

**Policy Considerations and Recommendations**........................................32

**References**........................................33

**About the Author**........................................34

# Executive Summary

Although solar power currently generates less than 1 percent of the total electricity in New Jersey, it has become increasingly popular over the past decade, due largely to state financial incentives designed to encourage solar development. Solar power's appeal is also due to its lack of emissions of greenhouse gases or other pollutants, as well as the minimal upkeep and maintenance that the panels require once they are installed.

As of April 29, 2011, New Jersey had 9,032 solar projects with a total capacity of 321 megawatts. In total installed solar capacity, New Jersey ranks second only to California. Due to its much smaller land area, however, New Jersey has by far the most solar capacity per square mile of any state.

Because of New Jersey's small size, the effects of solar development on other land uses are more pressing than in other states. New Jersey may have both more demand for solar development and less developable land than any other state. As solar development continues, the issue of whether a solar installation is the best use of a given parcel of land will become increasingly salient.

There are three main types of impacts from solar development. These include: 1) direct impacts on the site itself from both construction and the installed panels; 2) impacts on surrounding uses, including noise and visual disruption; and 3) the opportunity costs of the land or rooftop used. These impacts are almost always significantly greater for ground-mounted installations than for rooftop installations.

So far, solar development in New Jersey has largely proceeded in a way very consistent with smart growth principles. Most of the development has been on rooftops in developed areas, rather than on sensitive lands in rural areas. As of March 31, 2011, rooftop installations accounted for 91 percent of total solar installations and 73 percent of solar capacity.

New Jersey's Solar Advancement Act of 2010 calls for adding 4,109 megawatts of electricity capacity from solar by 2026, a 13-fold increase from today's level. This goal could be met using an estimated 24 square miles of land or 327 million square feet of rooftop — or, most likely, a combination of the two. There is plenty of potential for continued rooftop development to meet long-term goals for increased solar electricity generation. According to one estimate, New Jersey in 2010 had a total rooftop potential for solar capacity of 9,138 megawatts.

Whether rooftop or ground-mounted, the largest solar facilities in New Jersey to date have primarily supplied electricity for on-site use. There has been much discussion recently, however, about the potential for increased development of large "utility-scale" solar facilities on greenfield sites that would feed power directly into the transmission grid. As of April 31, 2011, one utility-scale project was in operation in New Jersey and four were under construction. An additional seven utility-scale projects were "under development," meaning they were in the development pipeline but still somewhat speculative. While it is not clear how realistic these proposals are, state and local governments should act now to ensure that solar development in the future continues to follow the smart growth trends of the past, rather than moving in a more problematic direction.

The following general principles would ensure that solar development remains consistent with smart growth:

- Rooftop development is preferable to ground-mounted development.
- Brownfield sites, especially landfills, and other marginal sites, such as underutilized industrial sites, have great potential for solar development, but considerable attention must be paid to the issue of whether a more active use of a given site, especially in a developed area, might be preferable.
- Utility-scale solar development on farmland and other undeveloped land should be further reviewed for long-term land use impacts and benefits before support is continued.
- Governments should take special care to enact and enforce regulations mitigating any negative impacts on surrounding land uses from solar developments during construction, use or decommissioning.
- Government agencies with control over incentive programs should structure these programs to encourage good siting practices and/or discourage bad ones.

# Introduction

Solar power has become increasingly popular in New Jersey over the past 10 years, due largely to a set of state financial incentives designed to encourage solar development in the state. In a highly environmentally conscious state like New Jersey, incentivizing solar is a straightforward way to demonstrate the state's commitment to environmental sustainability and decrease the use of fossil fuels for electricity generation. The popularity of solar is certainly understandable in light of its lack of emissions of greenhouse gases or other pollutants, as well as the minimal upkeep and maintenance that the panels require once they are installed. Rooftop solar panels are becoming very common throughout the state, and there have recently been numerous proposals for large-scale solar installations that would feed directly into the electric grid. As of April 29, 2011, New Jersey had 9,032 solar projects with a total capacity of 321 Megawatts (MW) (NJCEP 2011)[1].

Widespread solar development is not without its drawbacks, however. While they do not generate the pollution and other major environmental impacts of fossil-fuel power plants, large-scale solar plants in particular can have detrimental effects on their neighbors through noise, visual impacts and other concerns. In addition, solar may not necessarily be the most responsible land use in many of the areas where it is being proposed, particularly in rural areas where it may be displacing valuable farmland or forested land. On the other hand, in some other contexts solar may be a more responsible use of land than, for example, sprawling residential development, and in some circumstances, such as landfills and certain abandoned industrial sites and remediated brownfield sites, solar installations can allow productive use of land that would otherwise likely sit vacant and unusable. The implications of solar development for land-use issues are complex, and this report represents an attempt to elucidate them in the context of smart growth principles as reflected in the New Jersey State Development and Redevelopment Plan.

This report aims to assess the current state of solar development in New Jersey as of spring 2011, and the implications of current solar siting patterns for land use and smart growth concerns. The land-use issues raised by solar development are numerous and complex, and the policy and regulatory options available to state and local government agencies to deal with them are equally diverse and complicated. These policy issues are beyond the scope of this report and will require further careful study.

---

[1] The New Jersey Board of Public Utilities, which regulates energy facilities in the state and administers the state incentives for renewable energy, estimates that one Megawatt of solar capacity in New Jersey can be expected to generate 1,200 Megawatt-hours (MWh) or 1.2 Gigawatt-hours (GWh) of electricity in a year (NJBPU 2011).[1] Thus, the 321 MW of installed solar capacity in New Jersey can be expected to generate 385,200 MWh or 385.2 GWh per year.

This figure can be compared to the state's goals for solar output under the Solar Advancement Act of 2010, which mandates a certain amount of generation for each "Energy Year" (running June 1 to May 31) to come from solar. Utilities in the state are required to submit Solar Renewable Energy Certificates (SRECs) to meet this requirement; one SREC is generated for every MWh of electricity generation from solar in the state. If they are unable to meet the requirement with SRECs, which has been the case in all Energy Years so far, they must make up the shortfall with a Solar Alternative Compliance Payment (SACP). The goal for Energy Year 2011, running from June 1, 2010 to May 31, 2011, is 306 GWh (NJBPU 2011). The 385 GWh that could potentially be generated from currently installed capacity could therefore theoretically meet the goal for Energy Year 2011 without the need for any SACPs, although since much of this capacity was installed over the course of the year it will not have been running for the entire year and the goal will thus not necessarily actually be met. Still, the fact that solar capacity is for the first time now adequate to meet the state's aggressive goals for solar generation is a sign of how much progress the solar industry has made in New Jersey. If the current rate of growth continues, the state likely will meet the goal of 442 GWh of generation in Energy Year 2012, which would require about 368 MW of installed capacity.

In general, current trends indicate that solar development in New Jersey has been proceeding in a manner very compatible with smart growth principles. The vast majority of installed solar capacity has been in small-scale rooftop systems serving the energy needs of the on-site uses, rather than in large-scale ground-mounted installations that provide electricity directly to the grid and have the potential to seriously affect surrounding land uses and the reliability of the grid. While there have been some indications that future development may turn in this direction, very little of this sort of development has transpired as of spring 2011, and there is still ample opportunity for concerned local governments, state agencies and citizens to act to ensure that future solar development remains as responsible as past development has been.

# The Role of Solar in the Energy System

The amount of energy put out by the sun is immense. Incoming solar radiation, known as insolation, provides the ultimate source for almost all of the energy we use on earth. Plants convert this energy to a usable form using photosynthesis, and humans in turn unlock the energy from plants by eating them (or eating animals that eat them), by burning them for heat or by burning their fossilized remains to generate electricity. There are, however, significant downsides to the use of fossil fuels such as coal, oil and natural gas as energy sources, foremost among them the fact that doing so releases not only the energy that ancient plants absorbed from the sun, but also the carbon dioxide that they absorbed from the atmosphere. The release of this carbon dioxide has been the largest component of the human contribution to global climate change, which is becoming an increasing problem for human societies as its concrete effects begin to be felt, for example, through the melting of glaciers and Arctic sea ice.

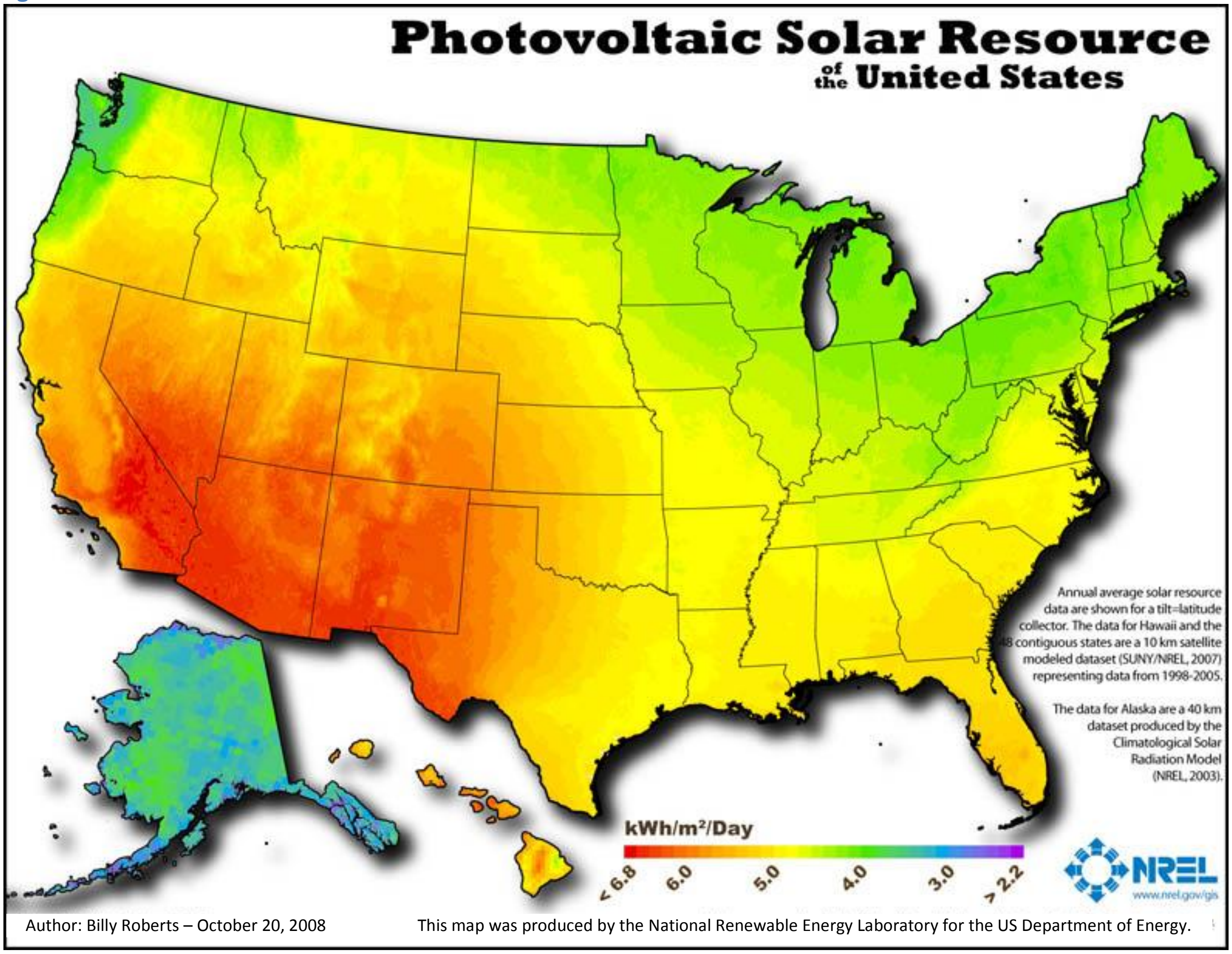
It is possible to harness the sun's energy in ways other than burning fossil fuels, however. Solar heat can be captured directly to heat water or interior spaces using so-called "passive solar" systems, which have become increasingly popular over the past few decades in Europe and some other places, such as Israel. There are limits to how far heat can be transported, however, so solar heating can really be used only on the scale of individual buildings.

It is also possible to generate electricity from solar energy, which allows for a much wider distribution of solar energy through the power grid. One way to do this is to concentrate incoming solar radiation through a mechanism such as a dish or trough, and use the resulting heat to boil water or another liquid to produce steam, which can be used to spin a turbine and generate electricity. This is known as "concentrated solar power," or CSP, and it operates on the same principle as a traditional fossil-fuel or nuclear power plant. It has the downside, however, of requiring large amounts of consistent, direct solar radiation throughout the year, which makes it practically suitable only for sunny desert areas such as California and Nevada, where increasing numbers of large-scale CSP plants have been built in the past few years and plans are under way to build many more. In New Jersey, which gets less sun, this is not nearly so practical.

What is practical in New Jersey, and anywhere else that gets even a little bit of sunlight, is photovoltaic generation. This uses a chemical reaction in a panel to generate electricity directly from diffuse sunlight, so it does not need the large amounts of direct insolation necessary for CSP. Any amount of sun will do, although places that get more sun are, of course, able to generate more power from a given panel than places that get less. Figure 1 shows the amount of insolation available for photovoltaic generation throughout the country as determined by the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

As is apparent from Figure 1, New Jersey ranks near the middle of the country in terms of solar resource. Fundamentally, however, virtually all of the United States has sufficient solar resource for photovoltaic development to be effective. The main constraint is cost. Photovoltaic systems have decreased significantly in cost over the past few years, but they remain much more expensive than other sources of energy. This makes government financial incentives crucial in stimulating solar development, as discussed below. New Jersey has been particularly aggressive in enacting policies to encourage solar, which has led the state to a leading position in the country in solar development despite its middling solar resource. All of the solar development under these policies has been photovoltaic, and the remainder of this report will focus exclusively on photovoltaic technology.

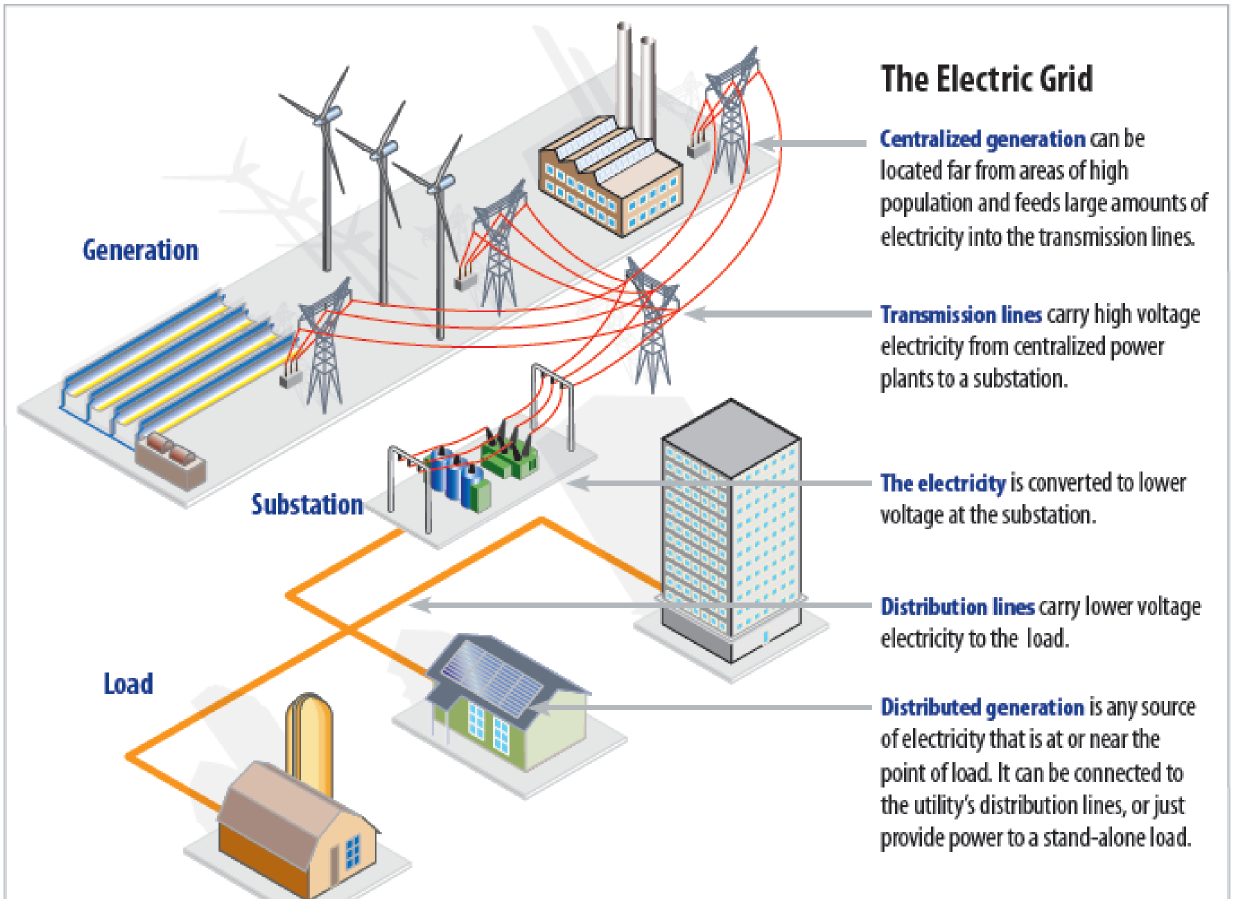
Figure 1




Although it is possible to use photovoltaic panels to provide electricity for remote locations that are far from the grid (and this has been done in many cases, especially in the western United States), in a place like New Jersey virtually all solar capacity is attached to the grid. Different types of solar installation have different relationships to the grid, however, and understanding why requires a brief overview of the electric grid and how it works.

Figure 2 shows a schematic of the structure of the electric grid. The grid is divided into four main parts: generation, transmission, distribution and load. *Generation* refers to the centralized production of electricity from a variety of means, including traditional fossil-fuel and nuclear power plants, large hydroelectric dams and utility-scale wind and solar installations. These are typically located based primarily on consideration of the location of the resources used in generation (e.g., coal plants are typically near coal mines and wind farms are in places with lots of wind), rather than on consideration of the places with the most demand for electricity, which may be far away. *Transmission* is the process of getting the electricity from where it is produced to where it is needed using high-voltage power lines. The voltage needs to be high to minimize losses in transmission, which tend to be fairly small (on the order of 8 percent). When the transmission lines reach the areas where the electricity is needed, they connect to substations that step the voltage down to a lower level for the distribution system.

Figure 2




Source: National Renewable Energy Laboratory for the US Department of Energy (NREL), 2010b

*Distribution* refers to the process of getting the electricity from these substations to the places where it is used. This is done using either underground wires or the familiar utility poles seen throughout developed areas, and is typically the responsibility of local regulated utility companies. These companies may or may not also handle generation and distribution; if they do not, they buy the power from other companies that do and resell it to retail customers. *Load* is the term used from an engineering perspective to describe these customers; from an economic perspective, they constitute the demand for electricity, while generation constitutes the supply. While most generation comes from centralized power plants, it is also possible to have some generation at or near the load, in which case it is known as "distributed generation." Rooftop solar panels are one common form of distributed generation. The key attribute of such on-site generation from the perspective of the grid is that it does not generally need to move over the grid at all, since it services a load that is directly on-site. This means that its main function is to reduce the amount of load that must be met by centralized generation through the grid, which helps to reduce congestion on the grid.

## Types of Solar Installations

Functionally, solar installations can be divided into two major categories: those that are net-metered and supply electricity predominantly for on-site use, and those that feed into the grid. In land-use terms, net-metered installations are typically classified as accessory uses, while grid-scale installations are usually principal uses.

**Net-Metered Installations**

Net-metered installations are those that primarily serve on-site load -- electricity used at the location where the panels are installed. In the case of a residential rooftop installation, this would be the electricity used by the inhabitants of the house. In the case of a large roof- or ground-mounted array at an industrial facility, it would be the electricity used by that facility. These installations are typically net-metered, meaning that any electricity they generate is used to offset the electricity they draw from the grid, and if at times they generate more than is necessary to meet the on-site load, the excess is put back into the grid. When this happens, the electric meter spins backward and the customer gets a credit on his or her utility bill. New Jersey has strong laws favoring net metering; all utilities in the state are required to allow it and to pay back the excess at the retail rate of electricity. To be covered by these net-metering laws, however, a system cannot be designed to produce substantially more electricity than is needed on-site. The idea is that while the solar installation will cover some portion of the on-site load, there will still be a need to draw electricity from the grid, and these installations are not expected to consistently produce more than is needed on-site. From the point of view of grid management, net-metered installations serve primarily to reduce the load that must be met by the grid through its standard power sources. The times when the meter spins backward do introduce some complexities into handling the injection of power, but in general this type of installation is not very difficult to integrate into the existing grid system.

Physically, net-metered solar installations can be located on rooftops or on the ground, but smaller ones are generally on rooftops. Rooftop systems are usually added onto existing rooftops, so the structural properties of the roof are important to consider in designing the system. Residential rooftop systems are typically small, both because rooftop space is limited and because the on-site need for electricity is relatively small. Commercial rooftops, which are typically flat, offer much greater areas for net-metered installations. A 4 MW rooftop solar array was completed in Edison, NJ in April, which was the largest rooftop array at that time (Caroom 2011). At industrial facilities and some other sites with extensive electricity needs and large amounts of land available, net-metered solar installations may be mounted on the ground. This is the case, for example, at the Rutgers Solar Farm in Piscataway, NJ, which generates about 11 percent of the electricity used on the university's Livingston Campus (Rutgers University 2009).

**Utility-Scale Installations**

If a solar installation does, by design, consistently produce more electricity than is needed on-site, it is functioning as a power provider, much like a coal-fired or nuclear power plant. Unlike a traditional power plant, however, a solar plant operates intermittently and its output cannot be easily controlled to respond to changes in electricity demand throughout the day. The grid management issues posed by these installations are therefore much more challenging than those in the net-metering case, and the regulatory framework is correspondingly more complicated. Many projects of this scale have been proposed recently in New Jersey, especially in the southern part of the state (Table 1). Both regulatory challenges and difficulties obtaining financing, however, have contributed to a general lack of progress on most of these projects. Unlike net-metered installations, utility-scale systems must be carefully evaluated by the grid operator, which in New Jersey is an organization known as PJM, to ensure that they can be properly integrated into the grid. For any utility-scale project, PJM must conduct a series of technical studies to ensure that it will work, and this process can take months. Utility-scale solar developers therefore tend to try to get their projects into the PJM “queue” long before they begin construction, and generally even before they get financing or regulatory approvals. This means that the queue has many projects in it that may be totally unrealistic either technically or financially, which is one reason that the “under development” category of projects is so large in Tables 1 and 2.

An additional complication is that the current incentive program in New Jersey, based on Solar Renewable Energy Certificates (SRECs), allows solar projects to gain SRECs only if they connect directly to the distribution system (i.e., to local utility poles with a voltage of 12 kV). This requirement is intended to ensure that SRECs go only to solar installations physically located in New Jersey, since electricity is generally transmitted across state lines only at higher voltages. It poses considerable engineering and grid management challenges, however, since it means that large amounts of electricity are being put into the grid in areas where the infrastructure is really designed to distribute electricity from the transmission system to consumers. A bill under consideration in the New Jersey Legislature would allow utility-scale solar installations to connect to the smaller transmission lines at 69 kV, which would still limit the program to installations within the state but would make it easier to handle the engineering issues involved with the input of large amounts of solar generation into the grid. If this change is enacted, PJM would likely heavily favor projects connecting to 69-kV lines in its technical analyses, which would have the effect of channeling solar development into corridors served by these lines.

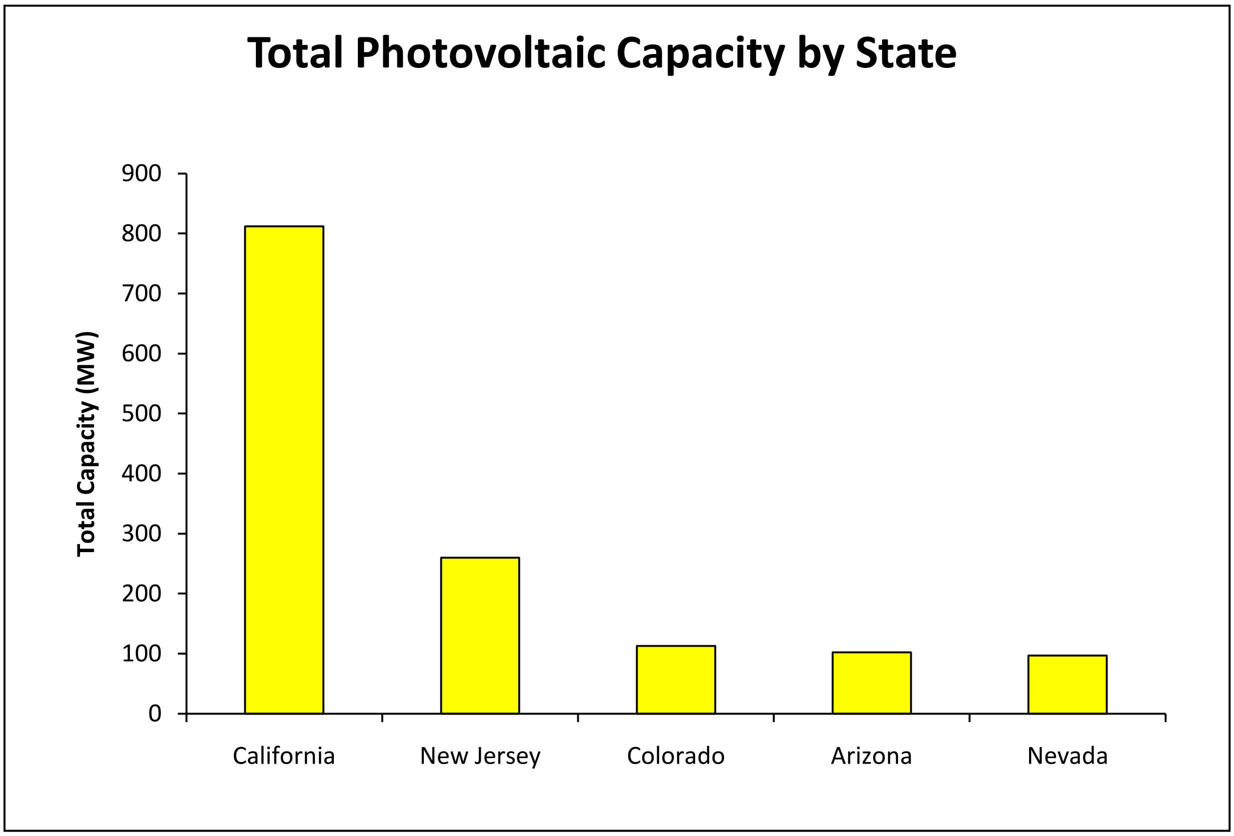
Utility-scale projects typically pose the largest land-use concerns of any type of solar installation, due to their scale and their proposed locations, which have often been on productive farmland in rural areas where residents have expressed many concerns about the local impacts. There is some potential, however, for this type of project to be placed on brownfield sites, such as closed landfills, or other locations where other use is unlikely for a variety of reasons. Most of the projects of this scale that have been constructed in New Jersey so far, primarily by the utility company PSE&G, have been on sites such as these. In those cases, the land-use impacts would likely be much reduced compared to greenfield developments, although there still remains a concern over whether solar is the best use for a given brownfield site when there are other options available.

## Magnitude of Solar Installations

**Installed Capacity in New Jersey**

As of April 29, 2011, New Jersey had 9,032 solar projects with a total capacity of 321 MW (NJCEP 2011). In total installed solar capacity, New Jersey ranks second only to California, which has a similarly aggressive policy but much more land and a much better solar resource, as shown in Figures 1 and 3 (NREL 2010; SEIA 2010, 2011a).[2] Due to its much smaller land area, New Jersey has by far the most solar capacity per square mile of any state (Figure 4). As a result, the effects of solar development on other land uses are more pressing in New Jersey than in most other states. The state has both more demand for solar development and less developable land than almost any other, and as solar development continues, the issue of whether solar is the best use of a given parcel of land will become increasingly salient.

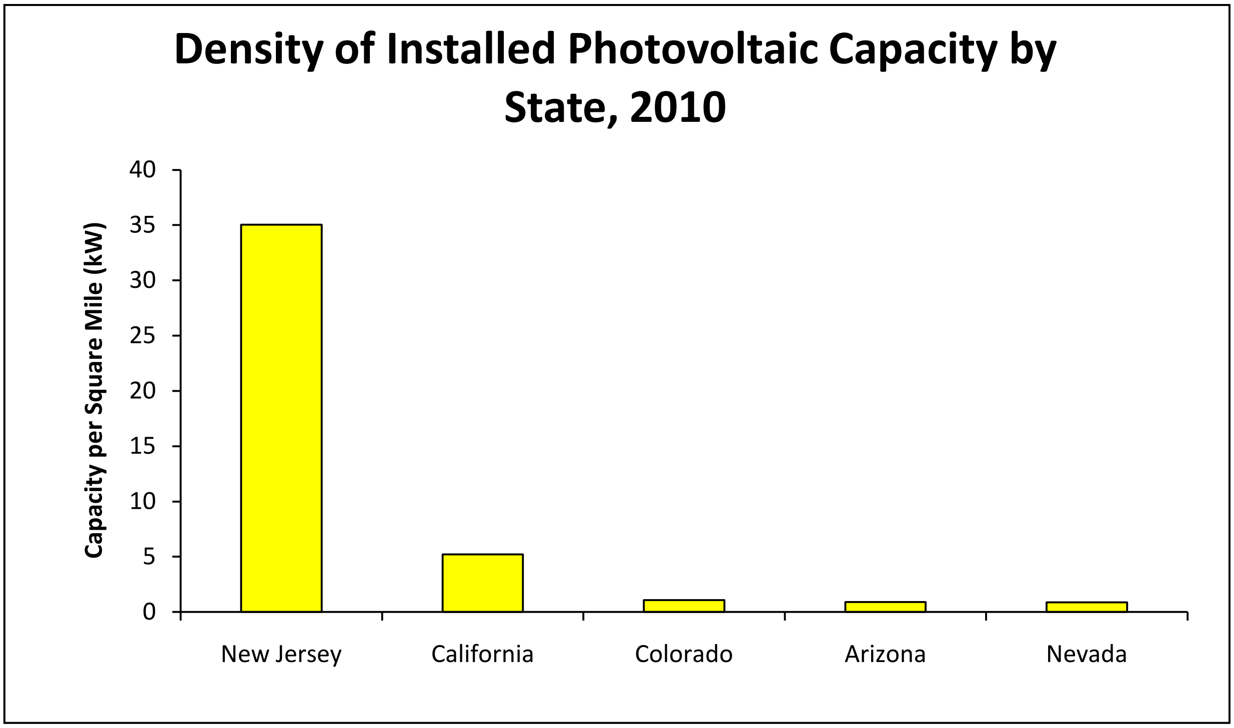
Figure 3




Data Sources: NREL 2010, SEIA 2010, 2011a. Data as of December 31, 2010

[2] Figures 3 and 4 show total installed capacity as of December 31, 2010, when New Jersey had 260 MW. Most other tables and figures in this report use the most recent available numbers for New Jersey, which show 321 MW as of April 29, 2011, but similarly recent data are not available for all states, so the figures showing state comparisons use the 2010 totals. Using the 321 MW figure, New Jersey has 43 kW per square mile, up from the 35 kW per square mile shown in Figure 4.

Figure 4



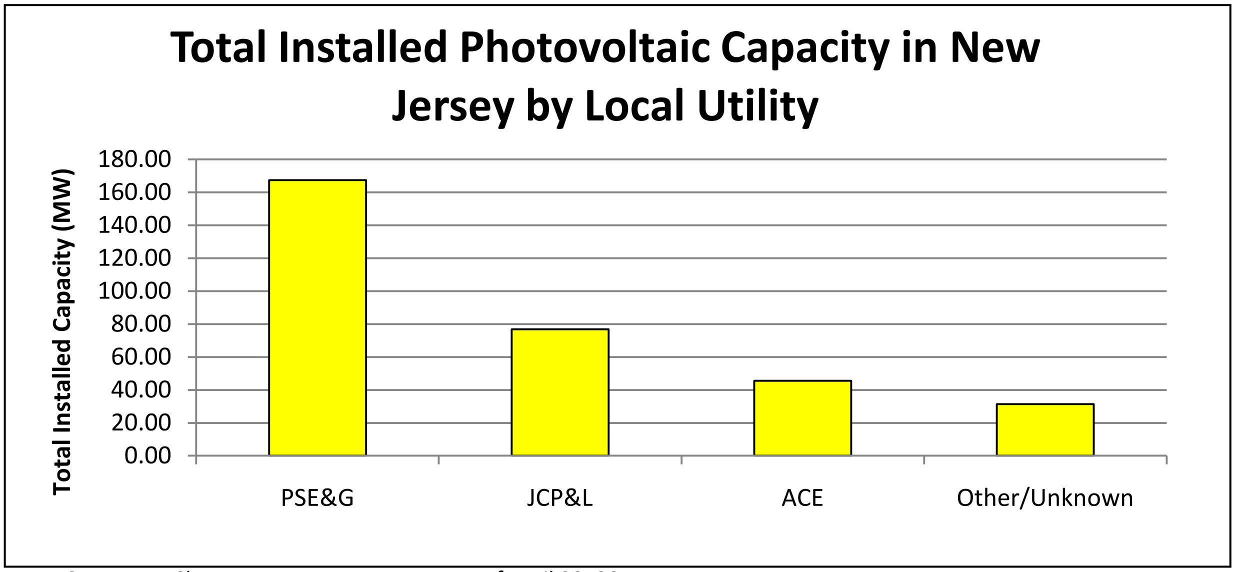

Data Sources: NREL 2010, SEIA 2010, 2011a. Data as of December 31, 2010.

As of April 29, 2011, a bare majority (52 percent) of the installed solar capacity in New Jersey was in territory served by PSE&G, the state's largest utility (Figure 5 and Table 1). The two other major utilities, Jersey Central Power & Light and Atlantic City Electric, had 24 percent and 14 percent, respectively. The remaining 10 percent of solar installations comprised those served by smaller utilities and those for which the New Jersey Board of Public Utilities, which collects data on solar installations in the state, did not have information on the utility involved. In addition to serving the largest number of solar installations in the state, PSE&G has embarked on an ambitious program to install 80 MW of solar capacity on its own. This program, known as Solar4All, will consist ultimately of 40 MW of small solar modules installed on utility poles throughout the PSE&G service area and another 40 MW of larger installations on land owned or leased by the company (PSE&G 2009). As of December 31, 2010, this program had installed 28 MW of capacity, of which 14.7 MW came from the small pole-attached panels and the remainder from 11 utility-scale installations (NJBPU 2011).

Geographically, solar capacity in New Jersey is distributed throughout the state but most heavily concentrated in Middlesex and Mercer counties in the central part of the state (Figures 5-9).[3] Probably not coincidentally, this is within PSE&G's service area. Average installation size varies widely by county, with the largest by far being in Hudson County, due mainly to a disproportionate number of installations there being rooftop systems at schools.

[3] The most recent data on installed solar capacity in New Jersey as of April 29, 2011 are not broken down by county. The most recent data available by county are as of December 31, 2010.

Figure 5



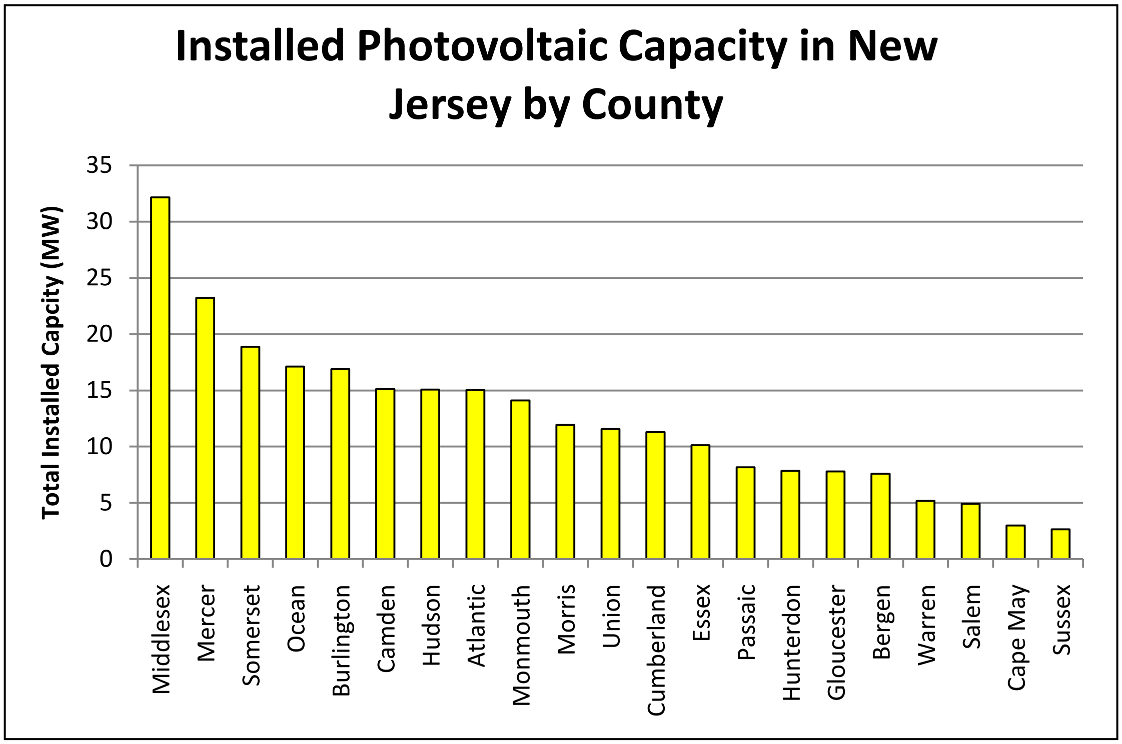

Data Source: NJ Clean Energy Program. Data as of April 29, 2011

**Table 1. Total Installed Photovoltaic Capacity in New Jersey by Local Utility as of April 29, 2011**

| Utility | Total Installed Capacity (MW) | Percent of State Total |
|---|---|---|
| PSE&G | 167.49 | 52% |
| JCP&L | 76.83 | 24% |
| ACE | 45.49 | 14% |
| Other/Unknown | 31.34 | 10% |
| Total | 321.14 | 100% |

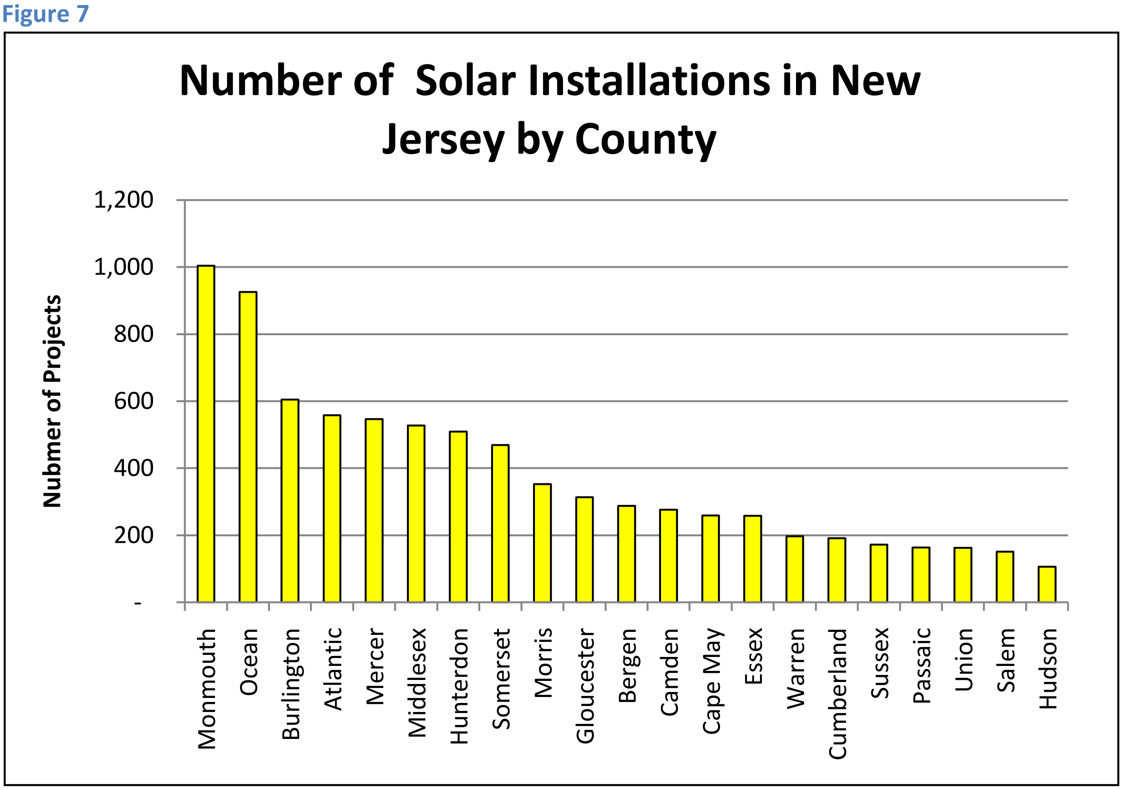
Data Source: NJ Clean Energy Program

**Figure 6**



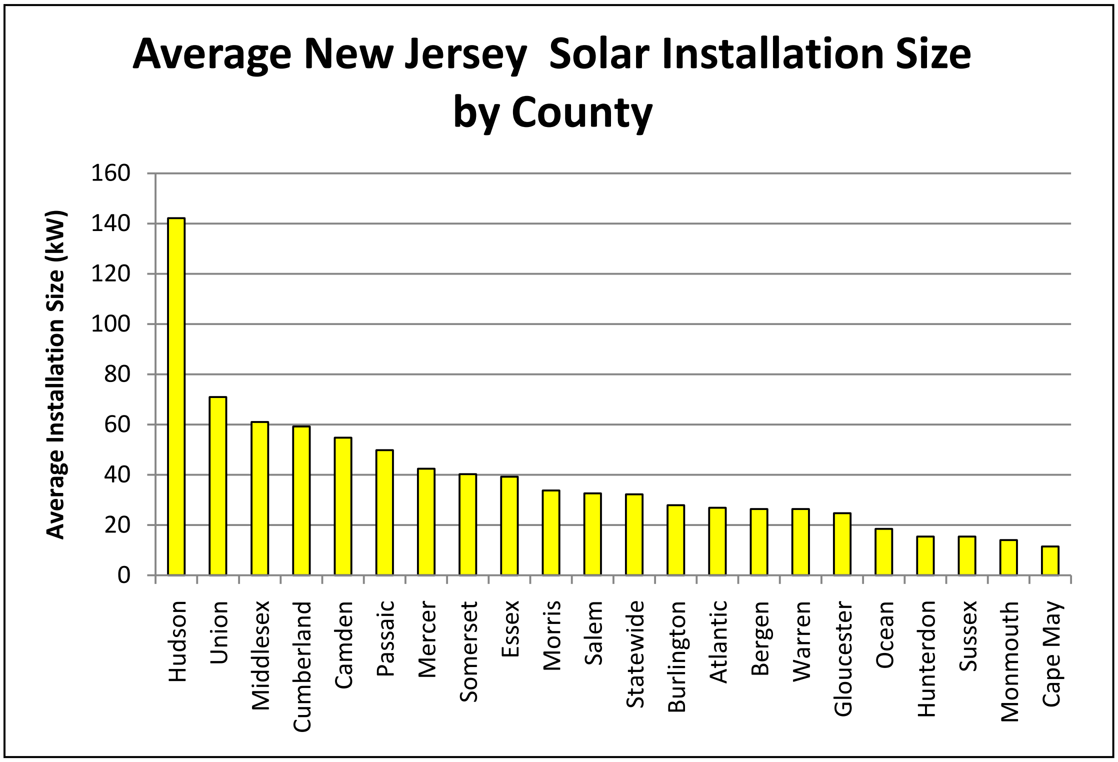

Data Source: NJ Clean Energy Program. Data as of December 31, 2010.

**Figure 7**



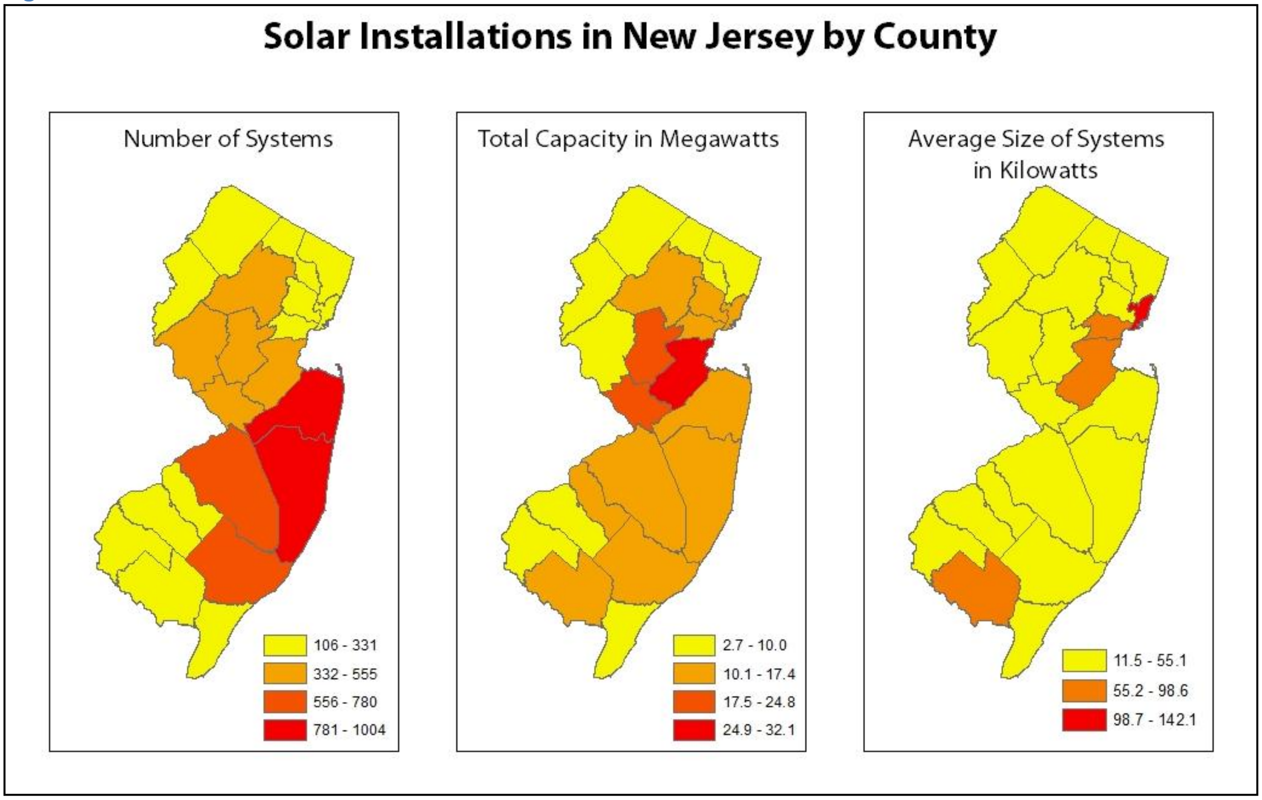

Data Source: NJ Clean Energy Program. Data as of December 31, 2010.

Figure 8




Data Source: NJ Clean Energy Program. Data as of December 31, 2010.

**Figure 9**




Data Source: NJ Clean Energy Program. Data as of December 31, 2010.

Most of the installed capacity in the state as of March 31, 2011, was in rooftop systems, with ground- and pole-mounted systems comprising only a small proportion of both number of systems and installed capacity. Due to the higher average capacity of individual ground-mounted systems, however, as shown in Figure 10, the proportion of capacity they represent is larger than the proportion of total projects. Table 2 summarizes these statistics.

**Table 2. New Jersey Solar Installations by Mounting Type as of March 31, 2011**

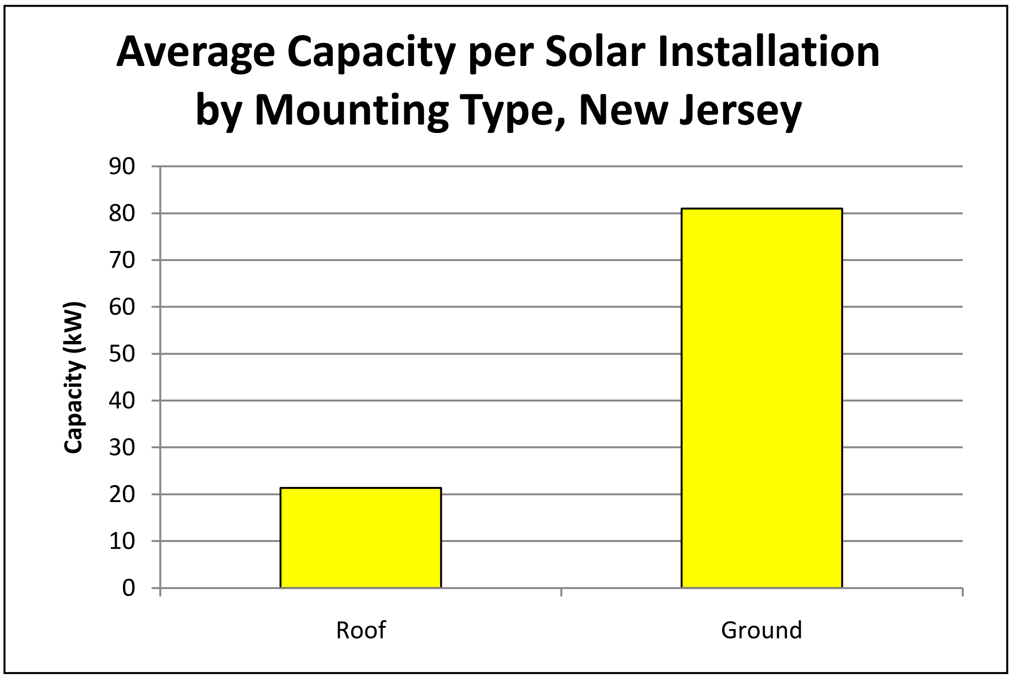
| Type | Capacity (Megawatts) | Number of Installations | Average Capacity per Installation (kW) | Percent of Number | Percent of Capacity |
|---|---|---|---|---|---|
| Roof | 174 | 8,172 | 21 | 91% | 73% |
| Ground | 36 | 453 | 81 | 5% | 15% |
| Pole | 7 | 125 | 59 | 1% | 3% |
| Unknown | 20 | 222 | 90 | 2% | 8% |
| Total | 238 | 8,972 | 27 | 100% | 100% |

Data Source: NJ Clean Energy Program. Data include only systems for which information on mounting type is available, which is a subset of the total number of systems considered "installed." This is why the total capacity listed here is 238 MW as opposed to the 321 MW mentioned elsewhere.

As of April 29, 2011, more than 99 percent of the installed solar projects in New Jersey were net-metered. Due to the larger size of utility-scale projects, however, they accounted for about 11 percent of the total installed capacity in the state despite their small number. According to data collected by the

Solar Energy Industries Association (SEIA), as of April 13, 2011, there were 12 utility-scale[4] solar projects either operating, under construction or under development in New Jersey (SEIA 2011b). Table 3 shows these projects, and Table 4 and Figures 11 and 12 give summary data on the number of projects and total capacity by stage in the development pipeline. Note that while the "operating" and "under construction" projects are quite tangible, many of the "under development" ones are speculative, particularly those that apparently have not yet secured a purchaser for their electricity. Not all of these projects will necessarily be financed or built. Judging from their locations, many of these are likely greenfield developments on current farmland, so from a land-use perspective they would likely have problematic impacts on a number of fronts -- and it is not necessarily a tragedy if they never get built. The four projects in Table 3 with PSE&G listed as the electricity purchaser are part of PSE&G's Solar4All program; they form the large-scale half of the program as opposed to the more visible half that consists of small pole-mounted panels.

**Figure 10**



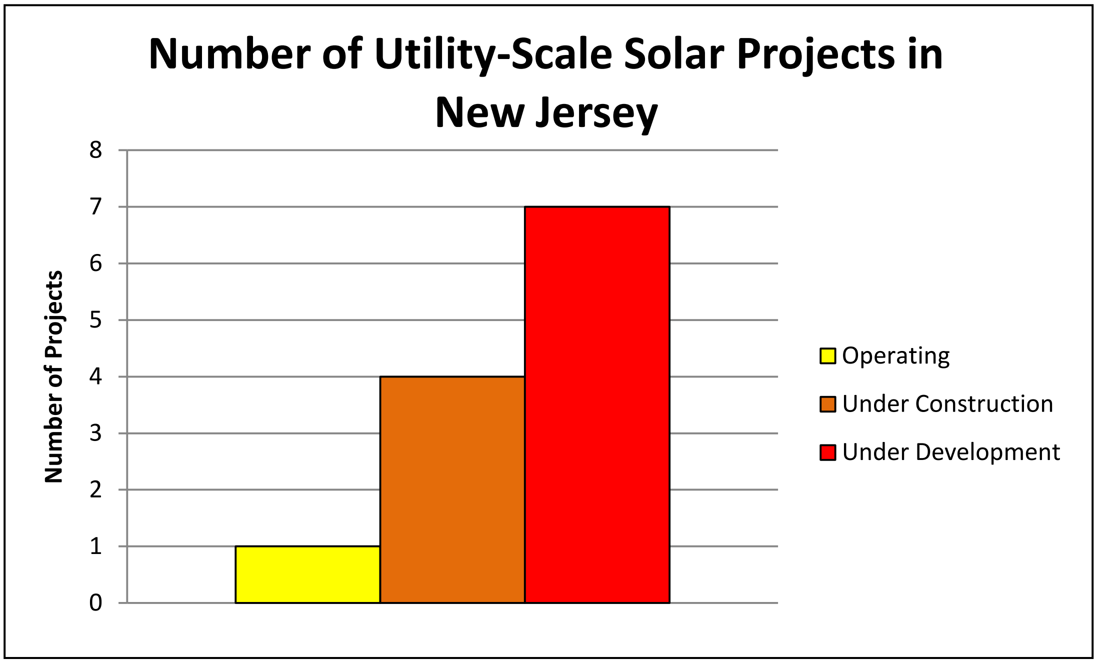

Data Source: NJ Clean Energy Program. Data as of March 31, 2010.

[4] SEIA defines "utility-scale" installations as "ground-mounted utility-scale solar power plants larger than 1 MW that directly feed into the transmission grid." This is a more restrictive definition than the one used by the New Jersey Board of Public Utilities in its lists of completed projects, so the numbers in Table 2 do not necessarily match those used elsewhere in this report (such as in Figure 3) based on BPU data.

| Table 3. Utility-Scale Solar Projects in New Jersey as of April 13, 2011 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Developer** | **Project Name** | **Electricity Purchaser** | **City/County** | **State** | **Status** | **Land Type** | **Online Date** | **Capacity (MW)** |
| Conectiv Energy | Vineland Solar One | Vineland Municipal Electric Utility | Vineland | NJ | Operating | Private | 2009 | 4 |
| American Capital Energy | Yardville Solar Farm | PSE&G | Hamilton | NJ | Under Construction | Private | - | 5 |
| Con Edison/Panda Energy | ? | ? | Pilesgrove Township | NJ | Under Construction | Private | - | 20 |
| J. Fletcher Creamer & Son | Silver Lake Solar Farm | PSE&G | Edison | NJ | Under Construction | Private | - | 2 |
| SunEdison | Trenton Solar Farm | PSE&G | Trenton | NJ | Under Construction | Private | - | 1 |
| Advanced Solar Products | Linden Solar Farm | PSE&G | Linden | NJ | Under Development | Private | - | 4 |
| American Capital Energy | ? | ? | Vineland | NJ | Under Development | Public | - | 5 |
| Atlantic Green Power | ? | ? | Salem County | NJ | Under Development | Private | - | 80 |
| Conectiv Energy | Vineland Solar One Expansion | Vineland Municipal Electric Utility | Vineland | NJ | Under Development | Private | - | 12 |
| Lincoln Renewable Energy | NJ Cedar Solar Plant | ? | Manning Township | NJ | Under Development | Private | - | 10 |
| Lincoln Renewable Energy | NJ Oak Solar Farm | ? | Fairfield Township | NJ | Under Development | Private | - | 10 |
| PPL Renewable Energy | Warren County Project | PPL Renewable Energy | Warren County | NJ | Under Development | ? | - | 5 |
| Data Source: Solar Energy Industries Association | | | | | | | | |

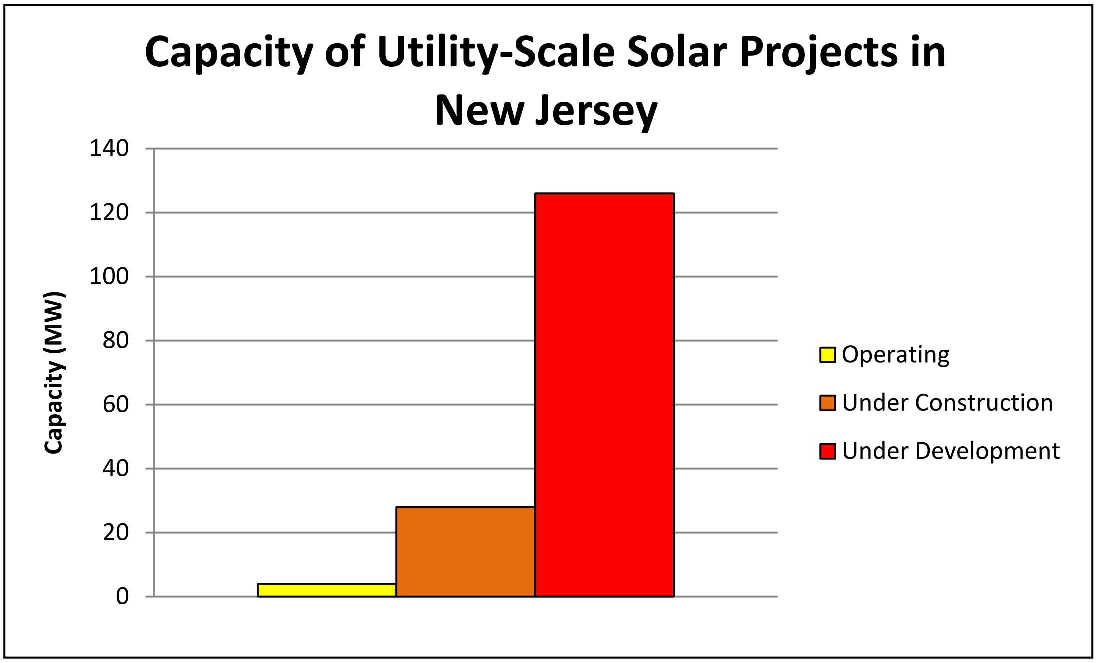
| Table 4. Existing and Potential Utility-Scale Solar Projects in New Jersey as of April 13, 2011 | | |
|---|---|---|
| **Status** | **Number of Projects** | **Capacity (MW)** |
| Operating | 1 | 4 |
| Under Construction | 4 | 28 |
| Under Development | 7 | 126 |
| Total | 12 | 158 |
| Data Source: Solar Energy Industries Association | | |

**Figure 11**




Data Source: Solar Energy Industries Association. Data as of April 13, 2011.

**Figure 12**




Data Source: Solar Energy Industries Association. Data as of April 13, 2011.

## Solar Land Use

Calculating the actual amount of space (land or square footage) a given amount of solar capacity will take up is difficult. The layouts of solar facilities are very flexible and can be changed in response to a variety of factors, including site size, site orientation, solar resource quality, price of land and others. One study by the National Renewable Energy Laboratory found that array configuration is a more important factor in determining energy density (the amount of energy produced from a given land area)[5] than solar resource (Denholm and Margolis 2008). This finding has important implications, especially in New Jersey, with its limited land area and middling solar resource, because there is an important economic tradeoff for developers between the cost of land and the cost of equipment in installing large-scale ground-mounted solar. The most efficient use of land, and thus the highest energy density, comes when the panels are laid flat. This is why residential rooftop installations, where space is at a premium, are usually flat. Tilting the panels, however, captures more incoming solar radiation (insolation) and thus results in higher output per panel. This higher output comes at a high cost in land, however, because the panels need to be spaced farther apart when tilted so that they do not shade each other. Adding a tracking system, which allows the panels to follow the sun through the sky throughout the day, increases the output per panel even more, but again requires even more spacing between rows of panels to avoid self-shading and allow for maintenance. Because of these factors, and because the panels themselves are still very expensive despite steep declines in cost over the past few years, developers of large-scale projects on flat commercial rooftops and on the ground typically tilt the panels and sometimes add tracking systems.

For New Jersey, these two considerations result in a fundamental conflict. The overall amount of land area available in the state is small compared to other states, and much of the land is already developed and devoted to other uses that are not always compatible with solar development (although, as with rooftops, they sometimes are), which means that land values are higher than in other states. This fact implies that developers will want to minimize the amount of land they use, which, in turn, implies that they will use flat arrays that maximize output per unit of land. The New Jersey solar resource, however, is not particularly distinguished compared to the resource in states like California (see Figure 1). The undistinguished quality of the solar resource in New Jersey implies that developers will want to maximize the amount of output they get per panel or module, which, in turn, implies that they will use tilted or tracking array configurations. But, as noted above, these take up more land, which is scarce and expensive. These two considerations point in different directions, and which one dominates is an empirical question that developers must address by comparing the costs of land and panels in a given context given its solar resource.

---

[5] There are two factors involved in calculating energy density: power density and energy generation. The distinction between power and energy is somewhat technical but crucial to understanding the land-use implications of solar development. Briefly, power is a measure of the capacity of a system, generally measured in Watts and determined by testing of the equipment under standard conditions. Energy, on the other hand, is a measure of the output of a system over a given period of time, which is measured in Watt-hours and determined by measuring the amount of electricity that actually comes out of a system after it is installed. "Capacity" and "output" are terms equivalent to "power" and "energy," respectively, that are perhaps more intuitively understandable. In the case of photovoltaic panels, output (energy) is determined primarily by the quality of the solar resource combined with the power (capacity) rating of the panels. The solar resource can be evaluated using modeling tools such as the National Renewable Energy Laboratory's PVWATTS, and the power rating of a given panel is among the specifications listed by the manufacturer. Power density, the other factor involved in calculating energy density, is simply the amount of capacity that can be installed in a given area, calculated based on the power rating of the panels and their size and making allowances for any spacing requirements due to tilting or tracking systems. Energy density is calculated by multiplying power density by energy generation. The result is in units of Watt-hours per unit of area. The following equation shows the calculation:

Energy density = Power density x Energy generation = (Power rating)/(Land area) x (Energy output)/(Power rating)

In New Jersey, judging by the proposals for large-scale solar which have been presented to municipalities so far, the cost of panels seems to take precedence over the cost of land, and large-scale systems are generally tilted (though not usually tracking). It is noteworthy, however, that the major rush to install solar has so far taken place mainly in the southern part of the state where land is cheaper. This may be due in part to the better solar resource there, and that is certainly how developers typically explain the choice when presenting to municipal boards– though, in fact, the quality of the solar resource varies very little across the state because of its small size. The resource is better in the south, but only slightly, and it is likely that land prices are playing at least as great a role as insolation in developers' decision to focus on South Jersey. There has been some recent interest by developers in the northwestern part of the state, which, like the south, is predominantly rural and has large tracts of contiguous land available but, unlike the south, has relatively high land values. It will be interesting to see, if and when developers start to propose specific projects in that area, whether they are flat or tilted in layout.

## Solar Footprint

The above-mentioned study of solar array configuration and land use (Denholm and Margolis 2008a) and other publications arising from the same research program (Denholm and Margolis 2007, 2008b) are part of the "ecological footprint" literature and are therefore focused largely on per-capita use of land and electricity, which are not very relevant to the purpose of this paper. These publications do, however, contain useful calculations of the amount of land necessary to meet each state's electricity demand entirely through photovoltaics using existing technology. This is an admittedly extreme and implausible scenario, but it does provide a useful reference point in evaluating the scale of land involved in solar development. For New Jersey, the estimates for various scenarios range from 84 $m^2$ (904 $ft^2$) per capita using all flat panels to 177 $m^2$ (1905 $ft^2$) per capita using all tracking systems, with their "base" scenario, a plausible mix of 25 percent rooftop arrays (some flat and some tilted) and 75 percent ground-mounted arrays (some at a fixed tilt and some using tracking systems), resulting in 146 $m^2$ (1571 $ft^2$) per capita (Denholm and Margolis 2008b). Multiplying these numbers by the population figures the authors used (Denholm and Margolis 2007), the total land area needed in New Jersey to meet 100 percent of electricity demand under these three scenarios would be about 314,000 acres for the base scenario, 380,000 acres for the all-tracking scenario and 180,000 acres for the all-flat scenario. These numbers represent 4 percent to 8 percent of the total land area of the state, the highest values for any state. This result is not surprising, given that New Jersey has the highest population density of any state. It also shows just how implausible these scenarios of total reliance on solar for electricity generation are for this context.

**Table 5. Electricity Generated in New Jersey in 2009**

| Source | Output (MWh) | Percent |
|---|---:|---:|
| Nuclear | 34,327,954 | 55.4% |
| Natural Gas | 20,624,990 | 33.3% |
| Coal | 5,099,868 | 8.2% |
| Renewables | 959,831 | 1.5% |
| Other | 1,000,310 | 1.6% |
| Total | 62,012,953 | 100.0% |

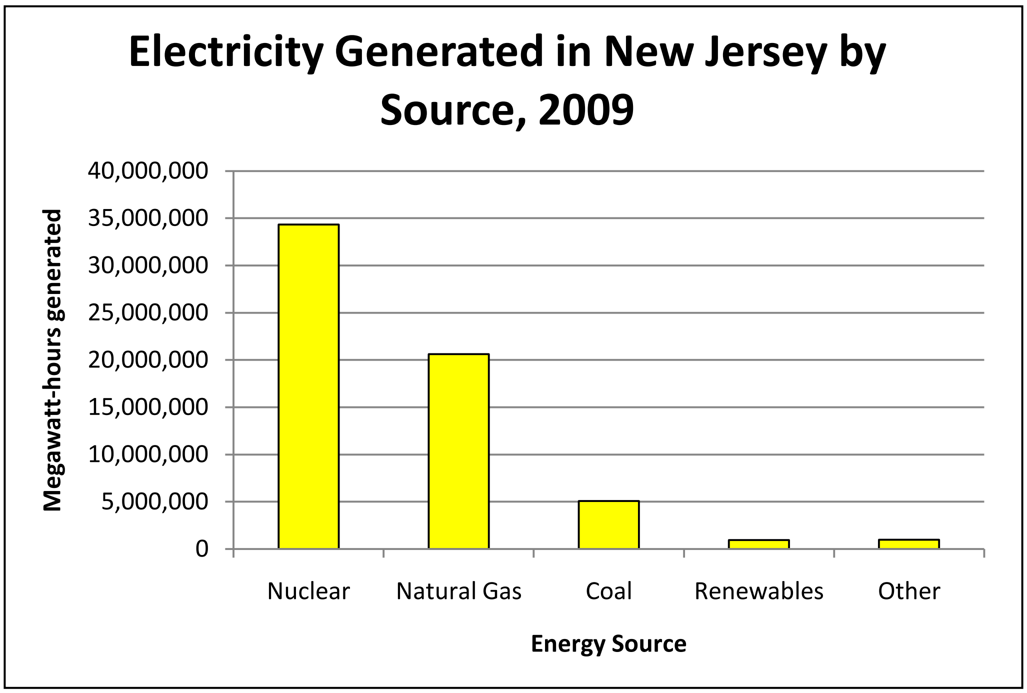
Data Source: US Energy Information Administration. "Renewables" includes solar, wind, and biomass. "Other" includes oil, hydroelectric, and miscellaneous other sources.

Solar currently generates less than 1 percent of the total electricity used in New Jersey. In 2009, the most recent year for which data are available, the total amount of electricity generated in New Jersey was 62,013 GWh, of which 55 percent came from nuclear, 33 percent from natural gas and only 1.5 percent from all renewables, including wind and biomass in addition to solar (EIA 2011; see Table 5 and Figure 13). The solar portion even of the renewables is quite small; for Reporting Year 2010, which ran from June 1, 2009 to May 31, 2010, the state's Renewable Portfolio Standard required utilities to submit SRECs equivalent to 171 GWh of solar generation, which would amount to 0.28 percent of the state's total 2009 generation, or about 18 percent of the amount of renewable generation in 2009.[6] Even this benchmark was not actually met, however, and only 124 GWh, or .020 percent of total 2009 generation (13 percent of renewable generation), was actually generated (NJBPU 2011). The remainder of the 171 GWh requirement was met by Alternative Compliance Payments. The way this system works is

[6] RPS data is from NJBPU 2011. Note that while these data are for Reporting Year 2010, the overall data from EIA are for the calendar year 2009, so these figures are not strictly comparable. They do give a sense of the relative magnitudes involved, however.

discussed more fully below, but the important point is that even with the rapid growth of solar in New Jersey, it still remains a very small part of the state's energy supply. This is likely to continue for quite a while, too. Even the state's aggressive goals for solar development under the Solar Advancement Act of 2010 reach a maximum generation requirement of 5,316 GWh in 2026, which is equivalent to 8.6 percent of the total generation in 2009 (NJBPU 2011). Since it is likely that total demand for electricity will also grow over this period along with general economic growth, the requirement will likely constitute a somewhat smaller percentage of actual generation in 2026. Thus, while relying exclusively on solar to provide for New Jersey's electricity would use up a lot of land in a state that has relatively little land left, it is very unlikely that the state will face this situation any time in the near future.

**Figure 13**




Data Source: US Energy Information Administration

Coming up with an estimate of the actual land likely to be used by solar under more reasonable assumptions requires estimating the amount of land used by the types of solar installations being installed in New Jersey. Estimates of the amount of land taken up by solar installations vary widely, subject to the same factors discussed above. Using Denhom and Margolis's data, a range of estimates for the number of acres needed per Megawatt of capacity can be generated. The results range from 1.8 acres/MW for the highly space-efficient rooftop installations to 12.3 acres/MW for the much more sprawling 2-axis tracking ground-mounted systems. A ground-mounted system at a fixed 25-degree tilt, typical of large-scale installations currently being built and proposed in New Jersey, gives a figure of 3.8 acres/MW, which is probably the best approximation to use in evaluating the land-use implications of large-scale solar development in New Jersey. Table 6 shows the projected land taken up by the utility-scale projects described in Tables 3 and 4 given this figure.

| Table 6. Estimated Land Requirements for Utility-Scale Solar Installations in New Jersey | | |
|---|---|---|
| **Status** | **Megawatts** | **Acres** |
| Operating | 4 | 15 |
| Under Construction | 28 | 106 |
| Under Development | 126 | 479 |
| Total | 158 | 601 |
| Data from Solar Energy Industries Association and Denholm and Margolis 2007, 2008a, 2008b. | | |

Support for the use of a conversion factor of 3.8 acres per Megawatt for utility-scale solar in New Jersey comes from the fact that the estimated land required for the one project in Table 1 that has already been built, the 4-Megawatt Vineland Solar One project, is 15 acres, which is indeed the amount of land it covers.[7] This project uses a 15-degree fixed tilt for its panels, also validating the use of that arrangement to estimate land requirements for similar projects in New Jersey.

Looking at the results in Table 6, it seems that the land requirements for the currently proposed large-scale solar projects in New Jersey is fairly modest, totaling 601 acres, or a little less than one square mile. Note that this is including all of the projects on SEIA's list, including the highly speculative "under development" projects, some of which are unlikely ever to be built. This is not to say that large amounts of land will never be used for solar development if interest in the state's solar incentives among developers continues, only that the state has not yet reached that point as of spring 2011.

Of course, as noted above in Table 2, the vast majority of solar installations in New Jersey as of 2011 are on rooftops rather than on the ground. In terms of land-use policy, rooftop solar has a very different impact from ground-mounted solar, as it occupies land that is already being used and does not require any change in the underlying use. From a zoning perspective, rooftop solar is typically an accessory use rather than a primary use. Rooftop solar is not necessarily devoid of any adverse impacts to surrounding uses, since under certain circumstances (such as in historic districts) it can cause substantial aesthetic concerns, but these impacts are much rarer than those associated with ground-mounted solar. The potential impacts on other land uses of solar development can therefore be addressed in large part by encouraging rooftop rather than ground-mounted solar wherever feasible. This, in turn, raises the question of how much rooftop space is actually available for solar development.

Because the amount of space available on a given roof is fixed, the tradeoff between the cost of land and the cost of panels mentioned above tends to be resolved differently for rooftop installations than for ground-mounted ones, with the result that energy density rather than total output is maximized. In other words, the objective with a rooftop system is to pack as many panels as possible in the given space, rather than getting the highest output per panel. One study that looked at this issue nationally concluded that in states with a cool climate, such as New Jersey, 22 percent of residential roof space and 65 percent of commercial roof space is available for solar development (Paidipati et al. 2008). The factors considered in arriving at this figure were the total amount of roof space, the typical pitch of roofs, roof orientation, the amount of shading by trees and other obstacles, and structural adequacy. The assumptions behind these calculations, in addition to the effects of averaging across such a broad geographic area, mean that the results are not necessarily exact measures, especially when looking at a

[7] http://www.vinelandsolarone.com/vtour1.html

smaller area such as the state of New Jersey. These are the best figures available, however, and the assumptions used are reasonable for New Jersey.

The assumptions used by Paidipati et al. to estimate available roof space in colder climates were:

- Power density for rooftop solar installations is 10 MW per million square feet in 2007, increasing to 13.7 MW per million square feet in 2015 due to increases in panel efficiency
- 92 percent of residential roofs are pitched, with the pitch angle assumed to be 18°
- Of the pitched residential roofs, 59 percent are not overly shaded by trees or other obstacles, and 30 percent of these are properly oriented to take in sufficient sun for solar development
- Of the 8 percent of residential roofs that are flat, 65 percent are suitable for solar development
- 100 percent of commercial roof space is flat, structurally adequate to support solar panels, and properly oriented
- 65 percent of commercial roof space is not overly shaded

The resulting factors for determining how much roof space is available for solar development are 22 percent of total residential roof area and 65 percent of total commercial roof area. Furthermore, 20 percent of this roof space was assumed be needed for inverters, wiring and space between modules for maintenance access. These factors were then applied to data on total floor area of residential and commercial buildings, collected by McGraw-Hill, and data on the average numbers of floors in buildings from the Energy Information Administration. These data were apparently available for each state, but Paidipati et al. do not include the raw data in their final report.

These calculations resulted in a total rooftop potential for New Jersey of 9,138 MW in 2010. As noted above in Table 3, the total rooftop capacity installed as of the end of 2010 was 105 MW, so there is clearly a great deal of potential for further use of rooftops to meet state solar goals.

## Solar Energy Goals and Land-Use Implications

New Jersey's Solar Advancement Act of 2010 mandates 2,164 GWh of electricity output from solar in 2020 and 5,316 GWh in 2026 and every year thereafter (Chandramowli and Felder 2011, NJBPU 2011; see Tables 7 and 8). The New Jersey Board of Public Utilities estimates that in New Jersey, 1 kW of solar capacity puts out 1,200 kWh in a year, so 2,120 GWh of output would require approximately 1,803 MW of capacity and 5,316 GWh would require about 4,430 MW.[8] Assuming that all of this would be met by utility-scale projects similar to Vineland Solar One (a very unlikely prospect), less the 321 MW already installed as of April 2011, the additional land required to meet the 2020 goal would be approximately 5,600 acres, or 8.8 square miles, and the additional land to meet the 2026 goal would be about 16,000 acres, or 24 square miles. Either of these would be a significant amount of land for a small, densely populated state like New Jersey. For context, 5,600 acres is slightly less than 1 percent of the 566,000 acres of farmland in New Jersey in 2007, while 16,000 acres is slightly less than 3 percent of that figure (Hasse and Lathrop 2010).

A loss of 1 to 3 percent of the state's farmland to solar development is presumably not something most New Jersey residents would want, but note that it is highly implausible that all of the additional capacity to meet this goal would come from utility-scale installations. As noted above, there are plenty of rooftops left, and it is quite possible, indeed likely, that a substantial portion of the additional capacity needed to meet the long-term goal will come from the same kind of net-metered installations that have so far formed the overwhelming majority of solar projects in the state. If all the additional solar capacity were met exclusively by rooftop installations (which is somewhat unlikely but much more likely than the prospect of it all being met by ground-mounted utility-scale installations), meeting the 2020 and 2026 goals would require 118 and 327 million square feet of roof space, respectively. The total amount of impervious surface in New Jersey in 2007 was about 22 billion square feet (Hasse and Lathrop 2010). While not all of this is rooftop space, of course, other types of impervious surface, such as parking lots, are also plausible locations for solar installations similar to those used on rooftops, and the immense amount of developed land in a state as densely populated as New Jersey leaves plenty of potential for this type of additional development that uses no additional land. In short, there is likely to be more than enough rooftop space in New Jersey to meet any plausible long-term goals for solar development. This is an important consideration to keep in mind in evaluating specific proposals for ground-mounted systems that may have substantial local land-use impacts. In addition, an updated Energy Master Plan, which will presumably have new targets for long-term solar development, is expected to be released in summer 2011, and these new goals may well inspire binding legislation that would set new Renewable Portfolio Standard requirements and supersede the Solar Advancement Act.

[8] Note that Chandramowli and Felder use a slightly different conversion factor to convert from capacity to output, so the numbers they come up with for the amount of capacity needed to meet the state output goals are different from those presented here. The conversion factor used here is based on the one used by the New Jersey Board of Public Utilities in its 2010 annual report on the status of the Renewable Portfolio Standard program (NJBPU 2011).

| Table 7. New Jersey Solar Generation Goals and Estimated Locational Requirements | | | | |
|---|---|---|---|---|
| Energy Year | Requirement (GWh) | Requirement (MW) | Est. Acres | Est. Square Feet |
| | | | | |
| 2011 | 306 | 255 | 969 | 20,331,109 |
| 2012 | 442 | 368 | 1,400 | 29,367,158 |
| 2013 | 596 | 497 | 1,888 | 39,599,154 |
| 2014 | 772 | 643 | 2,446 | 51,292,864 |
| 2015 | 965 | 804 | 3,057 | 64,116,080 |
| 2016 | 1,150 | 958 | 3,643 | 76,407,764 |
| 2017 | 1,357 | 1,131 | 4,299 | 90,161,162 |
| 2018 | 1,591 | 1,326 | 5,040 | 105,708,481 |
| 2019 | 1,858 | 1,548 | 5,886 | 123,448,371 |
| 2020 | 2,164 | 1,803 | 6,855 | 143,779,480 |
| 2021 | 2,518 | 2,098 | 7,977 | 167,299,783 |
| 2022 | 2,928 | 2,440 | 9,276 | 194,540,812 |
| 2023 | 3,433 | 2,861 | 10,875 | 228,093,787 |
| 2024 | 3,989 | 3,324 | 12,637 | 265,035,280 |
| 2025 | 4,610 | 3,842 | 14,604 | 306,295,473 |
| 2026 | 5,316 | 4,430 | 16,841 | 353,203,196 |
| 2027 | 5,316 | 4,430 | 16,841 | 353,203,196 |

Goals from New Jersey's Solar Advancement Act of 2010. Data from New Jersey Board of Public Utilities, New Jersey Clean Energy Program and Denholm and Margolis 2007, 2008a, 2008b. Energy Years run from June 1 to the following May 31. Acres are based on a conversion factor of 3.8 Megawatts per acre, typical of large ground-mounted systems. Square feet are based on a conversion factor of 12.54 Megawatts per million square feet, typical of rootop systems.

| Table 8. Estimated Land Requirements for New Jersey Solar Development Goals beyond Current Capacity | | | | |
|---|---|---|---|---|
| | **Megawatts** | **Acres** | **Square Miles** | **Million Square Feet** |
| Installed as of 4/29/2011 | 321 | 1,220 | 1.91 | 25.6 |
| 2020 Goal | 1,803 | 6,854 | 10.71 | 143.8 |
| Needed to meet 2020 Goal | 1,482 | 5,634 | 8.80 | 118.2 |
| 2026 Goal | 4,430 | 16,841 | 26.31 | 353.2 |
| Needed to meet 2026 Goal | 4,109 | 15,620 | 24.41 | 327.6 |

Data from New Jersey Board of Public Utilities, New Jersey Clean Energy Program and Denholm and Margolis 2007, 2008a, 2008b. Acres are estimated based on a conversion factor of 3.8 Megawatts per acre, typical of large ground-mounted systems. Square feet are estimated based on a conversion factor of 12.54 Megawatts per million square feet, typical of rooftop systems.

## Impacts of Solar Development

There are three main types of impacts on land use from solar development. These are direct impacts on the site itself, impacts on surrounding land uses and the opportunity cost of using the site for solar rather than another use. There has been very little study of the impacts of solar development, but from the research that has been done, some reasonable guesses at the magnitudes of these impacts can be made.

**Direct Impacts**

The impacts to a site that is used for solar development vary based on the type of installation. Rooftop systems are generally considered to have no direct impacts, as they are mounted on top of buildings on already developed land. Ground-mounted systems, whether net-metered or grid-tied, do have impacts on the land they occupy, especially when that land is previously undeveloped. The main impacts of the physical construction of the systems can be minimized with proper site planning, but they minimally include the frames by which the panels are mounted and the foundations (usually concrete) for supporting equipment, such as inverters and transformers, that are necessary to transmit the electricity generated by the panels to the grid. This construction will necessarily disturb the ecology of the land. If the land was previously forested, it will have to be cleared before construction, which constitutes a major impact to the ecological system. If the land is already clear, the impact is less, but it may still be disruptive to the local animal and plant communities. Another possible impact is to groundwater recharge from the addition of impervious surface, which is one of the major environmental concerns about land development in general (Hasse and Lathrop 2010). In New Jersey, a recent state law (S.921) has declared solar facilities exempt from state and local stormwater regulations regarding impervious surface, which means that municipalities are unable even to measure the impacts from these installations (Reardon 2010).

**Impacts on Surrounding Uses**

The main impacts to neighboring land uses from a large-scale solar development are in the form of what one study calls “loss of amenity” (Tsoutsos et al. 2005: 290). These impacts include noise and visual disruption, and they can largely be mitigated by local regulation requiring careful site planning. Other types of impacts typically associated with industrial uses, such as emissions from operations and increased traffic from employee commuting, are less of a concern with solar.

<u>Emissions</u>

There are no emissions from photovoltaic panels while they are producing electricity, so air and water pollution is not a concern under normal circumstances. Under exceptional circumstances, such as a major fire, the panels may be destroyed and some materials contained in them may be released into the environment. Most types of panels, including the crystalline silicon ones that dominate the market, contain no materials that would be hazardous under these circumstances, but cadmium telluride panels, a type of “thin-film” technology, contain cadmium, which is toxic and could potentially be released in the event of a fire (Tsoutsos et al. 2005: 292). The amount of cadmium contained in these panels is very small, however, and cadmium telluride panels made up only 8 percent of the market in 2008 (NREL 2010: 24). Moreover, fires of this scale are unlikely to be frequent occurrences. Nevertheless, it is important that regulators require large-scale facilities to have plans to deal with such emergency situations.

There are some emissions associated with the manufacture of photovoltaic panels, especially crystalline silicon ones as the process of producing and purifying the silicon is very energy-intensive (Stoppato 2008: 228). These are quite small, however, compared to the emissions from many other types of electricity generation, and in any case are primarily a concern for the areas where the panels are manufactured, rather than those where they are installed.

Noise

The panels themselves do not make any noise, but the inverters that are necessary for them to be hooked up to the grid do make a slight noise, comparable in amplitude to a refrigerator compressor. This noise can be effectively mitigated by requiring the inverters to be placed away from the edges of a parcel where they might be heard by neighbors.

Visual Impacts

Visual impacts are hard to quantify, as they tend to be highly personal and dependent on individual aesthetic assessments. Nevertheless, it is quite plausible that many people in areas with large solar facilities will find them visually unpleasant. This can be addressed by requiring the use of effective screening with trees or other vegetation and setbacks. In urban areas, rooftop solar panels may be considered inappropriate in certain contexts, such as historic districts. In other contexts, however, such as when they are integrated into new construction, they may be used creatively by architects to make a visual statement (Tsoutsos et al. 2005: 293).

Construction

Most of the major impacts suffered by neighbors will likely be during construction. The process of construction of solar facilities is relatively quick, generally taking only a few months for a large system, but during that period neighbors would certainly be affected by noise, emissions from construction vehicles and equipment, and other issues (Tsoutsos et al. 2005: 293). These impacts are likely inevitable, although local regulation may be able to mitigate them to some extent.

**Opportunity Cost**

Probably the most important impact of solar development from a land-use perspective is the opportunity cost of the land used. When a solar project is installed on a piece of land, the land generally cannot be used for any other purpose during the period the project is in operation. Rooftop installations are an exception to this, as the land is already being used and the addition of solar does not necessarily mean that use must cease.[9] Large-scale ground-mounted installations, however, pose major questions about whether solar is the best use for the land and what other uses are being forgone by the development of solar. The answer is ultimately going to be dependent on the specific circumstances in each case, as the possible uses for one plot of land will differ significantly from those for another. In the case of New Jersey, where land is very valuable, this issue becomes particularly important, and local governments and other regulatory bodies should keep it in mind when making regulations for solar development or reviewing specific development applications. There has been little to no formal study of this question in the context of solar, which is not necessarily surprising, since evaluating it depends in part on assumptions about the relative value of different land uses that are not shared by all people and are not always reflected in the purchase price of land or other easily quantifiable measures. This difficulty does not make the issue any less important to consider, however.

[9] It should be noted, however, that this issue is not entirely absent with rooftop systems, since rooftop space can be used in other ways, such as for green roofs or solar water heating,that may conflict with photovoltaic development.

# Incentives

### State

The early growth of solar in New Jersey was spurred mainly by a rebate program that reduced the upfront cost of installing solar. That program has now been phased out and, as of 2008, has been completely replaced by a market-based system of Solar Renewable Energy Certificates (SRECs), which can be used by utilities to meet their obligations under the state's Renewable Portfolio Standard (RPS) to get a certain percentage of their power from renewable sources, with a designated percentage specifically for solar. The way the system works is that an SREC is generated every time a solar installation produces 1 Megawatt-hour (MWh) of electricity (Chandramowli and Felder 2011). If the installation is owned by a utility, it can just hold on to the SREC and use it to meet its RPS requirements at the end of the year. If, as is more often the case, the installation is owned by someone else, that owner can sell the SREC to a utility, which can then use it to meet its RPS requirement. If a utility cannot acquire enough SRECs to cover its RPS requirements, it must make an alternative compliance payment of a set amount per MWh ($693 in 2010). The alternative compliance payment thus sets a ceiling on the price of SRECs. SRECs have recently been trading at relatively close to that ceiling, over $600 per SREC, and it is that potential income stream that has driven the recent surge of proposals for utility-scale solar plants in New Jersey. This is a relatively new system, however, and it is difficult to tell how SREC prices are going to change in the future, so banks are currently unwilling to extend much credit on the basis of the future income stream from SRECs, which has so far stymied the actual construction of any of these large projects. As more capacity is installed, the price of SRECs should decrease due to increased supply, which will make solar development a less profitable speculative investment as well as alleviate the cost of the RPS to electricity consumers.

There are a few other incentives New Jersey has for solar and other renewable energy development, including rebates for wind and biomass installations, a sales tax exemption for solar equipment, local property tax exemptions for solar installations serving on-site load (with a special provision for farms receiving farmland assessment), financial incentives for use of solar panels and related equipment manufactured in New Jersey and opportunities for New Jersey ratepayers to opt to choose clean energy sources for their electricity.[10] The scale of these other programs, and their effect on the development of the state's solar industry, has been very modest compared to the SREC program, which has been the main driving force in the development of solar in New Jersey since the rebate programs it replaced were discontinued.

### Federal

There are also numerous incentives for solar development at the federal level (see NREL 2010a for detailed descriptions). Among the most important is the investment tax credit (ITC), which allows for a reduction in tax liability equivalent to 30 percent of the cost of installing a solar facility and is available for both residential and commercial installations. It is currently in place through 2016. Another important incentive is a cash grant program included in the Stimulus Bill in 2009 that allows for a grant

[10] Some of these programs are described on the New Jersey Clean Energy Program website:
http://www.njcleanenergy.com/renewable-energy/programs/renewable-energy-incentive-program
http://www.njcleanenergy.com/renewable-energy/programs/renewable-energy-manufacturing-incentive
http://www.njcleanenergy.com/renewable-energy/programs/cleanpower-choice-program/new-jersey-cleanpower-choice-program

A full list of state incentives for renewable energy is available at the Database of State Incentives for Renewables & Efficiency (DSIRE) website: http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=NJ

equal to 30 percent of project cost in lieu of the ITC, which had become less useful with the economic downturn. This grant program was initially slated to expire at the end of 2010, but was recently extended for an additional year. Under the program as it exists now, projects must begin construction before the end of 2011 to be eligible. This program has been an important driver of the current interest in large-scale solar development in particular. Other federal incentives include accelerated depreciation and loan guarantees for solar projects.

## Policy Considerations and Recommendations

As noted at the beginning of this report, a detailed assessment of policy issues involved in solar development and land use is beyond the scope of the present project. New Jersey has seen very rapid growth in the solar industry due to the incentives mentioned above, and along with that growth has come a series of legislative and executive actions that have only made understanding the policy environment more challenging. Furthermore, the policy environment changes very quickly, and an assessment of current policies at one point is likely to become obsolete soon.

So far, solar development in New Jersey has largely proceeded in a way very consistent with smart growth principles. Most of the development has been on rooftops in developed areas, rather than on farmland or other sensitive lands in rural areas, and there is plenty of potential for continued rooftop development to meet long-term goals for increased solar electricity generation. There has been some discussion recently, however, about the potential for increased development of large utility-scale solar facilities on greenfield sites. While it is not clear at this point how realistic many of these proposals are, it is imperative for the state and local governments to act now to ensure that solar development in the future continues to follow the trends of the past rather than moving in a more problematic direction. One way to do this would be to tailor incentive programs to encourage sound siting principles, rather than applying these programs uniformly as is currently done. For example, rather than an SREC being produced for every 1,000 MWh generated by any solar installation, installations that do not meet specified siting guidelines could get SRECs only for every 1,500 or 2,000 MWh generated, or, alternatively, installations that do meet the guidelines could be given an SREC for every 500 or 800 MWh generated. The specifics of how to structure a program like this would have to be carefully studied to make sure the incentives align properly, but there are many options for how this could be done. If the state is reconsidering its goals for solar as part of the development of a new Energy Master Plan, adjusting the SREC program or the Renewable Portfolio Standard to take into account siting and land-use issues would be one option to consider. At the local level, a more regulatory approach would generally be necessary, with local governments that are concerned about the impacts of solar development passing ordinances setting strict standards to minimize those impacts.

In general, the following general principles should be considered as guidelines for solar development consistent with smart growth:

- Rooftop development is preferable to ground-mounted development when possible. There are still plenty of rooftops available.
- Brownfield sites, especially landfills, have a lot of potential for solar development, but there must be considerable attention paid to the issue of whether a more active use of a given site, especially in a developed area, might be preferable.
- Other marginal sites, such as underutilized industrial sites, may also have significant potential for solar.
- Utility-scale solar development on farmland and other undeveloped land should be further reviewed for long-term land use impacts and benefits before support is continued.
- Governments should take special care to enact and enforce regulations mitigating any negative impacts on surrounding land uses from solar developments during construction, use or decommissioning.
- Government agencies with control over incentive programs should structure these programs to encourage good siting practices and/or discourage bad ones.

## References


California Solar Initiative. 2011. "California Solar Statistics." Available online at http://www.californiasolarstatistics.ca.gov/

Caroom, Eliot. 2011. "NJ Solar Energy Boom's Frantic Pace Could Slow." The Star-Ledger, April 20. Available online at http://www.nj.com/business/index.ssf/2011/04/nj_solar_energy_booms_frantic.html

Chandramowli, Shankar N., and Frank A. Felder. 2011. Solar Power in the Garden State. *Advance & Rutgers Report*, Issue Paper Number 5, 3–7. Available online at http://policy.rutgers.edu/reports/arr/A&RR5_May_2011.pdf

Denholm, Paul, and Robert M. Margolis. 2007. The Regional Per-Capita Solar Electric Footprint for the United States. National Renewable Energy Laboratory Technical Report NREL/TP-670-42463.

Denholm, Paul, and Robert M. Margolis. 2008a. Impacts of Array Configuration on Land-Use Requirements for Large-Scale Photovoltaic Deployment in the United States. National Renewable Energy Laboratory Conference Paper NREL/CP-270-42971. Presented at SOLAR 2008 – American Solar Energy Society (ASES), San Diego, California, May 3–8, 2008.

Denholm, Paul, and Robert M. Margolis. 2008b. Land-Use Requirements and the Per-Capita Solar Footprint for Photovoltaic Generation in the United States. *Energy Policy* 36: 3531–3543.

Energy Information Administration (EIA). 2011. New Jersey Electricity Profile, 2009 Edition. Available online at http://www.eia.doe.gov/cneaf/electricity/st_profiles/new_jersey.pdf

Hasse, John E., and Richard G. Lathrop. 2010. Changing Landscapes in the Garden State: Urban Growth and Open Space Loss in New Jersey 1986 through 2007.

National Renewable Energy Laboratory (NREL). 2010a. 2008 Solar Technologies Market Report: January 2010. NREL Report TP-6A2-46025; DOE/GO-102010-2867. Available online at http://www.nrel.gov/analysis/pdfs/46025.pdf

National Renewable Energy Laboratory (NREL). 2010b. Solar Power and the Electric Grid, Energy Analysis. Fact Sheet NREL/FS-6A2-45653. Available online at http://www.nrel.gov/analysis/pdfs/45653.pdf

New Jersey Board of Public Utilities (NJBPU). 2011. New Jersey's Renewable Portfolio Standards 2010 Annual Report, Draft for Public Comment. Released April 13, 2011. Available online at http://www.njcleanenergy.com/files/file/Renewable_Programs/Draft_2010_Annual_Report_for_New_Jersey_041311_version.pdf

New Jersey Clean Energy Program (NJCEP). 2011. "Program Status Reports." Available online at http://www.njcleanenergy.com/renewable-energy/project-activity-reports/program-status-reports/program-status-reports

Paidipati, J., L. Frantzis, H. Sawyer, and A. Kurrasch. 2008. Rooftop Photovoltaics Market Penetration Scenarios. National Renewable Energy Laboratory Subcontract Report NREL/SR-581-42306.

PSE&G. 2009. "PSE&G Solar 4 All Program." Available online at http://pseg.com/family/pseandg/solar4all/attachments/Solar4allfactsheet.pdf

Reardon, Cheryl. 2010. Land Use Strategies in the Solar Age. *ANJEC Journal*, Fall 2010.

Rutgers University. 2009. "Rutgers University Opens Seven-acre Solar Energy Facility, Accepts 2009 Energy Educator Award from State." Available online at http://news.rutgers.edu/medrel/news-releases/2009/10/rutgers-university-o-20091027

Solar Energy Industries Association (SEIA). 2010. US Solar Industry: 2009 Year in Review. Available online at http://seia.org/galleries/default-file/2009%20Solar%20Industry%20Year%20in%20Review.pdf

Solar Energy Industries Association (SEIA). 2011a. US Solar Market Insight Year in Review: Executive Summary. Available online at http://www.seia.org/cs/research/SolarInsight

Solar Energy Industries Association (SEIA). 2011b. Utility-Scale Solar Projects in the United States: Operating, Under Construction, or Under Development. Available online at http://www.seia.org/galleries/pdf/Major%20Solar%20Projects.pdf

Tsoutsos, Theocharis, Niki Frantzeskaki, and Vassilis Gekas. 2005. Environmental Impacts from the Solar Energy Technologies. *Energy Policy* 33: 289–296.

## About the Author

Jedediah Drolet worked for New Jersey Future as an intern during the Spring semester 2011. He received his Master of City and Regional Planning degree from the Bloustein School of Planning and Public Policy at Rutgers, the State University of New Jersey in May 2011. While at the Bloustein School he worked for the Center for Urban Policy Research and served as a graduate student representative to the Rutgers Energy Institute, a university-wide consortium of faculty and staff involved in energy-related research and policy initiatives.