Sunshine in the City: Photovoltaics for Local Power

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Local governments in sunny areas like the southwestern United States can use sunlight to generate some of their electricity needs by installing photovoltaic arrays, which convert sunlight to electricity. These installations represent an incremental step toward more sustainable localities, where human activity is compatible with the natural environment and where businesses and residents make use of locally available resources.

This article assesses the degree to which photovoltaics-the technology known as "PV" for short-may serve as a sustainable energy source for residential, commercial, and industrial activity in urban areas and identifies steps that a city or county may take to increase the deployment of PV. There are, of course, other renewable energy resources that may be employed, depending on the availability of the renewable resource, its costs, and its environmental impacts. Some examples are landfill gas, solar thermal electric power, solar hot water, and wind power.

Photovoltaic Technology

Photovoltaic cells, of course, convert sunlight into electricity. PV cells are assembled into modules with appropriate wiring: modules, in turn, can be assembled into arrays, which produce the desired amount of power. PV arrays can be mounted on a fixed frame, on a frame that turns on one axis with the movement of the sun across the sky, or on a frame that turns on two axes. Because PV modules produce direct current, an inverter must be used in applications for which alternating current is needed.

In the U.S. mix of electric generation technologies, PV plays only a cameo role. In 1999, there were about 15 to 20 megawatts (MW) of operating photovoltaic generating capacity (1 MW equals 1,000 kW). Operating PV capacity is highly concentrated in a few states, with California accounting for about 61 percent of that capacity and a total of 12 states accounting for 94 percent of operating PV capacity overall. For reference: in 1999, about 786,000 MW of utility and nonutility electric generating capacity existed in the U.S.

PV modules tend to produce their highest output from mid-morning through mid- to late afternoon in the summer and from mid- or late morning to mid-afternoon in the winter. Peak electrical demand at some utilities occurs on summer afternoons, so grid-connected PV systems can reduce the need for conventional peaking power. The specific decrease in conventional peaking power depends on utility demand characteristics, as well as on the PV system's characteristics.

PV in the Mix

PV is one part of the mix of electric generation resources but unlike some generation technologies, PV facilities have the advantage of being modular and thus can be sized to fit many situations in urban areas. Among common urban locations are:

- Rooftops. Residential rooftop installations generate typically 1 to 4 kW each, with installations on office, industrial, or mixed-use buildings potentially larger. Urban rooftop installations usually are grid-connected, so that the consumer on whose property the modules are located can obtain some power from the conventional generation/transmission/distribution system. Consumers may feed power into the grid if the PV power generated exceeds the consumer's demand at a given time. Rooftop systems may be owned by a utility, by the property owner, or possibly by a third party.

- Covered parking structures.

- Building exteriors. Building components can be constructed so that PV modules will serve as both the exterior of the building and as an energy resource. For example, PV can be integrated into the facade, windows, or roof of a building.

- Central stations. A small PV power plant can be assembled from modules to produce from 50 to 2,000 kW of power or more. These facilities are typically owned by utilities; may be located on utility distribution or generation property or vacant land; and may feed power into the distribution grid for delivery to many customers. For instance, in early 2001 in the Phoenix, Arizona, metropolitan area, there were about 830 kW of central-station PV generation, and in the Tucson, Arizona, metropolitan area, there were about 155 kW of "large" central-station PV facilities.

- Nongrid-connected urban installations. In built-up areas, PV is used for emergency or temporary lighting and for park lighting where underground distribution systems are required. These applications may be less costly than putting in temporary or underground distribution lines or may address a need for lighting during emergencies that knock out the grid power. Nongrid-connected applications can use batteries to provide power when the sun is not shining.

Several cities have included the use of renewable energy from photovoltaics in their strategies, among them these two metropolitan areas:

Sacramento, California. By the end of 1999, the Sacramento Municipal Utility District (SMUD) had installed more than 7,000 kW of PV systems at about 600 sites on rooftops, parking lots, and substations. Part of SMUD's scheme was its PV Pioneers Program, in which customers pay a premium of $4 per month if they permit SMUD to install PV systems on their roofs. Donald Osborn of SMUD reported that, by the end of that year, Sacramento had about 550 such systems, producing about 2 MW of power.

Austin, Texas. The Austin City Council resolved that 5 percent of Austin's electricity would be derived from renewable resources by 2005. Austin Energy, the municipal utility, offers customers the option to subscribe to electricity from renewable resources, including wind turbines, landfill gas projects, and PV installations. The largest PV programs are located at a power plant, on parking structures, and at an airport.

The federal Energy Information Administration has prepared national forecasts for PV on residential and commercial buildings. For 2010, the reference-case forecast is that about 1 billion kWh will be generated by PV installations at residential and commercial buildings. (To produce 1 billion kWh per year, about 570 MW of PV capacity will be needed, assuming a national average capacity factor of 20 percent.)

Factors Promoting the Deployment of PV

Foremost among these factors has been the adoption of state standards to require that sellers of electricity derive at least a certain percentage of their retail kWh sales from renewable energy technologies. These "portfolio standards" increase demand for renewable energy to a level greater than it might otherwise have been. Texas, Arizona, and Nevada legislators and utility regulators have adopted such requirements. The Texas goal is 2,000 MW of new generation of renewable energy by 2009. In Arizona, the requirements for new renewable generation start at 0.2 percent of retail sales in 2001 and increase to 1.1 percent by 2007. The kWh required to be derived from eligible technologies (of which PV is one) are reduced if certain "extra-credit multipliers" are used.

These multipliers are granted for in-state siting and manufacturing of eligible technologies, "green pricing," installations on customer premises, and early installation. At least 50 percent of the kWh must be derived from solar electric technologies in Arizona, with this percentage rising to 60 percent by 2004. Nevada legislation signed by the governor in June 2001 requires the Public Utilities Commission to establish a portfolio standard that starts at 5 percent of retail electricity sales by certain retailers in 2003 and rises to 15 percent by 2013. Of the total energy from renewable resources, at least 5 percent must come from solar energy systems.

Arizona utilities have requested proposals from vendors to meet their portfolio requirements or are otherwise planning to construct eligible resources. The predominant proposed technologies to date are PV, landfill gas, solar thermal (to power an absorption chiller that will cool inlet air at a combustion turbine, thus increasing the efficiency of the turbine), solar hot water, and possibly biomass plants (using wood chips or agricultural waste as fuel).

Of these, only PV and solar thermal projects are eligible to meet the Arizona requirement that 50 to 60 percent of the kWh come from solar electric resources. Under the Arizona portfolio standard, about 60 MW of solar electric generating capacity will be needed by 2007. PV is commercially available in 2001, but the solar thermal technology proposed by a vendor has not yet been deployed as of this year.

The second factor favoring deployment of urban PV is limitations on conventional power generation resources. New conventional electric generation could supply the growing demand for power and avert blackouts like those that occurred in California in 2001 and that might occur in other places. These new power plants can be located on remote sites and the power transmitted to urban load centers. Alternately, new generators can be sited in urban areas.

But conventional solutions face difficulties. Existing transmission capacity into some urban areas may encounter bottlenecks. Utilities in the Southwest have indicated that peak demands in Phoenix, Tucson, Las Vegas, and El Paso cannot be entirely met by importing power because of limitations on transmission capacity. A study conducted for the California Independent System Operator by Power Technologies, Inc., has identified Los Angeles, San Diego, Sacramento, Fresno, and San Francisco, among other cities, as localities where generation is required to run during peak demand periods to maintain a reliable electric system, or to meet local demand, because of transmission bottlenecks.

Transmission capacity additions are not being made rapidly, compromising generators' ability to deliver electricity from remote power plants to load centers. The North American Electric Reliability Council attributes the dearth of new transmission capacity to several causes:

- Generation developers and utilities don't coordinate their plans with transmission providers because they don't wish to disclose their marketing strategies.

- New and different flows on the transmission system are occurring in response to the dispersal of buyers and sellers of power in newly competitive wholesale and retail markets. This makes it difficult to model the load flow patterns and to plan transmission around expected flows.

- Fewer long-term commitments are being made between power consumers and power suppliers in the current competitive market, again making it difficult to plan for long-term transmission investments.

In a report to the Edison Electric Institute, Eric Hirst has identified several obstacles to building new conventional transmission capacity: local opposition, local and state regulatory review, and investor uncertainty about future returns on transmission investment. With regard to investor uncertainty, the Federal Energy Regulatory Commission policy is to treat transmission service providers as common carriers because all transmission customers, including nonutility power suppliers and purchasers, should have nondiscriminatory access to transmission lines. But the rules of this new game are still being worked out, often with great controversy, making investments risky at this time.

Congestion on transmission lines coming into a city can be avoided by putting power plants near load centers. Siting conventional power plants in urban areas, however, may be difficult because of visual impacts, air-quality consequences, and perhaps other spillover effects. The Salt River Project (SRP), for example, proposed locating a new natural gas-fired power plant adjacent to its existing Kyrene Power Plant site in Tempe, Arizona, near Phoenix, but met with local opposition, which focused on the proposed plant's exports of power to other areas, air-quality impacts, and noise.

As a compromise with neighborhood groups, SRP agreed, among other concessions, to reduce the capacity of the new plant from 825 MW, as originally proposed, to 250 MW; to limit production at the existing plant to a 1 percent capacity factor; to reduce emissions at the existing plant; to comply with Tempe's noise ordinance; and to comply with county clean air standards.

Photovoltaics sited in urban areas can partially fill the need for new power supply that is otherwise constrained by transmission congestion and by the environmental incompatibility of many power-plant locations in urban areas. Transmission capacity from remote areas to the city would not be needed by PV systems sited in urban places, and PV may be less damaging environmentally than conventional power plants.

Market Factors and Policies Inhibiting the Deployment of PV
High capital cost is the main reason why PV is not more widely used. Module costs have fallen from about $5.56 per peak watt in 1993 (in constant 1996 dollars) to about $3.46 per peak watt in 1999. (All dollar figures in this paragraph are in constant 1996 dollars.) Turnkey installation costs, including the utility's installation-related expenses, have fallen from $9.34 per watt in 1993 to $4.91 in 1998 in Sacramento's PV Pioneers Program. Nonetheless, PV generation still runs about 30 to 40 cents per kWh or more, depending on the amount of sunlight, the design of the PV system, the discount rate used, and the estimated lifetime of the PV system.

The cost disadvantage of PV has decreased as falling PV expenses and rising electricity prices have moved closer together. Between May 2000, when southwestern spot-market electricity prices unexpectedly took off, and December 2000, the average Dow Jones firm's on-peak Palo Verde price (as published daily in the Wall Street Journal) was about 15 cents per kWh. From January through April 2001, the average Dow Jones firm's on-peak Palo Verde price was about 21 cents per kWh. Spot market prices subsequently fell back to more normal levels.

Where utilities have installed PV in urban areas, the cost has generally been socialized over all or nearly all ratepayers and often has been subsidized by federal government programs. Green pricing programs are common. Under these programs, consumers voluntarily pay a premium for energy from renewable resources. In the Arizona Public Service Company's voluntary Solar Partners Program, customers pay a $2.64 monthly premium for 15 kWh of solar energy generated by several central- station plants in the Phoenix, Prescott, and Flagstaff areas. The revenues from green pricing partially offset the costs of the renewable energy program.

A second factor inhibiting the widespread deployment of PV in urban areas is the potentially limited land supply for central-station PV plants. In general, 1,000 kW of PV generation capacity would need between 5 and 10 acres of land, depending on the amount of sunlight available and on the design of the PV system. Where urban lots of several acres each are not available or are very expensive, however, PV can still be deployed on rooftops and covered parking structures. And because PV systems are modular, it is not necessary to site PV power plants in any one location. They can be scattered around on rooftops and urban lots.

Third, the transaction and ownership costs associated with installations may inhibit the deployment of PV. These costs include fees and charges for permitting; electrical and structural code inspections; utility interconnection requirements, including insurance; and utility services, like special metering, for facilities installed on a consumer's premises.

Other constraints on the use of urban PV are restrictive covenants or similar restrictions that prohibit the installation of rooftop or other PV equipment in order to control the appearance of the housing stock. Often, a homeowners' association's architectural review committee must approve a PV system to be placed on residential property.

A Toolkit for Accelerating the Deployment of PV
Managers and planners who wish to encourage PV in the mix of energy resources serving their communities can take several actions to accelerate the deployment of PV:

Designing PV into the urban plan. PV can be an organizing theme in a land use plan, reflecting the use of indigenous energy resources. In particular, PV can be included in a plan by explicitly allowing for central-station PV as a commercial or industrial land use and by specifically allowing rooftop and other structural applications of PV.

Promoting green pricing and green marketing. A segment of the population is willing to pay more for green energy. This potential base of support for renewable energy can be used to foster the deployment of PV through "green marketing." Ed Holt has identified six factors leading to successful green marketing: program simplicity, customer environmental awareness, utility credibility, project visibility, community pride, and personal marketing efforts by the utility.

Working with utilities. Utilities are a dominant force in PV deployment decisions, and some have taken an interest in urban PV facilities, either in response to renewable portfolio standards or on their own. Local government managers and planners can help utilities find suitable sites for PV facilities within the larger context of a general plan and can endorse green marketing programs.

Some utilities may resist PV and other forms of distributed generation; overcoming such resistance may require communication with the utility and active participation by local government in regulatory proceedings, including rate cases, to remove barriers to PV.

Putting significant amounts of PV onto public buildings. While some examples do exist of localities putting PV on public buildings, a larger commitment would accelerate the use of PV and make the technology more visible in the community.

Removing barriers to PV. Several potential barriers are under the control of a locality. First, permit and inspection fees for PV installations on consumers' premises should be reviewed to see if they significantly reduce incentives to install PV systems. Second, safety codes should be reconsidered to ensure that they incorporate the latest revisions to the National Electrical Code, which reflect the most recent standards on PV.
Third, it may be possible to limit restrictive covenants that hinder residential applications of PV. Such restrictions are often the products of a developer who prepares the initial bylaws of a homeowners' association. Working with developers' attorneys to make them friendlier toward future PV installations may result in greater deployment of PV over the long run. The states of Arizona, Colorado, Florida, Hawaii, Massachusetts, Nevada, and Wisconsin ban "unreasonable" restrictive covenants or limitations that effectively preclude PV, and a city or county might assist in legal action to enforce these laws.

For those localities that have their own electric utilities, it may be possible to reduce interconnection requirements, inspections required, and fees charged while still protecting the safety of the electric grid and those who work on it and without compromising the reliability of the electric system.
Greater application of PV results in a greater diversity in primary energy resources. With diversity comes an enhanced ability to manage the risks of specific resource shortages and of volatile fossil-fuel prices like those we have seen in the United States in 2000 and 2001.

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