SOLAR SOLUTIONS

Incorporating Photovoltaics Into Public Infrastructure

WESTERN RESOURCE ADVOCATES

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The report is dedicated to the memory of Ben Chinitz, a pioneer in urban studies and an insightful, wise, and inspiring colleague.

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Western Resource Advocates' mission is to protect the West's land, air, and water.

Our lawyers, scientists, and economists:

1) advance clean energy to reduce pollution and global climate change
2) promote urban water conservation and river restoration
3) defend special public lands from energy development and unauthorized off-road vehicle travel.

We collaborate with other conservation groups, hunters and fishermen, ranchers, American Indians, and others to ensure a sustainable future for the West.

WESTERN RESOURCE
ADVOCATES

2260 Baseline Road, Suite 200
Boulder, CO 80302
Tel: (303) 444-1188

www.westernresourceadvocates.org
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TABLE OF CONTENTS

Executive Summary I

1 // Introduction 01

2 // Photovoltaics 04

Benefits of distributed PV 04

Avoided costs of conventional generation, transmission, and distribution 05

Reduced water consumption 06

Reduced air emissions 06

Stable prices 07

PV price trends 09

Trends in deployment of PV 10

3 // Incorporating PV into Infrastructure 12

Sustainable cities and regions 12

Infrastructure opportunities for PV 13

Solution multipliers 19

Community power 20

4 // Implementation 21

Policies to promote PV 21

Paying for PV 23

Creating opportunities 25

Barriers to PV 26

Other issues 28

Energy storage 28

Effect of high concentrations of PV 29

5 // Conclusions 30

Appendix: Summary of Projects 31

Projects in Parks, Restoration Areas, Gardens, and Open Space 31

Projects at Airports 33

Projects on Underutilized Land 34

Projects Serving Water Supply Systems 36

Projects on Shade Structures and Shelters 37

Projects on Public Buildings 39

Projects on Noise Barriers 40

Projects Incorporated into Public Art 41

EXECUTIVE SUMMARY

Many cities and regions are seeking to provide more sustainable public services. One element of sustainability is clean, stably priced energy to meet community needs. This report examines leading practices in incorporating solar photovoltaic (PV) projects in public infrastructure and demonstrates that PV is a practical and beneficial component of sustainable public services.

PV is a solution multiplier — when PV is incorporated into infrastructure, facilities provide both infrastructure services and clean energy. PV applications include projects located in parks, ecological restoration areas, gardens, and other open space; at airports; within the water supply system; on transportation structures such as covered parking structures or covered railroad platforms; on public buildings; and on highway or railroad noise barriers. In addition, PV projects can be located on underutilized public land such as decommissioned landfills.

PV projects have environmental benefits that foster sustainability. In contrast to electricity produced by burning fossil fuels, PV has no emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, or other air pollutants. Further, PV consumes negligible amounts of water to produce electricity, as opposed to steam powered electric generation. And PV incorporated into infrastructure generally does not create the environmental problems that might occur when siting new energy projects on undeveloped land.

For consumers, such as a municipal government, PV projects offer stable prices for electricity that serve as a hedge against uncertain future electric utility rates. This price stability occurs because there are no fuel costs and because most of the costs of PV are up-front capital costs. Contracts for purchases of electricity from PV projects typically have a fixed schedule of prices that is known from the outset.

PV facilities may be owned by the owner of the infrastructure, such as a municipality, water supply authority, or private sector company supplying infrastructure services. Alternately, electricity from PV may be obtained through a power purchase

Photo courtesy of the City of Tucson

PV on bus stop shelter.

agreement with a third party who owns the PV project and sells the electricity to the owner of the infrastructure.

Deployment of PV is concentrated in a few states due to favorable public policies and programs, such as renewable portfolio standards, set-asides for distributed generation or solar energy within portfolio standards, financial incentives for renewable energy, and local programs to promote sustainability. In those states, PV is provided by numerous suppliers and can be designed into new or existing structures by architects and engineers familiar with solar energy. Costs of PV have fallen in recent years, and utility, state fund, and tax incentives in some states have made PV projects even more attractive.

1 // INTRODUCTION

There is a growing interest in transitioning to more sustainable cities and regions, as evidenced by the abundance of local sustainability plans. The infrastructure provided by local government and by nongovernmental organizations presents opportunities for pursuing sustainability goals.[1]

This report advocates the joint supply of infrastructure services and photovoltaic (PV) solar energy, where reasonable to do so, as a way to advance sustainability.[2] It reviews reasons for deploying PV within a city or region, examines leading practices in incorporating photovoltaic projects in public infrastructure, including paying for PV, summarizes policies supporting PV, and identifies barriers to PV projects.

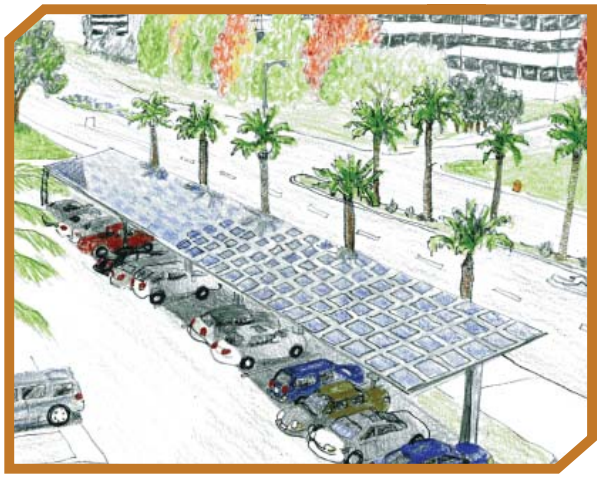
PV technologies convert sunlight directly into electricity. The electricity generated with PV systems is direct current (DC) and, for many applications, must be converted to alternating current (AC) using an inverter. PV systems are modular and can be designed to produce a few watts of power to multiple megawatts (MW) of power.[3] Because of this versatility, PV can be installed in a great variety of situations.

1 In the United States, there were 89,476 units of local government in 2007, consisting of counties, municipalities, towns and townships, school districts, and special districts. Source: U.S. Census Bureau, Statistical Abstract of the United States: 2010 (Washington, DC, 2009), Tables 416 and 417. In addition, there are nongovernmental providers of public services such as private fire companies and water companies. Many of these governmental and non-governmental organizations own and operate infrastructure such as water supply and treatment systems, wastewater collection and treatment systems, parks, and transportation systems.

2 There are, of course, many other ways to pursue sustainability, including deployment of other types of renewable energy and improved energy efficiency.

3 1000 watts = 1 kilowatt (kW), 1000 kW = 1 MW.

One of the purposes of this report is to encourage local governments to look for opportunities to site PV projects. Rooftops are one opportunity, but there are many more, including PV projects located in parks, ecological restoration areas, gardens, and other open space; at airports; within the water supply system; on shade structures and shelters such as covered parking structures or covered railroad platforms; and on highway or railroad noise barriers. In addition, PV projects can be located on underutilized public land such as decommissioned landfills.



PV on covered parking structure.

In some communities, PV projects are pursued as part of a comprehensive approach to sustainability. For instance, Freiburg, Germany has adopted a comprehensive strategy, encompassing energy efficiency, combined heat and power, renewable energy, recycling, land for conservation and watershed protection, and increased reliance on walking, bicycling, and public transportation.[4] Freiburg's success has been attributed to several factors, including a vision of integral sustainable development, a consensus on sustainability, a network of multiple stakeholders, citizen commitment, and citizen participation.

In addition to contributing directly to a more sustainable city or region, infrastructure projects can create visibility for PV. Residents and businesses can see how PV is incorporated into buildings and other structures and may follow through with their own PV projects.

Policies and programs must be favorable if PV projects are to be widely deployed. *Figure 1* summarizes factors leading to deployment of PV in local and regional infrastructure. Local sustainability plans, combined with state and federal renewable energy policies and with financial support, can create opportunities for PV projects as part of local or regional infrastructure. These factors are discussed throughout the report.

The principal audience for this report consists of local elected officials; managers of municipal government agencies and other organizations responsible for infrastructure; and legislators, electric utility managers, utility regulators, and state fund managers responsible for renewable energy policies and programs. Each can play a crucial role in the adoption of clean energy on a large scale. Local government officials and managers can provide leadership on advancing the sustainability of their communities and can identify, design, and implement specific projects. And legislators, utilities, regulators, and state fund managers can develop, refine, and

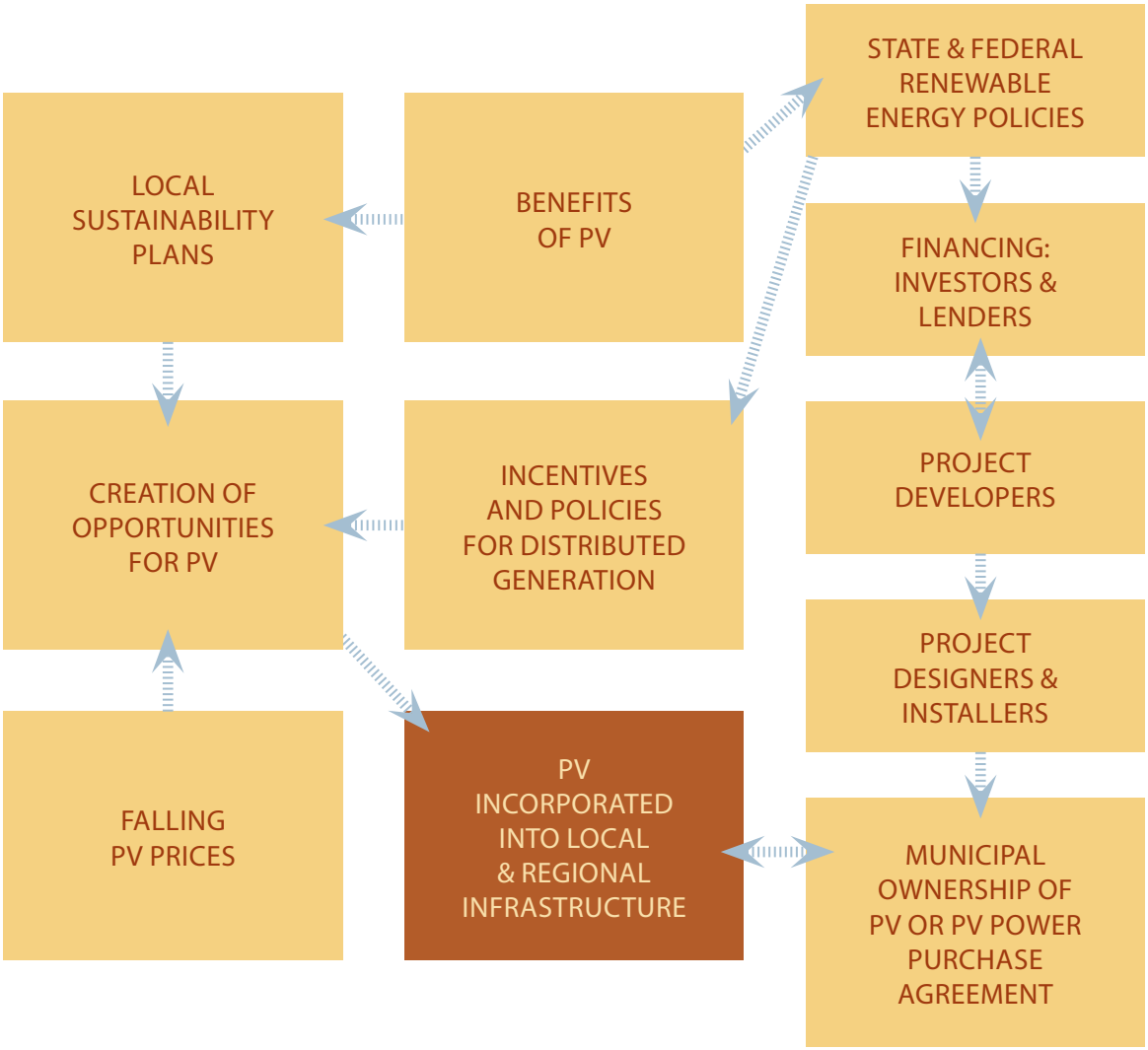
4 Dieter Salomon, "Freiburg Green City: Approaches to Sustainability," Presentation at European Green Capital Award, Brussels, 2009.

execute policies and incentives to support local sustainability efforts.

Because Western Resource Advocates works in the Interior West states and because the southwestern U.S. has an extensive solar resource, this report has a southwestern focus. Nonetheless, PV projects are being incorporated into infrastructure in many places and our basic findings are widely applicable.

Lastly, additional information on PV applications for municipalities can be found in the U.S. Department of Energy's *Solar Powering Your Community*[5] and in other documents cited throughout this report.

Figure 1. *Factors leading to deployment of PV in local and regional infrastructure*



5 U.S. Department of Energy, Energy Efficiency and Renewable Energy, and National Renewable Energy Laboratory, Solar Powering Your Community: A Guide for Local Governments, July 2009, DOE/GO-102009-2758, http://www.nrel.gov/docs/fy10osti/44947.pdf.

2 // PHOTOVOLTAICS

Before turning to applications of PV in urban or regional infrastructure, it is useful to review the benefits of PV, the costs of PV, and general trends in the adoption of PV. This section provides an overview of these factors. Benefits and costs of a specific project will depend on characteristics of the proposed PV project and of the conventional power generation that the project will displace.

BENEFITS OF DISTRIBUTED PV

The California Energy Commission defines distributed energy resources as "small-scale power generation technologies (typically in the range of 3 to 10,000 kW) located close to where electricity is used (e.g., a home or business) to provide an alternative to or an enhancement of the traditional electric power system."[6]

PV projects distributed around a region provide multiple benefits. They displace conventional power plant generation and thus avoid the costs of operating those plants; they may also avoid the costs of increasing conventional generation capacity and increasing transmission and distribution capacity. In addition, distributed PV projects avoid transmission and distribution line losses, thus reducing the amount of power needed to serve load. Because PV has no air emissions, the environmental impacts of power generation are reduced along with the costs of complying with air emissions regulations. In addition, PV uses no water for power production, unlike coal-fired and most gas-fired steam power plants. Finally, PV provides a stably priced

6 California Energy Commission, "California Distributed Energy Resources Guide," http://www.energy.ca.gov/distgen/, accessed October 18, 2010.

hedge against uncertain future prices of retail purchases of electricity from the local utility.

» *Avoided costs of conventional generation, transmission, and distribution*

Figure 2 shows the hourly output of the city of Tucson's 184 kW (AC) Hayden-Udall single-axis tracking PV plant for one day in August 2010.[7] Output is highest during the middle part of the day. PV output varies over the course of the year as shown in *Figure 3* for the same project — output tends to be highest in the summer, but clouds, temperature, and possibly operational problems affect monthly output as well.

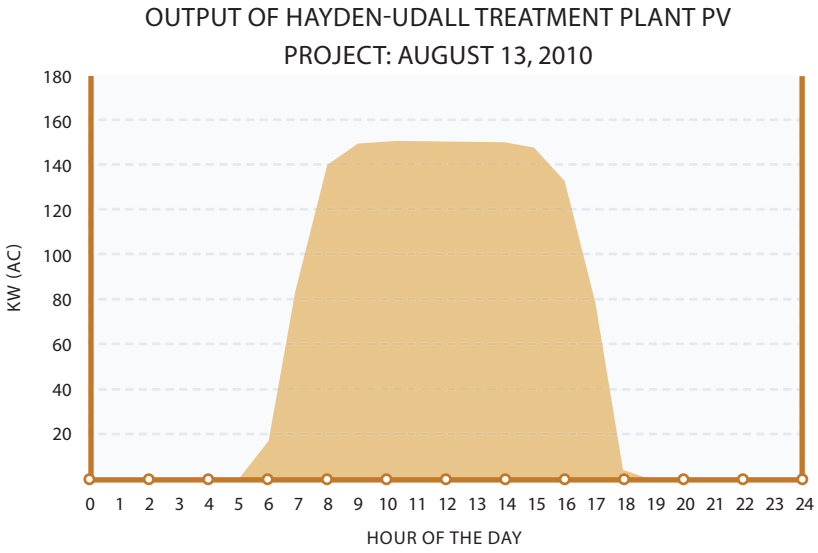


Figure 2.

The benefits of PV systems will generally be tied to the displacement of the power plants that would otherwise be running in the absence of PV projects. Given the pattern of output shown in *Figures 2 and 3*, the displaced power generation for a southwestern utility is typically (but not exclusively) that produced by natural gas-fired combined cycle, steam, and combustion turbine power plants. During some hours, coal-fired generation may be the marginal resource displaced by PV.

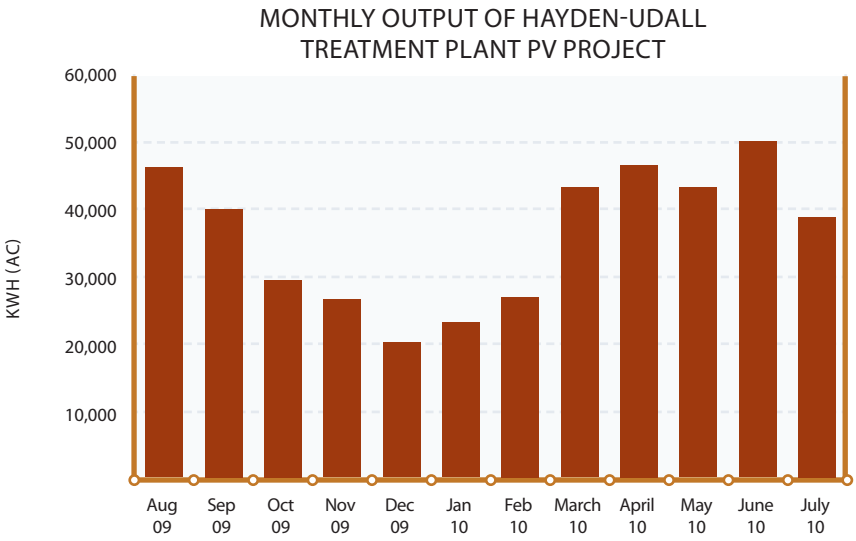


Figure 3.

Arizona Public Service Company (APS) engaged R.W. Beck to analyze the avoided costs of distributed solar energy in its service area. The principal sources of savings for APS were found to be fuel and purchased power savings (including avoided line losses) and savings in operating and maintenance

7 Data source: City of Tucson, "Hayden-Udall CAP Plant, Solar Photovoltaic Case Study," http://view2.fatspaniel.net/PV2Web/merge?&view=PV/standard/Simple&eid=285266.

costs. Transmission and distribution savings and generation capacity savings were found, in general, to be smaller.[8] A similar study was conducted for the city of Austin; the authors found that avoided conventional energy generation costs were the largest contributor to the value of a PV system.[9] Avoided or deferred conventional generation capacity was also important. Reductions in line losses and deferral of transmission and distribution facilities had the smallest values.

» *Reduced water consumption*

With regard to water consumption, PV power generation requires minimal water use (primarily for washing panels). In contrast, natural gas-fired combined cycle power plants consume roughly 180 gallons of water per megawatt-hour (MWh) generated, gas-fired steam generators consume about 660 gallons per MWh, and combustion turbines would consume small amounts of water. Coal-fired power plants in the Southwest consume about 540 gallons per MWh.[10]

Photo courtesy of the City of Tucson

» *Reduced air emissions*

Photovoltaics do not emit any pollutants into the atmosphere in contrast to coal- or gas-fired power plants. Average air emissions per gigawatt-hour (GWh) generated from natural gas-fired and coal-fired power plants and from PV projects in Arizona, New Mexico, Nevada, and Colorado in 2008 are shown in *Table 1.*[11]

8 R.W. Beck, Distributed Renewable Energy Operating Impacts and Valuation Study, Report to Arizona Public Service Company, 2009, p. 6-14. On the generation capacity value of PV, see R. Perez, R. Margolis, M. Kmiecik, M. Schwab, and M. Perez, Update: Effective Load-Carrying Capability of Photovoltaics in the United States (Golden, CO: National Renewable Energy Laboratory, 2006), NREL/CP-620-40068. This report indicates that generation capacity value depends on the penetration of PV, whether the PV system tracks the sun, and the orientation of the PV system.

9 Clean Power Research, The Value of Distributed Photovoltaics to Austin Energy and to the City of Austin, report prepared for Austin Energy, 2006.

10 Western Resource Advocates, A Sustainable Path: Meeting Nevada's Water and Energy Demands (Boulder, CO: 2008), Table 5. Some combined cycle power plants in the Southwest use dry cooling and therefore consume very little water.

11 Data for fossil fuel power plants from Energy Information Administration, State Historical Tables for 2008, Excel spreadsheets, released January 21, 2010. 1 GWh = 1000 MWh = 1,000,000 kWh. A watt-hour is one watt of power used or generated for one hour.

Table 1. Air emissions rates for power plants in 2008: AZ, CO, NM, and NV

RESOURCE TYPE	CO_2 METRIC TONS PER GWH	SO_2 METRIC TONS PER GWH	NOX METRIC TONS PER GWH
Gas-fired power plants	421	0.002	0.262
Coal-fired power plants	996	1.122	1.745
Photovoltaics	0	0	0

Carbon dioxide (CO_2) is a greenhouse gas and is the major contributor to human-caused climate change. Sulfur dioxide (SO_2) and nitrogen oxides (NOx) react with other compounds in the atmosphere to produce small particulate matter, which causes respiratory disease, heart attacks, and premature mortality. Particulate matter also impairs visibility by scattering sunlight in the atmosphere. Ground-level ozone is created by chemical reactions of nitrogen oxides and volatile organic compounds in the presence of sunlight. It causes smog, damages plants, and causes various respiratory problems in humans, including aggravation of asthma.[12]

By reducing air emissions, the impacts of power generation on human health, plants, and wildlife, and the contribution of power generation to climate change are all reduced. Thus, a major benefit of PV projects (as well as of many other renewable energy technologies and energy efficiency) is improved environmental quality.

» *Stable prices*

PV provides electricity at a stable price because most of the costs are determined at the outset, as they are capital costs. There are no volatile or uncertain fuel costs and no uncertain costs of complying with future air emission regulations. Thus, if a municipal government owns a PV system, it will be fairly certain of the future stream

12 See, for example: C. Arden Pope III, Majid Ezzati, and Douglas W. Dockery, "Fine-Particulate Air Pollution and Life Expectancy in the United States," New England Journal of Medicine, 360 (January 22, 2009): 376-386. James Hansen, Makiko Sato, Reto Ruedy, Ken Lo, David W. Lea, and Martin Medina-Elizade, "Global Temperature Change," Proceedings of the National Academy of Sciences, 103 (September 26, 2006): 14288-14293. Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson (eds.) Global Climate Change Impacts in the United States (Cambridge, UK: Cambridge University Press 2009). U.S. Environmental Protection Agency, "Ground-level Ozone," http://www.epa.gov/air/ozonepollution/index.html and http://www.epa.gov/air/ozonepollution/health.html (accessed August 27, 2010). Committee on Haze in National Parks and Wilderness Areas, National Research Council, Protecting Visibility in National Parks and Wilderness Areas (Washington, DC: National Academy Press, 1993). William C. Malm, Introduction to Visibility (Fort Collins, CO: Colorado State University, Cooperative Institute for Research in the Atmosphere, 1999).

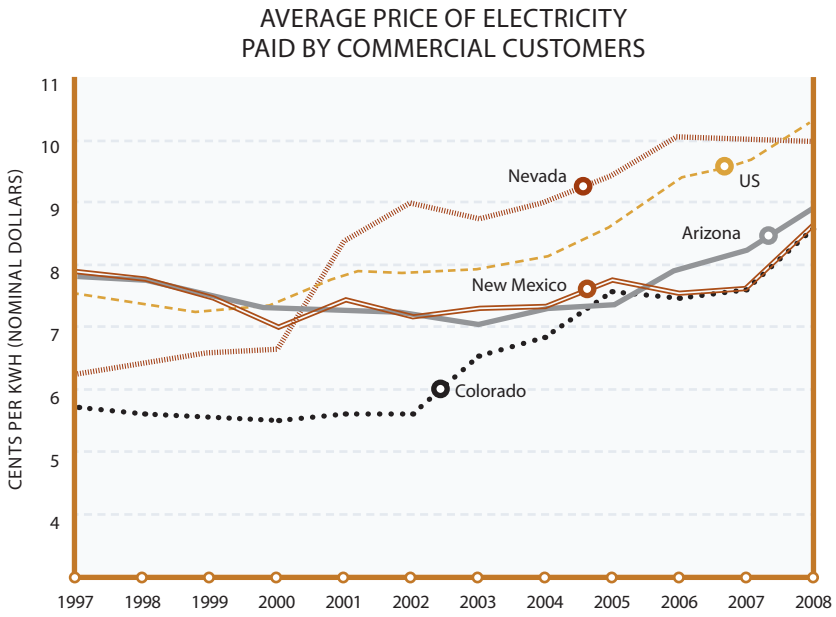


Figure 4.

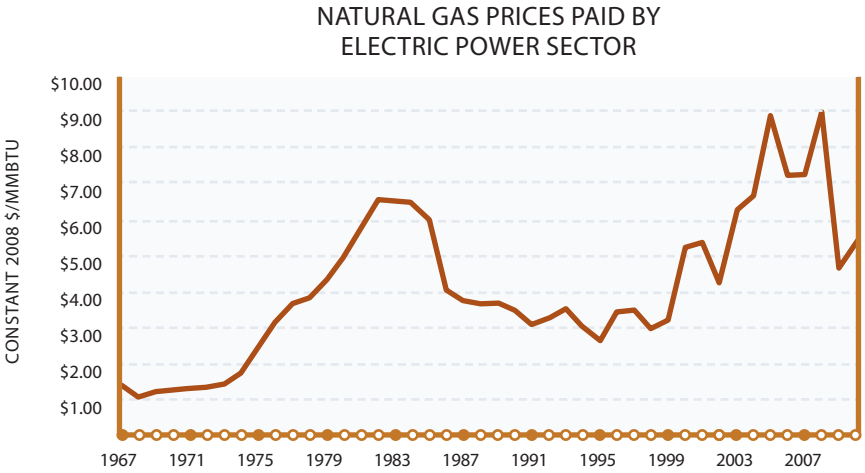


Figure 5.

of costs of electricity produced by the facility. In the case of contracts for purchases of electricity from PV plants, the price is typically fixed according to a pre-set price schedule, although some contracts are set at a specified fraction of the utility's rate for electricity.[13] In contrast, utility rates have been somewhat volatile. *Figure 4* shows commercial sector price trends for four southwestern states and for the U.S.[14] (Most municipal electric service is provided at commercial rates.) Future electric rates will reflect the effects of uncertain fuel cost changes and uncertain environmental regulatory costs such as those pertaining to the emission of greenhouse gases, reduction of visibility impairment near national parks, and reduction of health impacts of conventional power generation. In sum, PV is a stably priced hedge against uncertain future electric utility rates.

Because the conventional generation avoided by PV projects is often gas-fired, it is informative to look at the history of natural gas prices paid by the electric power sector. *Figure 5* shows these prices in constant 2008

13 For example, Denver International Airport buys electricity from a PV system at 90% of the utility's rate. Solar Novus Today, "1.6 MW Solar Project Completed at Denver International Airport," March 6, 2010, http://www.solarnovus.com/index.php?option=com_content&view=article&id=404:16mw-solar-project-completed-at-denver-international-airport&catid=41:applications-tech-news&Itemid=245

14 Data from U.S. Department of Energy, Energy Information Administration, State Electricity Profiles, various years.

dollars.[15] There has been enormous volatility in gas prices which are eventually passed onto consumers through changing rates.

PV PRICE TRENDS

PV system costs per kW depend on numerous factors, including the type of photovoltaic technology (thin film, crystalline silicon, etc.), whether a tracking system is used, whether a concentrating system is used, and whether economies of scale in installation occur.

In general, prices for PV projects have fallen dramatically in the last few years.[16] *Figure 6* shows the installed cost for a 4.4 kW residential rooftop PV system indicated on American Solar Electric's price lists for the Phoenix area in the summer of 2008, 2009, and 2010.[17] The prices reflect the installed cost *before* utility rebates or state and federal tax incentives are applied. Prices fell 30% (in nominal dollars) from 2008 to 2010. The price decrease is due to several

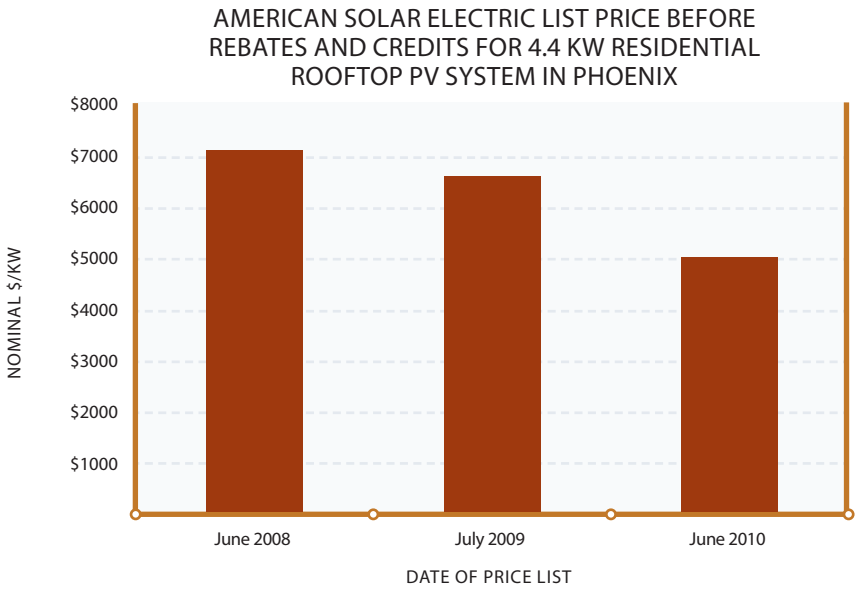


Figure 6.

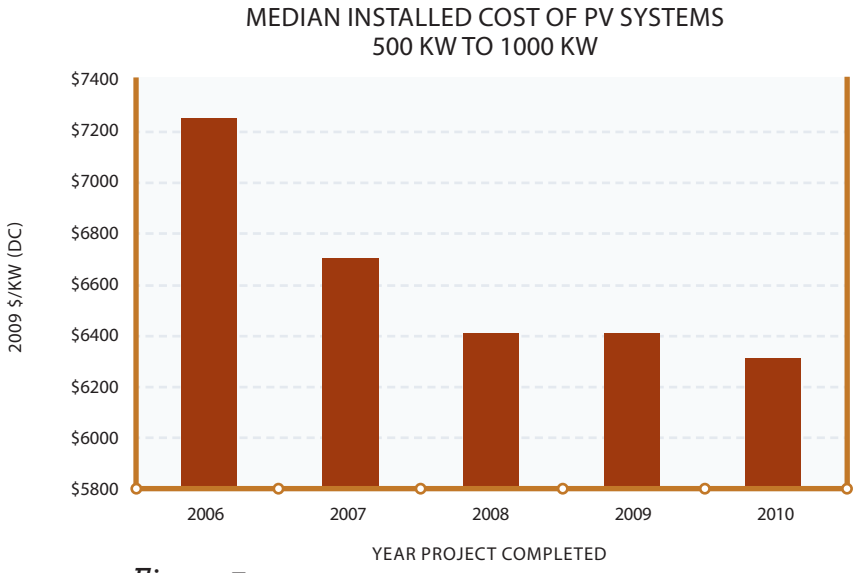


Figure 7.

15 Data from U.S. Department of Energy, Energy Information Administration, Annual Energy Review 2008, 2009, Tables 6.8 and A4, U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, March 2010, Table 9.11, U.S. Department of Energy, Energy Information Administration, Short-Term Energy Outlook, July 2010; Bureau of Economic Analysis, "National Income and Product Accounts," Table 1.1.9 for Gross Domestic Product Implicit Price Deflator.

16 Solar Energy Industries Association, US Solar Industry Year in Review 2009 (Washington, DC, 2010), p. 6. See also, Ryan Wiser, Glenn Barbose, Carla Peterman, and Naïm Darghouth, Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S. from 1998 to 2008 (Berkeley, CA: Lawrence Berkeley National Laboratory, 2009), LBNL-2674E.

17 Costs obtained from American Solar Electric web site over a period of several years. As of August 17, 2010, the current prices are posted at: http://www.americanpv.com/res_pricing.php.

factors, including falling module prices, economies of scale in installation, learning by doing in installation practices, and competition among numerous suppliers.

The falling cost trend is also evident for larger projects. *Figure 7* shows a 13% decline in real (inflation-adjusted) costs of PV projects of 500 kW to 1,000 kW capacity installed nationally over the period 2006 to early 2010.[18]

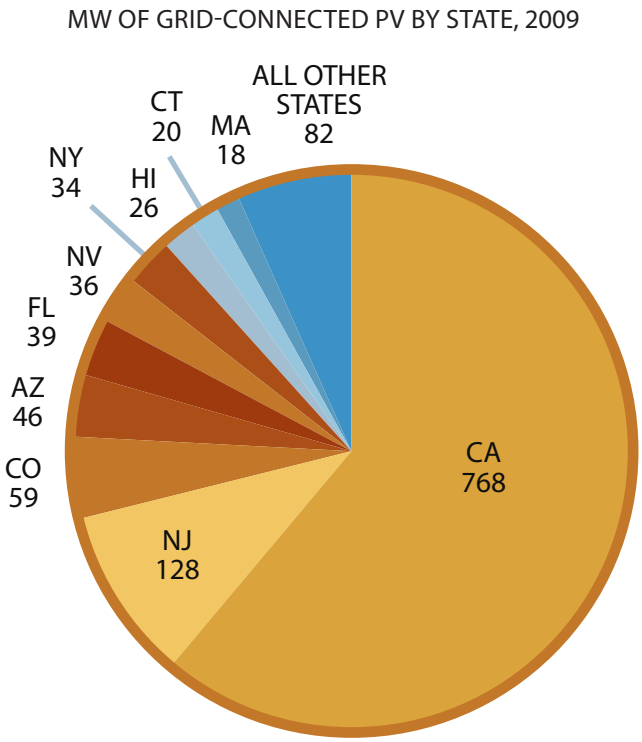


Figure 8.

TRENDS IN DEPLOYMENT OF PV

PV systems can be installed quickly and in many sizes. The technology is modular and facilities can be placed in individual park lights, on rooftops of various sizes, on other structures, and on the ground. Most PV projects installed to date are distributed rooftop systems on residential or commercial property. Some larger projects are ground-mounted facilities. Siting of PV facilities will be discussed in more detail in section 3, below.

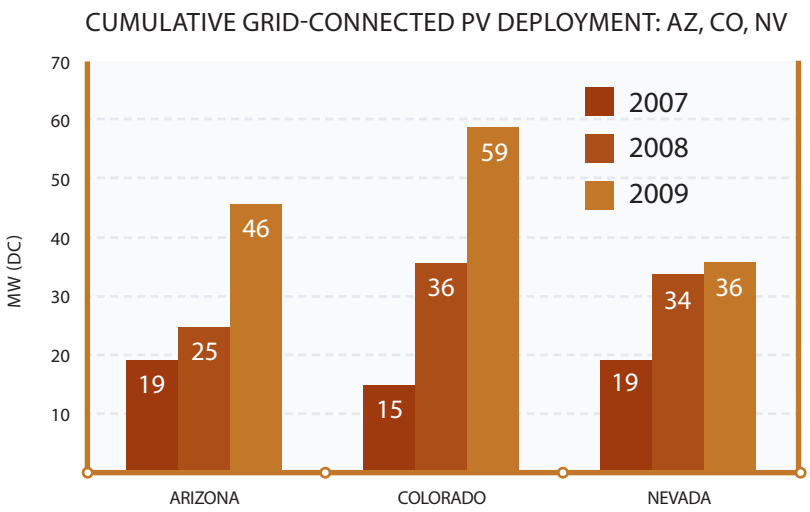
There is a huge geographic variation in PV deployment, with California having the largest amount of PV *(Figure 8)*. At the low end of the spectrum, 27 states each had less than 1 MW of grid-connected PV capacity in 2009. In the southwest, Arizona, Colorado, and Nevada have moderate and growing amounts of grid-connected PV *(Figure 9)*.[19]

Figure 10 shows the kW capacities of distributed PV projects in the service areas of the three largest utilities in Arizona -- Arizona Public Service Company (APS), Tucson

18 Data from National Renewable Energy Laboratory, The Open PV Project, http://openpv.nrel.gov/ (accessed September 9, 2010). These data cannot be considered a random sample, however.

19 Data for Figures 8 and 9 are from Larry Sherwood, U.S. Solar Market Trends, 2009 (Latham, NY: Interstate Renewable Energy Council, 2010). Larry Sherwood, U.S. Solar Market Trends, 2008 (Latham, NY: Interstate Renewable Energy Council, 2009). Larry Sherwood, U.S. Solar Market Trends, 2007 (Latham, NY: Interstate Renewable Energy Council, 2008).

Electric Power Company (TEP), and Salt River Project (SRP).[20] Note that the projects shown in *Figure 10* exclude projects receiving incentives from smaller utilities and cooperatives, and exclude utility-scale projects, such as TEP's Springerville facility.



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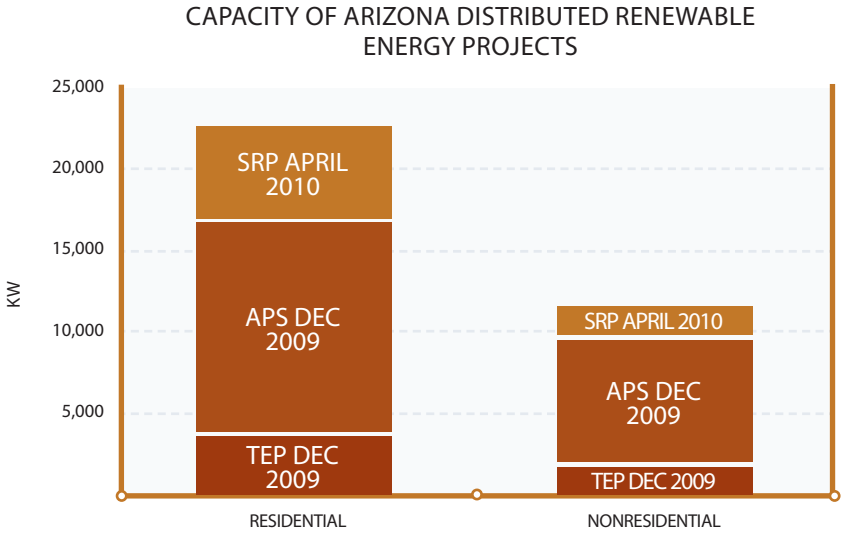


Figure 10.

20 Tucson Electric Power Company, Renewables Data for Year End 2009, filed in Arizona Corporation Commission Docket No. E-01939A-07-0594, April 1, 2010. Arizona Public Service Company, 2009 Renewable Energy Standard Compliance Report, filed in Arizona Corporation Commission Docket No. E-01345A-08-0331, April 1, 2010. Salt River Project, Fiscal Year 2011 Resource Plan, August 2010. p. 10. TEP data include a small amount of non-PV distributed projects and APS and TEP data include the small effects of multipliers for installations prior to 2006. Duncan Valley Electric Cooperative, Graham County Electric Cooperative, Mohave Electric Cooperative, and Trico Electric Cooperative reported 1,621 kW of PV projects as of the end of 2009, but the data are not disaggregated by residential versus nonresidential applications. See: Arizona Electric Power Cooperative, AEPCO Status Report for Renewable Energy Database, Year-End 2009, filed in Arizona Corporation Commission Docket No. E-0000D-93-0052, April 1, 2010.

3 // INCORPORATING PV INTO INFRASTRUCTURE

This section presents examples of imaginative applications of PV within a community's infrastructure. In many cases, these PV projects are part of a larger effort to put cities and regions onto a more sustainable path.

SUSTAINABLE CITIES AND REGIONS

Sustainability is a multi-dimensional concept, encompassing a very long run perspective; intergenerational equity; multiple objectives reflecting economic, social, and environmental values; and linkages between local and global economic, social, and environmental issues.[21] For example, the city of Asheville, North Carolina defined sustainability as follows:[22]

"Making decisions that balance the values of environmental stewardship, social responsibility and economic vitality to meet our present needs without compromising the ability of future generations to meet their needs."

Sustainability plans translate these kinds of broad principles into specific goals and actions. *Table 2* summarizes anticipated roles for renewable energy, as depicted in

21 John Ehrenfeld, Sustainability by Design (New Haven, CT: Yale University Press, 2008). Philip Berke, "Does Sustainable Development Offer a New Direction for Planning? Challenges for the Twenty- First Century," Journal of Planning Literature 17 (August 2002): 21-36.

22 City of Asheville, NC, Sustainability Management Plan, August 2009, p. 2.

several jurisdictions' sustainability plans.[23] Approaches vary greatly, from no specific plans for renewable energy to specific goals for various technologies.

Pima County, Arizona has developed a sustainable action plan for county operations.[24] One element of this plan is to increase the use of renewable energy so that by 2025, 15% of energy used by county facilities comes from renewable resources.

Guiding principles adopted by the county to deploy renewable resources include:

- Seeking innovative ways to obtain renewable energy for county facilities
- Working with public and private sector partners to identify suitable sites for renewable energy facilities
- Determining the most beneficial and cost-effective energy sources for a particular site
- Coordinating with other large power users to expand the market for renewable energy in the region
- Identifying funding sources to help offset the costs of renewable energy

In taking action to meet its goals, the county identified several specific activities as indicated in *Table 2*.

INFRASTRUCTURE OPPORTUNITIES FOR PV

Infrastructure consists of physical facilities or networks of facilities that provide services to a broad segment of the general population and businesses and that are necessary for society and the economy to function.[25] It typically includes roads and related structures (such as bridges, tunnels, and noise barriers), water supply and treatment systems, wastewater collection and treatment systems, airports, railroads, solid waste collection and disposal, parks, educational facilities, other government facilities (e.g., administrative buildings, police and fire stations), and electric services. The assets may be owned and operated by a municipal or other government

23 Sources for table: Pima County Board of Supervisors, AZ, Sustainable Action Plan for County Operations, 2008. Long Beach, CA, Office of Sustainability, Sustainable City Action Plan, 2009. City of Claremont, CA, Sustainable City Plan, 2008. City of Sacramento, CA, Creating a Sustainable City: 2010 Implementation Plan, 2010. Baltimore, MD, Office of Sustainability, The Baltimore Sustainability Plan, 2009. City of Sparks, NV, Sustainability Action Plan 2009, draft dated September 15, 2008. City of Asheville, NC, Sustainability Management Plan, 2009. Philadelphia, PA, Mayor's Office of Sustainability, Greenworks Philadelphia, 2009. City of Spokane, WA, Mayor's Task Force on Sustainability, Sustainability Action Plan, 2009.

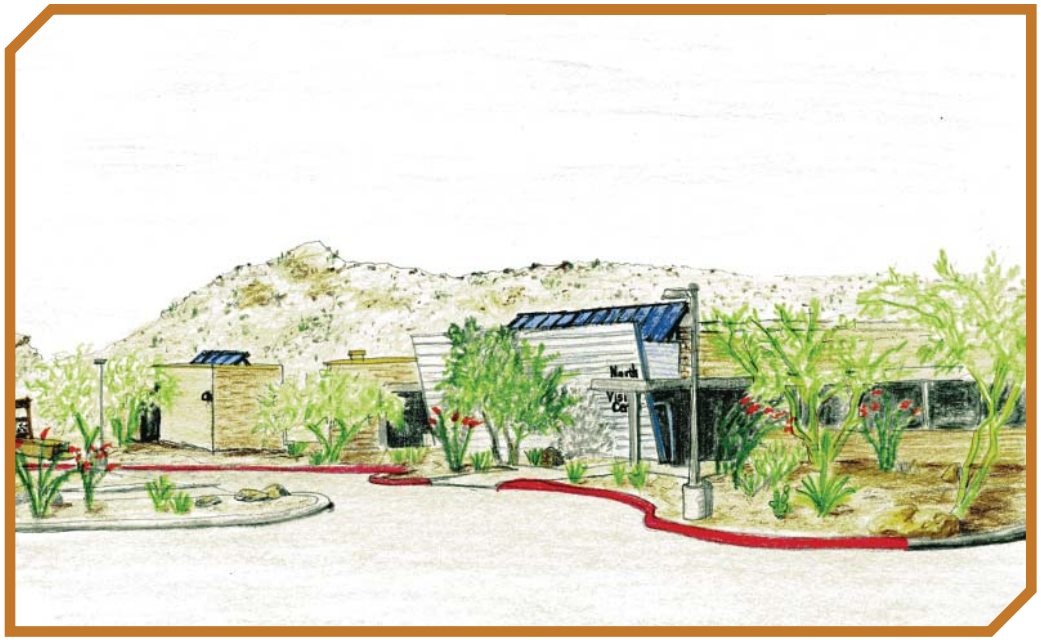
24 Pima County, AZ Board of Supervisors, Sustainable Action Plan for County Operations, 2008.

25 See John Moteff and Paul Parfomak, Critical Infrastructure and Key Assets: Definition and Identification, (Washington, DC: Congressional Research Service, 2004) Report for Congress, RL32631.

agency, a nonprofit organization, or a for-profit company.

Combining photovoltaic generation of electricity with infrastructure can advance sustainability by such means as:

- **Reduction of waste streams.** PV does not emit harmful pollutants into the atmosphere unlike the natural gas- or coal-fired power plants it displaces.
- **Reduction of water consumption.** By substituting PV for wet-cooled steam power generation, water use for power production will decrease.
- **Use of local resources.** Distributed PV generates electricity at or near the points of consumption.
- **Reuse of underutilized or unused sites, such as vacant buildings, vacant land, and decommissioned landfills.** The reused sites may include energy-efficient structures and PV systems.
- **Protection of human health.** As a result of using PV, decreased particulate matter in the air will reduce the incidence of respiratory disease, heart attacks, and premature mortality, and decreased ground level ozone will reduce incidences of respiratory disease.
- **Attainment of stable prices.** PV projects do not consume fuel and thus avoid the volatile and uncertain costs of obtaining that fuel. And because they do not emit air pollutants, they avoid the uncertain costs associated with air emission regulations.



PV on visitor center rooftop

Table 2. Examples of Renewable Energy in Sustainability Plans

JURISDICTION	RENEWABLE ENERGY ACTIVITIES AND GOALS (EXAMPLES)
Pima County, AZ	• Obtain 15% of energy used by county facilities from renewable resources by 2025 • Obtain methane from landfills and wastewater treatment • Use on-site renewable energy projects in LEED® buildings • Solicit proposals for power purchase agreements for renewable energy • Consider cooperative projects with other large energy users to achieve economies of scale in the purchase of renewable energy
Claremont, CA	• Install a PV system on at least one city facility • Facilitate new residential and commercial solar energy systems to generate clean power locally
Long Beach, CA	• Facilitate development of at least 2 MW of solar energy on city facilities by 2020 • Increase the number of solar-powered electric bus tracking signs that indicate bus wait times
Sacramento, CA (2010 Implementation Plan)	• Enter into a power purchase agreement for up to 5 MW of solar energy on city facilities • Install PV on utilities administration building • Find partners for 5 to 10 MW of PV at a landfill site
Baltimore, MD	• Develop 50 MW of renewable energy by 2020 (applies to entire city, not just city facilities) • Consider generation of electricity from methane extracted from wastewater treatment
Sparks, NV	• For new city buildings, generate at least 5% of energy with on-site renewable resources • Install PV on existing community center when utility incentives are available • Increase capacity of biogas combined heat and power plant at water reclamation facility
Asheville, NC	• Consider incorporating PV into water supply system
Philadelphia, PA (Mayor's plan)	• Purchase and generate 20% of electricity used in city (not just municipal uses) from alternative energy sources by 2015. - By 2011, have solar generation capacity of 2.3 MW - By 2021, have solar generation capacity of about 58 MW
Spokane, WA	• Use distributed technologies in city facilities (e.g. solar thermal, solar photovoltaic, fuel cells, wind) where practical and feasible • Increase the percentage of renewable energy the city acquires each year, targeting 100% by 2030

There are many opportunities for deploying PV within a city's or region's infrastructure as indicated in *Figure 11*.

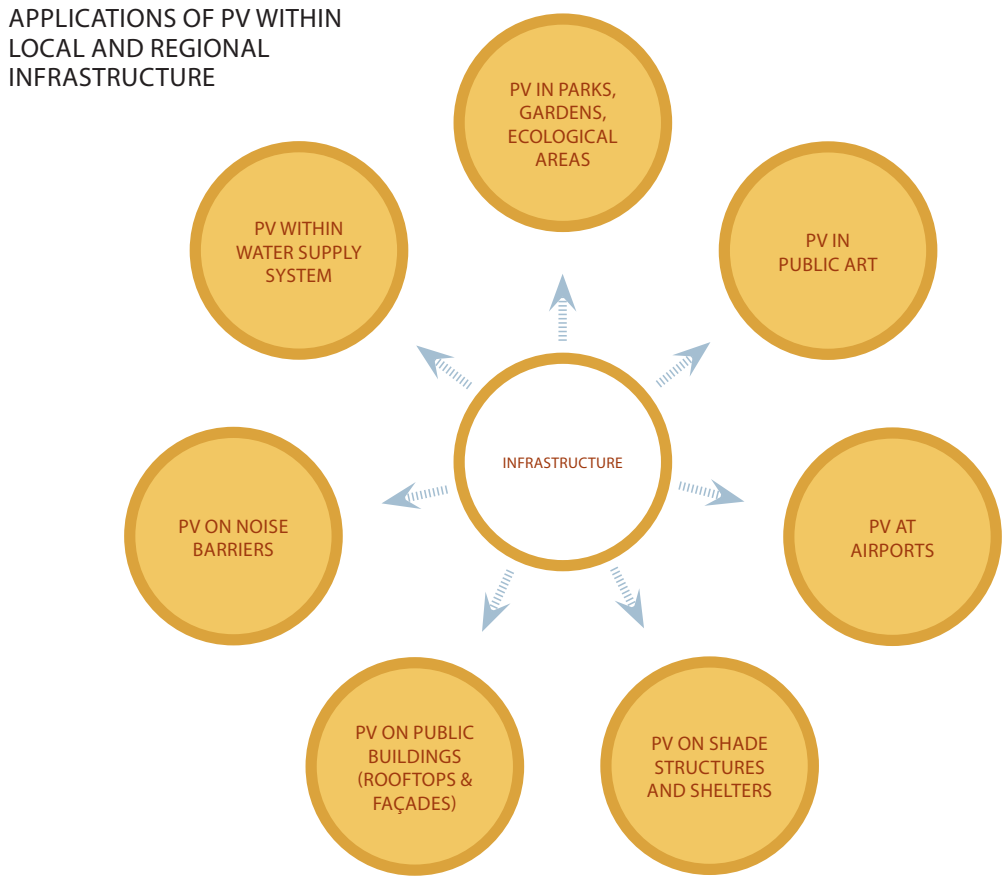


Figure 11.

In addition, PV projects may be constructed on vacant or underutilized land.

Table 3 lists examples of applications of distributed PV and the Appendix provides additional detail on specific projects.[26] *Figure 12* shows typical sizes of some common PV projects. A medium size city could readily deploy roughly 10 to 25 MW of distributed PV within its infrastructure.[27] Of course, opportunities for PV will vary from place to place and the potential may be much greater if large amounts of underutilized land are available for PV projects.

26 Other references providing examples of PV projects include: Patrina Eiffert and Gregory Kiss, Building-Integrated Photovoltaic Designs for Commercial and Institutional Structures: A Sourcebook for Architects (Golden, CO: National Renewable Energy Laboratory, 2000), NREL/BK-520-25272. European Commission, Photovoltaic Solar Energy Best Practices Stories (Munich, Germany: WIP, 2000). Dan Engström, PV-NORD – Paving the Way for BIPV in Northern Europe, Final Summary, January 18, 2005, http://www.pvnord.org/power_point/Final_Report_PV-NORD.pdf. PVUpscale, "PV Database, Urban Scale Photovoltaic Systems," http://www.pvdatabase.org/.

27 This rough estimate assumes PV is deployed on 10 small building rooftops and 10 large building rooftops, at one site within the water supply system, on 10 shade structures, on two noise barriers, and at one airport.

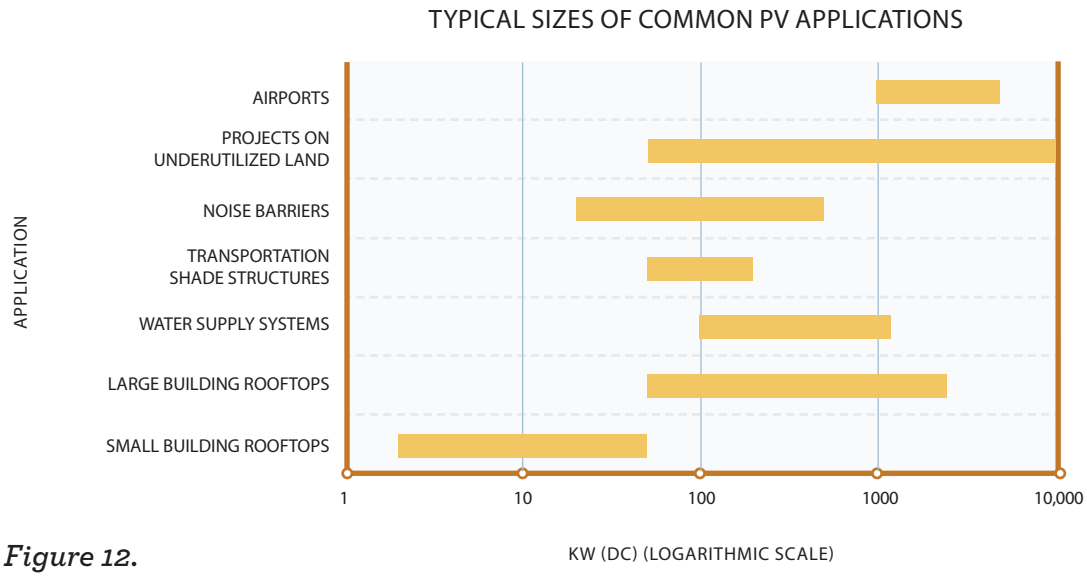
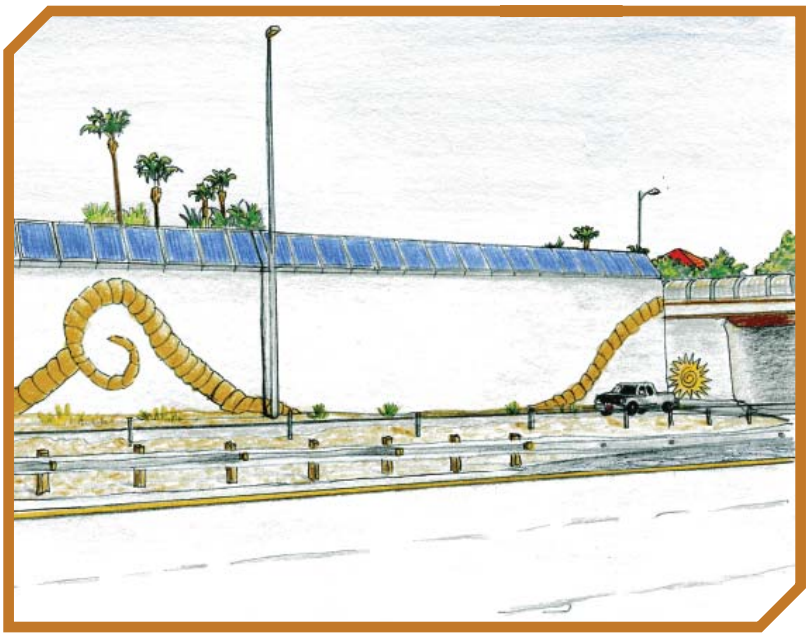


Figure 12.

Some of the PV applications listed in the table are on new structures and so the PV was designed as part of the structure. In other cases, the PV was added to an existing structure. And in some cases, the PV project was located on vacant, idle, or underutilized land such as a decommissioned landfill.

In general, incorporating PV into infrastructure places renewable energy projects on land that is already developed. Therefore, these projects would typically avoid conflicts with wildlife that may occur when locating large energy projects on land that has not been developed.



PV on roadway noise barrier.

Some PV projects can be designed and installed quickly. For example, PV park lighting, some rooftop PV facilities, and many ground-mounted projects are routine and benefit from economies of standardized design and installation processes. Others, however, are customized and may be more costly per kW than standardized projects.

*Table 3. Examples of PV Incorporated into Infrastructure or on Public Land**

APPLICATION	EXAMPLES
PV in parks, ecological restoration areas, gardens, and other open space	• Off grid park lighting in Santa Fe, NM • Bronx River Greenway River House, River Restoration Area, New York City (rooftop PV) • Audubon Center, Salt River Restoration Area, Phoenix, AZ (rooftop PV) • Queens Botanical Garden Visitor and Administration Center, New York City (rooftop PV) • Cheyenne Botanic Gardens, Cheyenne, WY (rooftop PV with batteries)
PV incorporated into public art	• Solar Sail, Münsingen, Switzerland • Straße der Solarenergie (Solar Street), Gleisdorf, Austria (3.5 km street segment with about 80 pieces of PV powered art and other equipment)
PV at airports	• Denver International Airport (ground-mounted) • Fresno Yosemite Airport (ground-mounted)
PV within the water supply system	• Southern Nevada Water Authority, River Mountains Water Treatment Facility (ground-mounted, concentrating PV) • Roger Road Reclaimed Water Reservoir, Tucson, AZ (installed on reservoir deck) • Valley Center Water District, Valley Center, CA (ground-mounted) • City of Arvada, CO, Ralston Water Treatment Plant (ground-mounted)
PV on shade structures and shelters	• Riverside, CA, Public Utilities Operation Center Solar Carport • Sun Tran Bus Maintenance Facility canopies, Tucson, AZ • Stillwell Avenue Terminal train shed, New York City
PV on public buildings	• Phoenix, AZ Convention Center (rooftop PV) • San Diego, CA Environmental Services Department (rooftop PV)
PV on noise barriers	• PV incorporated into A9 Highway noise barrier, Netherlands • PV incorporated into noise barrier, Tullamarine-Calder Interchange, Melbourne, Australia
PV on underutilized land	• PV system on former industrial land, Chicago, IL (ground-mounted) • Community PV project on vacant municipal land, Ellensburg, WA (ground-mounted) • PV system on decommissioned landfill, Fort Carson, CO (ground-mounted)

* See the Appendix for more detail on individual projects.

SOLUTION MULTIPLIERS

Incorporating PV into infrastructure maintains the benefits of the infrastructure without detracting from the main purpose of the park, airport, building, etc. The infrastructure produces clean power, for use on-site or off-site, and provides a traditional public service. Thus, PV projects can be solution multipliers:

- In a review of the history of PV on noise barriers, it was noted that: "The concept of a photovoltaic noise barrier combines two environmental objectives: the production of electricity from renewable resources and the protection of people from the noise of road and railroad traffic. This dual function of the photovoltaic noise barriers can reduce costs and does not require additional space for the solar panels."[28]
- Shade structures with PV achieve two goals — shading parked vehicles, pedestrians, or workers, and generating electricity.
- PV can complement an energy efficiency program. When a building is designed to be more energy efficient, not only is less energy wasted, but the decreased demand for electricity enables an on-site PV system of a given capacity to provide a greater percentage of the electricity used in the building. Some of the projects listed in *Table 3* have sought ways to reduce energy consumption and are certified by the Leadership in Energy and Environmental Design (LEED®) green building certification program.

Denver International Airport, with a commitment to energy efficiency, has built the largest solar farm at a commercial airport in the United States. Photo courtesy of D.I.A.

28 HESPUL, Etude Européenne du Potentiel Photovoltaïque des Murs Antibruit (Villeurbanne, France, 2002), p. 2. The original quotation is as follows: "Le concept de mur antibruit photovoltaïque réunit deux aspects de l'écologie: la production d'électricité à partir de source renouvelable et la protection des populations contre le bruit du trafic routier et ferroviaire. Cette double fonction des l'écrans acoustiques photovoltaïques permet la réduction des coûts et ne nécessite pas de surface supplémentaire au sol."

- Trash with flash. Solar trash cans in public places use the electricity generated by PV to compact the trash and reduce the number of trash pick-ups per week, thereby reducing transportation costs.[29]

COMMUNITY POWER

Community power projects serve multiple voluntary subscribers or participants. These projects may be owned by a cooperative or other community group, by a developer or other private sector company, or by a utility. The power generated by a community project would usually be fed into the electric grid, as opposed to individual consumers' buildings, and participants in a community energy project could then receive electric bill credits from the local utility or other payments reflecting the value of their share of the electricity generated by the project.[30]

The Ellensburg, Washington project listed in *Table 3* is a small community energy project. Ellensburg has a municipal electric utility and the city enters into contracts with electric customers in which the customers pay for a share of the PV project (minimum initial contribution is $250). Contributors receive a credit on their electric bills for their share of the wholesale value of the output of the PV project.[31]

29 Solar trash cans store electricity in batteries and when a can gets full, solar electricity powers a compactor to reduce the volume of trash. City of Long Beach, CA, "Solar Powered Trash Cans Debut in Long Beach," http://www.longbeach.gov/news/displaynews.asp?NewsID=4705&TargetID=100. See also, City of Asheville, NC, Sustainability Management Plan, August 2009.

30 See D. Hall, J. Rose, and L. Varnado, "Investing in Solar as a Community," Solar Today 24 (March 2010): 30-31, 34-35. Interstate Renewable Energy Council, Community Renewable Power – Draft Concept Proposal, 2010, http://irecusa.org/wp-content/uploads/2010/03/IREC-COMMUNITY-RENEWABLES-CONCEPT-PROPOSAL_final.pdf. Bonneville Environmental Foundation and Northwest Sustainable Energy for Economic Development, The Northwest Community Solar Guide (Portland, OR), 2009, http://www.nwseed.org/documents/NW%20Community%20Solar%20Guide.pdf.

31 City of Ellensburg, WA, Ellensburg Community Renewable Park Contribution Agreement, http://wa-ellensburg.civicplus.com/DocumentView.aspx?DID=253.

4 // IMPLEMENTATION

This section reviews elements of designing and acquiring PV resources. First is a summary of major policies that encourage PV. Then we discuss common ways to pay for PV projects. We also review steps to creating opportunities for PV, summarize barriers to PV, and briefly address energy storage and the effects of high concentrations of PV on the electric grid.

POLICIES TO PROMOTE PV

Many states and the federal government have adopted policies to promote renewable energy investments. Important policies include the following:

- **Renewable Portfolio Standards.** Portfolio standards require utilities to obtain a specified amount of energy from renewable energy resources. For example, in Colorado, investor-owned utilities must obtain 30% of their energy for retail sales from renewable resources by 2020, and electric cooperatives and municipal utilities serving over 40,000 customers must reach a 10% goal by 2020. In Arizona, 15% of electricity for retail sales must come from renewable resources by 2025. The Nevada portfolio standard is 25% by 2025, but up to a quarter of the standard may be met with energy efficiency. The New Mexico standard for investor-owned utilities is 20% by 2020.[32]
- **Distributed energy or solar set-asides.** Set-asides require utilities to obtain a portion of their renewable energy from either distributed resources or

32 For information on portfolio standards, see Database of State Incentives for Renewables & Efficiency, http://www.dsireusa.org/.

from specific technologies. In Arizona, a portion of the renewable energy standard must be met with distributed energy located at consumers' premises; after 2011 that portion is 30%. New Mexico has minimum percentages for various renewable energy technologies (e.g., at least 20% of the renewable energy requirement must be met with solar resources) and requires that 3% of renewable energy be obtained from distributed resources by 2015. For investor-owned utilities, Colorado requires an increasing amount of distributed generation from renewable resources, reaching 3% of retail sales by 2020.[33]

- **Utility and state incentives for PV.** Some utilities and state funds[34] offer incentives to install distributed renewable energy resources, usually to help fulfill renewable portfolio standard requirements. These incentives may be up-front payments, such as $2 per watt of generating capacity, or may be performance-based such as $0.15 per kWh generated. Because incentive programs are typically subject to caps on funding allocations in a given time period, incentives may not always be available or may be delayed, perhaps resulting in a boom and bust cycle for PV installations.

- **Tax incentives for PV.** There are federal investment tax credits and grants for renewable energy projects owned by tax-paying entities, and some states also offer income or other tax credits for renewable energy projects. These incentives can significantly reduce the cost of a renewable energy project to the owner.

- **Net metering.** Distributed renewable energy projects may serve electricity needs at the site and produce excess kWh during some time periods. Under a net metering policy, excess energy in one month is typically credited against the next month's electric utility bill by subtracting the excess kWh generated in the previous month from the current month's usage. Thus, the excess kWh are valued at retail electric rates. At the end of the calendar year (or at another specified time), any remaining excess kWh are paid for by the utility at avoided cost or at another specified rate, and the level of accumulated excess kWh is reset to zero.

- **Aggregated net metering.** Municipal governments typically have numerous places where utility electric service is delivered and consequently have numerous electric meters. A PV project at one site might produce more electricity than is consumed at that site and, with aggregated net metering, the excess could be used to offset (on paper) kWh consumption at another site owned by the same owner, thereby reducing the municipality's total electric bill. Some states permit aggregated net metering to accomplish this purpose within the legislative constraints on net metering. Oregon, for example, allows

33 Database of State Incentives for Renewables & Efficiency, http://www.dsireusa.org.

34 A state fund administers renewable energy or other clean energy programs, typically with revenues coming from utility ratepayers. Examples are the Connecticut Clean Energy Fund http://www.ctcleanenergy.com/Default.aspx?tabid=62, the New York State Energy Research and Development Authority, www.nyserda.org, the Massachusetts Clean Energy Center, www.commonwealthsolar.org, and the Energy Trust of Oregon, http://energytrust.org/.

a customer generating renewable energy to combine multiple meters on the same rate schedule on contiguous property.[35]

- **Interconnection standards or guidelines.** These standards specify the rules under which a distributed generation project connects to the utility's grid. The specifications are standardized and are often intended to remove unnecessary barriers to interconnection, such as high insurance requirements or unreasonable limits on project capacity.

- **Feed-in tariffs.** Feed-in tariffs provide a standardized rate or standardized bidding process for wholesale sales of electricity and renewable energy credits from eligible generation resources to a utility. These tariffs have been used in Europe, resulting in large investments in renewable energy projects because there is a market for the electrical output at a price high enough to make the investments economically attractive to project owners. Feed-in tariffs may be especially useful for projects that would not use electricity on-site, such as projects located on noise barriers or located on underutilized land. In the US, wholesale transactions involving investor-owned utilities are generally (but not always) subject to federal jurisdiction.[36]

PAYING FOR PV

There are several common ways to pay for PV incorporated into urban infrastructure. Some projects are owned by the local government or a quasi-governmental agency or authority. These projects may be paid for using bonds and may be eligible for rebates or other financial incentives from the electric utility or state fund.[37] PV projects may be included in capital programs funded through general obligation bonds or through

35 Public Utility Commission of Oregon, Order No. 07-319, July 24, 2007, pp. 17 - 18, and Net Metering Rules, 860-039-0065. More generally, see Keyes and Fox, LLP, Aggregated Net Metering in Arizona, report to the Arizona Corporation Commission, filed in Docket No. E-00000J-10-0202, November 30, 2010.

36 In general, wholesale sales to investor owned utilities are governed by the Federal Energy Regulatory Commission (FERC). Under the Public Utility Regulatory Policies Act of 1978, a class of generating facilities was created to receive special rate and regulatory treatment. These facilities are "qualifying facilities" (QFs), and consist of: a) qualifying small power production facilities (renewable energy facilities under 80 MW), and b) qualifying combined heat and power facilities. Wholesale purchases from QFs can be at rates up to a utility's avoided cost. For more information, see Federal Energy Regulatory Commission, "Qualifying Facilities," http://www.ferc.gov/industries/electric/gen-info/qual-fac.asp. The wholesale rate for sales from a renewable energy project may be composed of a component equal to or less than the purchasing utility's avoided cost plus a component representing the value of the renewable energy credits. See Federal Energy Regulatory Commission, California Public Utilities Commission, Order on Petitions for Declaratory Order, Docket Nos. EL10-64-000 and EL10-66-000, 132 FERC ¶ 61,047 (July 15, 2010), and Federal Energy Regulatory Commission, "California Feed-In Tariff Petitions," July 15, 2010, http://ferc.gov/industries/electric/indus-act/rto/caiso/07-15-10-fact-sheet.pdf.

37 For a general discussion, see Karlynn Cory, Jason Coughlin, and Charles Coggeshall, Solar Photovoltaic Financing: Deployment on Public Property by State and Local Governments (Golden, CO: National Renewable Energy Laboratory, 2008), Technical Report NREL/TP-670-43115.

revenue bonds associated with a specific revenue-producing project such as a water treatment facility incorporating PV. Some of the projects listed in Table 3 were financed with Clean Renewable Energy Bonds (CREBs), which provide a federal tax credit to bond owners instead of interest payments.[38]

Photo courtesy of the City of Tucson

Another approach is a power purchase agreement. Several of the projects listed in *Table 3* use this approach (see the Appendix for more information). A developer or other party owns the PV system and the municipality or other entity purchases the electrical output at a specified price over a specified contract period. The purchaser typically pays no up-front costs, but instead pays for kilowatt hours produced at a fixed price schedule that serves as a hedge against uncertain future electricity prices charged by the local electric utility. These arrangements can be cost-competitive because the PV project may be eligible for utility or state fund incentives and because the project is owned by parties who can take advantage of tax incentives not available to a government agency. For example, in 2009, a school district in the Phoenix area entered into long-term power purchase agreements with a solar energy developer to buy electricity for 15 years at $0.09 per kWh.[39] The state of Nevada is also pursuing power purchase agreements for solar energy for state facilities.[40]

A third approach is to obtain revenues by selling solar energy at wholesale to the local utility. Feed-in tariffs are one way to make wholesale sales, but they are not, at present, widely used in the U.S. A further possibility is to lease a municipal site to a PV developer, who would then sell solar energy to another party. In this case, the municipality would receive revenues from the lease.

38 Emery B. McRill, "Renewable Energy Bond Financing Tools: Targeting New CREBs and QECBs," presentation at Council of Development Finance Agencies, Intro Bond Finance Course, Washington, DC: March 11, 2010, http://www.cdfa.net/cdfa/cdfaweb.nsf/fbaad5956b2928b086256efa005c5f78/bce5972155a79c2c862576e8004db0f8/$FILE/McRill%20CDFA%202010%20Presentation.pdf.

39 Arizona Corporation Commission Decision No. 71443, dated December 23, 2009. The Commission subsequently determined (Decision No. 71795, dated July 12, 2010) that solar service agreements (power purchase agreements) with a school, government, or non-profit entity, specifically limited to an individual customer serving only a single premises of that customer, are not subject to rate regulation.

40 Office of Governor Jim Gibbons, "Governor Announces Plan to Step Up State Solar Energy," press release, June 4, 2010.

Additionally, some projects may be funded, in part, by a foundation or other donor. For example, through May 2010, the Illinois Clean Energy Community Foundation provided 228 grants of $7.3 million for 1.5 MW of PV installations in municipal park facilities, museums, college buildings, a courthouse, other public and nonprofit facilities, and other buildings.[41]

CREATING OPPORTUNITIES

The purpose of this report is to encourage municipal governments, government agencies, and quasi-governmental organizations to systematically seek out multiple opportunities for obtaining electricity from PV projects, i.e., to incorporate PV into local or regional infrastructure. Typically, local governments and other quasi-governmental organizations take several steps to create opportunities, as listed below:[42]

- **Determine use of the electricity.** A PV project may generate electricity for on-site use (with bill credits for generation in excess of on-site use), or sell electricity to a utility or other purchaser.
- **Conduct an on-site evaluation.** This includes discussing the potential for a PV project with facility and program managers and determining electricity consumption and current costs at the site (if on-site use is being considered).
- **Determine how the project fits in with existing regulatory policy.** The viability of many PV projects may depend, in large part, on whether those projects are consistent with the regulatory framework within a state. For example, if aggregated net metering is not permitted, some projects may not be economically justifiable. Or if regulators developed a policy to promote relatively small distributed energy projects, such as those on rooftops, larger distributed PV projects may fall outside the scope of a utility's incentive program or may not help a utility meet its portfolio standard requirements, thus

41 Illinois Clean Energy Community Foundation, Summary of Foundation Grants through May 2010, May 2010, http://www.illinoiscleanenergy.org/images/ICEFC_PDFs/2010/ICECF%20Update%2005%2010.pdf. "The Illinois Clean Energy Community Foundation was established in December 1999 as an independent foundation with $225 million provided by Commonwealth Edison," as indicated in Illinois Clean Energy Community Foundation 2000-2009, p. 17, http://www.illinoiscleanenergy.org/images/ICEFC_PDFs/2010/10%20year%20report.pdf.

42 See the following sources: City of Tucson, Solar Integration Plan, March 2009. John Hoffner, Martin Gomez, Kurt Lyell, Doug Landfear, Ed Baynes, Jessie Denver, and Vipin Gupta, City of San Jose, California Identifies Up To 40 MW of PV on Municipal Facilities through the Solar America Showcase Project, American Solar Energy Society, Solar 2010 Conference Proceedings, http://www.ases.org/papers/198.pdf. International Energy Agency, PV in Non Building Structures – A Design Guide, Report IEA-PVPS T7-02:2000, 2001. Sigrid Lindner, "Solar Urban Planning – PV in Urban Environment Germany," 2007, http://www.iea-pvps-task10.org/IMG/pdf/Experiencias-internacionales_Alemania_Ecofys_SLidner.pdf. Karlynn Cory, Jason Coughlin, and Charles Coggeshall, Solar Photovoltaic Financing: Deployment on Public Property by State and Local Governments (Golden, CO: National Renewable Energy Laboratory, 2008), Technical Report NREL/TP-670-43115.

leaving a potential project in a regulatory black hole.

- **Assess site suitability.** This assessment is concerned with the availability of adequate space for a PV project, insolation, the potential for excessive dust or corrosion, and the adequacy of a structure or the ground to support PV facilities, such as roof condition and age. For example, the roof of an existing structure may not be able to support PV facilities without reinforcement, adding to the cost of a possible project. Some sites may also be shaded by trees or other structures, possibly making them a poor choice for a PV project.

- **Obtain architectural, engineering, and electrical designs.** This step provides detail about installing PV at a site. Whether the project is part of the refurbishment of an existing structure or a new structure, the integration of PV can be actively explored by analyzing site-specific situations and preparing site-specific designs.

- **Protect against the potential for damage.** PV panels may invite vandalism or theft. Thus, when siting individual facilities, planners will have to consider measures to prevent or at least make it difficult to damage or steal PV and related facilities.

- **Determine ownership of the facilities.** There are many possible ownership arrangements. Some common ones are as follows:

    - The project may be owned by the municipality or other agency, such as a water supply authority.

    - The municipality or other organization may purchase kWh from the project, which would be owned by a developer or other party.

    - The municipality may lease PV equipment from a developer or other third-party owner.

- **Review funding and financing options.** For a given ownership arrangement, there may be funding sources that reduce the net cost of PV to local government. These sources include rebates or performance-based incentives offered by utilities and state funds, tax incentives such as the investment tax credit (available only to tax-paying entities, which may help determine ownership), and grants.

BARRIERS TO PV

If critical factors leading to deployment of PV are absent, there may be obstacles to PV projects that make these projects more challenging than described above. Indeed, many states have very limited installations of PV,[43] possibly reflecting barriers to PV. Barriers include:

- **Inadequate government policies supporting renewable energy or distributed renewable energy.** For example, a state may not have a renewable portfolio standard or a functioning distributed energy set-aside. In general, without such supporting policies, very little distributed PV has been installed.
- **Absence of financial incentives.** At present, without sufficient financial incentives, PV is costly relative to conventional grid power, despite falling PV prices. If there is no utility incentive program or state fund program, few projects may be built.
- **Utility resistance.** Utilities may oppose aggregated net metering or other policies that encourage distributed PV, or they may severely limit the amount of incentives or limit the scope of projects eligible for incentives.
- **Limited financing options.** PV developers have been innovative in creating financing arrangements, such as power purchase agreements, but these arrangements may not be offered in states where PV markets are small. Or financing may not be available for projects that would be owned by the property owner.[44]
- **Insufficient supply of designers and installers.** In states that have a vibrant market in distributed PV projects, there are typically numerous competing firms with trained, skilled employees to design and install PV systems. However, in other states, the supply of design and installation services may be constricted due to the small size of the market, thereby making it more difficult to obtain distributed PV projects at competitive prices.

43 As noted above, in 2009, only 10 states had grid-connected PV capacity of 18 MW or more and 27 states had less than one MW of grid-connected PV capacity. See: Larry Sherwood, U.S. Solar Market Trends, 2009 (Latham, NY: Interstate Renewable Energy Council, 2010), Table 3 and Appendix C.

44 Ryan Randazzo, "Banks Leery of Loans for Solar Power," Arizona Republic, October 31, 2010.

OTHER ISSUES

» *Energy storage*

The Cheyenne Botanic Gardens rooftop PV project uses batteries to store PV power for on-site use at night or during cloudy periods.

Batteries may be used to store PV power for on-site use at night or during cloudy periods. The Santa Fe park lighting project and the Cheyenne Botanic Gardens rooftop PV project, listed in *Table 3*, incorporate battery storage.

Advances in battery technology and in battery applications are being pursued.[45] Manufacturers are seeking to develop batteries with longer lives and lower cost. Additionally, studies on battery applications are being carried out by utilities. The Sacramento Municipal Utility District (SMUD) will locate batteries at its headquarters campus and at a substation, and will investigate whether the battery system can augment peak period operations using electricity generated during off-peak hours. The project at the substation will store power at a central point rather than at individual PV facilities so that the value of aggregating multiple PV systems can be studied.[46] SMUD is also studying energy storage in 15 homes with PV and at three sites on SMUD's distribution system,

45 Batteries or other energy storage devices, such as flywheels, can serve a variety of purposes, including provision of utility ancillary services over short periods of time on very short notice and provision of utility operating reserves. This report is concerned with energy storage applications for the consumer. Typically, batteries for consumer use would be able to discharge over several hours on a regular basis. See Robert Schainker, Electric Power Research Institute, "Emerging Technologies to Increase the Penetration and Availability of Renewables: Energy Storage Executive Summary," presentation to California Energy Commission Integrated Energy Policy Workshop, July 31, 2008. Paul Denholm, Erik Ela, Brendan Kirby, and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation (Report Summary)" (Golden, CO: National Renewable Energy Laboratory, March 2010), NREL/PR-6A2-49396, pp. 15, 34. Dan Ton, Charles Hanley, Georgianne Peek, and John Boyes, Solar Energy Grid Integration Systems – Energy Storage (SEGIS-ES) (Albuquerque, NM: Sandia National Laboratories, 2008), SAND2008-4247.

46 Sacramento Municipal Utility District, "SMUD Named in Grant Funding for Energy Storage Project," news release, December 10, 2009.

evaluating whether PV can provide electricity during early evening hours.[47]

» *Effect of high concentrations of PV*

As the quantity of distributed photovoltaics increases within a small area, there may be impacts on the operation and stability of the distribution, transmission, or generation systems, especially if PV systems rapidly reduce power output due to passing clouds and then rapidly increase power output as the clouds move away.[48] Arizona Public Service Company has designed a project to evaluate the operational impacts of a large concentration of distributed renewable energy projects on the local grid.[49] APS plans to install (or have independent contractors install) about 200 distributed PV systems, about 50 solar water heaters, and about six small-scale wind turbines in a limited distribution area of Flagstaff, Arizona. Customers participating in the distributed PV portion of the pilot would receive electricity from the PV project on their property at a fixed price over 20 years. Using smart grid communication technology, APS will obtain information on how the distribution system reacts to changes in PV output and other information on system reliability.

Arizona Public Service Company plans to install about 200 distributed PV systems in a limited distribution area of Flagstff, AZ.

47 SustainableBusiness.com, "Saft to Provide Batteries for SMUD Pilot Program," June 22, 2010, http://www.sustainablebusiness.com/index.cfm/go/news.display/id/20538.

48 L. Moore and H. Post, "Five Years of Operating Experience at a Large, Utility-scale Photovoltaic Generating Plant," Progress in Photovoltaics: Research and Applications, 16 (April 2008): 249-259.

49 Arizona Public Service Company, Application for Approval of a Distributed Energy Initiative: The Community Power Project – Flagstaff Pilot, filed in Arizona Corporation Commission Docket No. E-01345A-09-0227, May 11, 2009. Arizona Corporation Commission Decision No. 71646, dated April 14, 2010.

5 // CONCLUSIONS

Deploying PV facilities jointly with infrastructure helps transform cities and regions into more sustainable systems. A city's or region's infrastructure offers numerous opportunities for installing photovoltaic facilities in parks, ecological restoration areas, gardens, and other open space; at airports; within the water supply system; on transportation structures such as covered parking structures or covered railroad platforms; on public buildings; on highway or railroad noise barriers; and so forth. These sites are typically built-up anyway and adding PV does not, in general, create additional environmental impacts. Moreover, incorporating PV into infrastructure substitutes renewable energy for conventionally generated electricity, thereby reducing the environmental impact of power generation and providing a stably priced resource in place of uncertain utility rates and uncertain utility costs of complying with future environmental regulation of conventional power plants.

The projects reviewed in this report indicate convincingly that PV is a practical addition to infrastructure where policies and programs are favorable. PV is a well-understood technology. In some states, PV is provided by numerous suppliers and is designed into new or existing structures by architects and engineers familiar with solar energy. Costs of PV have fallen in recent years and, where available, utility, state fund, and tax incentives make PV projects more attractive economically. PV facilities may be owned by the owner of the infrastructure, such as a municipality, water supply authority, or a private sector company. Alternately, electricity from PV may be obtained through a power purchase agreement with a third party who owns the PV project and sells the electricity to the owner of the infrastructure.

APPENDIX // SUMMARY OF PROJECTS

PROJECTS IN PARKS, RESTORATION AREAS, GARDENS, AND OPEN SPACE

BRONX RIVER GREENWAY RIVER HOUSE, NEW YORK, NY	
Description of project	• PV panels mounted on daylight roof monitors of new educational and administrative building in restored area along the Bronx River • Owner: New York City Department of Parks and Recreation • Occupant: Bronx River Alliance • Expected LEED® Platinum rating
kW (DC)	48 kW
Date installed	To be constructed in 2010
Sources	Kiss + Cathcart, Architects, Productive Architecture Project Portfolio 2010, Brooklyn, NY, http://www.kisscathcart.com/pdf/BRGRiverhouse.pdf.

NINA MASON PULLIAM RIO SALADO AUDUBON CENTER, PHOENIX, AZ	
Description of project	• Rooftop PV panels cantilevered over a walkway to provide shade • New nature center in Phoenix's Rio Salado Habitat Restoration Area • Houses headquarters of Arizona office of the National Audubon Society • LEED® platinum certification
kW (DC)	26 kW
Date installed	2009
Sources	Audubon Arizona, "Nina Mason Pulliam Rio Salado Audubon Center," http://az.audubon.org/Center_RioSalado.html. Arizona Solar Center, "Audubon Center," http://www.azsolarcenter.org/images/docs/az/tours/2009/audubon-2009.pdf. Salt River Project, "Community Solar Projects Funded Through EarthWise Energy," http://www.srpnet.com/environment/earthwise/projects.aspx.

QUEENS BOTANICAL GARDEN VISITOR AND ADMINISTRATION CENTER, NEW YORK, NY

Description of project	• Rooftop PV panels in new building • LEED® Platinum certification
kW (DC)	16 kW
Date installed	2007
Sources	Joann Gonchar, Green Source Case Study, "Queens Botanical Garden," April 2008, http://www.resgreensmr.construction.com/projects/0804_Queensbotanicalgarden.asp. Fred A. Bernstein, "A Garden Blooms in Queens," MetropolisMag.com, February 20, 2008, http://www.metropolismag.com/story/20080220/a-garden-blooms-in-queens.

CHEYENNE BOTANIC GARDENS, CHEYENNE, WY

Description of project	• Rooftop PV panels • Batteries: solar power is stored in industrial grade lead-acid batteries for use during periods when sun is not shining
kW (DC)	2 kW
Date installed	Not indicated
Sources	Cheyenne Botanic Gardens, "Solar Electricity," http://www.botanic.org/Solar_Electricity.asp. Cheyenne Botanic Gardens, "Renewable Energy at the Cheyenne Botanic Gardens," http://www.botanic.org/SolarEnergy.pdf.

PARK LIGHTING, SANTA FE, NM	
Description of project	• Off grid PV lighting using LEDs in Frenchy's Field Park • PV on each lighting structure • PV charges battery
kW (DC)	• 0.065 kW solar cells on top of each fixture • Each fixture uses 0.0198 kW
Date installed	2010
Sources	Renewable Energy Focus USA, "Santa Fe Public Parks Switch to Solar LED Light Fixtures," September 7, 2010, http://www.renewableenergyfocususa.com/view/12281/santa-fe-public-parks-switch-to-solar-led-light-fixtures/. Julie Ann Grimm "City to Test New Solar LED Lights at Frenchy's Field," The Santa Fe New Mexican, September 14, 2009, http://www.santafenewmexican.com/Local%20News/City-to-test-new-solar-LED-lights-at-Frenchy-s-Field. Qnuru, "Customer Case Study, Frenchy's Field, Santa Fe, NM," available at http://www.qnuru.com/index.php?page=success-story.

PROJECTS AT AIRPORTS

DENVER INTERNATIONAL AIRPORT, DENVER CO	
Description of project	• Two ground-mounted projects • Single axis tracking • 7.5 acres and 9 acres of land used for the projects • Airport obtains electricity through a power purchase agreement
kW (DC)	• 2,000 kW (first project) • 1,600 kW (second project)
Date installed	• 2008 (first project) • 2009 (second project)
Sources	U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Denver International Airport Dedicates 2-Megawatt Solar System," August 20, 2008, http://apps1.eere.energy.gov/states/state_news_detail.cfm/news_id=11944/state=CO?print. Renewable Energy World, "1.6-MW Sharp Solar Array at Denver International Airport Goes Online," March 5, 2010, http://www.renewableenergyworld.com/rea/news/article/2010/03/1-6-mw-solar-system-completed-at-denver-airport.

FRESNO YOSEMITE AIRPORT, FRESNO, CA	
Description of project	• Ground-mounted project • Single-axis tracking • 21 acres • Airport obtains electricity through a power purchase agreement
kW (DC)	2,400 kW
Date installed	2008
Sources	Solar Power Partners, Project Profile, "Fresno Yosemite International Airport," http://www.solarpowerpartners.com/projects/profiles/fresnoap.html.

PROJECTS ON UNDERUTILIZED LAND

WEST PULLMAN PV, CHICAGO, IL	
Description of project	• Single-axis tracking PV project located on former industrial site in Chicago • Exelon leases about 40 acres of the West Pullman Industrial Redevelopment Area from the city of Chicago for the project. • Exelon Generation owns and operates plant • Cost approximately $60 million
kW (DC)	10,000 kW
Date installed	2010
Sources	Exelon, "Exelon City Solar," http://www.exeloncorp.com/assets/energy/powerplants/docs/pdf_ExelonCitySolarFact.pdf. Exelon/SunPower, "Exelon and SunPower to Develop Nation's Largest Urban Solar Power Plant," news release, April 22, 2009. PV Tech, "Chicago City Council Greenlights Lease for Exelon/SunPower 10 MW Urban Solar Power Plant," July 30, 2009, http://www.pv-tech.org/lib/printable/5827.

ELLENSBURG COMMUNITY SOLAR PROJECT, ELLENSBURG, WA	
Description of project	• Owned by municipal electric utility • Located on vacant municipal land • Community solar project — customers of municipal utility may purchase shares of electrical output through 2031 ($250 minimum) • Subscribers receive credit on electric bills based on their share of wholesale value of kWh produced by PV project • Shares are transferable to another customer of municipal electric utility
kW (DC)	• 36 kW (Phase 1) • 22 kW (Phase 2)
Date installed	2006 (Phase 1), 2009 (Phase 2)
Sources	Northwest Community Energy, "Ellensburg, Washington's Community Solar Project," http://nwcommunityenergy.org/solar/solar-case-studies/chelan-pud. Sustainability Foundation "Ellensburg Community Solar Project," Case Study, 2009, http://www.solaripedia.com/files/435. City of Ellensburg, WA, Ellensburg Community Renewable Park Contribution Agreement, http://wa-ellensburg.civicplus.com/DocumentView.aspx?DID=253. Claudine Benmar/Grist, "Cities of the Future: Ellensburg, WA," http://smartercities.nrdc.org/articles/cities-future.

FORT CARSON LANDFILL PV PROJECT, FORT CARSON, CO	
Description of project	• Thin film, ground-mounted PV system • Located on a decommissioned landfill • Site prepared by installing four foot thick earthen cover and re-vegetated with drought-resistant prairie grass. • PV project occupies 12 acres • Cost, $13 million
kW (DC)	2,000 kW
Date installed	2008
Sources	US Environmental Protection Agency, RE-powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites — Fort Carson, Colorado Success Story, February 2009, http://www.epa.gov/renewableenergyland/docs/success_fortcarson_co.pdf.

PROJECTS SERVING WATER SUPPLY SYSTEMS

SOUTHERN NEVADA WATER AUTHORITY RIVER MOUNTAINS WATER TREATMENT FACILITY, HENDERSON, NV

Description of project	• Concentrating PV with dual-axis tracking • Technology requires 5 acres of land per MW of installed capacity
kW (DC)	308 kW
Date installed	2009
Sources	Southern Nevada Water Authority, 2009 Annual Report, pp. 13-14. Amonix, "CPV Solar Power Helps the Southern Nevada Water Authority Produce Clean Water While Protecting the Environment."

CITY OF TUCSON ROGER ROAD RECLAIMED WATER RESERVOIR, TUCSON, AZ

Description of project	• Installed on reservoir deck • Single-axis tracking system • Project paid for through Clean Renewable Energy Bonds • Utility incentives applied to project • Cost $848,000
kW (DC)	110 kW
Date installed	2009
Sources	City of Tucson, AZ, Solar Photovoltaic Case Study, "Roger Road Reclaimed Water Reservoir," http://cms3.tucsonaz.gov/files/energy/Case%20Study%20-%20RRR.pdf.

VALLEY CENTER WATER DISTRICT, VALLEY CENTER, CA

Description of project	• Ground-mounted single-axis tracking system • Project serves part of pumping load • Power purchase agreement
kW (DC)	1,100 kW
Date installed	2008
Sources	Solar Power Partners, Project Profile, "Valley Center Water District," 2009, http://www.solarpowerpartners.com/projects/PDFs/ValleyCenter.pdf.

ARVADA RALSTON WATER TREATMENT PLANT, ARVADA, CO	
Description of project	• Ground-mounted system on 6.5 acres • Single-axis tracking system • $4 million cost, subsidized by federal tax credits and Xcel Energy renewable energy credits and rebates • Project serves 88% of water treatment plant demand • Power purchase agreement: $0.058/kWh with annual increase of 2% over 20 year term of contract
kW (DC)	650 kW
Date installed	2008
Sources	City of Arvada, CO, "Arvada Sustainable Action Plan, ASAP in Action," http://arvada.org/about-arvada/asap-in-action/. City of Arvada, CO, "Treatment Plant Going Solar," http://arvada.org/about-arvada/treatment-plant-going-solar/. City of Arvada, CO, 2008 City of Arvada Annual Report, p. 28, http://static.arvada.org/docs/12337700102008%20annual%20report.pdf. Quanta Renewable Energy Services, "Arvada Ralston Water Treatment Plant," http://www.quantarenewable.com/index.php?id=53.

PROJECTS ON SHADE STRUCTURES AND SHELTERS

RIVERSIDE PUBLIC UTILITIES OPERATION CENTER SOLAR CARPORT, RIVERSIDE, CA	
Description of project	• Structure provides shade for 152 parking spaces • PV mounted on top of structure • Carport structure and PV built at same time • Paid for with public benefits funds
kW (DC)	151 kW
Date installed	2001
Sources	Riverside Public Utilities, "Utilities Operation Center Solar Carport," http://www.riversideca.gov/utilities/comm-gp-uoc.asp. California Solar Center, "Schott Applied Power Completes 113 kW Solar Carport in Riverside," http://www.californiasolarcenter.org/solareclips/2001.10/20011030-3.html.

SUN TRAN BUS MAINTENANCE FACILITY, TUCSON, AZ	
Description of project	• LEED® Gold facility • PV on 6 parking canopies • Cost of solar arrays = $545,000, excluding canopies
kW (DC)	84 kW
Date installed	2009
Sources	City of Tucson, AZ, "Solar Photovoltaic Case Study, Sun Tran Bus Maintenance Facility," http://cms3.tucsonaz.gov/sites/default/files/energy/Case%20Study%20-%20STBMF.pdf.

STILLWELL AVENUE TERMINAL TRAIN SHED, NEW YORK, NY	
Description of project	• Train shed covering 4 platforms and 8 tracks • Renovation of old station • Thin film, building integrated PV system • Design allows day-lighting of platform under normal day-time conditions
kW (DC)	199 kW
Date installed	2006
Sources	U.S. Department of Energy, Energy Efficiency and Renewable Energy, "Stillwell Avenue Terminal Train Shed," http://eere.buildinggreen.com/energy.cfm?ProjectID=822. "Electric Shed," Architecture Week, August 22, 2007, http://www.architectureweek.com/2007/0822/.

PROJECTS ON PUBLIC BUILDINGS

PHOENIX CONVENTION CENTER, PHOENIX, AZ	
Description of project	• PV integrated into roof of renovated convention center • Thin film PV • Cost $850,000 for PV • City received financial incentive from utility for project ($2.50 per DC watt)
kW (DC)	100 kW
Date installed	2008
Sources	City of Phoenix, "Solar and Other Renewable Energy Projects," http://phoenix.gov/greenphoenix/sustainability/solarproj.html. City of Phoenix, Award Entry, 2007 Alliance for Innovation, J. Robert Havlick Award for Innovation in Local Government and Thomas H. Muehlenbeck Award for Excellence in Local Government, "Photovoltaic System at Phoenix Convention Center West Building," www.transformgov.org/Documents/Document/Document/107270.

ENVIRONMENTAL SERVICES DEPARTMENT BUILDING, SAN DIEGO, CA	
Description of project	• Project transformed vacant office complex into a green municipal building • Light weight building integrated PV system on roof • PV on carport
kW (DC)	• 66 kW for roof installation • 4 kW for carport installation
Date installed	2003
Sources	SunPower Corporation, "Case Study: City of San Diego Adopts Clean, Reliable Solar Energy with SunPower," 2008.

PROJECTS ON NOISE BARRIERS

A9 HIGHWAY NOISE BARRIER, NETHERLANDS

Description of project	• 1650 meter long PV installation on highway noise barrier • Highway segment with PV runs east-west, PV faces south • Noise barrier was designed and constructed with PV modules integrated into barrier • Noise barrier reduces highway noise for 700 nearby houses • Accumulated traffic dust on modules reduces energy output by about 8%
kW (DC)	220 kW
Date installed	1998
Sources	N.J.C.M van der Borg and M.J. Jansen, Photovoltaic Noise Barrier at the A9 Highway in The Netherlands: Results of the Monitoring Programme, report prepared for NUON International/Duurzame Energie and the European Commission, ECN-C-01-021, 2001. European Commission, Photovoltaic Solar Energy Best Practices Stories (Munich, Germany: WIP, 2000).

NOISE BARRIER, TULLAMARINE-CALDER INTERCHANGE, MELBOURNE, AUSTRALIA

Description of project	• 500 meter long PV installation on noise barrier • Noise reduction achieved by the PV glass which deflects sound • Power feeds into electric grid • Impact of shade cast by traffic signs was minimized by using shade-tolerant amorphous silicon • Business as usual practice would have been concrete noise barrier • Incremental cost of PV noise barrier results in 15 year payback for PV
kW (DC)	24 kW
Date installed	2007
Sources	Going Solar Projects, Renewable Energy and Environmentally Sustainable Design Case Studies: PV Noise Barrier for the Tullamarine-Calder Interchange, 2007, http://www.goingsolar.com.au/pdf/casestudies/Tullamarine_Calder_Interchange-PV.pdf.

PROJECTS INCORPORATED INTO PUBLIC ART

SOLAR SAIL, MÜNSINGEN, SWITZERLAND	
Description of project	• Sail-like art work (22 meters high) incorporating PV modules • Located at psychiatric clinic • Power sold into grid
kW (DC)	8.2 kW
Date installed	1999
Sources	PV Resources, "Photovoltaic Touched by Design," http://www.pvresources.com/en/art.php. "The PV Aesthetic Sets Sail," Photon International, June 2000. Swiss Federal Office of Energy and SwissEnergy, "The Power of Art," Energy Extra 3.04, June 2004, p. 5.

SOLAR STREET, GLEISDORF, AUSTRIA	
Description of project	• 3.5 km street segment with about 80 pieces of PV powered art and other equipment (including a solar tree, solar clock, solar advertising boards, solar lighting) • Largest PV project on the street is a 10 kW façade-integrated system • Most of the objects were financed by utility
kW (DC)	Not specified
Date installed	Various
Sources	PVUpscale, Solar City Gleisdorf, 2007, http://www.pvupscale.org/IMG/pdf/Gleisdorf.pdf.

WESTERN RESOURCE
ADVOCATES

2260 Baseline Road, Suite 200
Boulder, CO 80302
Tel: (303) 444-1188

www.westernresourceadvocates.org
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