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Photovoltaics for Municipal Planners

Cost-effective Municipal Applications of Photovoltaics for Electric Power

**Cover photos and map courtesy of the City of Littleton, Colorado;
Susan Thornton, Mayor, City of Littleton; and NREL**

The City of Littleton, Colorado, is one of many municipalities using PV in the urban environment. (left) The "10,000 Trees" array provides 2.5 kW of electric power to pump 208 cubic meters (55,000 gallons) of water per week, to irrigate a reforestation project along the South Platte River. The array was cost-shared by the Public Service Company of Colorado and the U.S. Department of Energy. (right) A Littleton policeman controls traffic along a busy thoroughfare using a PV-powered speed monitor.

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PHOTOVOLTAIC POWER FOR CITIES

Cost-Effective Systems for Urban Applications

This booklet is intended for city and county government personnel, as well as community organizations, who deal with supplying, regulating, or recommending electric power resources. Specifically, this document deals with photovoltaic (PV) power, or power from solar cells, which is currently the most cost-effective energy source for electricity requirements that are relatively small, located in isolated areas, or difficult to serve with conventional technology. Recently, PV has been documented to be more cost-effective than conventional alternatives (such as line extensions or engine generators) in dozens of applications within the service territories of electric, gas, and communications utilities.

Here, we document numerous cost-effective urban applications, chosen by planners and utilities because they were the most cost-effective option or because they were appropriate for environmental or logistical reasons. These applications occur within various municipal departments, including utility, parks and recreation, traffic engineering, transportation, and planning, and they include lighting applications, communications equipment, corrosion protection, irrigation control equipment, remote monitoring, and even portable power supplies for emergency situations.

For these applications, the cost of extending conventional utility service can be prohibitive compared to the alternative of PV power. For example, installing power lines, plus any required service drop equipment (i.e., transformer, meter, etc.), can cost thousands of dollars, even for relatively small applications.

As shown on the following map, city personnel around the country are recognizing the benefits of PV-powered systems for

MASTER

urban applications. Presently, more than 65 cities in 24 states have installed PV-powered systems for various applications. As is evident, the cities are located in all regions of the country. So, PV systems do not require a “sunbelt” climate to provide a valuable and cost-effective service in urban areas.

PV Power Basics

Photovoltaic power is electricity generated when light falls on solid-state devices called PV cells. When photons of light collide with atoms within the PV cells, they transfer energy to the electrons and cause them to flow into wires connected to the cells. When multiple cells manufactured into a PV module, they can produce enough power to run small appliances, lights, or other electrical loads. When greater power is needed, many modules can be connected in series and in parallel, and the resulting PV array can range in size from a simple two-module system with minimal capacity for small loads to a vast field of modules that can provide bulk power for utility electrical grids.

Photovoltaic cells have been used since the 1950s, when the first modern cells powered satellites in orbit. Since then, researchers and manufacturers around the world have steadily achieved the scientific breakthroughs and engineering development needed for higher energy conversion efficiencies and lower cost.

All of the commercially available PV modules are assembled from one of three types of silicon-based PV cells. One type is fabricated from a single-crystal wafer of silicon. This type of cell was the first to be used in practical applications (such as the arrays, or “wings,” on orbiting satellites). The second type is made of polycrystalline silicon, manufactured from wafers with many separate crystals. The third type is made of amorphous silicon—a thin layer of silicon on an inexpensive base, such as glass. While they are used in some field applications, you would be most familiar with this type of PV from its use in solar calculators and watches.

PV power is different from a conventional power source in several respects. All PV cells, modules, and arrays produce direct current (dc) electricity, with no moving parts, requiring no conventional fuel, and producing no noise or other pollution. If alternating current (ac) is needed for a particular application, a device called an inverter must be used to convert the power from dc. However, all of the isolated applications discussed in this booklet have been designed to use dc electricity.

Today's cost-effective PV systems generally consist of modules, mounting hardware, controls, and storage batteries, and some use inverters (for ac power). In particular, PV systems used for remote applications usually have batteries to store power for use at night and on cloudy days. Furthermore, the modular nature of PV systems allows for easy expansion and simple repair or replacement of the system's components.

Booklet Purpose and Organization

The purpose of this booklet is to provide specific examples of cost-effective PV applications appropriate for urban areas, in addition to information on where and how to buy them. In particular case studies from 14 cities shown on the previous map are described, including a description of the application (i.e., system cost, performance, and reliability information); any future plans the city might have regarding additional uses for PV-powered systems; and a contact person at the city. Additionally, a list of other cities with similar PV installations is provided; for some applications, we include a description of the widespread use of PV power for those particular applications.

The case studies in this booklet have been organized according to typical departments found within a city government. The separation of case studies into these departmental areas is not intended to imply that particular applications can only occur within particular departments. However, the applications identified seem to occur predominantly within the particular departments shown.

The information contained in this table differentiates between specific case studies and applications that should also be considered by various departments. No case studies were developed for these latter applications because insufficient information was available. Additionally, the table indicates that all applications should be considered by the electric utility department. Because the electric utility department in many cities will receive requests for services from other city departments, utility department personnel should be aware of all possible applications where PV-powered systems can be cost-effective.

APPLICATION	MUNICIPAL DEPARTMENT					
	Electric Utility	Parks & Recreation	Traffic Engineering	Water & Gas Utility	Planning	Transportation
LIGHTING						
Pathway Security	●	X				
Bus Stop Shelter	●					●
Streetlight	●		X			
Sign	●				X	
Traffic Hazard Sign	●		X			
Traffic Control Sign	●		X			
School Zone Flasher	●		X			
Fire Station Pre-emption	●		●			
Railroad Crossing	●		●			
MONITORING						
Water Meter	●			X		
Automatic Traffic Recorder	●		X			
Road Ice Detection System	●					●
COMMUNICATION						
Emergency Call Boxes	●	X				X
Variable Message Board	●		●			
Community Warning Siren	●				X	
Emergency Communication	●				●	
IRRIGATION CONTROLS						
Median Strip Irrigation	●	X				
Park Irrigation	●	X				
MISCELLANEOUS						
Fleet Battery Charging	●					●
Pond Aeration	●	X				
Portable Power	●	●			●	
Cathodic Protection	●			X		
● = application in use but not used as an example in this booklet; X = example shown in this booklet						

The City of Austin Electric Utility provides a specific example of this approach. Due to the success of its PV-powered installations, the utility is implementing a program that will enable utility personnel to identify potential PV applications in Austin. As requests for line extensions are submitted by customers, including other utility departments, the utility designers will use a screening method to identify possible cost-effective PV installations. Another benefit of this approach is the fact that personnel in other City of Austin departments can rely on the electric utility department for support with identifying cost-effective PV applications.

The final section of this booklet contains information on the cost, performance, and reliability of remote PV-powered systems. This information is divided into two segments: a broad look at these factors that resulted from other studies and organizations; and a narrow look at cost, performance, and reliability details specific to the systems described in this booklet.

WHAT YOU CAN EXPECT FROM PV-POWERED SYSTEMS

As described throughout this booklet, PV power is currently the most cost-effective energy available when the electricity requirements are relatively small, are located in isolated areas, or are difficult to service with conventional technology. For the urban applications previously documented, the cost of extending conventional utility service was higher compared to the alternative PV power cost.

However, cost is only one criterion for evaluating the usefulness of PV-powered systems. Three other essential criteria are system performance (e.g., operational characteristics and customer satisfaction), system reliability (e.g., component failures), and maintenance requirements. The information contained in this section summarizes system cost, performance, reliability, and maintenance trends evident from the case studies and other similar installations. As a result, the reader will know "what to expect" from PV-powered systems.

System Costs

According to the U.S. Department of Energy's 1992 Solar 2000 plan, PV module costs are now 1/100 of those in 1972, dropping from \$500 per watt to about \$5 per watt in 1990. These price decreases are expected to continue as the PV market grows, as manufacturing techniques improve, and as module efficiencies increase.

For all the PV systems identified, the installed costs were less—on a first-cost basis—than the cost of utility service. In all cases, the installed cost included the PV equipment (i.e., module, controllers, wiring, etc.), the "application" equipment, and the installation costs. For example, the school-zone flashers purchased by the City of Carrollton included the PV system, a sign, a pole, and the flashing yellow lights. Shown in the table below are typical installed system costs for many of the 22 applications described in both the case study and "other applications" sections. For those applications where installed costs were not identified in particular case studies, cost estimates were obtained from manufacturer's estimated prices and combined with typical installation costs.

For the applications identified, the installed costs ranged from \$50 (battery chargers) to approximately \$19,000 (community warning siren) per installation. However, for many of these applications the PV power supply cost was trivial compared to the total installed cost. For example, the PV power supply costs (i.e., PV module, battery, and controls) for the call boxes were in the range of \$200 each, compared to the total installed cost of ap-

proximately \$3,350 per installation. For the community warning siren, the PV power supply costs were approximately \$2,000 compared to the total installed cost of \$19,000. As a result, the cost-effectiveness of these PV-powered systems compared to utility power was often much greater than the total installed costs indicate, as the "application" equipment costs would have been added to the utility interconnection costs as well.

Many reasons other than cost were used by city personnel to justify the installation of PV-powered systems. These reasons included

- *avoiding monthly utility bills;*
 - *eliminating siting problems due to easement restrictions on private property;*
 - *increasing siting flexibility for regulated installations like school zone flashers;*
 - *reducing required installation lead time by eliminating the need to request utility service hook-ups;*
 - *creating a more aesthetic installation by eliminating overhead electrical lines;*
 - *reducing environmental impacts by using a non-polluting technology;*
 - *increasing system reliability by using a power supply that can survive power outages in emergency situations;*
 - *using a portable power supply that can be moved as needs change; and*
 - *increasing system efficiency by using a dc power supply for dc loads.*
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System Performance

The PV installations documented in this booklet have demonstrated proper performance in various regions of the country, operating in varying climates, in both summer and winter, and under differing solar resources. In virtually all examples identified, the city personnel responsible for the PV-powered systems were satisfied with their system's performance. In an informal survey of these city personnel, each one rated their satisfaction as "high," implying strongly that the PV-powered systems were "getting the job done." Several cities were so pleased with the PV systems that they decided either to use PV in as many cost-effective applications as possible or to install more of the existing applications.

According to the Electric Power Research Institute, there are many reasons why PV power may have great potential for widespread application. PV systems are highly modular, and they work the same in small or large applications. This flexibility allows users to start small and expand gradually. PV power supplies have no moving parts and accomplish the sunlight-to-electricity conversion entirely with solid-state electronic components. This operation provides high equipment availability and low maintenance costs.

PV systems do not require full sun to be effective. On partly cloudy days, they can produce up to 80% of their rated energy; on hazy/humid days, about 50%; and on extremely overcast days, they still produce about 30%. Furthermore, PV systems release no pollutants, and except for land use, they ensure minimal environmental impact.

Despite the overwhelming satisfaction with the PV-powered systems, a few complaints did occur. Generally, these complaints were aimed at the application equipment (e.g., irrigation controls) rather than the PV power-supply equipment (e.g., PV modules, batteries, etc.). For example, one city official complained that a particular PV irrigation system did not have the desired schedule flexibility (i.e., the irrigation timer could not be programmed as required).

As shown in the following table, more than 1,500 installations were identified in this study, totaling approximately 23,000 watts of PV. The majority of these installations (1,100) were call boxes, which required only 5 watts of PV power. So, the typical system size excluding the call boxes was approximately 50 watts. All of the applications except one (pond aeration) required battery backup. The average battery storage capacity included in each system was approximately 10 days, though the storage capacity ranged from 4 (streetlights) to over 20 days (call boxes). Finally, the average system age for all of the installations was nearly 3 years, with ages ranging from 3 months to 10 years.

PARK IRRIGATION

City of Littleton, CO

SYSTEM SPECIFICATIONS

Number of Systems:	1
PV Power Output:	2,500 watts
Operating Voltage:	80 volts dc
Battery Capacity:	No Batteries
Battery Reserve (from full charge):	No Batteries
Total Cost of PV and Load Equipment:	\$41,300
Estimated Cost for Utility Connection:	\$24,500

Throughout this booklet, the documented PV system sizes have been relatively small, ranging from 5 watts per installation to nearly 300 watts. However, a park irrigation system in Littleton, Colorado, demonstrates that large PV systems can be useful in an urban setting as well. As part of "10,000 Trees," a revegetation project, the City of Littleton wanted to water 1,400 newly planted trees along the Platte River. The trees extended along a 2.7 kilometer (1.7-mile) section of the river and lined a bike path. Because of the large size of this system and its proximity to the existing utility grid, the PV system cost was more expensive than extending the electric grid. However, the PV-powered system was installed for three reasons. First, aesthetics were important, and unsightly overhead electrical lines within the park were not desirable. Second, the PV system can be transferred to another site after the trees were established and watering is no longer required. Finally, the local electric utility, Public Service Company of Colorado, wanted to gain experience with the PV-powered system.

This irrigation system was installed in April 1992 and included two controllers, two pumps, and 43 solenoid valves powered by approximately 2,500 watts of PV. Forty 63-watt modules were divided into five arrays and were mounted on single-axis solar trackers. The system was designed to deliver 68 liters (18 gallons) of water per minute over 70.4 meters (231 feet) of lift during daylight hours. The system actually pumps 114 liters (30 gallons) per minute, which provides excess water to all the trees.

All the project participants, which included the utility, the Department of Energy, NREL, and the South Suburban Parks and Recreation Department, have been extremely satisfied with the performance of the PV-powered system. In addition, the Littleton City Council was "so pleased" with the system that special recognition was given to all the participants, and the city has installed a second, though smaller, PV-powered park irrigation system since this installation.

System Reliability

For most of the systems identified in this study, the excellent reliability record of PV power supplies documented by other organizations remained in tact. No PV module failures were identified, and the few battery failures identified were due in large part to a lack of proper maintenance.

According to NREL, today's PV modules are exhibiting lifetimes of about 20 years, a statistic that is supported by the experiences of organizations and industries over a number of years:

- *The U.S. Coast Guard has more than 10,000 PV-powered navigational aids operating in coastal locations throughout the United States;*
- *The Southwest Technology Development Institute in Las Cruces, New Mexico, has tested the performance of thousands of PV modules throughout the U.S. over the past 13 years. The generally positive details of these investigations are available in reports published by Sandia National Laboratories and EPRI;*
- *A few utility-owned, PV-powered installations have been operating reliably for more than 10 years. For example, a PV-powered microwave relay station installed by Public Service Company of New Hampshire has operated reliably since 1979;*
- *A recent survey conducted by EPRI of 250 PV-powered pumping installations identified no PV module failures out of nearly 500 modules installed during the past 11 years;*
- *The telecommunications industry has been installing PV systems for over 10 years and continues to install and operate systems in harsh environments around the world;*

However, a few cities identified failures in the "application" equipment. For example, a lamp ballast failed for a pathway light in Austin, and the City of Lakewood's community warning siren failed to operate during a test once, though the reason for the failure was unknown. Additionally, 35 out of 40 PV-powered irrigation systems failed in one city due to water leaking into the battery housing and causing battery failures (this problem has since been corrected by the manufacturer).

When damage to PV modules did occur, most were due to vandalism. More than 40 acts of vandalism were documented for the case-study applications alone. Most of the vandalism was directed against the application equipment rather than the PV systems. However, when the PV equipment was vandalized, it centered on the modules. For example, the City of Anaheim had 15 PV modules stolen from emergency call boxes, and a module

on the cathodic protection system in Las Vegas was damaged by a rock (though the system was still operating).

In several cities not documented by the case studies, vandalism was a major cause of concern. However, some of these same cities considered vandalism a manageable problem with careful planning and proper system design. For example, the PV module on a bus shelter can be hidden on the roof (i.e., with an "apron" around the roof's perimeter) or PV modules can be mounted on 5-meter (15-foot) poles to minimize access.

Maintenance Requirements

To ensure satisfactory PV system performance and high reliability, maintenance will be required for any stand-alone PV application. Most of the required maintenance will stem from system monitoring (i.e., preventative maintenance) and battery replacements. A failure to adopt these practices will likely cause some system failures and performance dissatisfaction. Specifically, in talking with the numerous city personnel for this project, city officials were very satisfied with the performance of the PV systems where preventative maintenance programs existed. On the other hand, officials that were disappointed in the systems usually had no preventative maintenance program.

One city's experience typifies the problem of not having a preventative maintenance program. The City of Tucson installed several PV-powered bus stop lighting systems in 1984, and the systems were never maintained. The reason a maintenance program was not in effect was that the PV system supplier indicated that the system was "maintenance free" and that "the batteries would last 15 to 25 years." Because typical PV system batteries are replaced at least every 5 years, it was remarkable that several of the lighting systems were still operating after 9 years. However, the majority of the systems had failed, causing obvious dissatisfaction by city personnel.

To avoid this situation, implementing a preventative maintenance program has become standard practice in many cities. Specifically, the City of Tucson will correct the lack of PV maintenance activities by hiring a part-time individual to coordinate system maintenance as well as search for new PV opportunities.

The actual implementation of preventative maintenance programs has varied from city to city. Several cities specify a minimum of one annual visit to the site, while others are visiting a given site six times per year. The schedule variations probably occur relative to the application equipment needs (e.g., lamp replacements) and to recommended battery maintenance schedules. Battery manufacturers typically recommend particular preventative maintenance activities, as well as proper maintenance intervals. These recommended intervals will become, in some cases, the maintenance intervals for the entire system.

The average annual cost for preventative maintenance was approximately \$75 per site for the cities that implemented programs, though the annual costs ranged from \$20 to \$190 per site. The higher cost was associated with the 1,100 emergency call boxes that were maintained by the manufacturer and included equipment replacement costs.

How To Buy

In considering a municipal PV system, it is best to contact others who have experience in specifying and purchasing similar systems. Items to consider in a typical procurement include equipment warranties and service agreements, in addition to system performance under field conditions.

There are many experienced contractors and dealers, and it is always best to ask for information on other PV projects they have completed.

As a start, you might choose to begin by contacting those listed with the sample projects in the next section or any of the companies listed in the resource list in the back of this booklet.

What Follows

The following section provides examples of cost-effective municipal PV systems, broken down by planning department. These examples have been drawn from a large pool of systems installed in urban environments across all geographic regions in the United States. Be aware, though, that these are only municipal examples, and there are thousands of systems, publicly and privately owned, operating in more remote or less accessible areas. In addition, there are much larger PV installations that were not included because they are utility-owned and operated rather than municipal systems.

PARKS AND RECREATION

A city's Parks and Recreation department has several responsibilities that include maintaining attractive and safe areas for the city's residents. One responsibility is irrigating parks that may not be close to the utility's electrical lines. In addition, the department needs to ensure the safety of the facility's users. Safety can be provided with general lighting as well as emergency phones.

Therefore, five PV-power applications were documented for parks and recreation departments. These are

- Median strip irrigation;
- Park irrigation;
- Pond aeration;
- Pathway lighting; and
- Emergency call boxes.

This department, however, is not limited to these applications. Several lighting applications exist in this department that can be PV-powered. Park entrance signs, as well as parking lot lights, could be PV-powered. In addition, festivals and other park events could benefit from a PV system to power portable lights and the public address systems.

Pathway Security Lighting

Austin, Texas

SYSTEM SPECIFICATIONS

Number of Systems:	2
PV Power Output:	172 watts
Operating Voltage:	24 volts dc
Battery Capacity:	360 amp-hours
Battery Reserve (from full charge):	6 days
Total Cost of PV and Load Equipment:	\$ 6,000
Estimated Cost for Utility Connection:	\$12,000

To ensure pedestrian safety, the City of Austin installed two PV-powered overhead lights at the entrance of a city park hiking path. The electrical power for the lights comes from four batteries. Without recharging, the batteries can supply power for 6 days. However, the batteries are recharged during the day by 172 peak watts of power generated by four 43-watt PV modules.

The initial cost of the PV lighting system was \$6,000, or \$3000 per light. This included the modules, controls, lighting equipment (one 55-watt low-pressure sodium, and one 55-watt high-pressure sodium bulb), and installation. However, the cost of these installations was only half the cost of utility service. Even though an electrical line was only 100 meters away, the cost of the line extension and the transformers was estimated to be \$12,000.

The two PV systems were installed in January 1992. Austin officials have been satisfied with the performance, as the two systems have required little maintenance or repair. After a year of operation, the only equipment failure has been a lamp ballast. Each year, however, two inspections are conducted to monitor system performance. To date, no preventative maintenance has been required.

FUTURE PLANS

The City of Austin is presently planning to install 150 PV-powered lights on a city bicycle path. By choosing PV, Austin believes the overall cost of lighting the path will be lower than the traditional method of extending electrical distribution lines.

CONTACT

Kenneth Ragsdale, City of Austin, (512) 332-6288

OTHER CITIES

Queens, NY; Miami, FL; Chicago, IL; Albuquerque, NM; Tucson, AZ; Davis, CA

THE BIG PICTURE

Based on its successful pathway lighting project in Queens, the New York State Power Authority is developing a program to evaluate PV cost-effectiveness for various applications, including street, area, and/or path lighting.

Park Water Irrigation Little Rock, Arkansas

SYSTEM SPECIFICATIONS

Number of Systems:	1
PV Power Output:	60 watts
Operating Voltage:	12 volts dc
Battery Capacity:	100 amp-hours
Battery Reserve (from full charge):	10 days
Total Cost of PV and Load Equipment:	\$3,216
Estimated Cost for Utility Connection:	\$3,218

In October 1992, Arkansas Power and Light, the Arkansas Energy Office, the City of Little Rock, and the Central Arkansas Soccer Association installed a PV system to irrigate three soccer fields located in eastern Little Rock. The irrigation system requires electricity to power the sprinkler controls. A single 60-watt solar module charges a battery and enables the timer to operate for 10 sunless days during the spring, summer, and fall.

The PV system cost was virtually the same as the cost of providing power from the nearest electrical line. The total cost of grid-connection (including the installation of 300 meters of line, transformers, four poles, metering components, and conductors) was estimated at \$3,218 while the PV system cost was \$3,216. Even though the cost savings were insignificant, PV power was chosen because of its environmental and aesthetic benefits.

To date, all project participants have been very satisfied with the performance of the PV system. It has performed according to expectations and has not required any maintenance due to component failures. However, two preventative maintenance visits per year are scheduled at an annual cost of \$20.

FUTURE PLANS

The city plans additional playing fields for the soccer complex, and the irrigation of these fields will be controlled either by the existing PV system or by another similar system.

CONTACT

Chris Benson, Arkansas Industrial Development Commission
Arkansas Energy Office, (501) 682-8065

OTHER CITIES

Littleton, CO

Pond Aeration

Queens, New York

SYSTEM SPECIFICATIONS

Number of Systems:	1
PV Power Output:	240 watts
Operating Voltage:	Not Available
Battery Capacity:	No Batteries
Battery Reserve (from full charge):	No Batteries
Total Cost of PV and Load Equipment:	\$5,000
Estimated Cost for Utility Connection:	\$7,500

The Kissena Lake in Queens, New York, uses PV power for water aeration. Four 60-watt PV modules power an air compressor that aerates the pond during daylight hours. Pond aeration is required to minimize algae growth in the lake and provide a better habitat for the local wildlife. No batteries are required, as the lake receives sufficient aeration during daylight hours.

The cost of the PV system and the compressor was \$5,000. Because the ideal location for the aerator is in the middle of the lake, the compressor floats on a raft in the lake. A utility line would have required 60 meters of underground cable and would have exceeded \$7,500 in cost, but the PV power supply could be floated on the raft.

Since the system was installed in September 1992 and the system was removed for the winter, no performance or reliability information has yet been determined.

CONTACT

Mark Kapner, New York State Power Authority, (212) 468-6725

OTHER CITIES

Highland Park, IL

THE BIG PICTURE

The pond-aeration system in Highland Park, Illinois, has been in operation for 7 years, and state officials estimate that 900 other lakes within the state could benefit from similar PV-powered aeration systems.

Median Water Irrigation

Reddington Shores, Florida

SYSTEM SPECIFICATIONS

Number of Systems:	12
PV Power Output:	5 watts
Operating Voltage:	Not Available
Battery Capacity:	Not Available
Battery Reserve (from full charge):	4 days
Total Cost of PV and Load Equipment:	\$15,000
Estimated Cost for Utility Connection:	\$26,000

The City of Reddington Shores, Florida, in conjunction with Florida Power Corporation, has installed 12 PV-powered median irrigation systems. Each system supplies electricity to a controller and low-power water valve actuators. One 5-watt PV module supplies sufficient energy for these requirements and 4 days of year-round battery storage.

Each PV system was considerably less expensive than the cost of providing power from the nearest electrical line. Though the electrical line averaged only 12 meters from the controller and actuators, the cost of boring under heavily traveled roadways was high. The cost to bring power to each median irrigation system was estimated at \$2,200. Thus, for the 12 median irrigation systems, the cost of connecting to the electric utility was \$26,000. The total cost for purchasing and installing 12 PV systems was \$15,000.

The City of Reddington Shores and Florida Power Corporation are satisfied with the performance of the systems. The only system failure occurred to a controller when it was hit by a car. No maintenance has been required during the six inspections conducted since their installation in March 1991.

CONTACT

Linda Tillis, Florida Power Corporation, (813) 866-5161

OTHER CITIES

Ft. Collins, CO; Salt Lake City, UT; Albuquerque, NM; Tempe, AZ; Encinitas, CA;L
Palm Desert, CA

THE BIG PICTURE

Manufacturers of PV-powered irrigation systems have sold more than 2,500 systems across the country. Due to monthly utility fees, several communities are considering replacing utility connected irrigation controls with PV power.

Emergency Call Boxes Sacramento, California

SYSTEM SPECIFICATIONS

Number of Systems:	22
PV Power Output:	5 watts
Operating Voltage:	12 volts dc
Battery Capacity:	10 amp-hours
Battery Reserve (from full charge):	20 days
Total Cost of PV and Load Equipment:	\$73,000
Estimated Cost for Utility Connection:	N/A

The Sacramento County Department of Parks and Recreation has installed 22 PV-powered emergency telephone boxes along the American River Parkway. This park consists of 2,000 hectares (5,000 acres) along a 37-kilometer (23-mile) stretch of river that passes through Sacramento. The call boxes were installed to increase safety and prevent vandalism along the trail. Electricity supplied by one battery powers the phone box 24 hours a day. The battery can maintain 20 days of low-level operation without sunlight. This battery can be fully recharge from the 5-watt PV module.

The phone units were installed over a 4-year period, from 1988 to 1992. Each unit costs \$3,320—for a total of \$73,000. Utility service was neither available nor an option, due to the park's location in a flood plain and its classification as a riparian reserve area.

Officials have been satisfied with the performance of the system during the past 4 years. No component failures or maintenance has occurred since the units were installed.

CONTACT

Gary Kukkola, Sacramento County Department of Parks and Recreation
(916) 366-2283

OTHER CITIES

New York, NY; Palm Beach, FL; City of Chattanooga, TN; Dallas, TX; Grapevine, TX;
Oakland, CA

BIG PICTURE

More than 340 emergency call boxes have been installed in parks, on college and university campuses, and in parking lots across the United States

TRAFFIC ENGINEERING

The traffic engineering department for the city provides for the safe use of public roadways. The department, therefore, must alert drivers of hazards (e.g., construction) and speed zones. Furthermore, cities must maintain vehicle flow and traffic pattern data for planning purposes.

In this booklet, we document five PV power applications for traffic engineering departments. These applications are

- Street lighting;
- Schools zone flashers;
- Automatic traffic recorders;
- Traffic hazard signs; and
- Traffic control signs

There are other applications this department should consider. Trailer-mounted PV-powered variable message boards can be used to direct traffic. In addition, traffic can be controlled by PV-powered railroad crossing signals and fire station pre-emption systems.

Traffic Hazard Sign

Carrollton, Texas

SYSTEM SPECIFICATIONS

Number of Systems:	2
PV Power Output:	90 watts
Operating Voltage:	12 volts dc
Battery Capacity:	936 amp-hours
Battery Reserve (from full charge):	18 days
Total Cost of PV and Load Equipment:	\$6,200
Estimated Cost for Utility Connection:	\$6,200

The City of Carrollton, Texas, a suburb of Dallas, uses PV-powered caution signs to alert traffic of an upcoming curve. The diamond-shaped signs posted on either side of the curve warn drivers with a flashing yellow light. The 90-watt PV array charges four deep-cycle batteries. The battery capacity enables the sign to operate 24 hours a day for 18 sunless days. The caution sign, which met all federal regulations and engineering standards, has controls that vary lamp intensity with varying ambient light conditions.

The initial cost estimate for the city to install an underground electric line, based on boring and trenching, concrete pad, and equipment costs, was \$3,100. The cost of the PV powered caution sign (concrete pad, equipment and installation) was also \$3,100. The City of Carrollton decided to use PV instead of the utility service because they had a good experience with PV-powered school zone flashers.

City officials are satisfied with the performance of the systems since their installation in 1991. Not only have the flashers performed according to expectations, but there have been no component failures. For preventative maintenance, the city budgets \$50 for one site-visit per year.

FUTURE PLANS

Carrollton is planning to install 10 variable-message signs that will direct traffic away from streets during flood conditions.

CONTACT

Richard Gurley, City of Carrollton, (214) 446-3609

OTHER CITIES

Washington, DC; Fayetteville, NC; Lexington, KY; Kansas City, KS; Roswell, NM; Flagstaff, AZ; Tucson, AZ; Los Angeles, CA; Bishop, CA

THE BIG PICTURE

Eleven state transportation departments currently use PV-powered traffic hazard signs. These states are Alaska, Arizona, California, Florida, Kansas, Louisiana, Oregon, New Mexico, North Carolina, Montana, and Vermont.

School Zone Flashers

Carrollton, Texas

SYSTEM SPECIFICATIONS

Number of Systems:	30
PV Power Output:	90 watts
Operating Voltage:	12 volts dc
Battery Capacity:	468 amp-hours
Battery Reserve (from full charge):	12 days
Total Cost of PV and Load Equipment:	\$102,000
Estimated Cost for Utility Connection:	N/A

The City of Carrollton, Texas, has installed 30 PV-powered school zone flashers for 15 schools. A 90-watt PV array charges two deep cycle batteries that power the flashers (one or two 35 watt halogen lamps) and the programmable controls. The flashers are used during the school year (fall, winter, spring) and can maintain operation for 12 sunless days when the battery is fully charged.

Installation of a grid-connected flasher (including the wire, pole, controls, sign, and flashers, as well as underground trenching of approximately 300 meters) was estimated to cost \$7,000. The cost to install a similar system using PV power instead was only \$3,400. The City of Carrollton also pays \$50 per site for a yearly preventative maintenance visit.

Since their installation in 1990, city officials have been extremely satisfied with the performance. Not only have the flashers performed according to expectations, but there have been no component failures. The residents of the city are also satisfied with the systems, and many have complemented the city. City officials have stated that they "have received more positive comments and pats on the back" for the PV-powered school zone flashers than on any other recent city project.

PLANS FOR THE FUTURE

Since these installations, Carrollton has made it a policy to install only PV-powered flashers. The city not only saves money but reduces paperwork and installation time. The city plans to install 75 more PV school zone flashers by the end of 1994. When this project is completed, all the schools in the Carrollton district will have PV-powered flashers.

CONTACT

Richard Gurley, City of Carrollton, (214) 446-3609

OTHER CITIES

Davis, CA; Topeka, KS; Spotsylvania, VA; Gaithersburg, MD; Southgate, MD; Los Alamos, NM

THE BIG PICTURE

Other communities are taking actions similar to Carrollton to change city policies. Los Alamos, New Mexico, has four PV-powered school-zone flashers, and they are thinking of replacing all the utility-connected flashers with PV-powered ones. They feel the PV flashers are more reliable as well as more aesthetically pleasing, as there are no unsightly overhead lines.

Sign Lighting

Grand Junction, Colorado

SYSTEM SPECIFICATIONS

Number of Systems:	2
PV Power Output:	225 watts
Operating Voltage:	12 volts dc
Battery Capacity:	Not Available
Battery Reserve (from full charge):	5 days
Total Cost of PV and Load Equipment:	\$4,600
Estimated Cost for Utility Connection:	N/A

The City of Grand Junction welcomes visitors to their city with a PV-powered road sign that displays the city's name and logo. Two of these signs have been located on either side of the city, on Highway I-70. Three 75-watt modules, located several feet from the sign, charge the batteries. The batteries provide energy for the lights for 8 hours each night. Thus, the lights remain on throughout the night during the summer and until 1 am during the winter. This lighting capacity can be maintained for 5 sunless days. The cost of each PV system was \$2,300—considerably less than a line extension. Furthermore, the systems have performed according to expectation since their installation in 1988.

Additionally, the signs have been well received by the entire community, because the lighted signs provide a pleasing highlight and architectural statement that is in keeping with the city's image.

CONTACT

Tim Woodman, City of Grand Junction, (303) 244-1509

OTHER CITIES

Limon, CO; Las Cruces, NM

THE BIG PICTURE

Billboard lighting is big business throughout the United States. Today, some 500 billboard lighting systems are PV-powered, which excludes the numerous PV-powered signs that have been installed in office parks and housing complexes.

Automatic Traffic Recorders

Missoula, Montana

SYSTEM SPECIFICATIONS

Number of Systems:	2
PV Power Output:	5 watts
Operating Voltage:	Not Available
Battery Capacity:	4 amp-hours
Battery Reserve (from full charge):	15 days
Total Cost of PV and Load Equipment:	\$100
Estimated Cost for Utility Connection:	\$200

The City of Missoula, Montana, installed two permanent PV-powered automatic traffic recorders (ATRs) within the city limits. The units record information regarding traffic flow rates and vehicle velocities, which then can be used in the transportation planning process. The recorded data are preserved by battery power. The battery is charged by either a 5- or 10-watt PV module and maintains 15 days of reserve power.

The PV addition to the ATRs cost \$50 per installation. The cost to power the ATRs using a utility connection, including the meter, wiring and regulator, would have been \$100 per installation, because utility power was at the site (see photograph). In addition to this cost, the city would have been assessed a minimal monthly charge by the local utility. As the low ATR energy requirements were far less than the energy usage implied by the minimum monthly charge, the city could not justify this cost and opted for PV power.

The city is very satisfied with the operation of the PV-powered ATRs, installed in September 1992. To date, the systems have required neither maintenance nor have they experienced any component failures.

CONTACT

Carl Thompson, Traffic Superintendent, City of Missoula, (406) 523-4620

OTHER CITIES

Sioux Falls, SD

THE BIG PICTURE

Transportation departments in 29 states currently use PV-powered ATRs. These states are Alabama, Arizona, Arkansas, Colorado, Florida, Hawaii, Idaho, Illinois, Iowa, Kansas, Louisiana, Michigan, Minnesota, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Rhode Island, South Carolina, South Dakota, Utah, Vermont, Virginia, and Wyoming.

Street Lighting

West Kendall, Florida

SYSTEM SPECIFICATIONS

Number of Systems:	26
PV Power Output:	92 watts
Operating Voltage:	24 volts dc
Battery Capacity:	48 amp-hours
Battery Reserve (from full charge):	4 days
Total Cost of PV and Load Equipment:	\$52,000 less than Utility Option
Estimated Cost for Utility Connection:	N/A

The Bent Tree Community Association, located in a west Miami suburb, installed 26 PV-powered street lights in the summer of 1991. Two 48-watt PV modules charge two batteries. The battery capacity enables the sign to operate 12 hours a night for four nights from a full charge.

The community association decided to use PV instead of the local utility service for three reasons. First, the initial cost of the PV street light was approximately \$2,000 less than the utility service, because of trenching requirements for the electrical line. Second, the city would have raised community taxes in order to pay for these utility street-light costs. Third, the community would have had to pay monthly utility bills for the lights. The high initial costs, tax increases, and monthly payments led the community association to pursue PV as an alternative energy option.

Both community officials and residents have been satisfied with the performance of the systems despite one case of vandalism. In fact, in the aftermath of hurricane Andrew when utility power was out for 33 hours, the only street lighting came from the 26 PV lights.

PLANS FOR THE FUTURE

Within the next 5 years, the Bent Tree Community Association hopes to install 25 additional PV-powered street lights to satisfy the resident's need for more lighting.

CONTACT

Velle Kollin, Bent Tree Community Association, (305) 380-6552

OTHER CITIES

Ft. Lauderdale, FL ; Waverly, IA; Phoenix, AZ; San Diego, CA; Los Angeles, CA

TRANSPORTATION

Many cities have a transportation department that provides services beyond the responsibility of the traffic engineering department. Such a service might be the coordination of the emergency response system along city highways.

One PV power application was documented for the transportation department. This application is

- Emergency call boxes

though there are other applications that might fall into this department. The public transportation department could use PV-powered lighting for its bus stops. The highway department could benefit from an ice-detection system that can be PV-powered. Finally, seldom-used vehicles in all departments could use a PV-powered battery charger.

Emergency Call Boxes

Anaheim, California

SYSTEM SPECIFICATIONS

Number of Systems:	1,100
PV Power Output:	6.5 watts
Operating Voltage:	12 volts dc
Battery Capacity:	17 amp-hours
Battery Reserve (from full charge):	38 days
Total Cost of PV and Load Equipment:	\$ 4,500,000
Estimated Cost for Utility Connection:	\$10,500,000

Anaheim, other cities in Orange County, and CALTRANS, a quasi state and municipal organization, have installed more than 1,100 PV-powered call boxes along urban highways. The call boxes are capable of several functions, including cellular phone communication, diagnostic features (e.g., battery state-of-charge, system self test, etc.), and relaying the call box location to a central computer. One 6.5-watt PV module charges a battery that will last 38 days when a call box is in its lowest state of readiness.

The total cost of the PV-powered call boxes was \$4.5 million—57% less than the \$10.5 million projected cost of a grid-connected call box system with identical capabilities. Besides economics, PV call boxes are portable and can be moved as traffic patterns change.

Installation of the PV call-box system was completed in 1988, and officials are satisfied with its performance. The county does, however, have a maintenance allotment of \$175,000 per year, or \$12.50 per month for each call box. As a result of this program, there have been few component failures in the past 5 years. However, 15 modules have been stolen, and numerous call boxes have been hit by automobiles.

CONTACT

Todd Murphy, Orange County Transportation Commission, (714) 638-9000

OTHER CITIES

New York, NY ; Columbus, OH; Minnesota, MN; Los Angeles, CA; San Diego, CA;
San Bernadino, CA; Paradise Valley, AZ

THE BIG PICTURE

The popularity of PV-powered emergency call boxes is growing. One manufacturer has sold more than 11,250 emergency call boxes to California counties and cities. In addition, officials in New York City have replaced their existing grid-connected emergency call boxes with 800 PV-powered units.

WATER AND GAS UTILITY

The water and gas utilities for a municipality use large quantities of underground piping to deliver services to the city residents. Naturally, these utilities want to measure the amount of water or natural gas that passes through its distribution network, as well as protect the pipes that transport the materials.

Therefore, two PV-power applications were documented for water and gas utilities. These applications are

- Water Metering; and
- Cathodic Protection

However, water and gas utilities should not be limited to these two applications. The utilities could use PV-powered lights for area or pathway illumination, as well as for charging batteries on seldom-used vehicles.

Water-Flow Metering

City of Austin, Texas

SYSTEM SPECIFICATIONS

Number of Systems:	15
PV Power Output:	53 watts
Operating Voltage:	12 volts dc
Battery Capacity:	200 amp-hours
Battery Reserve (from full charge):	15 days
Total Cost of PV and Load Equipment:	\$24,000
Estimated Cost for Utility Connection:	\$75,000

The City of Austin Electric Utility (Austin Electric) is using stand-alone PV systems to provide power to 15 water-flow meters used by the City's Water and Waste Water Department (Austin Water). During 1991, Austin Water began a metering program to determine water-use patterns throughout the system. A sample of 50 water customers, varying in size from large commercial to residential, was selected for the program.

Two types of water-flow meters were proposed by Austin Water—a small meter requiring 0.5 amps at 6 volts dc (3-watt), and another using 1.2 amps at 12 volts (15-watt). Two PV systems were designed and sized to power the two water-meter systems. One PV module (53-watt) was used with a 200-amp-hour, 6-volt battery, to power the small water-flow meters. Four modules with six 80 amp-hour, 12-volt batteries in parallel were used for the larger meters. These specifications provided each PV-powered system with approximately 15 days of battery back-up when fully charged.

When Austin Electric received line extension requests for the 50 meter distance, it determined that using PV systems would be less expensive than grid-connection for 15 of the 50 sites. The initial capital-cost savings for the 15 PV installations were substantial. The distribution line cost at one particular site was estimated to be \$35,000, and the estimated line extension cost for all 15 sites was approximately \$75,000. The total cost for installing the 15 identical PV systems was \$24,000, resulting in an initial savings of \$51,000. In addition, Austin Electric charges a monthly fixed fee of \$12 for each PV system to cover any required maintenance and future battery replacements.

PLANS FOR THE FUTURE

Because of the success of the 15 installations, Austin Electric is implementing a program that will enable utility personnel to identify potential PV applications in the city. As requests for line extensions are submitted by customers, including other city departments, the utility designers will use a screening method to identify possible cost-effective PV installations.

CONTACT

John Hoffner , City of Austin, Electric Utility, (512) 322-6284

OTHER CITIES

Steamboat Springs, CO; Phoenix, AZ; San Francisco, CA

Cathodic Protection Las Vegas, Nevada

SYSTEM SPECIFICATIONS

Number of Systems:	2
PV Power Output:	288 watts
Operating Voltage:	Not Available
Battery Capacity:	1,000 amp-hours
Battery Reserve (from full charge):	6 days
Total Cost of PV and Load Equipment:	\$18,000
Estimated Cost for Utility Connection:	N/A

The Las Vegas Valley Water District, in conjunction with the Bureau of Reclamation, installed two cathodic protection systems on the water pipeline leading from Lake Mead to downtown Las Vegas. The cathodic protection systems supply dc power to the steel pipe preventing galvanic corrosion, which occurs commonly in unprotected underground pipes. Eight PV modules supply 288 watts of dc power to six batteries in each system for 6 days of reserve power.

The cost of each PV system, which included modules, batteries, controls, and installation, was \$9,000. Even though utility service lines were only 30-60 meters away, PV power was used because it produced dc power directly and, therefore, was ideally suited for cathodic protection.

Both the water district and the Bureau of Reclamation have been satisfied with the operation of the PV-powered cathodic protection systems since their installation in February 1983. Representatives from each organization visit the site annually for preventative maintenance checks. The systems have experienced no component failures and only one case of vandalism.

CONTACT

Harry Remmers, Bureau of Reclamation , (303) 236-5997

OTHER CITIES

Denver, CO; Amarillo, TX

THE BIG PICTURE

The transportation departments in North Carolina and Florida are using PV-powered cathodic protection systems on steel bridges.

PLANNING

The city's Planning Department has several responsibilities that range from implementing billboard advertising regulations to ensuring a safe city for the residents. Therefore, two PV-power applications were documented for planning departments. These applications are

- City sign lighting; and
- Community warning sirens

Additional applications to consider include an emergency communication system setup to link decision-makers in the event of an emergency (e.g., hurricane or tornado) when utility power has been terminated, and emergency portable power units for deployment during disasters that interrupt the city's communication.

Community Warning Sirens

Lakewood, Colorado

SYSTEM SPECIFICATIONS

Number of Systems:	2
PV Power Output:	225 watts
Operating Voltage:	12 volts dc
Battery Capacity:	Not Available
Battery Reserve (from full charge):	5 days
Total Cost of PV and Load Equipment:	\$4,600
Estimated Cost for Utility Connection:	N/A

The City of Lakewood, Colorado, has installed 21 community warning sirens throughout the city. These sirens will warn residents of extreme weather conditions, such as tornadoes. The sirens are activated by a central console located on one of the sirens. Two deep-cycle batteries can power the sirens for 30 minutes when fully charged. The batteries are charged by two 40-watt PV modules.

The primary reason for using PV-powered systems is reliability. In the event of a natural disaster, a grid-connected system would likely be rendered inoperable, but the PV system would not. An estimated cost for connecting the 21 sirens to the local utility was not determined, but the city believed that the PV cost was lower. In addition to the cost of equipment, easements and rights-of-way would have been required for each site.

The city has been satisfied with the operation of the sirens since they were installed in the fall of 1986. The budget for maintaining the siren systems is \$4,000 per year. This funding allows for six preventative maintenance visits per year for each site, as well as any required equipment replacement. To date, there has only been one component failure, though a number of vandalism incidents have been reported.

CONTACT

Richard Nielsen, City of Lakewood, (303) 332-6288

OTHER CITIES

Aurora, CO

Other Uses for Photovoltaic Applications

The previous case studies have illustrated 14 cost-effective PV applications for various municipal departments. However, there are many other applications that have not been documented. Either there was not enough information about the application (e.g., vehicle battery charging) or it was not certain if a municipality would have jurisdiction over the applications (e.g., railroad crossing signs). This section discusses eight PV applications that municipalities should consider when implementing new service programs. These eight applications are

- Railroad crossings;
- Road ice detection system;
- Variable message boards;
- Fire station pre-emption system;
- Traffic control sign;
- Fleet vehicle battery charging ;
- Bus stop shelter lighting;
- Portable power; and,
- Emergency communication system

Railroad Crossings

Railroad tracks that bisect city streets require a signal to stop vehicle traffic when trains are present. These signals, which are flashing lights, can be PV-powered. Available as a turnkey system from a limited number of manufacturers, these systems have been used by railroad companies and some state departments of transportation. For example, Burlington Northern Railroad, headquartered in Denver, Colorado, installs PV-powered flashers on a regular basis. To date, an estimated 50 installations exist along Burlington's service lines.

Bridge Ice Detection

The Massachusetts Department of Transportation has a bridge ice detection system operating on the Massachusetts Turnpike. The PV-powered system monitors ambient conditions (e.g., temperatures, humidity, etc.) that lead to ice formation. When these conditions exist, the PV system triggers and sends a radio signal to the highway department.

Variable Message Boards

Variable message boards are available today as a packaged system. These boards, which are typically used at roadway construction sites, help direct or inform vehicle drivers with more than 250 messages in 100 possible sequences.

Fire Station Traffic Pre-emption

During an emergency, fire trucks must leave fire stations quickly. Stop lights are often placed on the roadway outside the station to stop traffic and allow fire trucks to proceed. Fire station traffic pre-emption systems automatically signal the stop lights to turn red. The expensive boring and trenching process, associated with the traditional utility approach, can be avoided by using PV. The PV system can be small—a 40 watt module and 20 amp-hours of battery capacity.

Traffic Control Sign

A PV-powered “arrow board” can be used to control traffic while streets are under construction. The PV arrow board can save money compared to engine-powered arrow boards due to the reduced labor (i.e., no refueling, oil changes, or other engine maintenance procedures) and materials (oil and fuel).

Fleet Vehicle Battery Charging

A PV battery charger can easily solve the problem of self-discharge in vehicles that are used infrequently. The PV charger can be placed on the dashboard of the vehicle and plugged into the cigarette lighter. When the sun hits the module, a small current trickle-charges the battery.

Portable Power

A portable PV-power unit could be used for multiple purposes, including emergency situations when electrical utility service is not available and for more routine situations. For example, one city uses a PV generating system to power a PA system and lighting equipment. This system is used, free-of-charge, by community organizations during festivals and other outdoor activities. Thus, the city can provide power as a service without using electrical outlet locations and securing the electrical cords.

Emergency Communication System

Several cities have purchased PV-powered emergency communication systems. These portable systems come with an emergency light, AM/FM radio, and a two-way mobile CB. A briefcase houses this equipment and the PV module.

Bus Stop Shelter Lighting

Bus stop shelters are often supplied with lighting to prevent vandalism and ensure safety.

CONCLUSIONS

In reviewing options for power sources in municipal applications, planners should consider photovoltaics, especially in instances where the load is small, the location is not convenient to an existing power line, or aesthetic or environmental concerns come in to play.

PV is a reliable, non-polluting, often portable energy source. It uses no moving parts and will work silently for decades.

Municipalities in all geographic and climactic regions of the country are using PV for applications ranging from emergency call boxes on highways to traffic control signs near schools and fire stations.

Whether local concerns are environmental or economic, PV is finding a home in urban America.

Manufacturers/Vendors of Packaged PV-Powered Applications

Street/Pathway Lighting

Ascension Technology, 617-890-8844
Electric Solar Products
Geosolar Energy Systems, Inc.
Hoxan America, Inc., 908/980-0777
Kyocera America, Inc., 619/576-2600
Lab Craft LTD.
Mobil Solar Energy Corporation, 508/667-5900
Omega Electronica, S.A.
Photocomm, Inc., 602/948-8003
Photowatt International S.A.
Precision Solar Controls, Inc., 214/278-0553
SAB Nife Power Systems, 919/830-1600
Scientific Analysis
Sharp Corporation
Solar Electric Engineering, 707/586-1987
Solar Electric Systems of Kansas City
Solar Outdoor Lighting
Solarex Corporation, 301/698-4200
Solec International, Inc., 310/970-0065
SunAmp Power Company, 602/833-1550

Irrigation

Photocomm, Inc., 602/948-8003
Soletrol

Traffic Hazard Signs

Electric Solar Products
Hoxan America, Inc., 908/980-0777
Kyocera America, Inc., 619/576-2600
Photocomm, Inc., 602/948-8003
Precision Solar Controls, Inc., 214/278-0553
SAB Nife Power Systems, 919/830-1600
Solar Electric Engineering
Solar Electric Systems of Kansas City
Trantex

Traffic Control Signs

Arron Chein Inc.
Allmand Bros., Inc.
Electric Solar Products
Fiberbrite Corporation
Hoxan America, Inc., 908/980-0777
Patterson and Associates
Power Plus, Inc.
Protection Services, Inc.

Renco, Inc.
Service & Materials Co., Inc.
Simpler Solar Systems, Inc., 904/576-5271
Sistemi Energetici Integrati (SEI)
Solar Tek
Sunwise Energy Systems, Inc., 914/687-6700
Trafcon Industries
Whelen Engineering Company
Work Area Protection Corporation

Railroad Signals

Integrated Power Corporation, 301/294-9133
Photocomm, Inc., 602/948-8003
Sistemi Energetici Integrati (SEI)
Suntrapper, 210/341-2001

Cathodic Protection

BP Solar Systems, LTD.
Integrated Power Corporation, 301/294-9133
Kyocera America, Inc., 619/576-2600
Photowatt International, S.A.
Solarex Corporation,
SunAmp Power Company, 602/833-1550

Emergency Call Boxes

Comarco
Cubic Communications
Electric Solar Products
GTE, 714-727-3021
Integrated Power Corporation, 301/294-9133
Solar Electric Engineering

Portable Power

ECS, 904-377-8866
Northern Power Units, 802/496-2955
Photocomm, Inc., 602/948-8003
SunAmp Power Company, 602/833-1550

School Warning Flashers

Photo Volt
Precision Solar Controls, Inc., 214/278-0553
Simpler Solar Systems, Inc., 904/576-5271
RGA, 804/794-1592

Emergency Communication

Solec International Inc., 310/970-0065

Bus Stop Lighting

Hoxan America, Inc., 908/980-0777
Photocomm, Inc., 602/948-8003
Solar Outdoor Lighting

Solec International, Inc., 310/970-0065
SunAmp Power Company, 602/833-1550

Sign Lighting

Kyocera America, Inc., 619/576-2600
Photocomm, Inc., 602/948-8003
Solar Outdoor Lighting
Suntrapper, 210/341-2001
Western Lighting

Variable Message Signs

Hoxan America, Inc., 201/980-0777
Work Area Protection Corporation

Fire Station Pre-emption Systems

International Solar Control Systems
RGA, 804/794-1592

Road Ice-Detection Systems

Ascension Technology, 617-890-8844

Community Warning Sirens

Federal Signal Corporation, 708-534-3400
Whelen Engineering Company

Vehicle Battery Charging

Earth Options, 800/832-1986
Solec International Inc., 310/970-0065
Suntrapper, 210/341-2001

Traffic General

Atlantic Solar Products, Inc., 410/686-2500
Golden River Instruments, Inc.
Trigg Industries, Inc.

The list does not include PV system suppliers that do not advertise system packages for these applications.

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Key Contacts

GOVERNMENT & INDUSTRY CONTACTS

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1000 Independence Ave., S.W.
Washington, DC 20585**

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City of Littleton, Colorado
Andrew McMinimee (303) 795-3720

Literature References

*Photovoltaics Program Plan
FY 1991 - FY 1995
DOE/CH10093-92
DE91002139
October 1991
Write: NREL, PV Program
1617 Cole Boulevard
Golden, CO 80401-3393*

*Solar Electric Applications and
Directory of the U.S. Photovoltaic Industry
Solar Energy Industries Association
777 North Capitol Street, N.W.
Suite 805
Washington, DC 20002
(202) 408-0660
Fax: (202) 408-8536*

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