

# **Four Federal Grid-Connected Photovoltaic Systems: Powering Our Nation's Capital with Solar**

**Preprint**

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*To Be Presented at the American Solar Energy Society  
(ASES) National Solar Conferences Forum 2001  
Washington, D.C.  
April 21-25, 2001*



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Contract No. DE-AC36-99-GO10337

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## **FOUR FEDERAL GRID-CONNECTED PHOTOVOLTAIC SYSTEMS: POWERING OUR NATION'S CAPITAL WITH SOLAR**

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### **ABSTRACT**

One of the fastest growing markets for photovoltaics (PV) is the urban sector. Municipal planners have discovered that PV systems operate favorably in their urban areas, and can be aesthetically integrated into the urban landscape. The federal government has a long history of using PV in a variety of applications, but until recently few applications have been in urban environments. During the last five years, four grid-connected PV systems have been installed on federally owned or federally leased facilities in the Washington, DC, area:

- Earth Day Park
- U.S. Department of Energy Headquarters
- The Pentagon
- Federal Energy Regulatory Commission Headquarters.

This paper reviews these four urban, grid-connected systems – particularly the issues of siting, permitting, and grid interconnection.

### **1. INTRODUCTION**

One of the fastest growing markets for photovoltaics (PV) is the urban sector. Cities and municipalities across the United States have discovered that PV is the best source of power for lighting bus shelters, bus stops, parking facilities, emergency call boxes, remote area lights, and variable message signs for highway traffic control. Municipal planners have also discovered that PV systems operate favorably in their urban areas, and can be aesthetically integrated into the urban landscape.

The federal government has a long history of using PV in a variety of applications, but until recently few applications have been in urban environments. Executive Order 13123, enacted in June 1999, sets a goal of 2,000 solar energy systems installed at federal facilities by the end of 2000 and 20,000 solar energy systems at federal facilities by 2010. (1) Currently, the federal government purchases more than 210,000 megawatt hours (MWh) annually of renewable electricity.

“For years we’ve seen the successes of the federal government’s use of off-grid photovoltaic applications, especially in the National Park Service and the Department of Defense,” said Elizabeth Shearer, director of the Federal Energy Management Program. “And now we are seeing grid-connected federal PV systems, which will generate clean energy for years to come. These grid-connected systems are significant because they are beacons showing us the possibilities for providing reliable non-polluting approaches to our secure energy future.” (2)

Off-grid PV applications, such as variable message signs and emergency call boxes, have been successfully used in metropolitan Washington, DC, for a number of years. Recently, the Washington Metropolitan Area Transit Authority (METRO) installed three solar-powered lighting devices at several of their bus shelters and stops. Also, PV-powered outdoor lighting is being installed at Anacostia Park in southeast Washington, DC. Grid-connected PV systems in urban environments have more complicated siting and installation aspects than their counterparts in rural settings.



Figure 1. View of the Earth Day Park PV system. In the background across the street is the Smithsonian's Arts and Industries Building. (Photo: B. Stafford)

During the last five years, the National Renewable Energy Laboratory (NREL) has facilitated four grid-connected PV systems that have been installed on federally owned or federally leased facilities in the Washington, DC, area:

- Earth Day Park
- U.S. Department of Energy Headquarters (DOE)
- The Pentagon
- Federal Energy Regulatory Commission Headquarters.

Experience with the projects proved that the consideration of approval and permitting issues is critical when installing a PV system in an urban environment. Approval and permitting requirements depend on the size and visibility of the PV system, the existing electric system within the building, and the building's location. The following reviews siting and permitting issues, as well as installation options and grid interconnections.

## 2. EARTH DAY PARK

Date dedicated	April 22, 1996
Size:	1.5 kW <sub>dc</sub>
Production:	2,200 kWh per year
Location:	Earth Day Park 1000 Independence Ave., S.W. Washington, DC
Utility:	Potomac Electric Power Company
Responsible party:	U.S. Department of Energy

In April 1996, former secretaries Hazel O'Leary, U.S. DOE and Federico Peña, U.S. Department of Transportation (DOT), dedicated this grid-connected PV array on land donated to the District of Columbia by both DOE and DOT. NREL and DOE's Engineering and Facilities Division worked with the District of Columbia government to secure the required permits. A briefing was held with Potomac Electric Power Company (PEPCO) to resolve interconnection issues. A Memorandum of Understanding was drawn up between the two federal departments and the District of Columbia regarding the use of the land.



Earth Day Park (formerly known as 9<sup>th</sup> Street Park) is bordered by Independence Avenue (north), C Street, (south), 9<sup>th</sup> Street (east) and the I-395 access ramp (west). The park is located directly over a freeway underpass leading to a traffic tunnel under the Mall, where the park actually forms the tunnel roof.

At DOE's request, NREL developed a conceptual design and worked with DOE to secure the necessary permits and approvals. The Commission of Fine Arts received a briefing on the PV system and gave their approval. Also, DOE secured a building permit from the Government of the District of Columbia, Department of Public Works, for the structure on top of the METRO stairwell. (3) PEPCO reviewed and approval the electrical interconnection. A locally licensed electrician made the final connection to the utility.

After all the permits and approvals had been secured, NREL fabricated and installed the PV system. Six ASE Americas modules are connected to a 4-kilowatt (kW) Trace sine wave inverter. This system is connected to the PEPCO utility grid and offsets the power consumed by the area lights for the park. A sign with a kWh meter provides description of the solar energy system and the park.

The Earth Day Park system is mounted over an abandoned pedestrian entrance to the METRO. Originally, the stairwell was closed, and installing the PV system was relatively easy. The mounting structure was made of aluminum angles with plywood sides. However, in 1998 METRO wanted to increase ventilation in the I-395 traffic tunnel, so the PV mounting structure had to be redesigned to accommodate air flow into the stairwell. This required a higher mounting structure that was ventilated, yet still designed to discourage vandalism. A custom-engineered aluminum superstructure with perforated aluminum side panels was made and placed over the stairwell.

### 3. U.S. DEPARTMENT OF ENERGY HEADQUARTERS

Date dedicated	April 21, 1999
Size:	3 kW <sub>dc</sub>
Production:	4,500 kWh per year
Location:	Forrestal Building 1000 Independence Ave, S.W. Washington, DC
Utility:	Potomac Electric Power Company
Responsible party:	U.S. Department of Energy



Figure 2. View of U.S. Department of Energy's cantilevered PV system on the Forrestal Building. (Photo: B. Stafford)

Cantilevered off the south wall of the Forrestal Building on Independence Avenue, this 3-kW PV system generates power that is used by the DOE Headquarters. In late 1998 and early 1999, NREL performed a site survey, developed a system design, and installed the PV system, which includes a kWh meter to show the amount of energy generated. Since the General Services Administration (GSA) is responsible for the building, they performed an analysis of the loading on the wall and determined where the module supports should be placed. Also, PEPCO played a significant role in the successful installation of this system by agreeing to and approving the interconnection design in a timely manner. Twelve ASE Americas modules are mounted at a 45° tilt to the support brackets attached to the south wall. The system is connected to PEPCO's grid inside the Forrestal building via a single-phase, 120-volt, 60-hertz Omnion 2400 inverter. The system operates without storage, supplying energy to the building whenever sufficient solar resource is available for operation. (4)

In April 1999, then Energy Secretary Bill Richardson dedicated this PV system. "We're celebrating Earth Day in our own backyard by installing a solar panel that will help power our headquarters, save taxpayer dollars and protect the environment," (5) he said. The PV system is part of DOE's dedication to using solar power on its own facilities.

#### 4. THE PENTAGON

Date dedicated	June 28, 1999
Size:	15 kW <sub>ac</sub> and 15 kW <sub>dc</sub>
Production:	45,000 kWh per year
Location:	The Pentagon, Arlington, Virginia
Utility:	Dominion Virginia Power
Responsible party:	U.S. Department of Defense

Unlike the cantilevered installation on the Forrestal building, the U.S. Department of Defense (DoD) decided to place its 30-kW PV system on an unused plot of land inside an exit ramp adjacent to the Pentagon. High visibility was a consideration in siting the system since thousands of commuters pass the site daily. To fit the curve of the exit ramp, the arrays were placed in four concentric arcs that follow the contour of the landscape. DoD has used solar power in many of its remote operations for communications and lighting. This PV system generates power for the grid connected to the Pentagon. Moreover, this cost-shared project is a partnership between DoD and DOE to conduct PV reliability research in the field. The project was performed via a Memorandum of Understanding between DoD and DOE. Dominion Virginia Power, Johnson Controls, the Utility Photovoltaic Group, and Schott Applied Power Corp. also provided cost-sharing support. (6)



Figure 3. View of the Pentagon's ground-mounted 30-kW PV system showing 4 arcs of PV modules. (Photo: P. Plympton)

An agreement was reached between Dominion Virginia Power and DoD where DoD supplied an electric interface to Dominion Virginia Power's grid. Dominion Virginia Power is providing detailed monitoring of the power output of this system to learn more about the performance of the AC PV systems, how it matches Pentagon power loads, how well it integrates with the existing electric grid, the quality of the power produced by the system, and whether the PV system will aid power stability. Dominion Virginia Power is a founding partner in the Virginia Alliance for Solar Electricity, a program to provide cost sharing for and evaluation of residential and commercial PV installation in the mid-Atlantic area.

In December 1998, NREL performed a site survey and conceptual design for the Pentagon at DOE's request. NREL subsequently developed the specification and procurement for the first phase of the system. This PV system was completed in two phases — the first 15 kW was installed in June 1999 and the second 15 kW in October 1999. Ascension Technology designed and installed both phases of the system. (7) The Federal Energy Management Program initiated the second phase. Originally conceived as part of the Greening of the Pentagon initiative, 60 Ascension Technology (now part of Schott Applied Power Corporation) SunSine® 300 AC modules were installed on the grounds of the Pentagon for a dedication ceremony in April 1999. These AC modules integrate a large-area PV module with a small inverter on each panel, allowing for redundant backup in case of inverter failure. The actual capacity of the first phase is 17 kW due to higher-than-specification performance from the PV modules.

The second phase includes two conventional DC arrays containing 64 ASE Americas PV modules and two Trace Technologies 10-kW inverters. Each array, supplying separate inverters, is comprised of four monopolar source circuits, each containing four modules. The 10-kW inverters' 208-volt, three-phase output passes through a 9-kilovolt-amp (kVA) isolation transformer and is connected to the same load center that collects the output of the AC module array. (8)

##### 5. FEDERAL ENERGY REGULATORY COMMISSION HEADQUARTERS

Date dedicated	January 18, 2001
Size:	2.4 kW <sub>dc</sub>
Production:	3600 kWh per year
Location:	888 First Street, N.E. Washington, DC
Utility:	Potomac Electric Power Company
Responsible party:	Federal Energy Regulatory Commission Headquarters



Figure 4. View of roof-mounted FERC PV system.  
(Photo: P. Plympton)

The Federal Energy Regulatory Commission (FERC) moved to its new headquarters building at 888 First Street, N.E., in 1994. Since that time, FERC, in conjunction with the building owner, has incorporated a number of energy-efficiency measures that not only substantially improved the building's performance, but also resulted in at least one prestigious award. In 1997, FERC received a cost estimate for a 10-kW PV system from the building's designers; however, the proposal was not pursued at that time.

In January 2000, at the request of FERC, NREL staff and DOE program management performed a preliminary site survey of the FERC headquarters building to investigate the feasibility of installing a PV system on their roof. NREL suggested that the PV system be mounted on a steel framework, which in turn is supported by roof jacks and pans to eliminate roof penetrations. (9) In August 2000, NREL staff spent several days at FERC finalizing the site survey, preparing bid specifications for FERC, and coordinating with PEPCO, the local utility. The building is owned and managed by Union Center Plaza Management, Inc., who were supportive of the project and provided invaluable assistance.

In a strict sense, this PV system is not a grid-interconnected system. After applying for a grid-interconnection



agreement, PEPCO's engineering review stated that network protectors protect their grid from reverse power flow from the building complex to their grid. At that location, no PV system, or any other cogeneration source, can feed power back into PEPCO's grid. The network protectors are designed to trip under very small reverse currents. The PV system acts like a grid-interconnected system only because the PV-generated power will always be less than the building's demand. The minimum building load is always greater than 50 kW, whereas the PV system is rated at 2.4 kW. While a grid-interconnection agreement was not needed, it was critical to work with the local electric utility.

Regarding other permitting and approval issues, since the FERC building is neither in a residential nor historic district, there were no codes, covenants, or restrictions relevant to installing an unobtrusive PV system on the roof. However, building and electrical permits were needed.

In November 2000, FERC initiated the procurement, with cost sharing by DOE's Office of Solar Technologies and assistance from DOE's Federal Energy Management Program. The 2.4-kW system was installed on January 15-17, 2001, by Ascension Technology, a division of Schott Applied Power Corporation, using Aurora Energy, a local solar installer based in Annapolis, Maryland. The system uses eight ASE Americas panels and a Trace Sun-Tie inverter, and the installation was completed in three days. An LED readout display will be placed in the first floor lobby along with text and photographs.

On January 18, 2001, former FERC Chairman, the Honorable James Hoecker, dedicated the PV system on the roof of the 11-story headquarters building near Union Station. At the dedication, Chairman Hoecker said, "Today we set an example for other federal installations and energy consumers in our nation with the addition of this small but significant energy source. This PV system is a glimpse of the future of energy use. Because energy is the FERC's business, we want to demonstrate one way we can have an energy-secure future. As we struggle with serious energy supply and clean air problems in the western U.S., we should remember that a diverse supply portfolio and generation offer at least part of the solution." (10)

## 6. SUMMARY

These recently installed PV systems are providing environmental benefits. The total annual energy generated from these four systems is approximately 59,300 kWh. According to an EPA web site on global warming, use of these PV systems, which total 36.9 kW, avoids the annual emission of 68,488 lbs. of CO<sub>2</sub>, 346 lbs. of SO<sub>x</sub>, and 174 lbs. of NO<sub>x</sub>. The CO<sub>2</sub> savings alone are equivalent to the emissions from driving 115,243 miles in an average

passenger car, and equivalent to the amount of CO<sub>2</sub> absorbed by approximately 13 acres of trees in one year! (11)

For successful installations in urban areas, it is essential to secure the necessary permits and approvals well in advance of anticipated installation. Depending on the municipality or city, there could be multiple governing organizations that have responsibility for issuing permits and approvals. For example, in Washington, DC, approvals and/or permits were needed from the District of Columbia's government, such as, the Department of Parks and Recreation, PEPCO (local utility) and the Commission of Fine Arts. It is important that a locally licensed electrician make the final interconnection to the grid. It is possible to have PV systems in the urban environment that can be aesthetically integrated into the urban landscape.

## 7. ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy under Contract No. DE-AC36-99GO10337.

## 8. REFERENCES

- (1) Executive Order 13123, President William Clinton, June 1999 (available at <http://www.eren.doe.gov/femp/aboutfemp/exec13123.html>)
- (2) Conversation with Elizabeth Shearer, Director of FEMP, Washington, DC, January 24, 2001
- (3) Conversation with Cherylynne Williams, Special Assistant to the Director, Engineering and Facilities Management, U.S. Department of Energy, January 24, 2001
- (4) Statement of Work: Installation of Photovoltaic System for the Forrestal Building
- (5) U.S. Department of Energy, "Solar Energy, Pollution Prevention Take Center Stage in Earth Day Recognition Activities," press release, April 21, 1999
- (6) Bing, J., "PV at the Pentagon," *Solar Today*, pp. 32 – 35, Jan/Feb 2000
- (7) Ibid.
- (8) Ibid.
- (9) Plympton, Patricia and Thornton, John, NREL, "Site Survey for a Photovoltaic (PV) System at the Headquarters of the Federal Energy Regulatory Commission (FERC)," February 23, 2000
- (10) Conversation with James Hoeker, Chairman of FERC, Washington, D.C., January 18, 2001
- (11) EPA Global Warming Site: <http://199.223.18.230/epa/rew/rew.nsf/solar/index.html>, accessed January 22, 2001



<b>REPORT DOCUMENTATION PAGE</b>			<i>Form Approved</i> OMB NO. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 2001	3. REPORT TYPE AND DATES COVERED Conference Paper		
4. TITLE AND SUBTITLE Four Federal Grid-Connected Photovoltaic Systems: Powering Our Nation's Capital with Solar (Preprint)			5. FUNDING NUMBERS  BE00.1001	
6. AUTHOR(S) Patricia Plympton, Patty Kappaz, Benjamin Kroposki, Byron Stafford, and John Thornton				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3393			8. PERFORMING ORGANIZATION REPORT NUMBER NREL/CP-710-29050	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161			12b. DISTRIBUTION CODE	
13. ABSTRACT ( <i>Maximum 200 words</i> ) One of the fastest growing markets for photovoltaics (PV) is the urban sector. Municipal planners have discovered that PV systems operate favorably in their urban areas, and can be aesthetically integrated into the urban landscape. The federal government has a long history of using PV in a variety of applications, but until recently few applications have been in urban environments. During the last five years, four grid-connected PV systems have been installed on federally owned or federally leased facilities in the Washington, D.C. area: (1) Earth Day Park, (2) U.S. Department of Energy Headquarters, (3) the Pentagon, and (4) Federal Energy Regulatory Commission Headquarters. This paper reviews these four urban, grid-connected systems—particularly the issues of siting, permitting, and grid interconnection.				
14. SUBJECT TERMS photovoltaics; PV; grid-connected PV; municipal planning; urban planning; siting; permitting; grid interconnection			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT  UL	