

GPG-005 | DECEMBER 2012

PHOTOVOLTAIC SYSTEM PERFORMANCE



Researchers Perform Climate-Specific Assessment of Multiple PV Systems

Photovoltaic systems represent a promising source of renewable energy. Whether they are practical, however, depends on the specific PV technology in question, the application, the cost of energy, and the location of the installation, among other things. With these issues in mind, GSA's GPG program recently assessed five different PV systems installed at the Bean Federal Center in Indianapolis, Indiana. The five systems fall into two categories, one containing a single commercial-scale, 2 megawatt (MW), high-efficiency crystalline PV system, the other containing four smaller "laboratory" systems, each roughly 3 kilowatts (kW) in size and utilizing a different photovoltaic material, construction, or design. The objective of the commercial-scale system study was to investigate the practicality of on-site, large-scale renewable energy generation on a Federal property in a Midwestern climate. It focused on quantifying cost savings, reducing dependency on fossil fuels, and reducing greenhouse gas emissions. The purpose of the laboratory systems study was to determine which of the four technologies, if any, offered a clear performance advantage in a diffuse, four-season climate. Findings for the commercial-scale system include a 7.9% overall site load reduction, while laboratory findings argue that none of the systems evaluated has a clear advantage over others under cool, cloudy skies.

INTRODUCTION



“More than 90% of our in-state electricity generation is coal-based. Efficient PV has a considerable impact on our carbon footprint.”

Todd Reeder
Property Manager, FMA
Major General Emmett J. Bean Federal Center
Indianapolis, Indiana
GSA

What We Did

PERFORMANCE DATA COLLECTED OVER THE FIRST YEAR OF OPERATION

As part of a modernization project at the Bean Federal Center, funded by the American Recovery and Reinvestment Act, five PV systems were installed. Because few studies have been conducted that investigate performance and economics of PV installations in the Midwest, GSA's GPG program worked with researchers at Sandia National Laboratories and New Mexico State University's College of Engineering to evaluate the systems during their first year of service, a 12-month period beginning in May of 2011 and ending in April 2012. To provide high quality production and performance data, researchers built and installed a dedicated, laboratory-grade data acquisition system (DAS), which monitored research parameters such as PV module temperature and sunlight intensity. To supplement the DAS instruments, the local utility, Indiana Power and Light, installed revenue meters that recorded the systems' total AC energy production.

PERFORMANCE SPECIFICATIONS

Energy Efficiency

EFFICIENCY

High-Efficiency Crystalline	19.5%
Medium-Efficiency Crystalline	13.4%
Thin-Film Panel	9.0%
Thin-Film Cylindrical	7.7%
Thin-Film Laminate	6.3%

What We Measured

EVALUATION OF LARGE AND SMALL SYSTEMS INCLUDED WIDE RANGE OF PARAMETERS

The commercial-scale high-efficiency crystalline PV assessment utilized both the DAS instruments and revenue meter data to achieve the following research objectives: record system energy production, calculate system efficiency per installed watt and per unit area, validate pre-installation performance projections, determine what portion of the overall energy load the on-site energy generation represents, calculate life cycle cost and system payback period (in years), calculate avoided greenhouse gas (GHG) emissions, and finally, investigate different operations and maintenance programs.

The research objectives associated with the laboratory PV systems included a side-by-side comparison of energy production for the four different PV technologies under evaluation, a comparison of clear-sky and cloudy-sky performance efficiencies among the four systems, and a calculation of overall efficiency of each system per installed watt and per unit area of roof covered.

FINDINGS



COMMERCIAL-SCALE SYSTEM GENERATES 7.9% OF SITE LOAD The large PV system installed at the Bean Federal Center generated 2,384,138 kWh in the 12-month study period. This represented 7.9% of all energy used at the Bean Federal Center and was enough energy to supply the annual electricity needs of 216 average Indianapolis homes. On-site energy generation by this system also offset the purchase of utility-generated electricity, produced, in large part, by the burning of coal. GHG emissions avoided were equivalent to taking approximately 434 cars off the road.



A SIMPLE PAYBACK OF 19 YEARS Based on annual revenue of \$524,510 (2,384,138 kWh x 22 cents/kWh), it will require 19 years to reach a simple payback value equal to the initial purchase price of the large PV system (\$8,700,000 plus an annual operations-and-maintenance cost of \$25,000). This is well within the life expectancy of the high-efficiency crystalline PV system, which is approximately 25 years. Revenue, in this case, is the sum of avoided energy purchase (2 cents/kWh) and the IPL renewable-energy incentive (20 cents/kWh) that is currently in place. It should be noted that steady worldwide decline in PV cost will also positively influence payback.



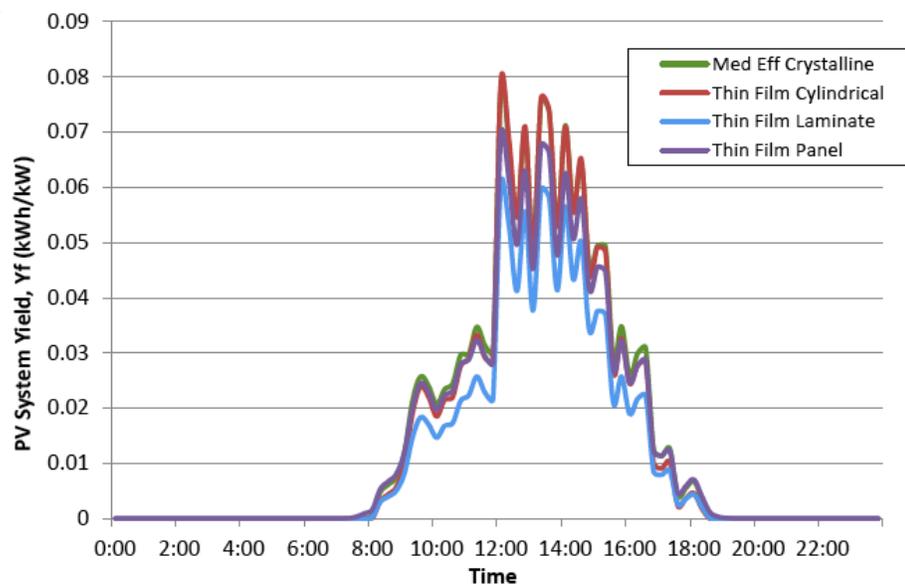
PARITY AMONG LABORATORY SYSTEMS UNDER CLOUDY SKIES Over the course of the 12-month assessment period, Thin Film Cylindrical PV produced more energy and more energy per installed watt than the other laboratory system technologies. However, the small differences in performance among the four technologies under cloudy conditions did not equate to overall favorability in annual energy production.



PRICE SHOULD DRIVE PV SYSTEM SELECTION Given the statutes and executive orders directing GSA to increase renewable energy use, targeted deployment of PV systems is recommended. Parity among the laboratory systems tested in the Midwestern climate suggests that commodity price (cost per watt) should drive PV system selection. If rooftop space is a concern and renewable energy production an objective, efficiency per square foot should also be considered.

Laboratory Systems Perform Similarly Under Cloudy Skies

PV System Yield on Cloudy Day, March 3, 2012



CONCLUSIONS

These Findings are based on the report, “Photovoltaic System Performance, Major General Emmett J. Bean Federal Center” which is available from the GPG program website, www.gsa.gov/gpg

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Technology for test-bed measurement and verification provided by Sunpower, Evergreen Solar, Solyndra, United Solar Ovonic, and Abound Solar.

What We Concluded

COMMERCIAL-SCALE HIGH-EFFICIENCY CRYSTALLINE PV DELIVERS PRACTICAL ENERGY SOLUTION

The commercial-scale high-efficiency crystalline PV system is a practical, on-site energy generation solution, even in a diffuse, four-season climate. It offset 7.9% of the Bean Federal Center’s energy load during the study period, helping the Center meet statutory goals for improving energy performance and reducing GHG emissions. A simple payback of 19 years is well within the technology’s demonstrated lifespan.

Lessons Learned

SYSTEM MODELING IS A HIGHLY ACCURATE PERFORMANCE GUIDE

The commercial-scale high-efficiency crystalline PV system performed almost exactly as the pre-installation models predicted. The 3kW laboratory systems also performed to nameplate expectation. System modeling tools available to energy engineers, building managers, and PV system professionals today are adequate to produce accurate simulation results for both sunny and cloudy climates.

THIN-FILM OUTPERFORMS CRYSTALLINE PV ONLY IN UNIQUE FORM FACTOR

While there has been debate as to whether thin-film PV would outperform crystalline PV in cool, cloudy climates, results from the laboratory study indicate that it does not. The one system that outperformed crystalline PV, the Thin Film Cylindrical system, did so as a result of its unique design and not its thin-film active material. When comparing crystalline and thin-film PV types of similar construction, the crystalline PV outperformed the thin-film systems.

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