General Services Administration
Public Buildings Service

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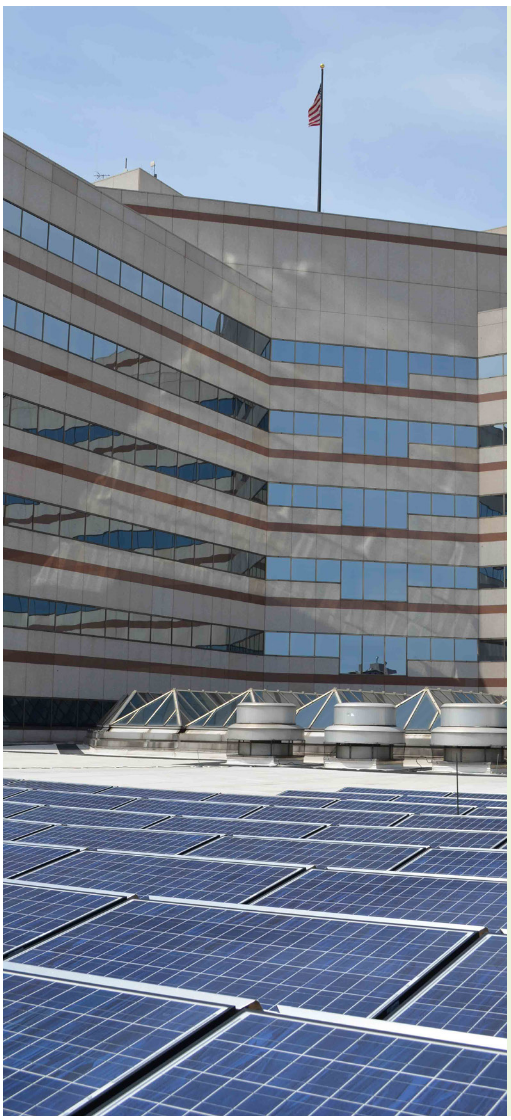
# PHOTOVOLTAIC-THERMAL HYBRID SOLAR SYSTEM

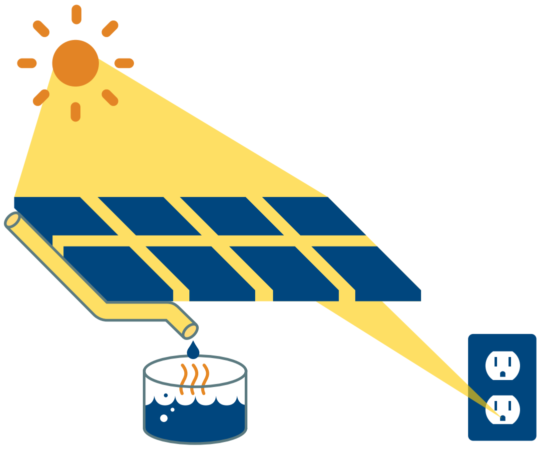


## PV-T Provides Electricity and Thermal Energy in a Single Footprint

In keeping with its long-standing commitment to renewable energy and in response to Federal energy mandates, GSA's New England Region installed the nation's first large-scale unglazed photovoltaic-thermal (PV-T) hybrid solar system at the Thomas P. O'Neill, Jr. Federal Building in Boston, MA. PV-T claims several advantages over separate PV and solar hot water (SHW) systems, including valuable rooftop-space savings and increased electricity production. GSA's GPG program commissioned the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) to provide independent, third-party measurement and verification (M&V) of the O'Neill PV-T system's performance. Because of complications in system design and conflicts in installation and commissioning, not uncommon in the deployment of early commercial technologies, the M&V process did not deliver definitive results. It did, however, provide numerous lessons in system design, as well as a list of best practices. Modeling based on "ideal" PV-T system design found that PV-T should target buildings in locations with high utility costs and electric hot water backup, such as Honolulu, Hawaii.

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance.

# INTRODUCTION



**PV-T Increases PV Panel Efficiency**

by lowering PV temperature and capturing heat for other uses such as domestic hot water

> *"Working through the M&V process taught us a lot about PV-T system design and also where best to deploy this early stage technology in the future."*
>
> —Jesse Dean
> Senior Engineer
> National Renewable Energy Laboratory

**PERFORMANCE SPECIFICATIONS**
O'Neill PV-T — Unglazed Flat-Plate

**SPECIFICATIONS**

| | |
|---|---|
| Gross Area (ft²) | 16.90 |
| Aperature Area (ft²) | 16.90 |
| Weight (lb) | 69 |
| Test Flow Rate (gpm/ft²) | 0.0281 |
| Performance Intercept | 0.34 |
| Performance Slope | 1.95 |
| Efficiency | 33.4% |

## What Is This Technology?

**PV-T COMBINES PV PANELS WITH SOLAR THERMAL COLLECTORS**

Conventional PV panels convert up to 20 percent of solar energy into electricity. Most of the energy that is not transformed into electricity is converted into heat, and because PV modules are semiconductor devices, they become less efficient as their temperatures rise. PV-T technology is a hybrid system that combines PV panels with solar thermal collectors and capitalizes on the untapped heat energy of the PV system. Water or air flowing through the thermal collector removes and captures heat from the PV cells, allowing a larger portion of the solar energy incident on the collector to be turned into either thermal or electrical energy. By combining the two technologies (PV and SHW) in one physical profile, PV-T increases energy production efficiency while occupying less space than would be required by separate PV and SHW systems.

PV-T technology includes a wide variety of products and configurations. The O'Neill Federal Building PV-T system used unglazed solar collectors that attach to the back of off-the-shelf PV panels.

## What We Learned

**BEST PRACTICES AND DESIGN DIRECTION FOR FUTURE INSTALLATIONS**

With support from Group 14 Engineering, a Colorado-based energy-systems subcontractor, NREL monitored the O'Neill Federal Building's PV-T system over a period of seven months. One of the study's primary goals was to identify what worked in the O'Neill Federal Building's PV-T system and what needed improvement. The following two sections, Best Practices and Design Direction, summarize the research team's discoveries.

# BEST PRACTICES

**IMPLEMENT EFFICIENCY FIRST** Analyze DHW equipment prior to the installation of an SHW system. Implement all reasonable water conservation and energy efficiency opportunities before sizing a solar thermal system.

**USE ACCURATE COMPONENT AND SYSTEM DESIGN TOOLS** Use a detailed hourly analysis tool, such as that provided by TRNSYS (Transient System Simulation Tool), combined with SRCC (Solar Rating and Certification Company)-rated panel performance data to aid in correct system sizing. A monthly analysis tool does not provide enough data to create an accurate picture of performance.

**DESIGN SYSTEMS WITH THE SAME UNIT FLOW RATE AT WHICH THE PANELS WERE TESTED** Set the flow rates through each solar thermal panel to match the SRCC test conditions. At the O'Neill Federal Building, the flow rate was 0.0281 gpm/$ft^2$.

**CAREFULLY SELECT HEAT EXCHANGERS** Properly size the heat exchangers that bridge the collection loops and storage tanks to ensure adequate system performance.

**CONSIDER CLIMATE IN PV-T SELECTION** Certain types of PV-T technology, such as flat-plate and evacuated-tube collectors, are better suited to cold climates. Unglazed systems, which are typically less expensive, perform best in climates where the outside air temperature is often above 90°F in the summer.

**INSTALL SUBMETERING** Install submetering to track thermal energy production and compare it to predicted energy production on a monthly basis.

## Modeled Energy Savings and Economics for PV-T

Cost-effective when electricity rates are high

| City | Electricity Rate ($/kWh) | City Cost Adjustment Multiplier | Solar Energy Production (kWh/yr) | Annual Cost Savings ($) | Installed Cost ($) | Simple Payback (yrs) | Payback with 30% Tax Credit (yrs) |
|---|---|---|---|---|---|---|---|
| Portland, OR | 0.09 | 0.992 | 6,698 | $581 | $56,765 | 98 | 68 |
| Boston, MA | 0.15 | 1.172 | 6,331 | $934 | $67,065 | 72 | 50 |
| Denver, CO | 0.11 | 0.943 | 11,063 | $1,198 | $53,961 | 45 | 32 |
| **Honolulu, HI** | **0.34** | **1.173** | **10,097** | **$3,488** | **$67,123** | **19** | **13** |
| Daggett, CA | 0.18 | 0.996 | 11,824 | $2,144 | $56,994 | 27 | 19 |
| Phoenix, AZ | 0.10 | 0.887 | 11,783 | $1,237 | $50,757 | 41 | 29 |

# CONCLUSIONS

These Findings are based on the report, "Photovoltaic-Thermal New Technology Demonstration," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

## Deployment Direction

**FUTURE PV-T INSTALLATIONS SHOULD FOCUS ON SITES THAT MEET THE FOLLOWING REQUIREMENTS:**

- **Limited Roof Space:** Facilities with limited roof space, relative to the size of the electrical and thermal load, are ideal candidates for PV-T. A PV-T system will produce more energy than will separate PV and solar thermal systems given the same amount of space.
- **High Energy Costs:** PV-T is most cost-effective where electric rates are greater than 30 cents/kWh. In locations with federal tax incentives, target facilities with electric rates of 15 to 20 cents/kWh or higher.
- **Hot Climates:** In addition to producing more hot water on an annual basis, PV-T systems in hot climates benefit more from increased electrical production as a result of greater PV cooling.
- **Central Hot Water Systems:** Facilities with small decentralized point-of-use DHW systems are not suitable for solar thermal installations.
- **Short Piping Runs:** The length of the home run should be as short as possible to minimize installation costs.
- **Small Facilities:** Larger facilities require larger PV-T arrays, which are more challenging to design and whose flow rates are more challenging to match to recommended SRCC flow rates. Note: The Boston PV-T system was designed without the aid of PV-T panel design tools, which did not exist at the time. TRNSYS combined with SRCC-rated panel performance data can aid in correct system sizing.

*Technology for test-bed measurement and verification provided by SunDrum Solar.*