Raise the Roof

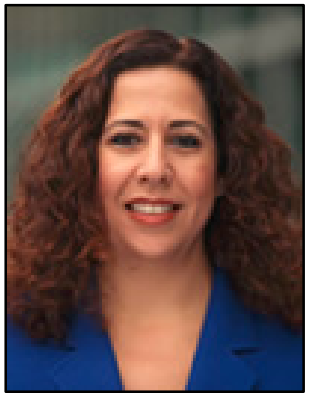
Increased Rooftop Solar Efficiency Beyond Flat Panel PV

February 19, 2015

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions

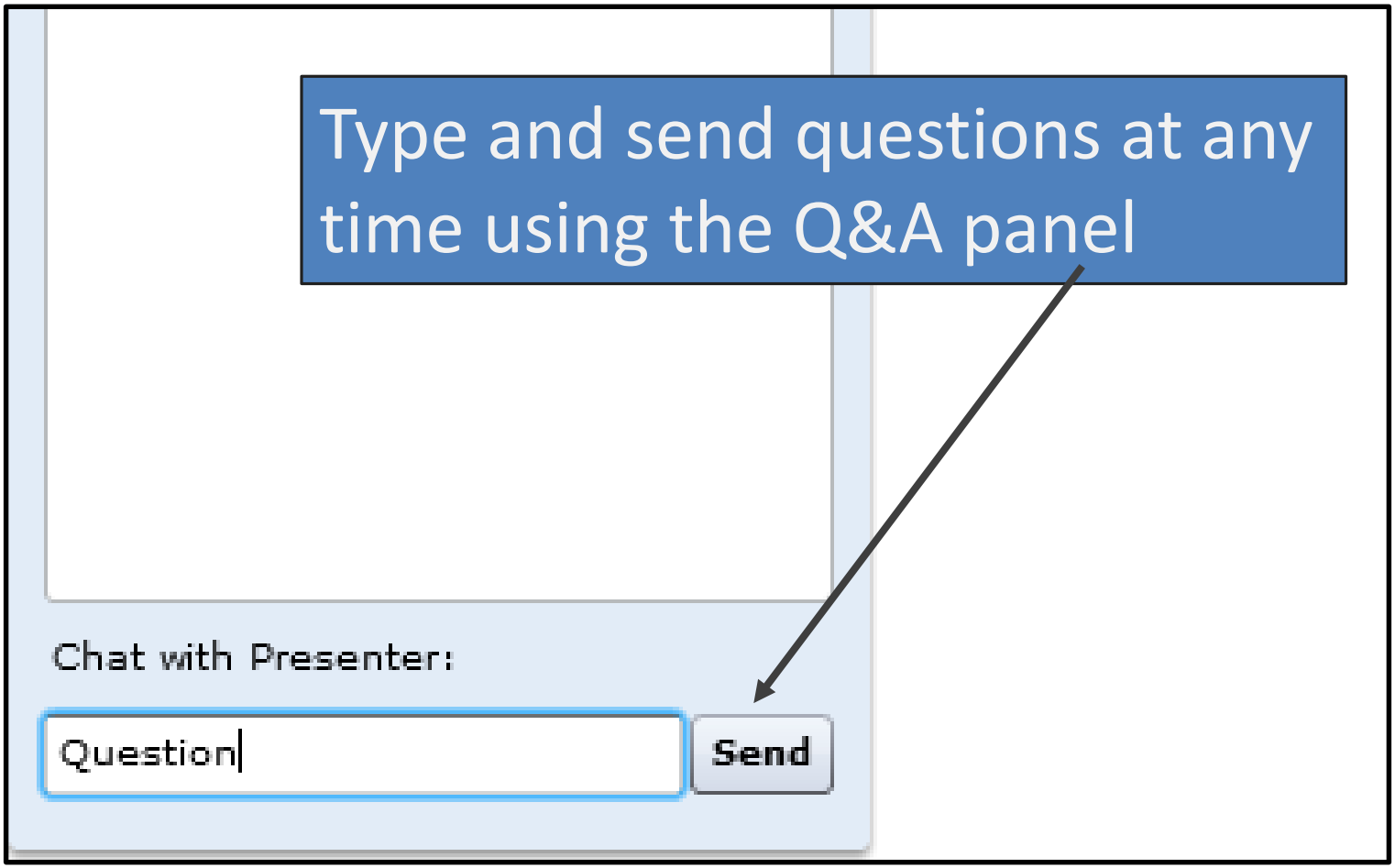
Rula Deeb, Ph.D.
Webinar Coordinator



Webinar Agenda

- Webinar Overview and ReadyTalk Instructions
  Dr. Rula Deeb, Geosyntec (5 minutes)
- Overview of SERDP and ESTCP
  Dr. James Galvin, SERDP and ESTCP (5 minutes)
- Concentrating Photo-Voltaic System for Department of Defense Rooftop Installations
  Deborah Jelen, Electricore, Inc. (25 minutes + Q&A)
- Solar Air Heating Metal Roofing for Reroofing, New Construction and Retrofit
  John Archibald, American Solar (25 minutes + Q&A)
- Final Q&A session

How to Ask Questions



SERDP and ESTCP Overview

Jim Galvin, Ph.D.
Energy and Water
Program Manager

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SERDP

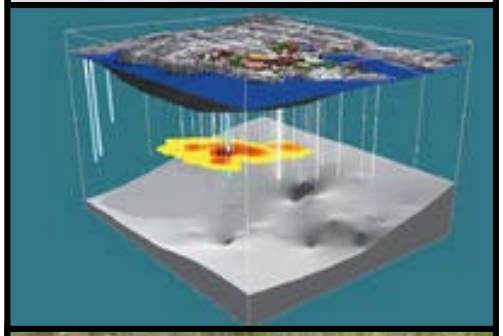
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

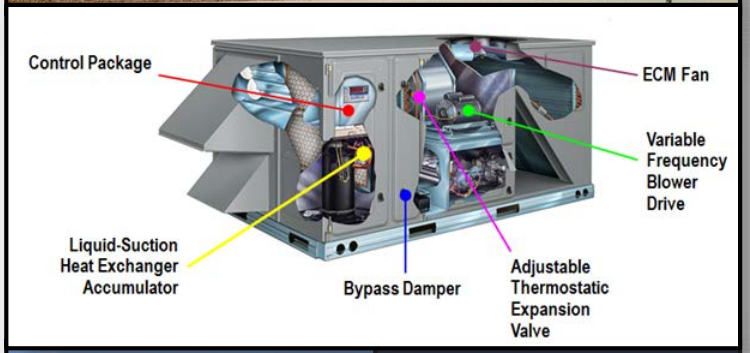
Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Climate Change
5. Weapons Systems and Platforms



Energy and Water

- Smart and secure installation energy management
  - Microgrids
  - Energy storage
  - Ancillary service markets
- Efficient integrated buildings and components
  - Design, retrofit, operate
  - Enterprise optimized investment
  - Advanced components
  - Intelligent building management
  - Non-invasive energy audits
- Distributed generation
  - Cost effective
  - On-site
  - Emphasis on renewables



SERDP and ESTCP Webinar Series

DATE	WEBINARS AND PRESENTERS
March 5, 2015	**Development and Assessment of Lead Free Components for Microelectronics Used for DoD Applications** • Dr. Peter Borgesen (Binghamton University, The State University of New York • Dr. Stephan Meschter (BAE Systems)
March 19, 2015	**Quantitative Framework and Management Expectation Tool for the Selection of Bioremediation Approaches at Chlorinated Solvent Sites** • Dr. John Wilson, Scissor Tail Environmental • Carmen Lebrón, Independent Consultant
March 26, 2015	**Environmental DNA: A New Tool for Species Inventory, Monitoring and Management** • Dr. Lisette Waits, University of Idaho • Dr. Alexander Fremier, Washington State University
April 16, 2015	**Blast Noise Measurements and Community Response** • Mr. Jeffrey Allanach (Applied Physical Sciences Corp.) • Dr. Edward Nykaza (U.S. Army Engineer Research and Development Center)

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

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Concentrating Photo-Voltaic System for Department of Defense Rooftop Installations

Deborah Jelen
Electricore, Inc.

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Concentrating Photo-Voltaic System for DoD Rooftop Installations

ESTCP Project EW-201146

Deborah Jelen, Electricore, Inc.

Agenda

- Background
- Objectives/approach
- Results
- Issues
- Lessons learned
- Benefits/technology transfer
- Conclusions

Background

- Electricore installed and conducted a 15 month demonstration of a 50kW Concentrating Photo-Voltaic (CPV) system at NAWS China Lake in California
  - CPV technology provided by Suncore, Inc. (formerly Emcore Corp.)
  - Installed 2 different generations of a commercially available rooftop CPV solar system:
    - 25kW SE-500X
    - 25kW Soliant 1000
  - The system was engineered specifically for rooftops in hot, dry, sunny areas using high-efficiency cells and dual-axis TipTilt Tracking™

Background

- CPV, much like flat-panel PV, generates electricity from sunlight using semiconductor materials
- The demonstrated CPV technology has the following characteristics:
  - Dual-axis TipTilt Tracking™
  - Concentrating element to focus sunlight onto multi-junction solar cells (25.3% module efficiency)
  - Reduced footprint required compared to conventional PV

Objective

Install and demonstrate the 50 kW CPV system at NAWS China Lake

- System was successfully installed and demonstrated for twelve months, completing the program in Fall 2014
  - As of today the CPV system is still in use and fully operational
  - A one-year extended warranty was added to the program
- Data was wirelessly collected and analyzed through an onsite Data Acquisition System, “Deck Monitoring”
  - http://live.deckmonitoring.com/?id=china_lake

Installation Site

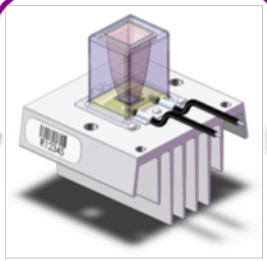
NAWS China Lake, Building 31440

Approach

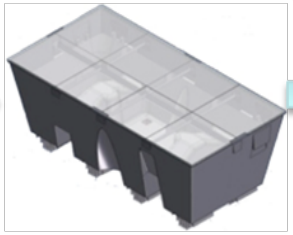
- Phase 1: Pre-demonstration
  - Conducted final site survey and energy audit
  - Selected final site for solar installation
  - Completed permitting and environmental assessments
- Phase 2: Demonstration and analysis
  - Installed solar modules (2 stages) and infrastructure at NAWS China Lake
  - Conducted 12 month demonstration (full year's worth of solar data)
  - Collected and analyzed operational and cost data

Technical Approach

High efficiency III-V cells: 38% => 45%

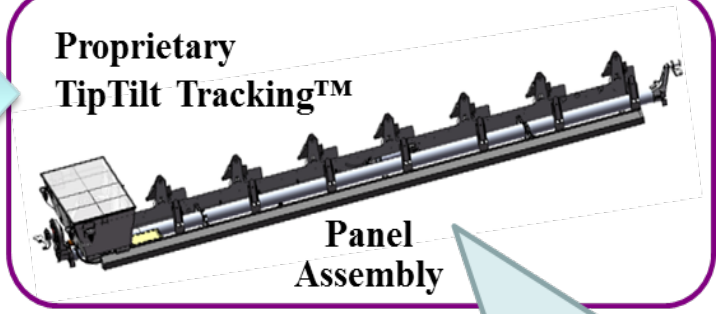


Receiver Assembly



Module Assembly

Proprietary TipTilt Tracking™



Panel Assembly

- ✓ Directs and homogenizes sunlight from the primary concentrating element onto the solar cell
- ✓ Converts the incident optical power into electrical power
- ✓ Dissipates the excess thermal power
- ✓ Provides tolerance to shading

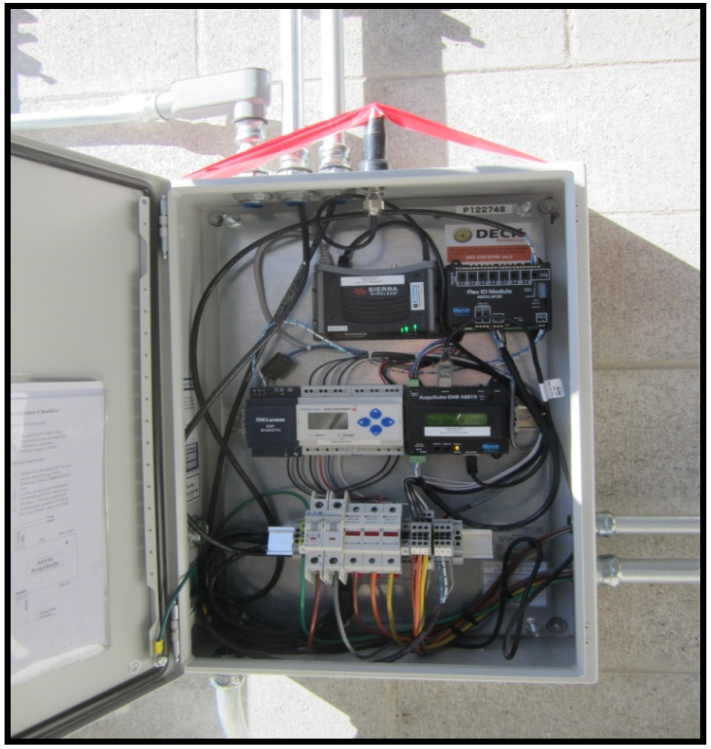
- ✓ Integrates and aligns receiver assemblies with the primary Fresnel lenses and associated wiring
- ✓ Provides a rugged electrical enclosure around the PV components

- ✓ Consists of a rigid main structure and two rotating elements
- ✓ Modules and the control system are attached to the panel assembly
- ✓ Enables high dual-axis tracking accuracy
- ✓ One rotation articulates east-west direction the other north-south

Building #31440
Anti-Radiation Guidance Lab

Delivery of panels and installed mounting rails in phase 2

Building #31440
Anti-Radiation Guidance Lab



Deck monitoring control panel

6 single phase 7-KVA inverters

Results

- Demonstration performance
  - **Annual energy**: 69,693 kWh delivered to site
  - **Annual solar resource**: 6.11 kWh/m^2/day measured on site
  - **Peak power**: 42 kW AC
  - **Greenhouse gas avoidance**: 81,541 lbs/yr CO_2

Results (Continued)

- Performance
  - **PV system projection**: 3.82 $kWh_{ac}/kW_{dc}/day$
  - **CPV system projection**: 5.06 $kWh_{ac}/kW_{dc}/day$
  - **Actual results**: 4.2 $kWh_{ac}/kW_{dc}/day$
    - Lower results were attributed to nearby building shading not accounted for in the original model and lesser availability during Phase 1 due to installation issues (connector/wire harness reliability)

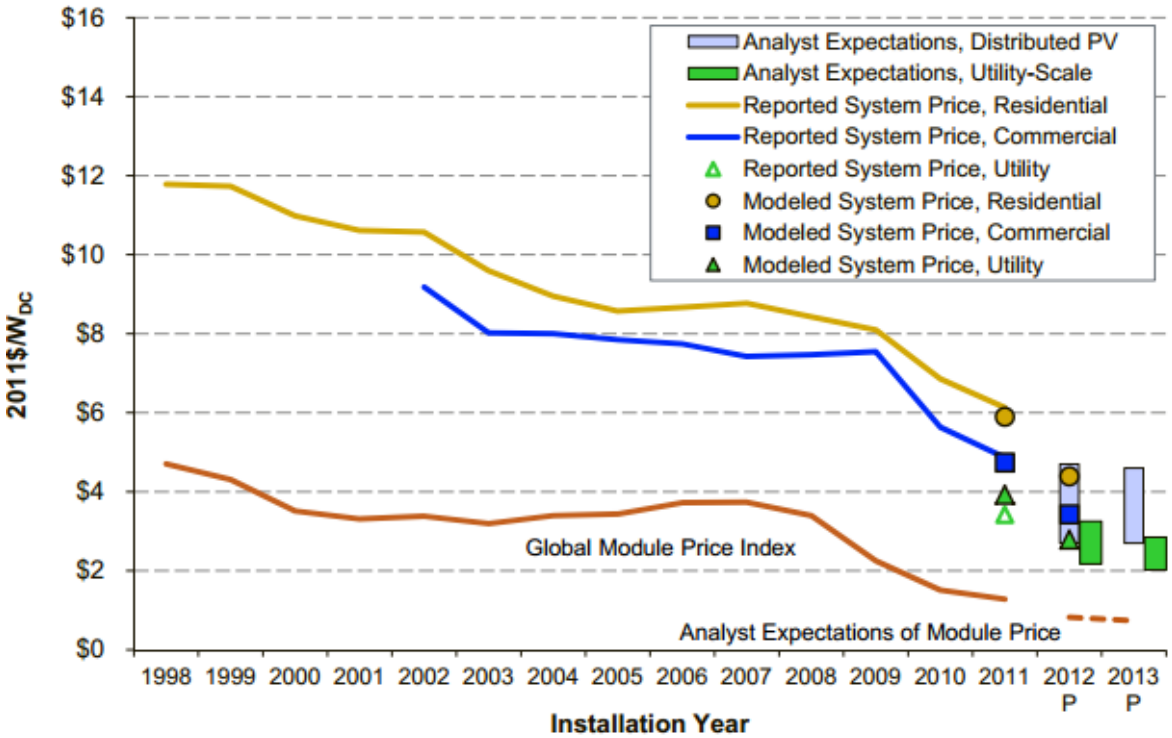
Results (Continued)

Cost Element	TOTAL
Solar Installation and Equipment	$205,383
Asbestos Remediation	$14,000
Solar Modules	$205,885
TOTAL	$425,268 ($8.51/W)*

** Total cost without additional expenses incurred by the project site changes was $351,132 ($7.02/W)*

System Price

- In 2010, system price was around $6.16/W (CSI Database)
- NREL shows the PV module prices rapidly declining at the beginning of 2010 into 2011



Manufacturer's Estimate of Typical Costs

Cost Element	$/W$_{DC}$ (Typical)
Mobilization	$0.01
PV Racking and Materials	$0.25
Inverters	$0.34
PV Racking Labor	$0.08
PV Module Cost	$1.87
PV Module Install	$0.13
Direct Job Expenses	$0.01
Demobilization	$0.02
Total	**$2.71 ($7.02 in demonstration)**

"Typical" values for materials are sourced from current commercial distributor pricing, whereas labor is calculated based on observed jobsite man-hours to complete a task

Lessons Learned

Integrated Racking

- During 1st installation, the team used a transport cradle designed to be collapsible on site, returnable and re-usable
  - Transport cradle cost: ~$0.22/W and was designed to be reused at least 50 times
- During 2nd installation phase, the team used a new integrated racking product to transport and carry the trackers directly to the rooftop from a flatbed trailer
  - Integrated racking cost: ~$0.25/W; however, it is designed to also replace the required mounting equipment

CPV Benefits

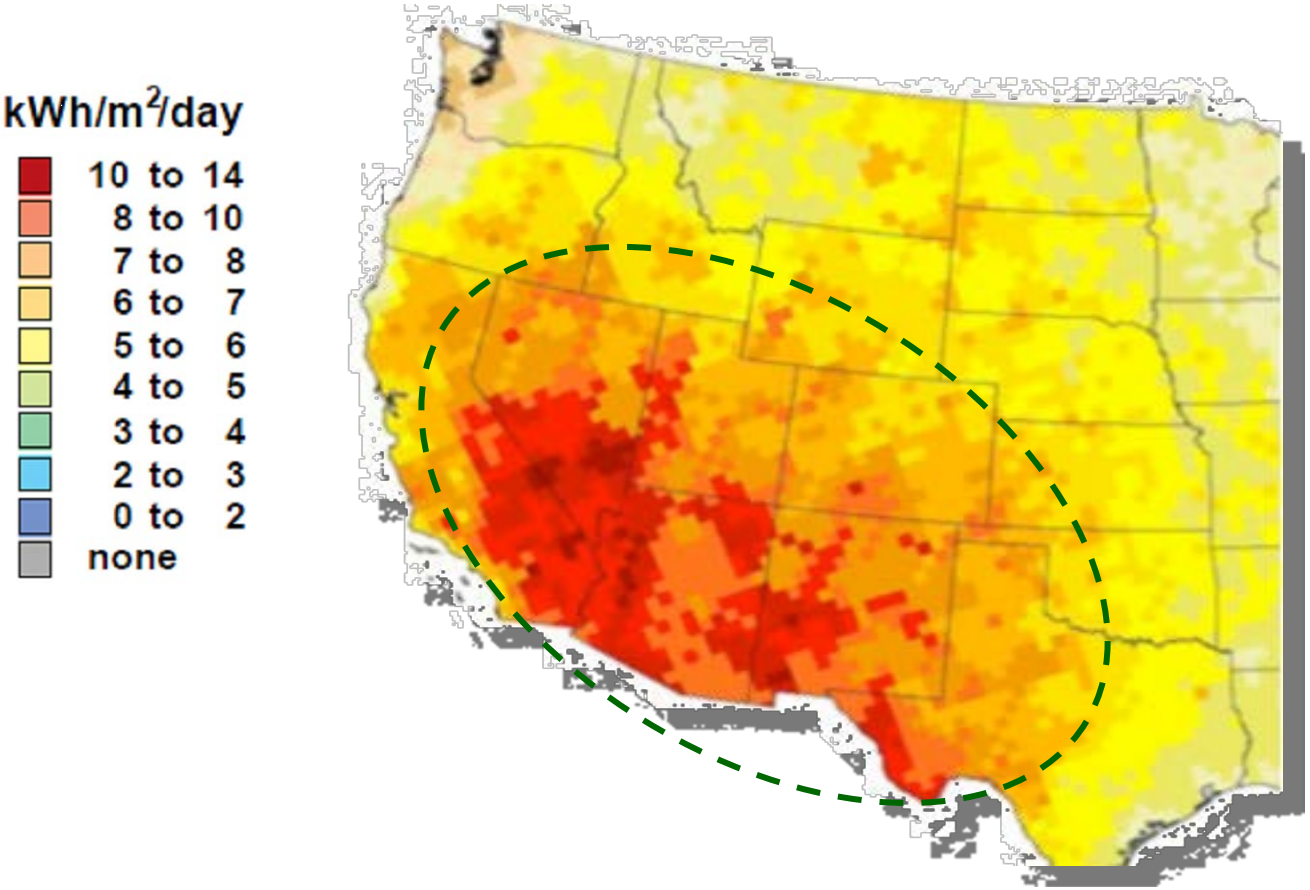
- CPV can offset base energy cost
  - The demonstrated system offset 69,693 kWh over 12 months
  - To date, the system has offset a total of 151,132 kWh for NAWS China Lake
- Potential solar rebates and tax incentives enhance payback, if eligible. Examples include:
  - California Solar Initiative - PV Incentives
  - Arizona Non-Residential Solar and Wind Tax Credit
  - New Mexico Renewable Energy Production Tax Credit
  - Utah Alternative Energy Development Initiative
- Minimal system maintenance (regular lens washing)
- No need to penetrate rooftop

Benefits

- **Energy Security**: Reduce vulnerability to power grid disruptions (50kW of on-site power production) and increase the use of year-round renewable energy generation at the selected building site
- **Cost Avoidance**: Energy produced will directly offset purchase of that energy from traditional utility grid sources
- **Greenhouse Gas Reduction**: The solar system and balance of plant components produce no greenhouse gas emissions

Technology Transfer

State	California	Nevada	Colorado	Utah	Arizona	New Mexico	Texas
# of Bases	24	2	5	3	5	4	4



Conclusions

- This technology can be replicated at virtually all DoD installations and other government facilities within the Southwest United States
- The system was successfully installed and remains functional
- The cost of CPV manufacturing has declined rapidly since this program was proposed in 2011

For additional information, please visit:

https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Distributed-Generation/EW-201146

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Q&A Session 1

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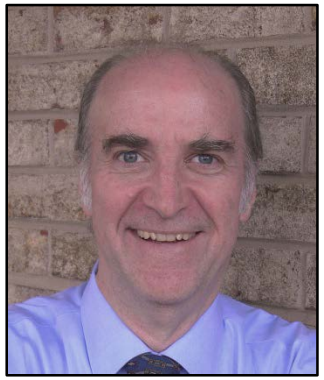
Solar Air Heating Metal Roofing for Reroofing, New Construction and Retrofit

John Archibald
American Solar



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Solar Air Heating Metal Roofing for Reroofing, New Construction and Retrofit

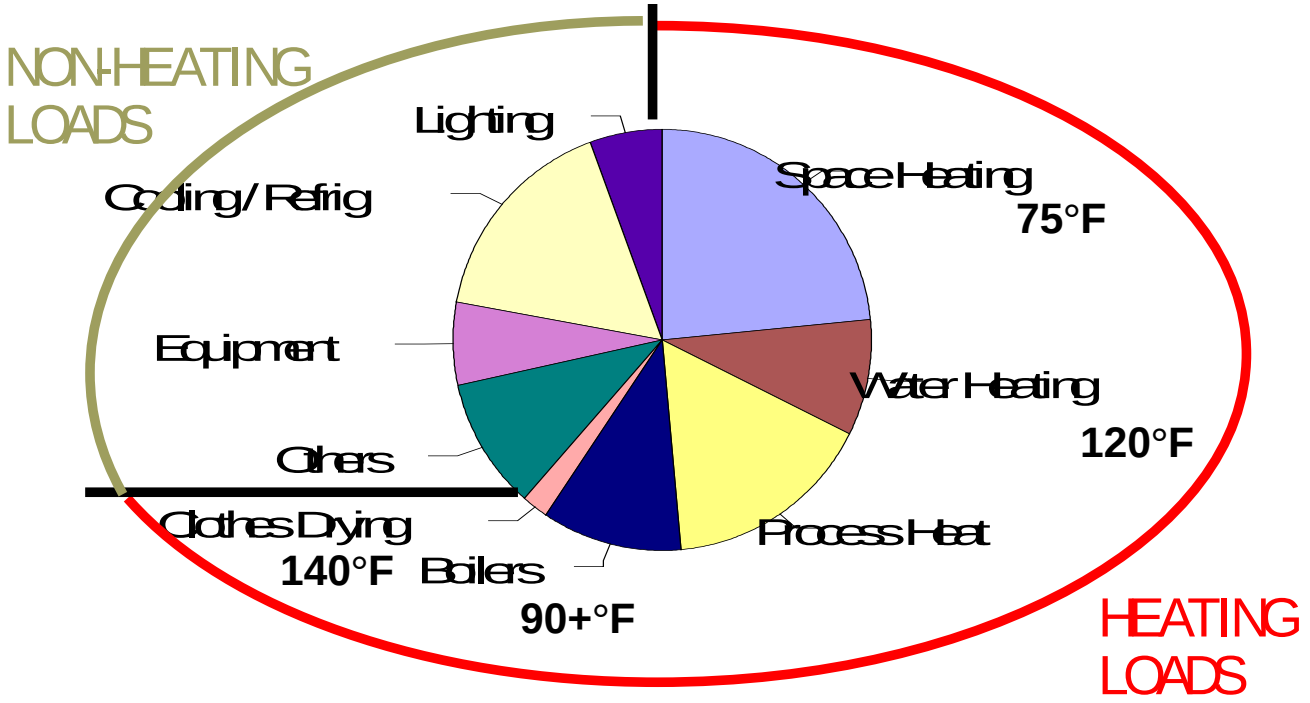
ESTCP Project EW-201148

John Archibald, American Solar, Inc.

Agenda

- Heating energy use
- DOD roofing and heating needs
- Solar air heating re-roof at Ft. Meade
- Ventilation preheat, space heat, water heat
- Energy and roofing performance
- Cost savings

The Largest Need for Energy in the United States is for Heating



Portions of all energy used in buildings and facilities (Source data: U.S. Energy Information Administration)

DOD Building Expenses

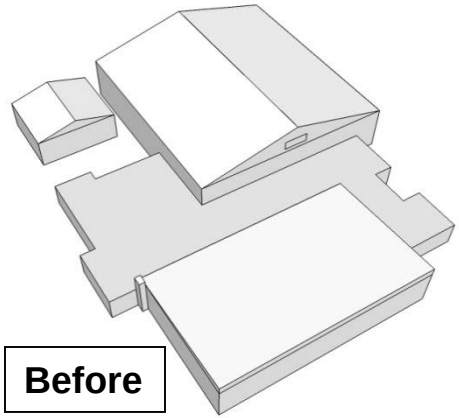
- DOD is a microcosm of the U.S. at large
- DOD has every building type
- 2 billion square feet buildings under roof
  - Require space heat, water heat, equipment heat
  - Require re-roofing every 15 years, on average
- Operations and maintenance expenses
  - Heating: $1.28/sqft/yr, $2.4 billion/yr
  - Roofing: $0.67/sqft roof/yr, $0.6 billion/yr

Fort Meade ESTCP
Solar Air Heating Re-Roof Project

- Re-roof fitness facility worn out roof
  - Provide better, lower life cycle cost roof
- Use roof to collect solar heated air for
  - Ventilation air preheat
  - Space heat
  - Domestic water preheat
- Reduce roof heat loss in winter
- Reduce roof heat gain in summer

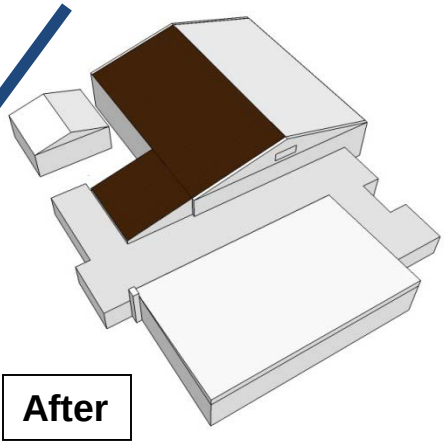
Solar Air-Heating Metal Re-Roof Over Built Up Roof

Gaffney Fitness Facility Fort Meade, MD



Before

Before:
Worn out
15 year roof
and
100% gas
heat



After

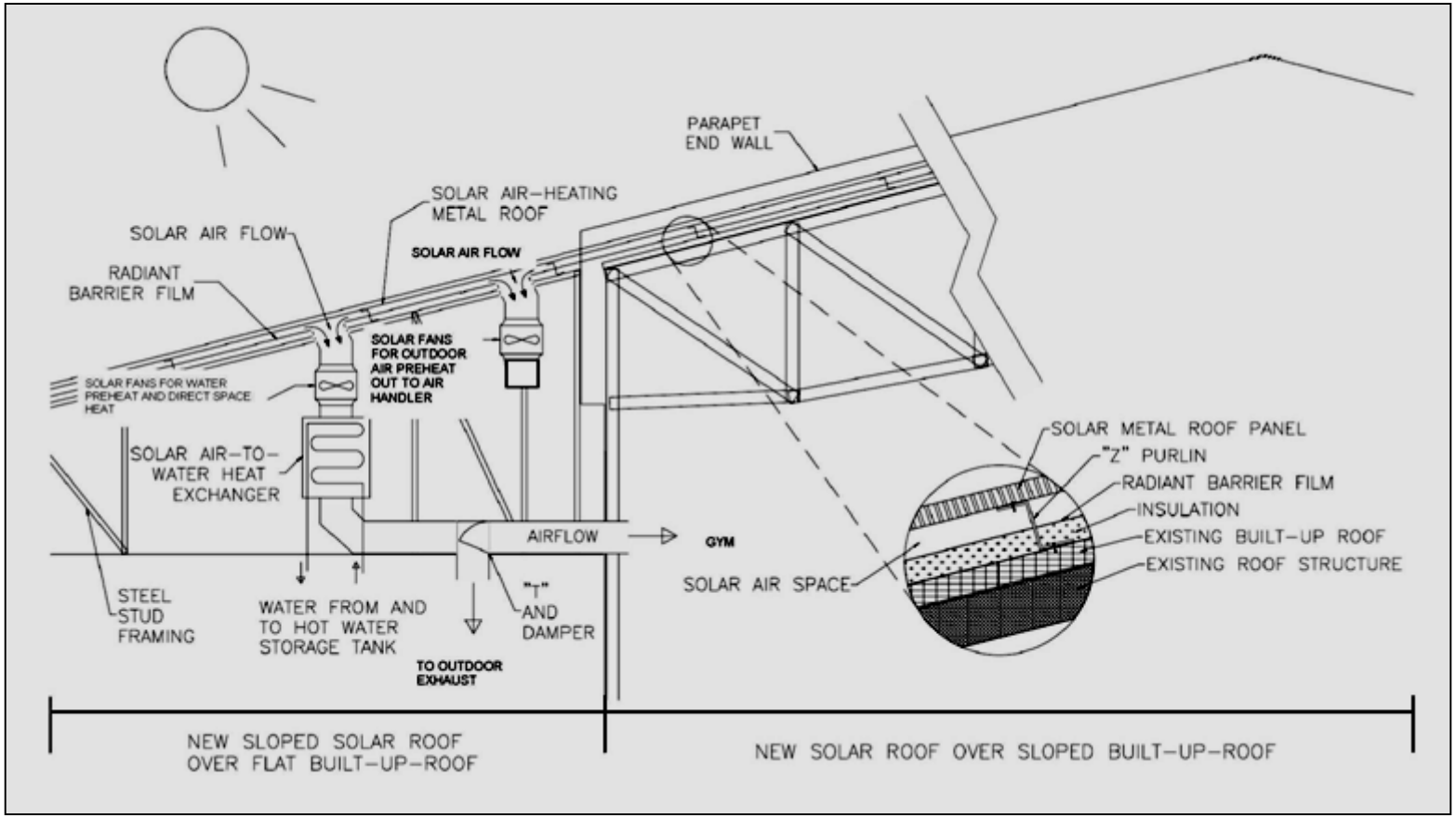
After:
40 year roof,
solar heat &
reduced gas heat

Roof Construction

- Conventional, code approved standing seam metal roof
- Structure installed over existing built up roof
- Insulation installed on built up roof
- Solar air space between insulation and metal roof panels
- New mechanical room formed over flat roof

Air and Water Systems

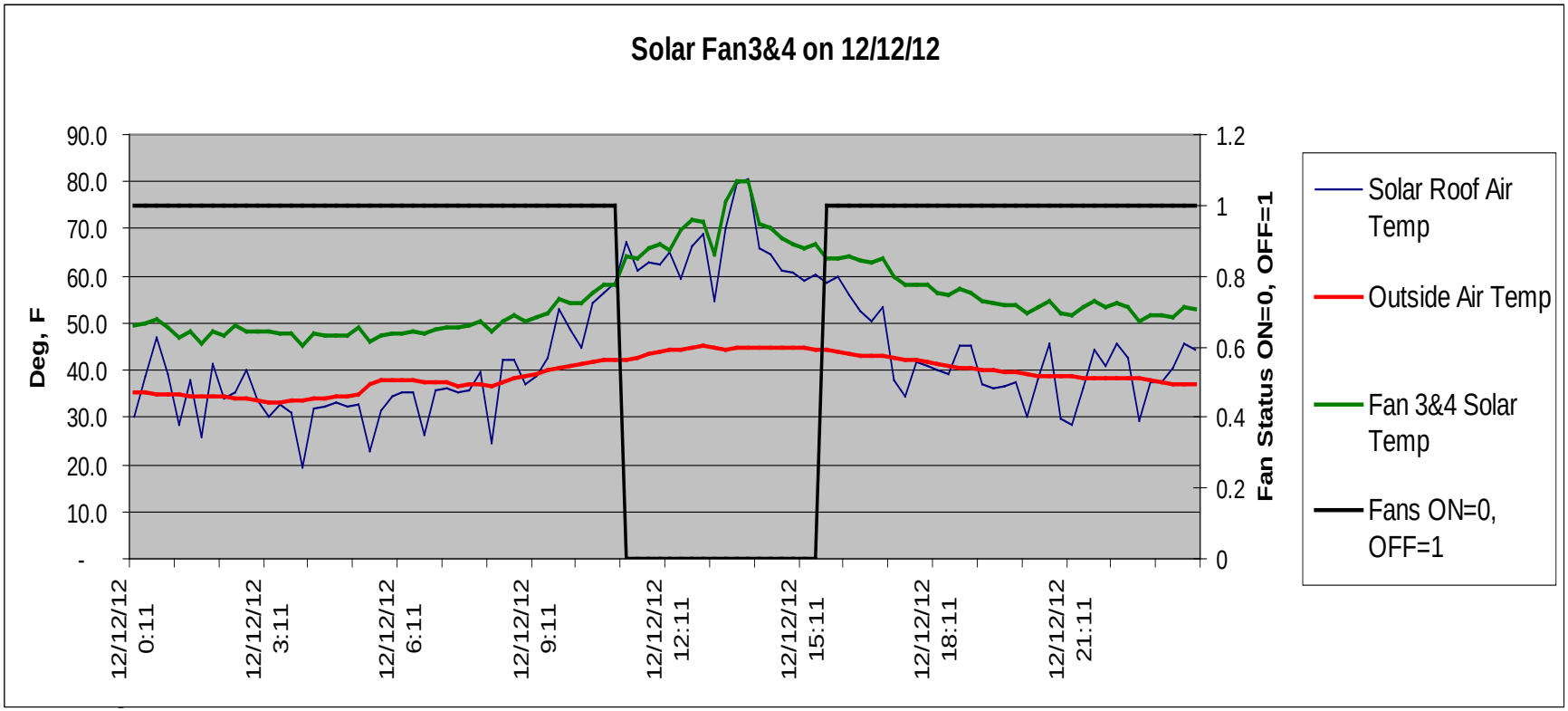
- Solar air drawn from ridge to mechanical room
- Cold water piped from city main to solar air-to-water heat exchanger



Gaffney Solar Air Heating Uses

1. Ventilation preheat
   - Solar air to outdoor air intake on air handler
   - Runs when:
     - Building needs heat, and
     - Solar air is warmer than outdoor air
2. Direct space heat
   - Solar air directly into gym
   - Runs when:
     - Building needs heat, and
     - Solar air is warmer than gym air, and
     - Solar air >75°F

1. Ventilation Preheat Performance

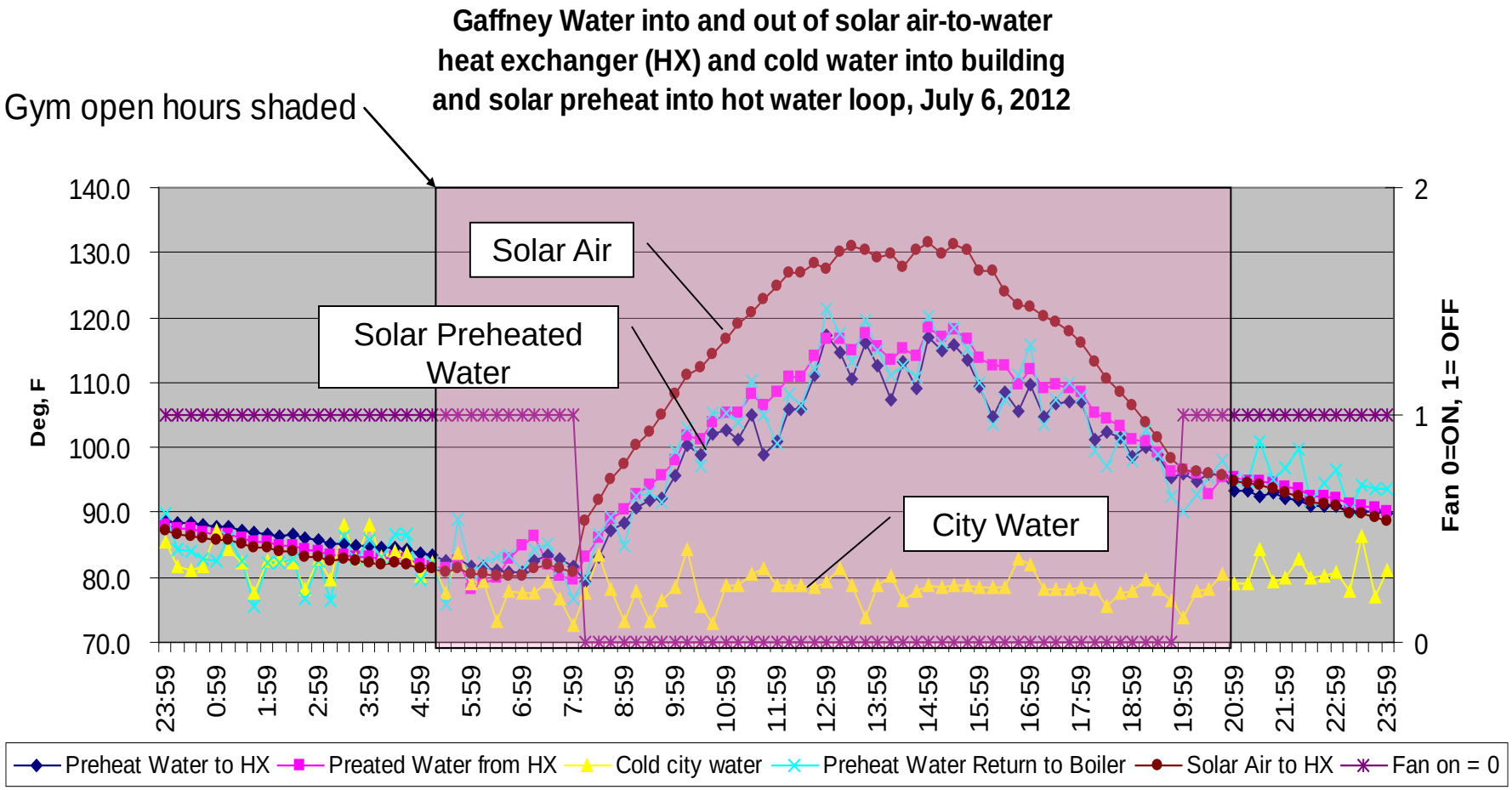


- Runs 1,800 hours per year
- Up to 143,000 BTU/hr to outside air

Gaffney Solar Air Heating Uses

3. Air-to-water preheat
   - Solar air to air-to-water heat exchanger
   - Water piped from heat exchanger to preheat storage tank
     - Upstream of domestic boiler
     - Small, low cost tank for short term storage
   - Runs when solar air is warmer than preheat tank
     - ~3,000 hours per year
   - 33 million BTU/yr, 112 million BTU maximum capacity

3. Air to Water Preheat Performance



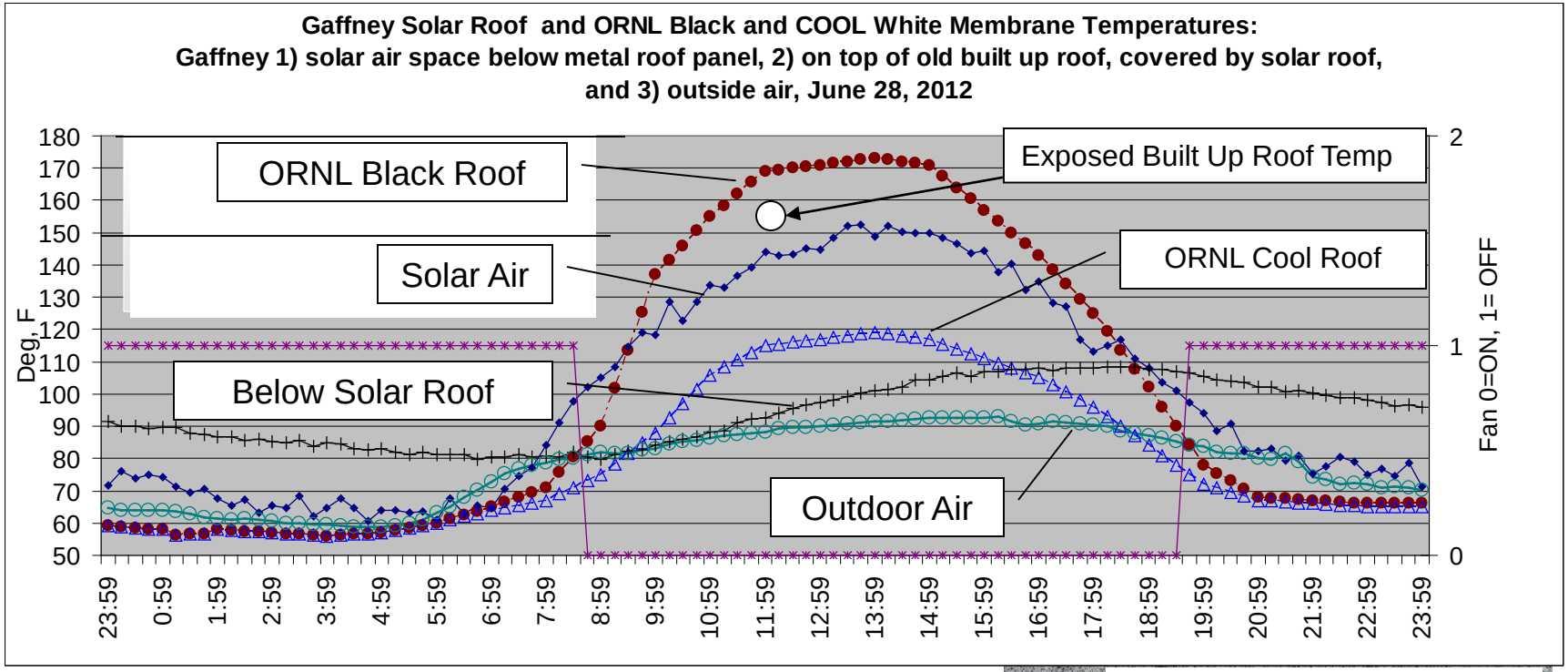
Building Envelope Performance

- Roofing
  - Metal roof outlasts ~2.5 built up asphalt roofs
  - Metal recognized as most life cycle cost effective
- Heating
  - Warmer in winter
  - Solar roof keeps built up roof below, warmer than the exposed built up roof
  - Due to insulation and daily heating

Building Envelope Cooling Performance

- Black solar roof cooler in summer than built up roof
  - Built up roof below solar roof
  - up to 65°F cooler than exposed built up roof
- …Equal to a “cool roof”
  - Peak temperature is 10°F cooler than a ‘cool’ white roof
  - Peak temperature delayed beyond peak utility rate periods

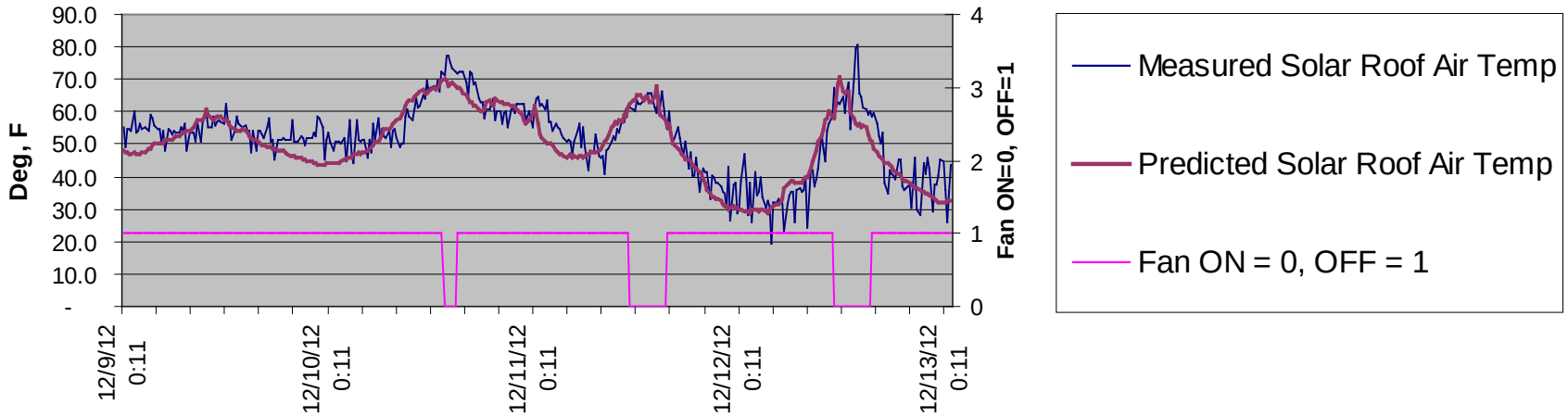
Solar Roof with 'Cool' Roof Performance



- ORNL BLACK MEMBRANE ROOF
- SOLAR AIR IN GAFFNEY ROOF
- ORNL COOL WHITE MEMBRANE ROOF
- OLD ROOF COVERED BY SOLAR ROOF
- OUTDOOR AIR TEMPERATURE
- FAN ON = 0

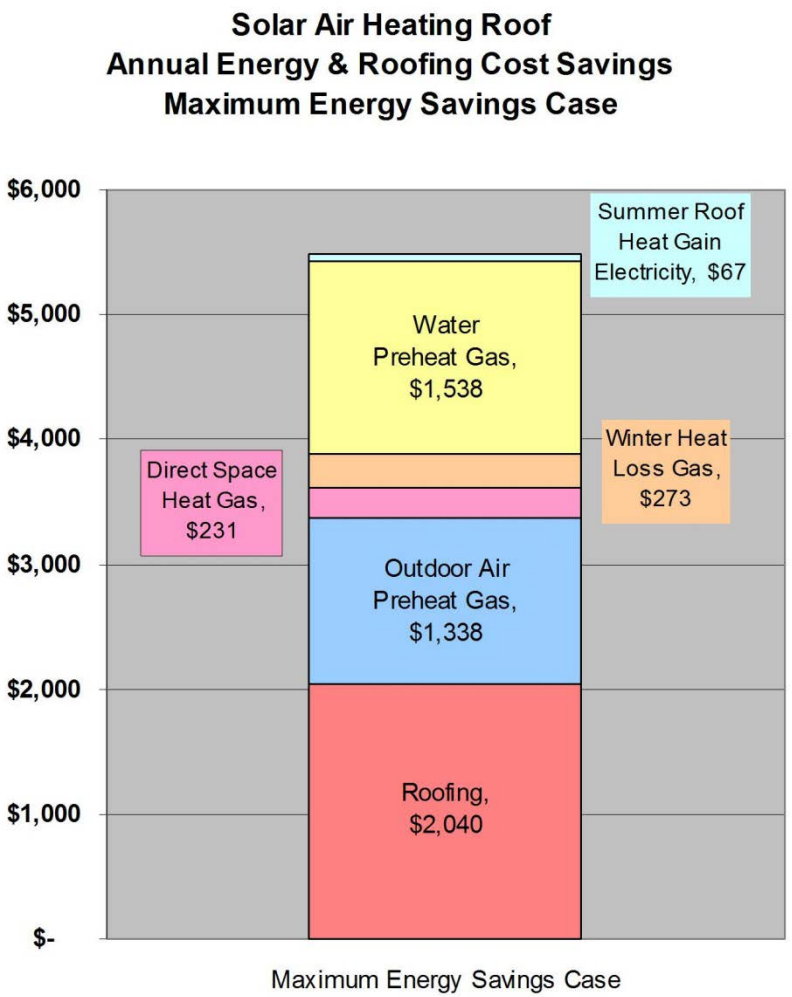
Performance Models

- Performance models created for:
  - Ventilation preheat
  - Space heat
  - Water heat
- Predictable performance anywhere in United States
  - Using local weather and solar data



Economics

- Maximum savings of more than $5,000 per year
  - ~$0.50/ sqft roof/year
  - Compare to $0.02/sqft roof/yr for “Cool Roof”
- Savings from roofing, heating and cooling
- Roof paid for by energy and roofing cost savings



Conclusions

- Solar air heating metal roof provides the following:
  - Longer life than membranes and built up roofs
  - Ventilation preheat, space heat and water heat
  - Cools building in summer
- Annual savings of ~$0.50/sqft of roof/yr
- Savings more than pay for the re-roof
- Serves building's largest energy use - heat

For additional information, please visit:
https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Conservation-and-Efficiency/EW-201148

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Q&A Session 2

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The next webinar is on March 5

Development and Assessment of Lead Free Components for Microelectronics Used for DoD Applications

http://www.serdp-estcp.org/Tools-and-Training/Webinar-Series/03-05-2015

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Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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