NIST Research:
Energy and the Built Environment

David Yashar
Deputy Chief, Energy and Environment Division
Engineering Laboratory
National Institute of Standards and Technology
U.S. Department of Commerce

Energy and Environment Division

Purpose: Anticipate and meet the measurement science and standards needs for energy efficient, high-performance green building standards

- Improve technical knowledge base supporting high-performance green building standards
- Improve energy performance and indoor air quality of new and retrofit buildings
- Move the building and construction industry towards high performance green buildings

Measurement Science and Standards

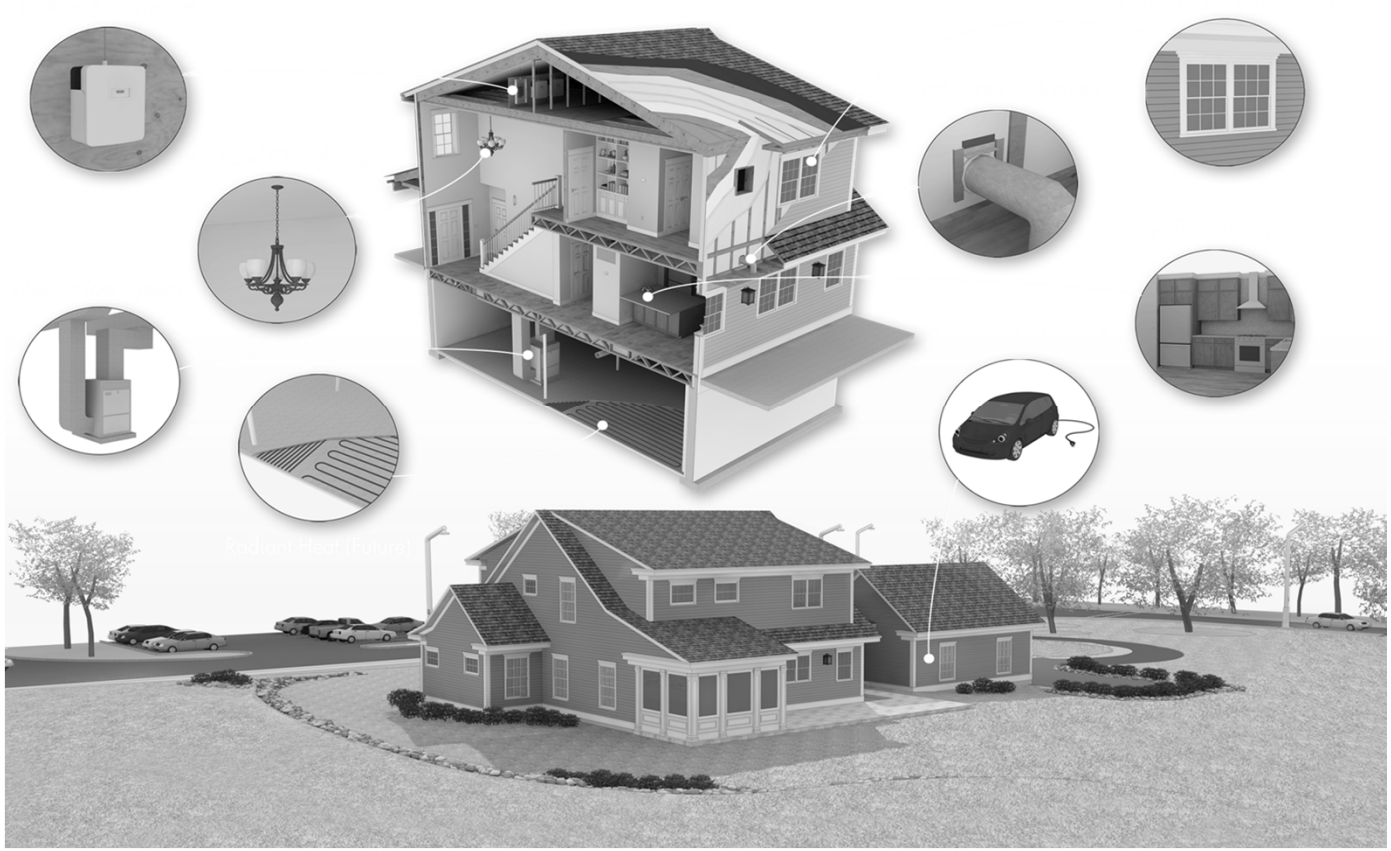
- Stakeholders
  - Trade Organizations (AHAM, ACCA, AHRI, etc.)
  - Standards Development Organizations (ASHRAE, ASTM, ASME)
  - International Documentary Standards Organizations (ISO, IEC)
  - Regulating Bodies (DOE, FTC)

Energy & Environment Division Research

Net-Zero Energy High Performance Buildings	Embedded Intelligence in Buildings
Assessment of High Temp and Innovative Insulation	Automated FDD for Mechanical Services in Buildings
Electrical Performance Measurements of Solar PV Cells/Arrays	Commissioning Building Systems for Improved Energy Performance
Measuring the Performance of NZE Homes	Smart Building Automation and Control Testbed and Standards
Space Conditioning Options for Energy-Efficient Buildings	Building Integration with Smart Grid
Contaminant Control in HPB's	FDD for AC's and HP's
Energy Measurements for Existing Residential Buildings	Intelligent Building Agents
Low GWP Refrigerants for High-Efficiency HVAC&R Equipment	
Ventilation and IAQ in Low-Energy Buildings	

Net-Zero Energy Residential Test Facility

- Test bed for in-situ measurements of components and systems
- Provide “real-world” field data to improve models and test procedures



Net-Zero Energy Residential Test Facility

Extensive Instrumentation

Solar Thermal Water Heating

Photovoltaics

3 HVAC System Options:
Traditional
High Velocity
Multi-split

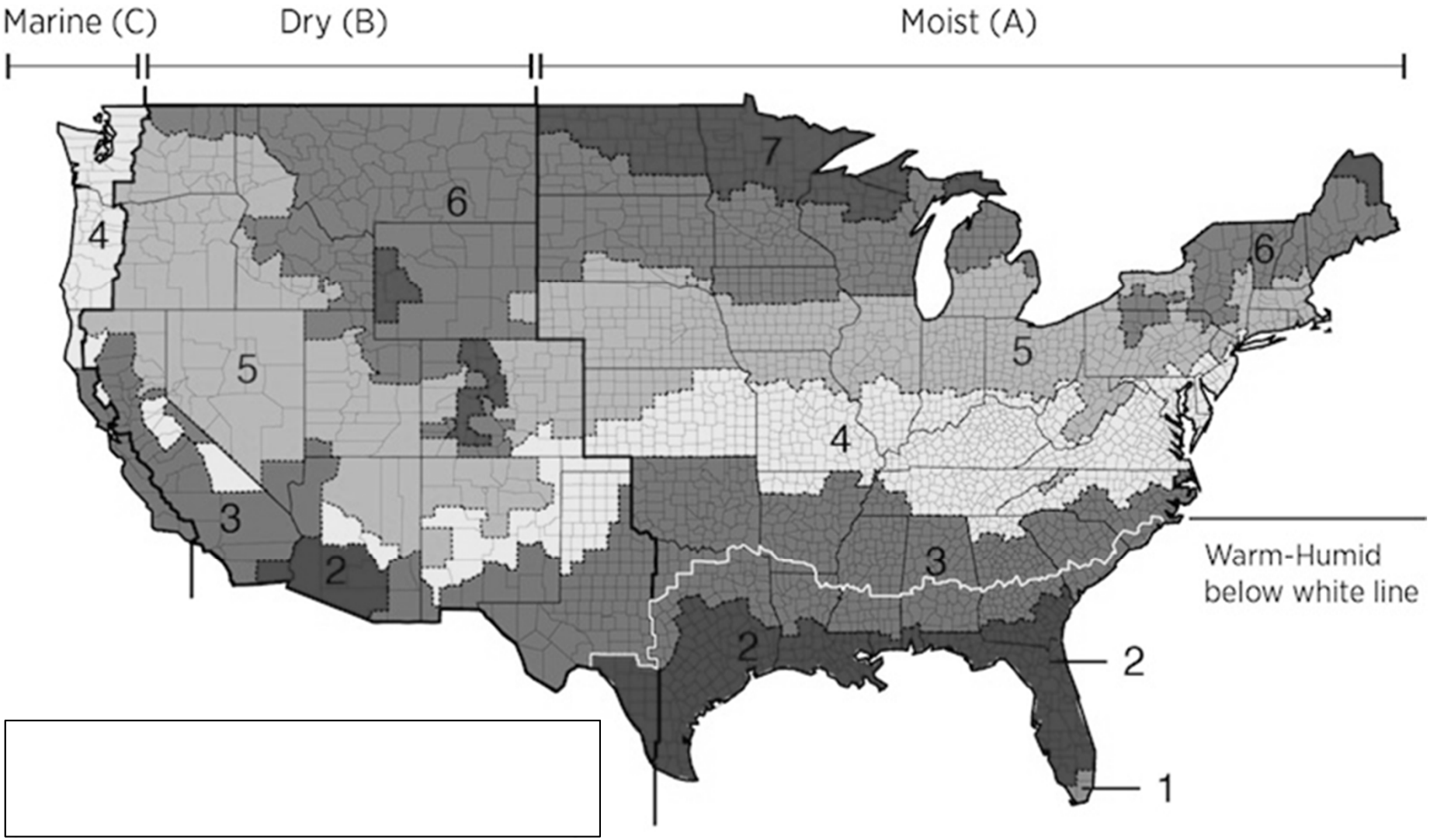
3 Ground Source Heat Pump Loops

Heat Recovery Ventilator

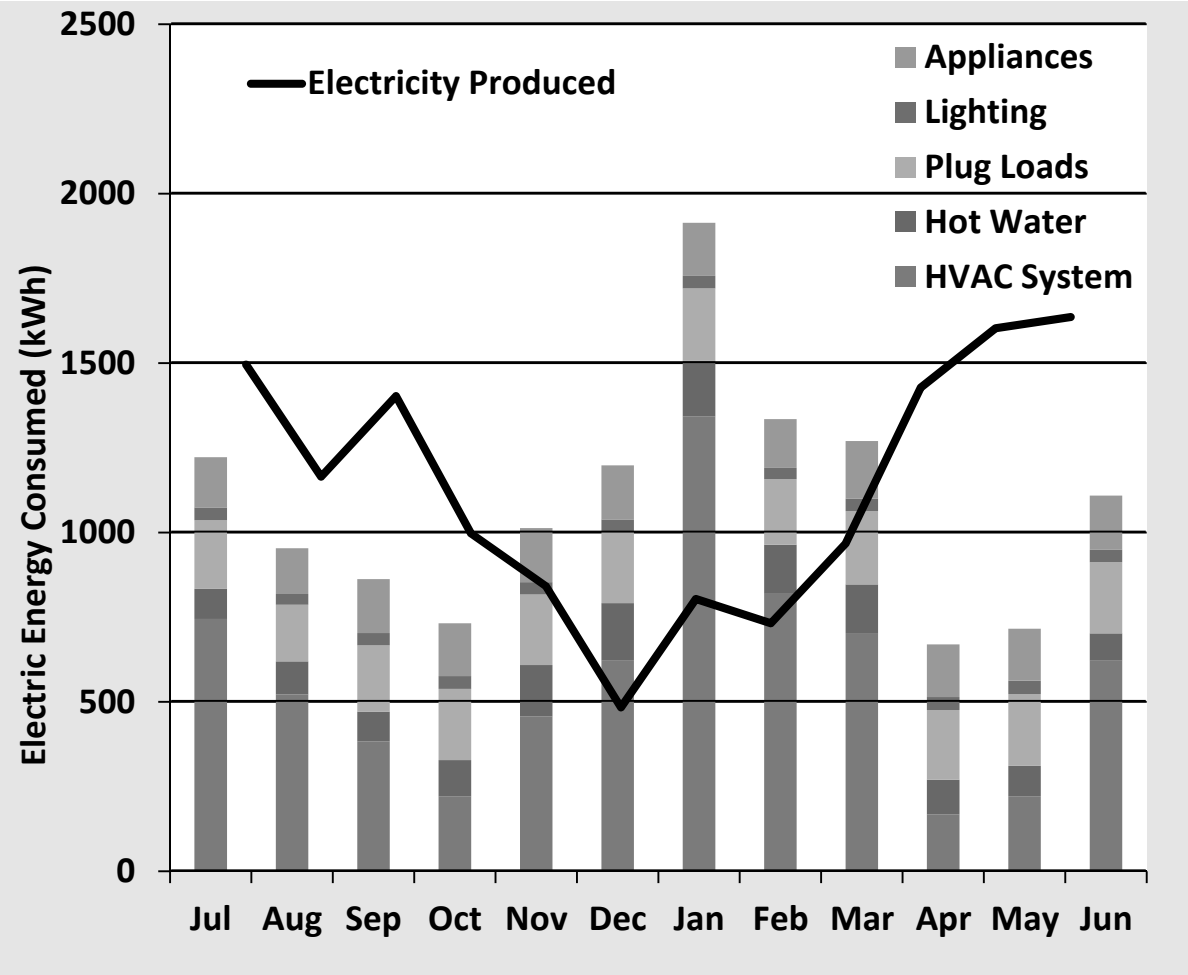
Occupant Simulation

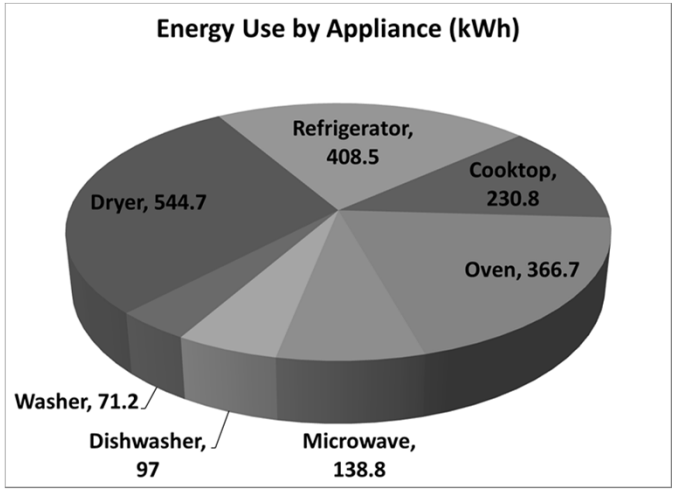
- Residential energy use highly dependent upon occupant behavior
- As a test facility, seek well-controlled conditions
- Devices will turn on and off according to occupancy schedule
- Simulating a family of four: two adults, two children
  - Sensible and Latent Heat from People
  - Water Usage
  - Appliances
  - Plug Loads

U.S. Climate Zone Map



NZERTF Annual Energy Balance



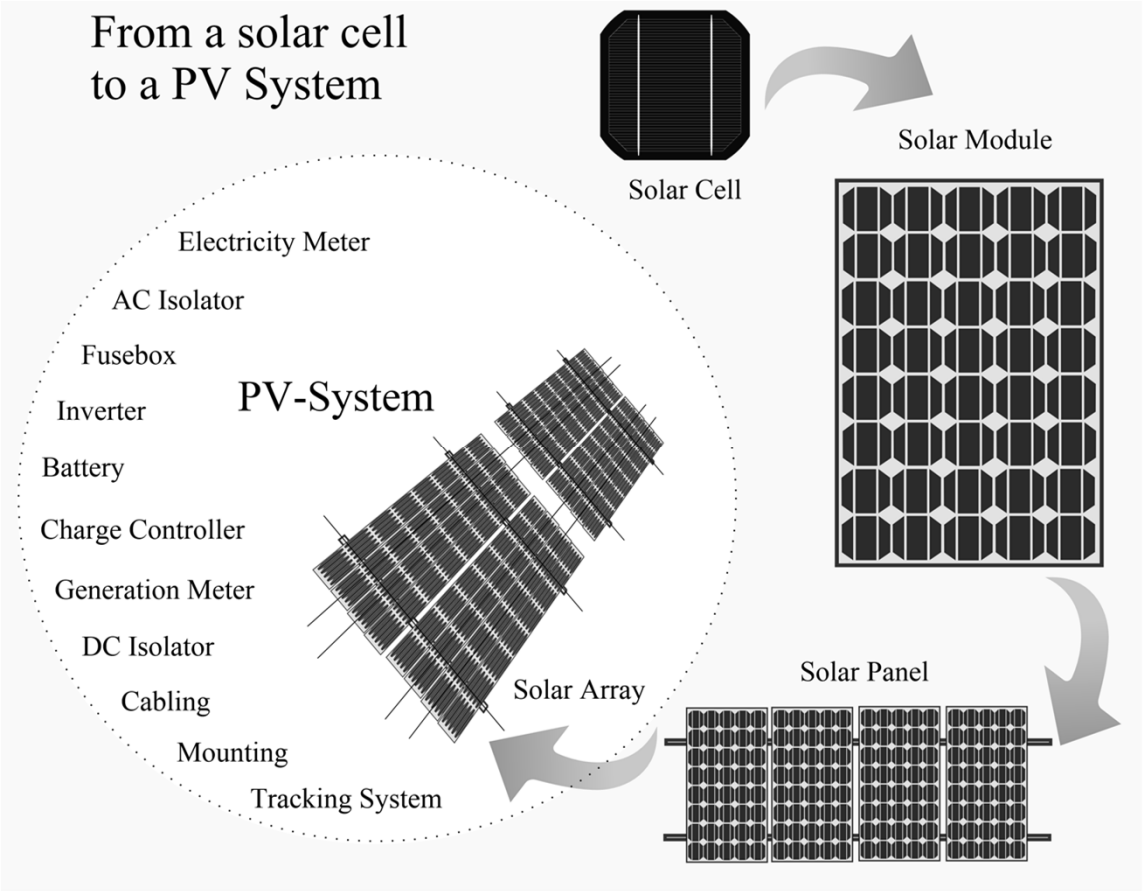


Photovoltaics

Standards:

- IEC
- IEEE
- UL
- Electric Codes
- ASTM

- Rated at 25°C, AM 1.5
- I/V curve
- V_{oc}, I_{sc}
- P_{max}, V_{pmax}, I_{pmax}

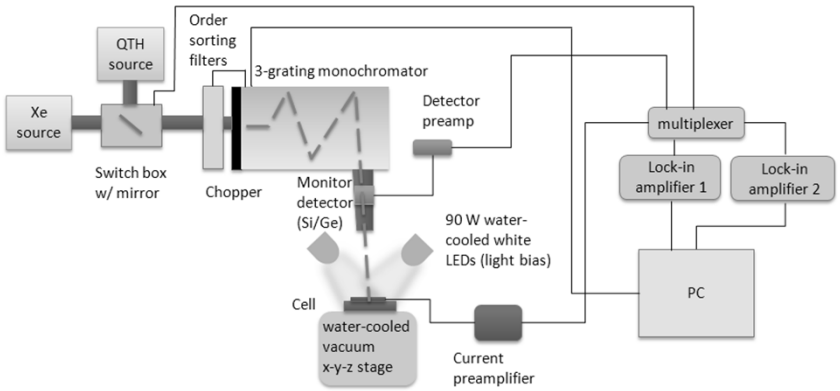


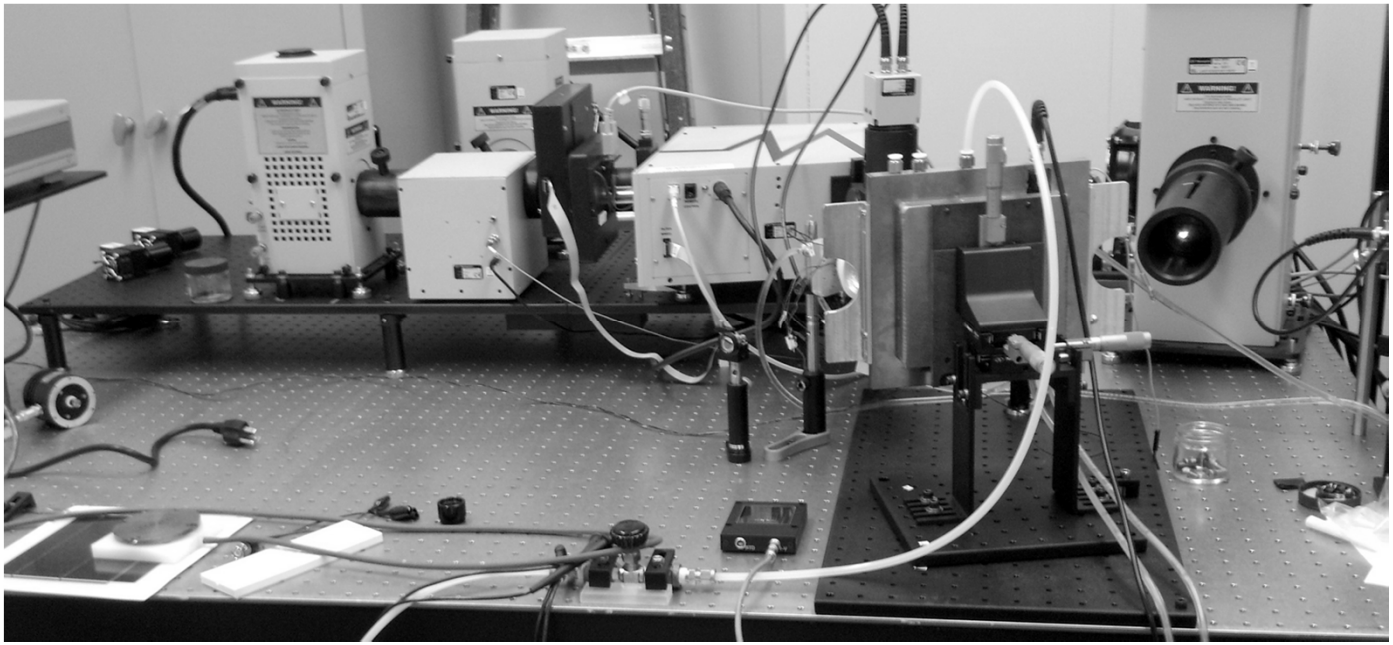
Spectral responsivity measurements

Monochromator-based (beam underfilling cell)

Unique features:

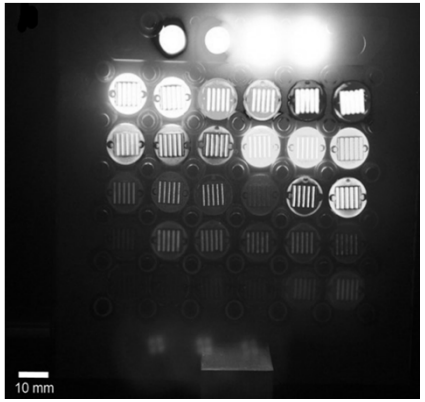
- Dual Xe and QTH light sources
- 300 nm -1900 nm measurement range, expandable to 2500 nm

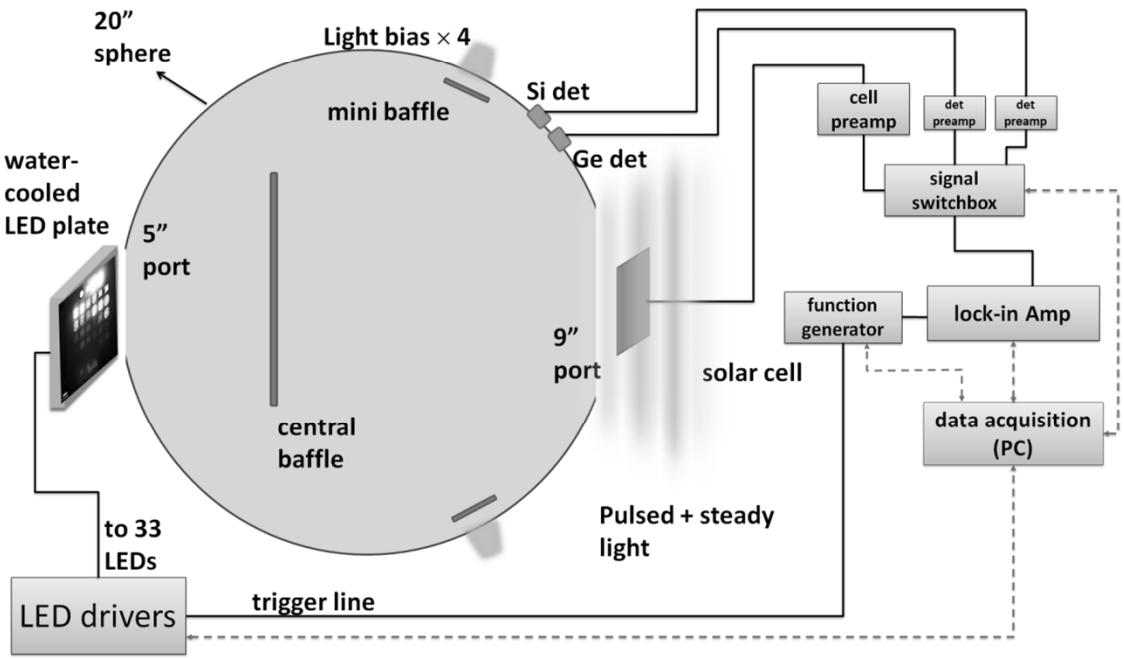


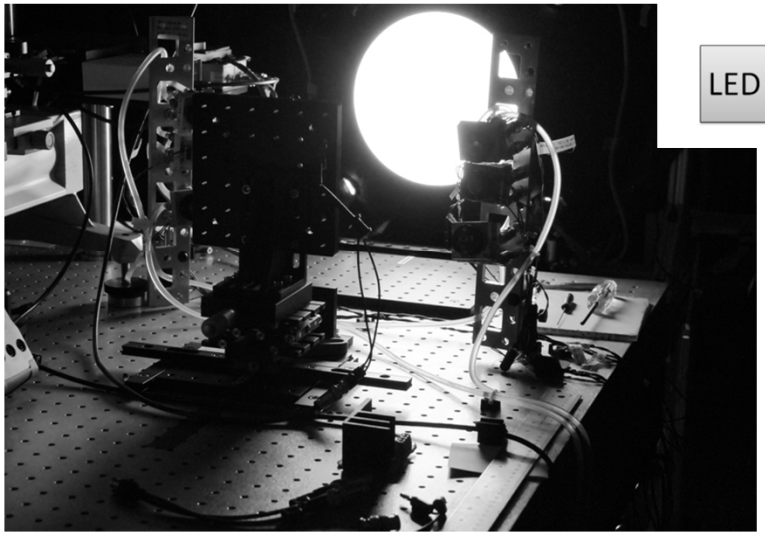


Spectral responsivity measurements

LED integrating sphere-based (beam overfilling)





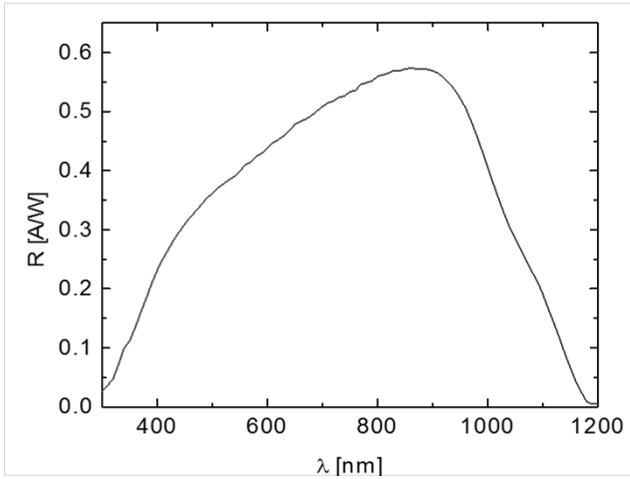


Sphere characteristics:

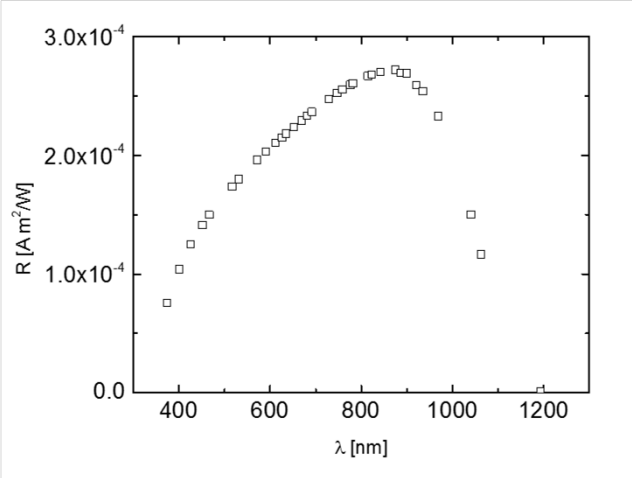
- 50.8 cm diameter
- 33 pulsable LEDs coupled in through the rear port
- Central baffle for improving light uniformity
- Irradiance uniformity better than 3% for a 12.5 cm cell
- Commercial LED drivers, triggered by a function generator run the LEDs sequentially

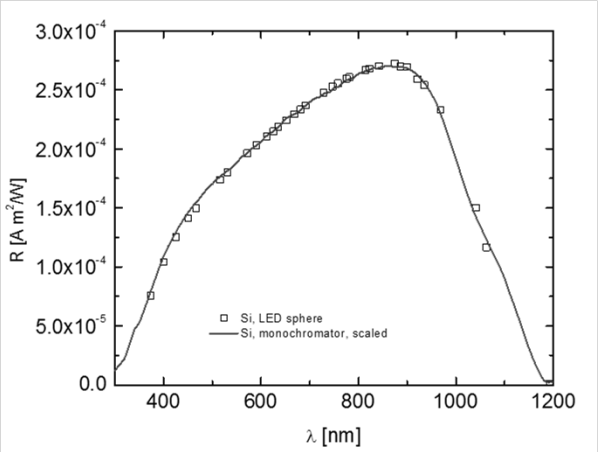
Spectral responsivity measurements

Obtain the power-mode SR with the monochromator



Obtain irradiance-mode SR at select wavelengths using LEDs

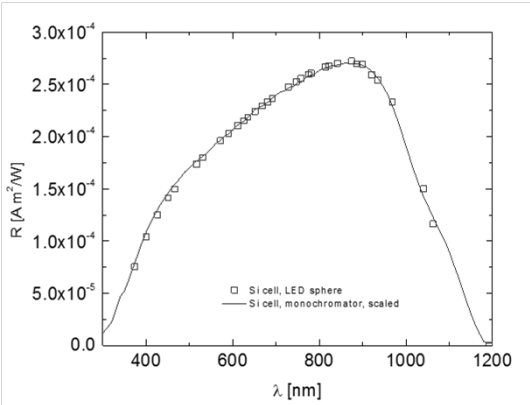




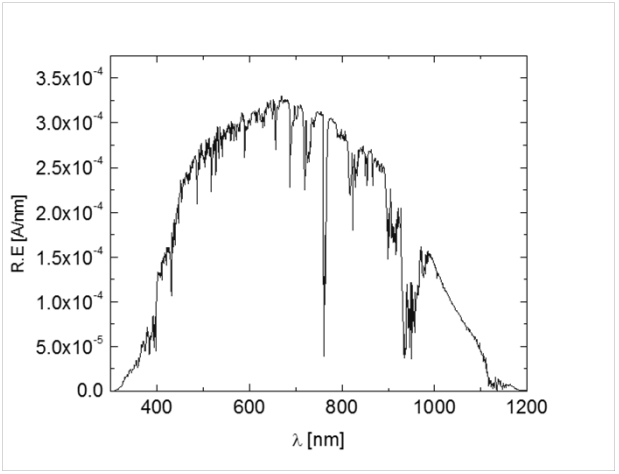
Fit the power curve to the LED based irradiance data

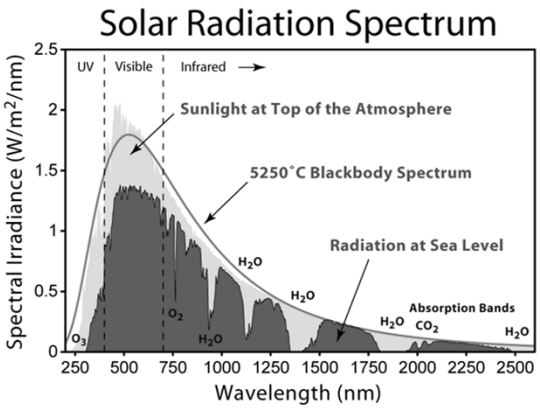
Primary cell calibrations

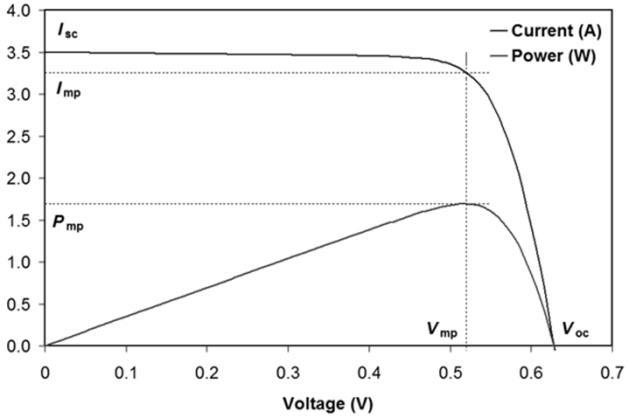
Only irradiance-mode SR can be used reliably for I_{sc} calculations



$$I_{sc} = \int R_{t,\ \mathrm{irrd\ mode}}(\lambda)\ .\ E_{AM1.5}(\lambda)\ d\lambda$$







Measurements of Installed Systems

Weather & PV Device Test Station

- Shortwave, Longwave, UV, Spectral
- I-V Traced Modules

Residential Rooftop Array

- 32 BC Mono-Si Modules
- 10.2 kW (DC rated)
- 18° due south

Horizontal Rooftop Array

- 234 Mono-Si Modules
- 35 kW (DC rated)

Tilted Rooftop Array

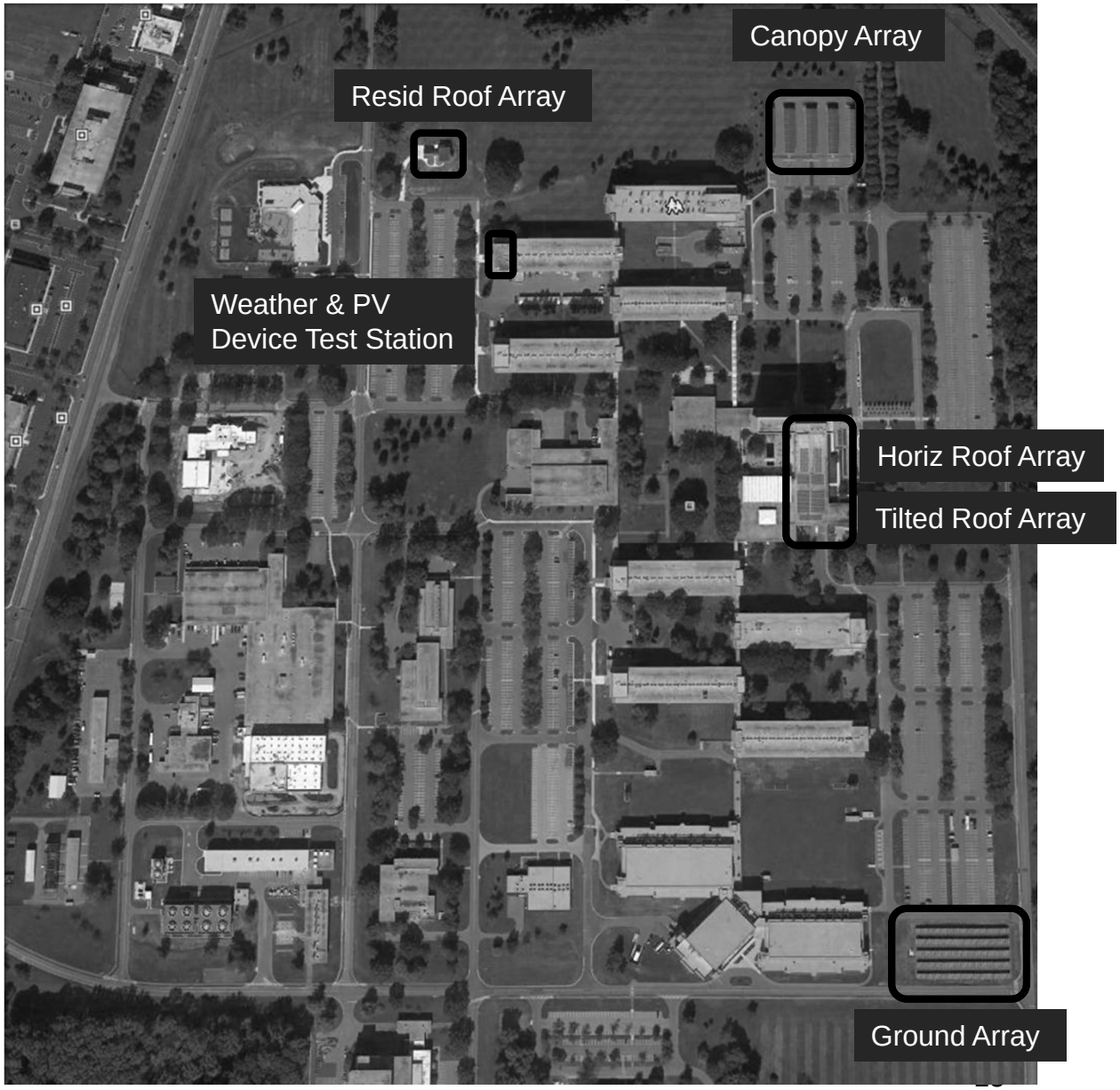
- 312 Mono-Si Modules
- 73 kW (DC rated)
- 10° due south

Canopy Array

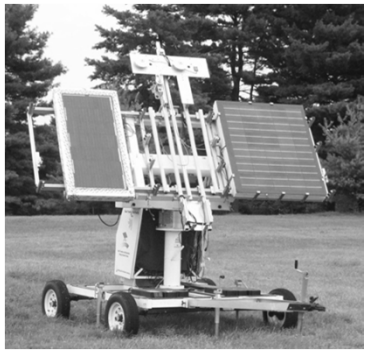
- 1032 Mono-Si Modules
- 243 kW (DC rated)
- 5° East/West

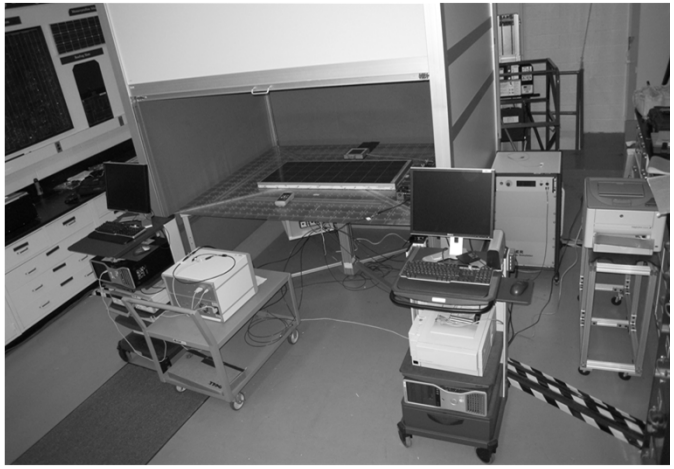
Ground Array

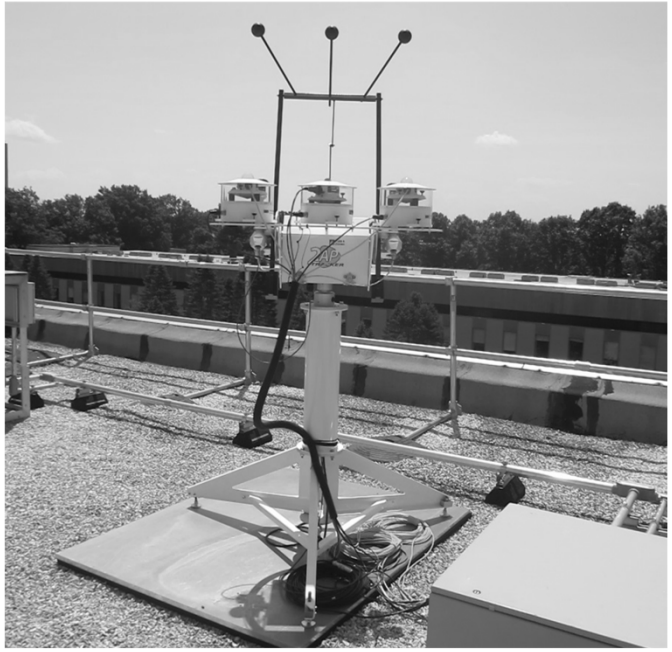
- 1152 Mono-Si Modules
- 271 kW (DC rated)
- 20° due south



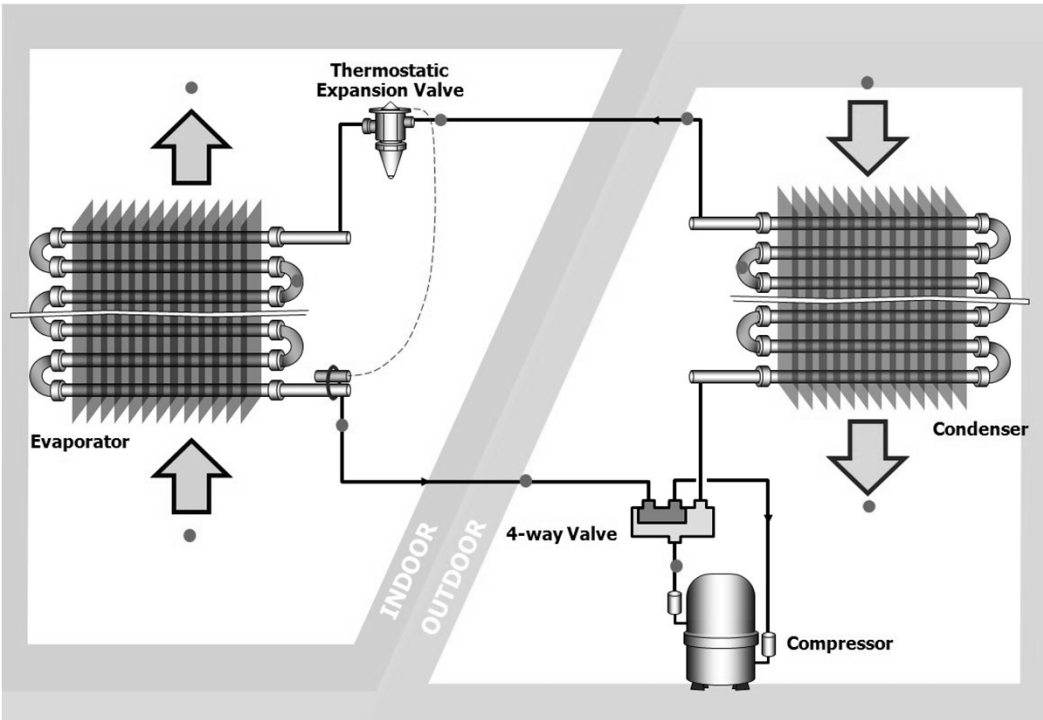
Solar Photovoltaic Test Beds and Weather Station

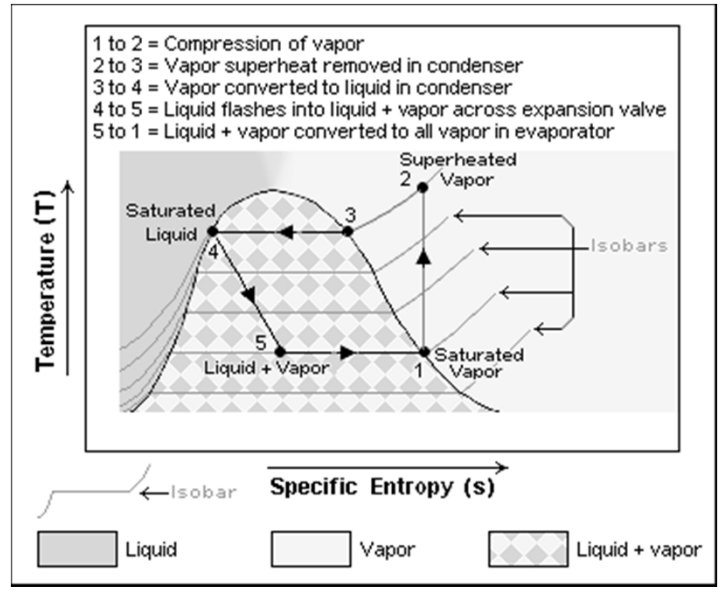






Air Conditioner/Heat Pump Performance

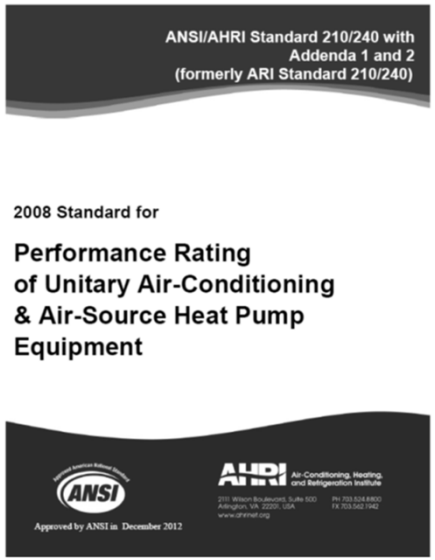


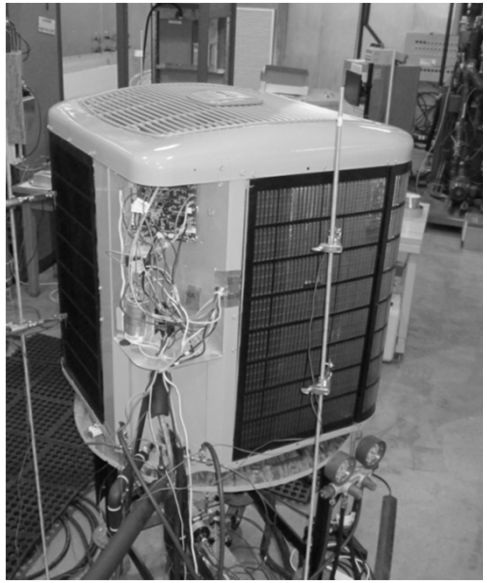


$$COP_{Carnot} = \frac{T_C}{T_H - T_C}$$

Actual COP is much smaller due to all of the real system efficiency losses (thermodynamic, transport, mechanical, electrical, operational)

Air Conditioner/Heat Pump Performance



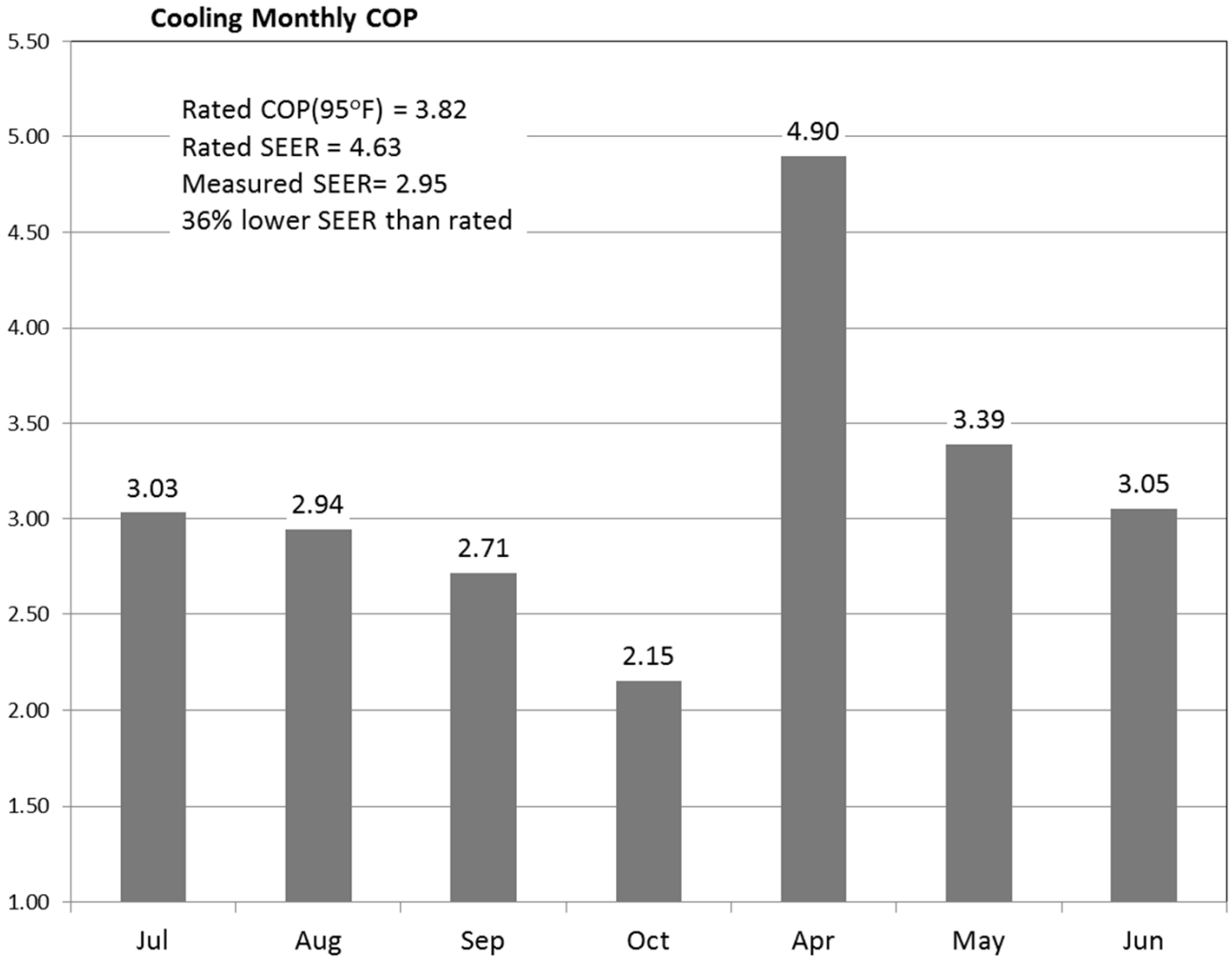


Standard: AHRI 210/240

- AHRI administered certification program
- Indoor condition – 80°F (db), 67°F (wb)
- Outdoor condition - 95°F (db), 75°F (wb) for cooling capacity
- - 82°F (db), 65°F (wb) for COP/EER
- SEER rating for cooling based on expected performance of 8 different outdoor temperatures
- HSPF rating for heating based on range of outdoor temperature

NZERTF 1st Year: Heat Pump Cooling Efficiency

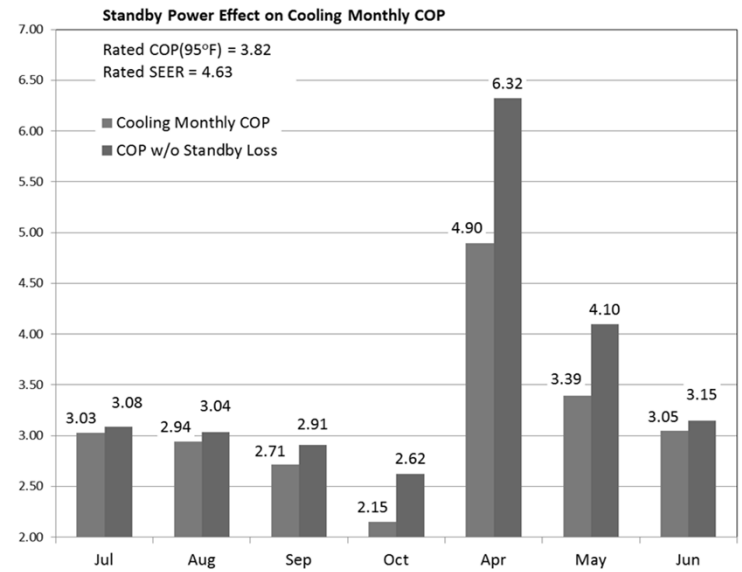
Cooling Thermal Loads
Jul2013: 2123 kWh
Aug2013: 1621 kWh
Sep2013: 937 kWh
Oct2013: 306 kWh
Apr2014: 67 kWh
May2014: 603 kWh
Jun2014: 1560 kWh



Cooling Standby Energy and Moisture Removal

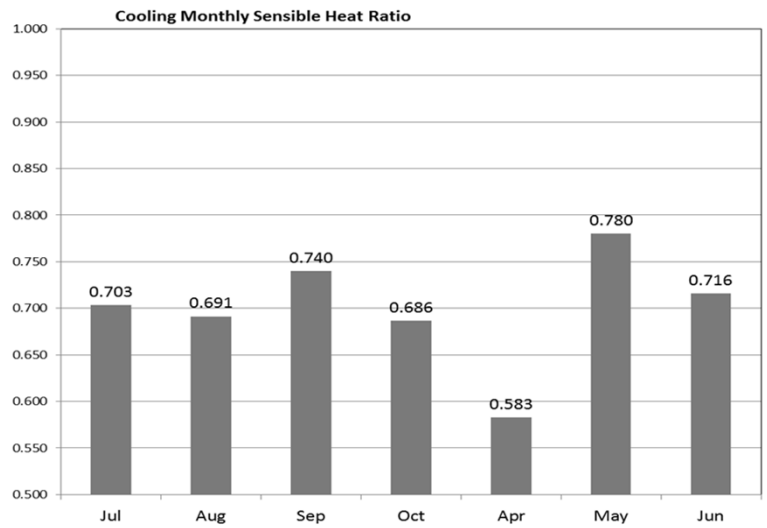
Cooling Standby Energy
127.7 kWh
5.2% of total cooling electrical energy

Standby Avg. Power (W)
Indoor: 10
Outdoor: 40

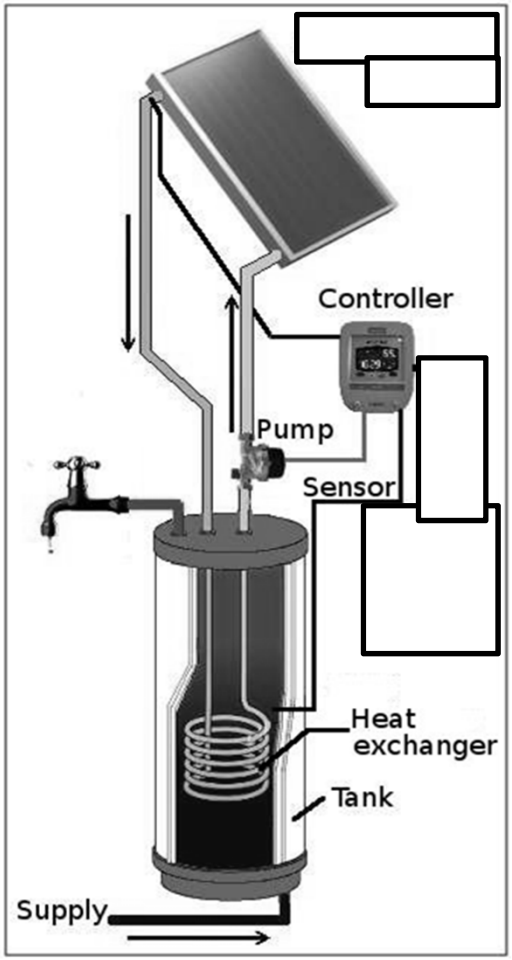


Current U.S. ratings do not prescribe Sensible Heat Ratio (SHR)

- Most high efficiency systems operate with SHR greater than 80%
- Moisture removal is a bigger issue in tight buildings



Water Heating System – Solar Preheat



Preheat - Solar thermal

- 80-gal tank
- Forced-circulation system with heat exchanger
- Four solar thermal flat-plate collectors

Standards

- SRCC certification recognized in the US and Caribbean
- Solar collectors rated to ISO 9806, ASHRAE 93
- System rated to ISO 9459 (outdoor test, component test, dynamic test with computer simulation)

Credit: Jim Huggins SRCC

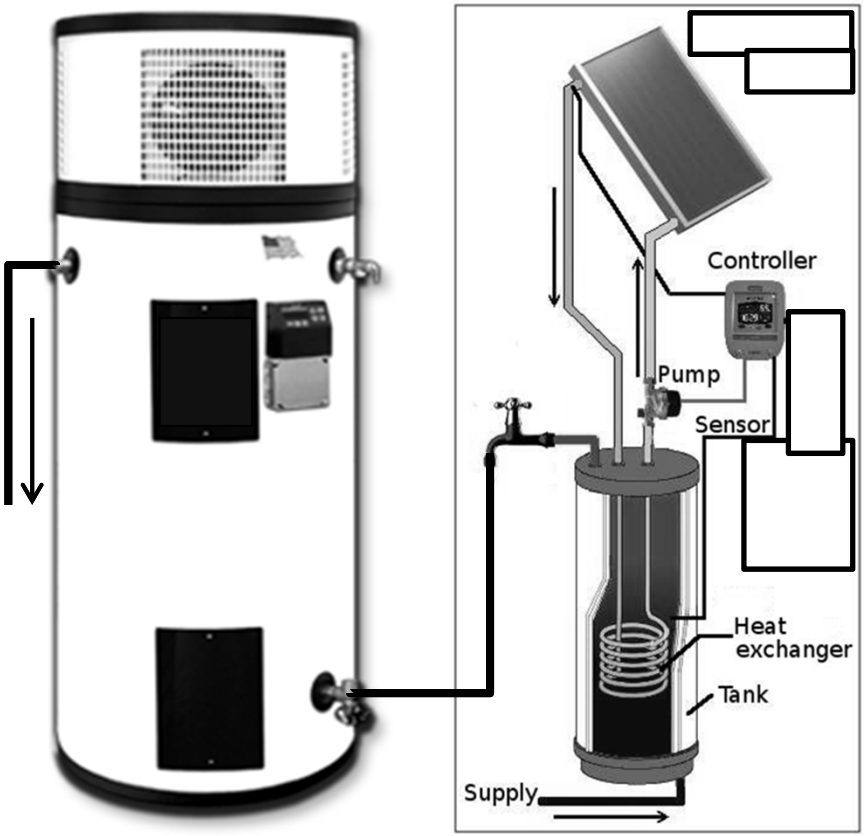
Water Heating System – HP Backup

Auxiliary - Heat pump water heater

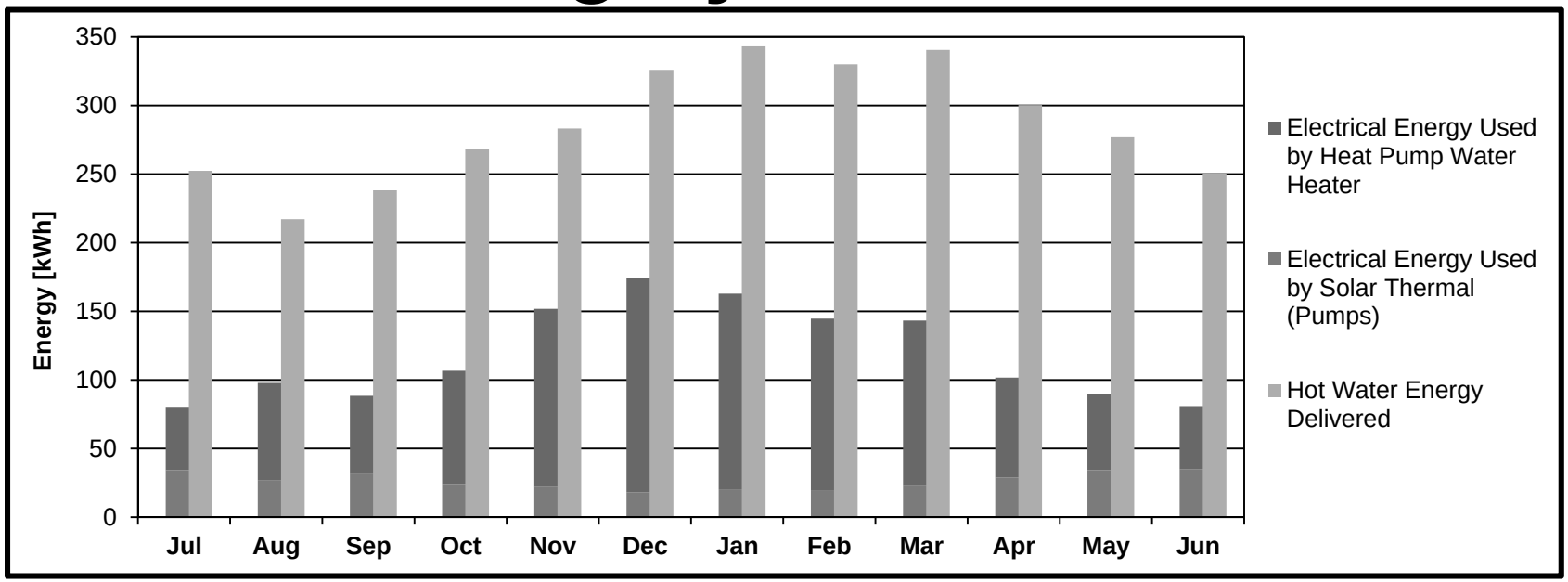
- 50-gal tank
- Energy Factor (EF) of 2.33
- Multiple operating modes: heat pump, hybrid, standard electric

Standard

- U.S. Department of Energy test method
- Previously ASHRAE 118.1
- Fixed ambient conditions
- Specified usage/draw patterns related to unit size

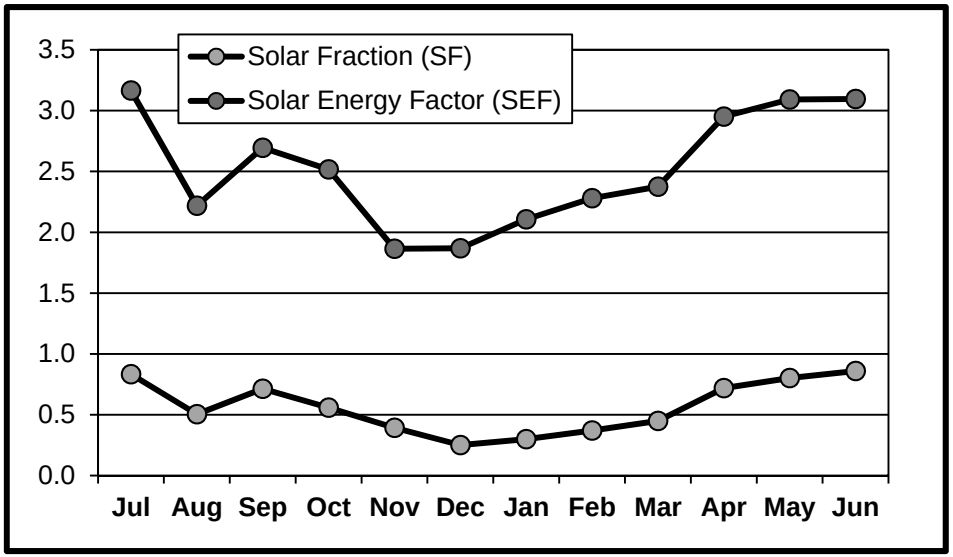


Water Heating System Performance



Year-to-Date Performance	
Total Hot Water Energy Delivered	**3427 kWh**
Total Electrical Energy Used	**1422 kWh**
Solar Fraction (SF)[1]	**0.54**
Solar Energy Factor (SEF)[2]	**2.41**

1. The **Solar Fraction** is the contribution of solar thermal water heating to the total hot water energy delivered.
2. The **Solar Energy Factor** measures overall system performance and is defined as the total hot water energy delivered divided by the total electrical energy put into the water heating systems.



Summary

Research Activities of the Energy and Environment Division

- Improved knowledge base for high-performance green building standards
- Performance metrics for Net-Zero energy homes
- Improved measurement techniques and data for photovoltaic cells and arrays
- Space conditioning for energy efficient buildings
- Hybrid solar water heater with heat pump backup

Energy and Environment Division

David Yashar

Deputy Chief

dyashar@nist.gov