



Current NIST Research: Building Energy Efficiency Solar Energy Electrical Measurements Smart Grid

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NIST R&D Role: Measurement Science and Standards

- Sustainable materials, components, and systems
- Building energy-use reduction through in-situ performance measurements
- Energy-use reduction through embedded intelligence in building controls
- Emerging building energy technologies
- Carbon footprint metrics and tools for computing those metrics



*High Efficiency HVAC
Systems and Controls*



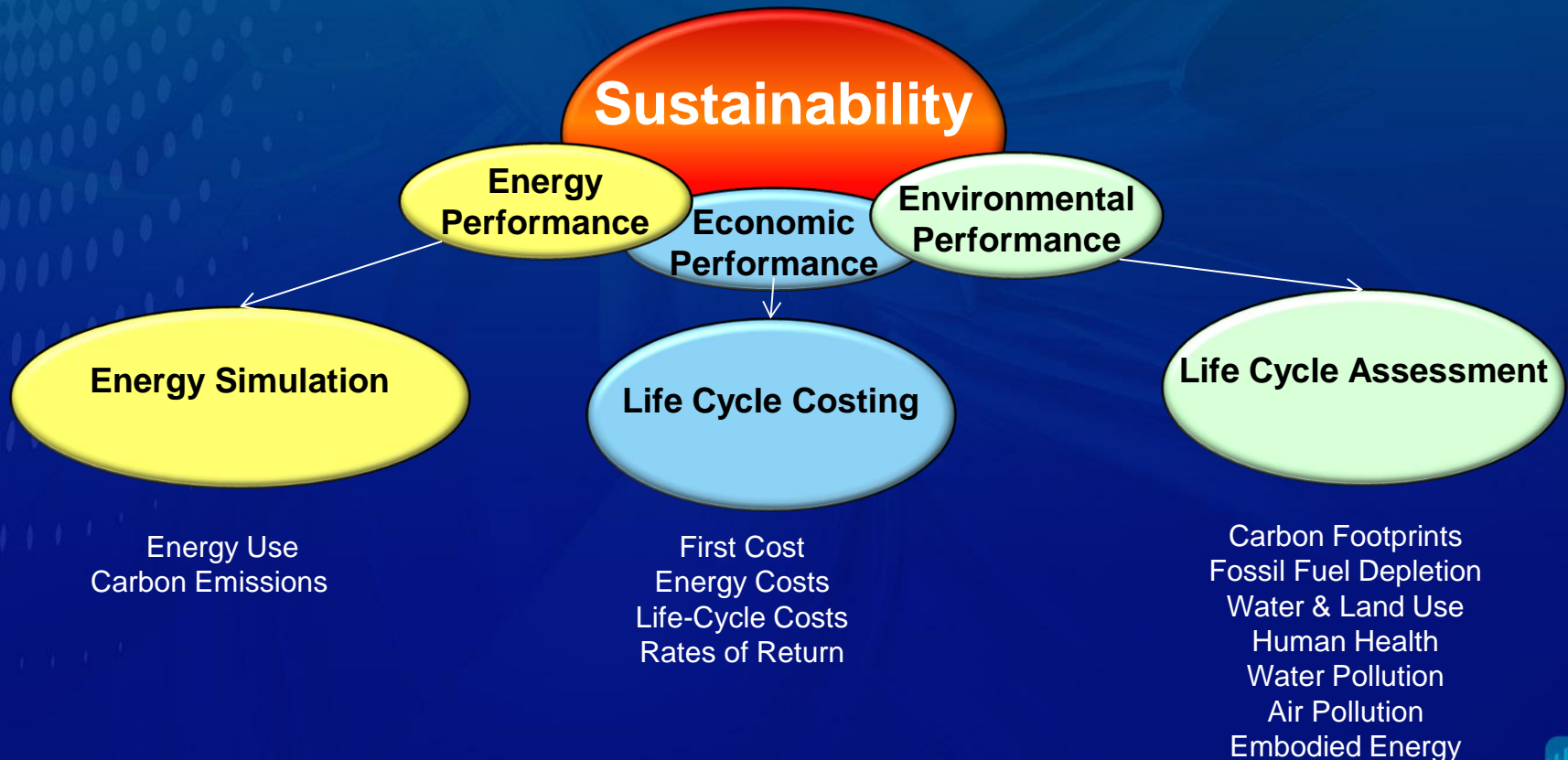
Fuel Cell Test Facility



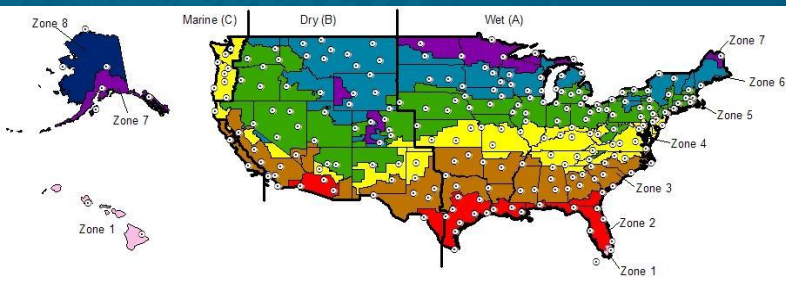
Metrics & Tools for Sustainable Buildings

A whole building sustainability measurement tool for adoption of

- More efficient and cost-effective energy codes
- More rigorous green building rating systems
- Science-based and cost-effective green building codes

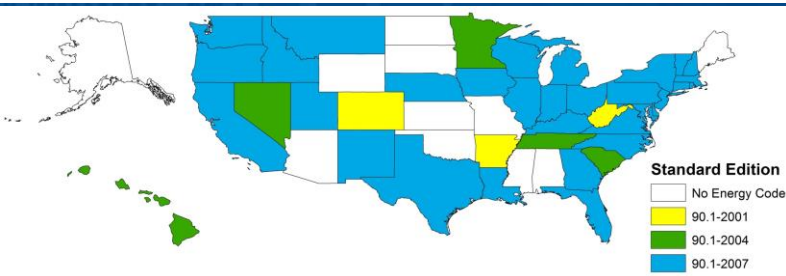


Building Industry Reporting and Design for Sustainability (BIRDS)



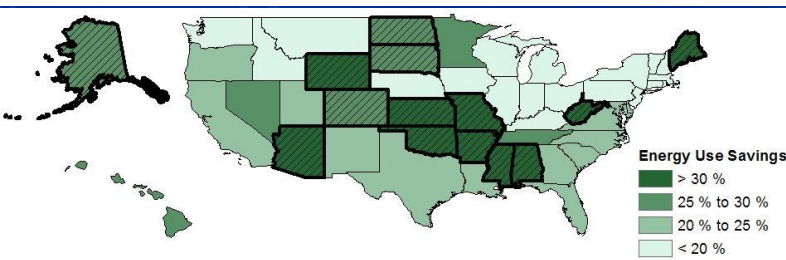
“Low Energy Case” design

- Goes beyond *ASHRAE 90.1-2007*
 - Insulation, fenestration, lighting densities, daylighting, and overhangs



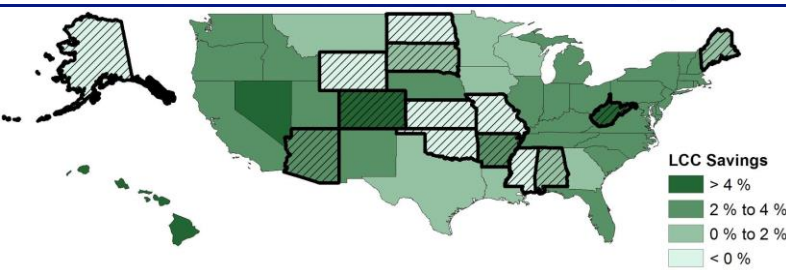
Adopting a “Low Energy Case” design for all commercial buildings decreases...

- Energy use, energy costs, and energy-related carbon emissions for all 50 states
- Life-cycle costs for 47 of 50 states for a 10-year study period



For a low-rise office building, over a 10-year study period...

- National average energy use decreases by 23.0%
- National average life-cycle costs decrease by 2.2%



Advanced Insulation Measurement Techniques

Develop measurement techniques, apparatus, and Standard Reference Materials to accurately measure/predict insulating capabilities of conventional/advanced insulation materials

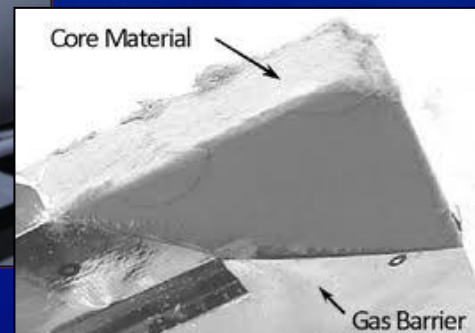
Aerogel insulation



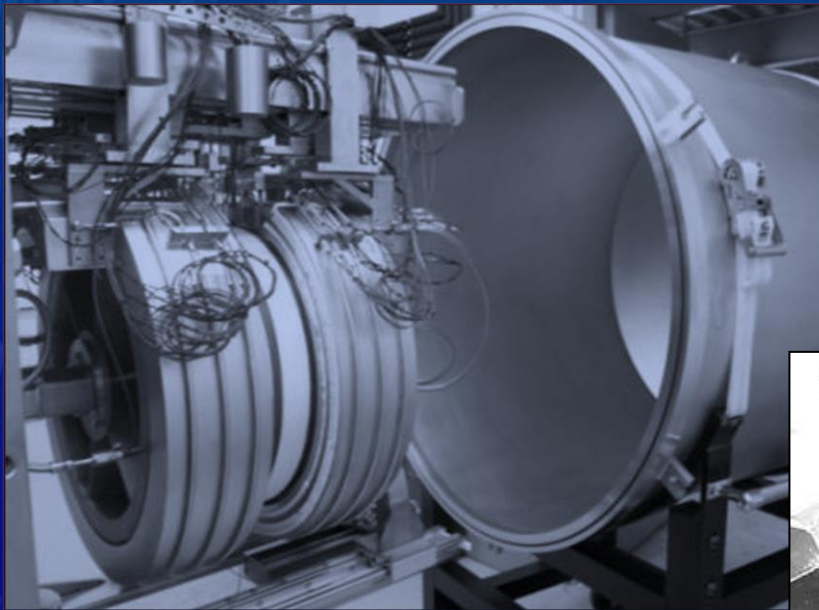
Phase Change Material (PCM)



Vacuum Panel Insulation (VIP)



NIST 500 mm Guarded-Hot-Plate Apparatus

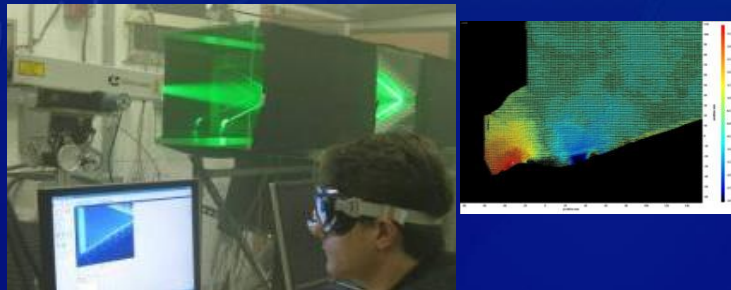


Design and In-Situ Performance of Vapor Compression Systems

- To support and improve commissioning methods for residential AC systems
 - Characterize sensitivity of heat pump performance to faulted operation
 - Recommendations to improve standards for quality installation
- To create novel simulation and optimization tools for designing highly efficient equipment and demonstrate their capability
 - Validate by working with equipment manufacturers and improving current products without increasing material cost



System analysis and fault classifier



Measure the air flow distribution through finned tube heat exchangers using Particle Image Velocimetry



Simulate heat exchanger performance with PIV data and employ evolutionary algorithms to modify refrigerant circuitry for optimal capacity

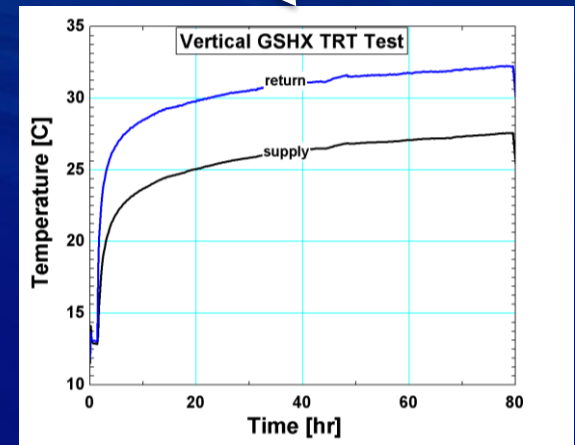


Geothermal Heat Exchanger Testing

- Compare performance of three common types of heat exchanger
- Evaluate design guidelines
- Evaluate long-term performance of GSHX integrated with Net-Zero Energy home



Thermal Response Test Rig



vertical borehole

horizontal u-tube

horizontal slinky



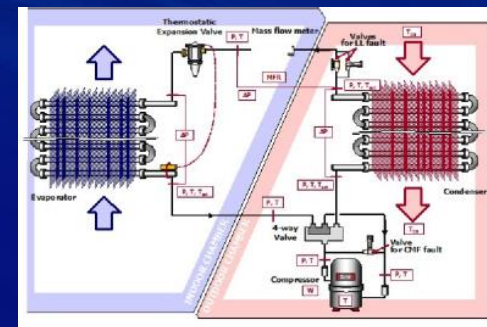
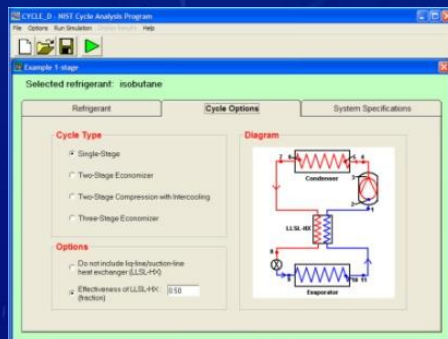
Novel Working Fluids for High-Efficiency HVAC&R Equipment

Concerns over global warming and ozone depletion will limit or phase out several refrigerants currently used in commercial and residential cooling and heating equipment



NIST will develop the tools necessary for the US industry to use to select replacement fluids:

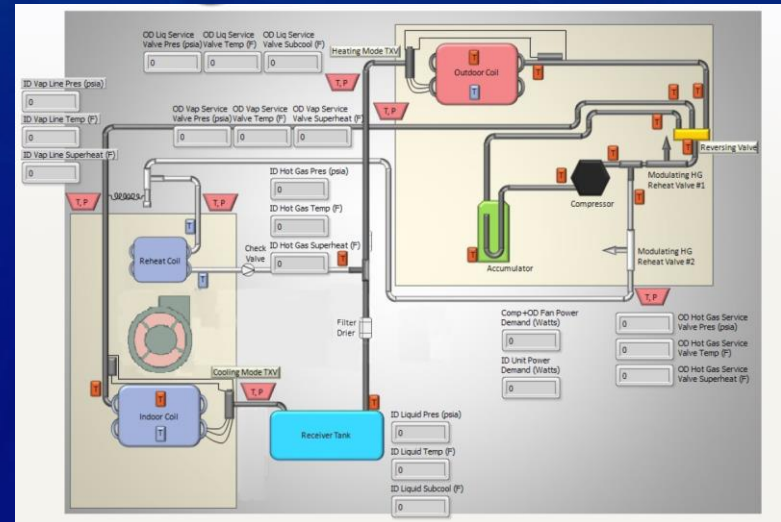
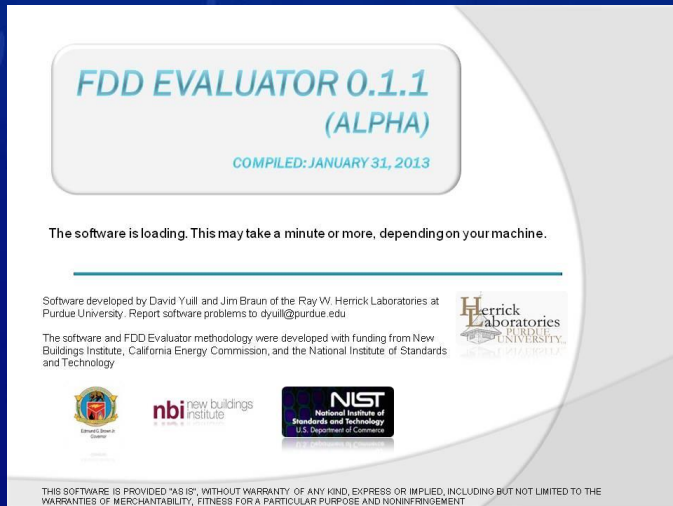
- Thermodynamic cycle performance evaluation
- Heat transfer and pressure drop measurements/correlations
- System optimized for new fluid



Fault Detection and Diagnosis for Air Conditioners and Heat Pumps



- FDD and Commissioning for Heat Pumps
- Test and Evaluate the Effectiveness of FDD Algorithms/Hardware
- Adaptive FDD Applied to Dedicated Dehumidifying Heat Pump Installed in NZERTF

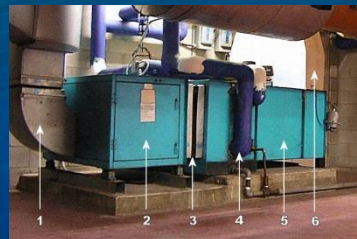


Automatic Fault Detection and Diagnostics (FDD) Embedded in Commercial Buildings

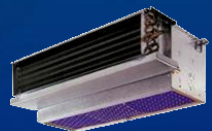
FDD module networks autonomously to data available within the HVAC control system...



...to automatically detect and diagnose malfunctions and wasteful conditions (faults) among the many HVAC system components.



Air Handling Units (1 – 10 units/bldg.)



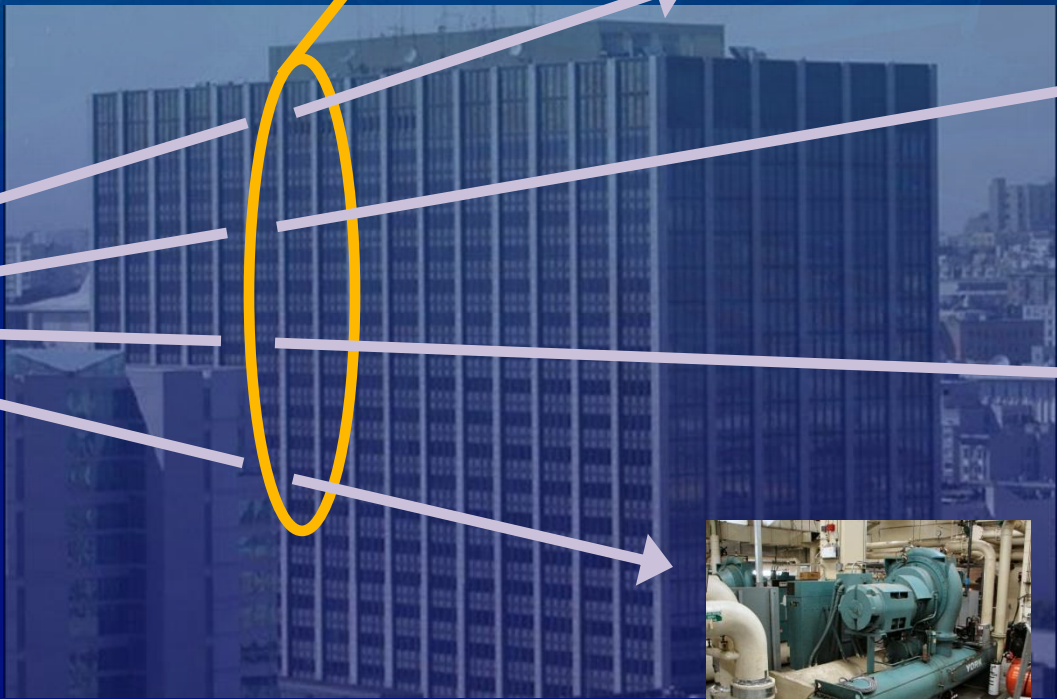
Distributed HVAC Devices (10's – 1,000's units/bldg.)



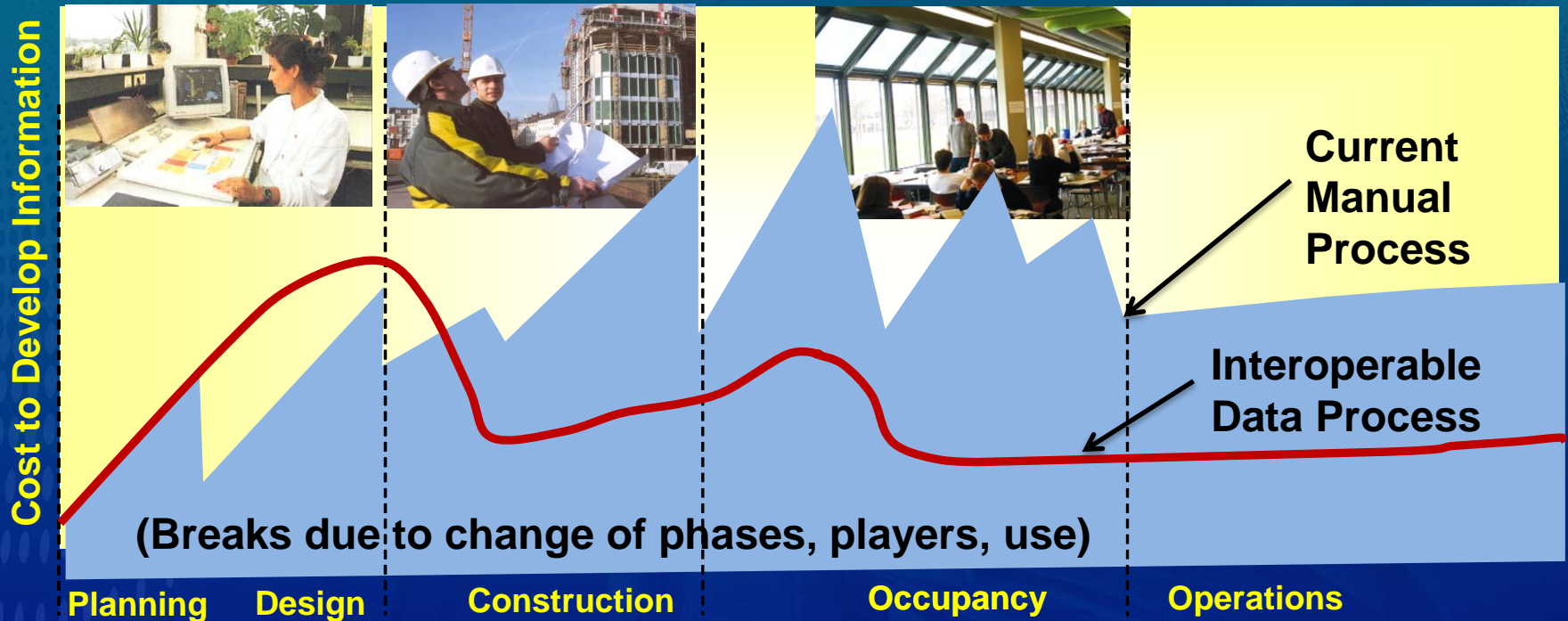
Central Cooling & Heating Plant (3 – 10 units/bldg.)



Existing HVAC System Controller



Commissioning Building Systems for Improved Energy Performance



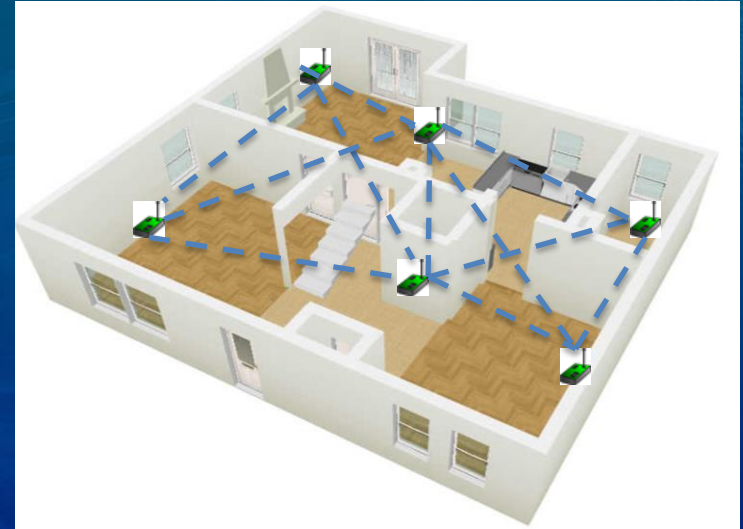
- Cx has the potential to enable continuous building evaluations, provide necessary feedback across building life-cycle
- Improve performance by 10 % to 30% using embedded intelligence software to automate labor-intensive commissioning process
- Accelerate adoption by demonstrating and documenting economic benefits for the U.S. building stock



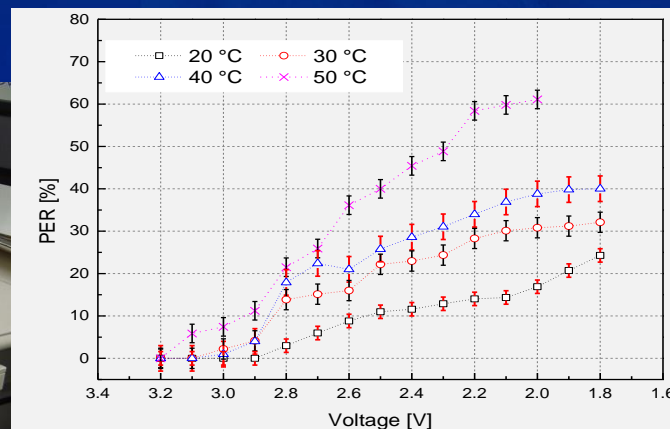
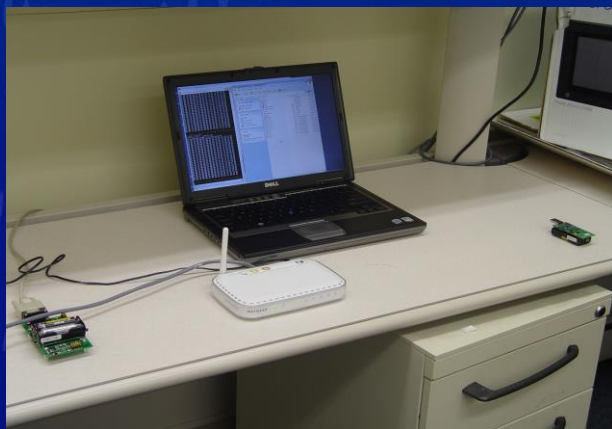
Sensors for Improved Building Monitoring

Explore novel sensor technology that could be used as part of monitoring systems to determine energy consumption in buildings

Develop test methods to assess the performance of wireless sensor networks for building applications



Mesh Network Connection



Wireless Communication Tests



Wireless Sensor Nodes



Building Automation Testbed and Standards

Laboratory testbed capable of emulating a variety of buildings and climates under normal operating conditions and a range of fault or hazardous conditions

- Supports Cx and FDD research
- Supports protocol enhancement research

Provide technical input for improving key industry standards including BACnet and BACnet conformance testing standards.

Number of BACnet Vendors



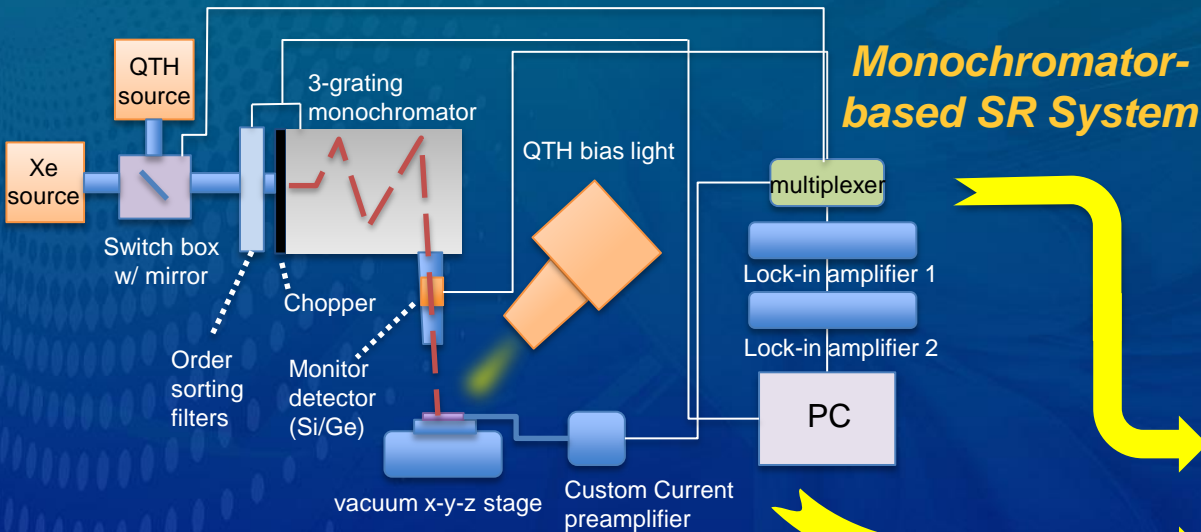
Virtual Cybernetic Building Testbed (VCBT)



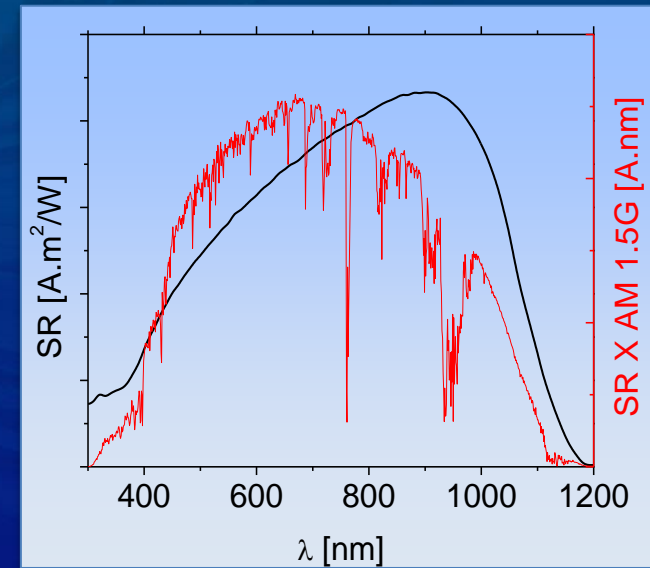
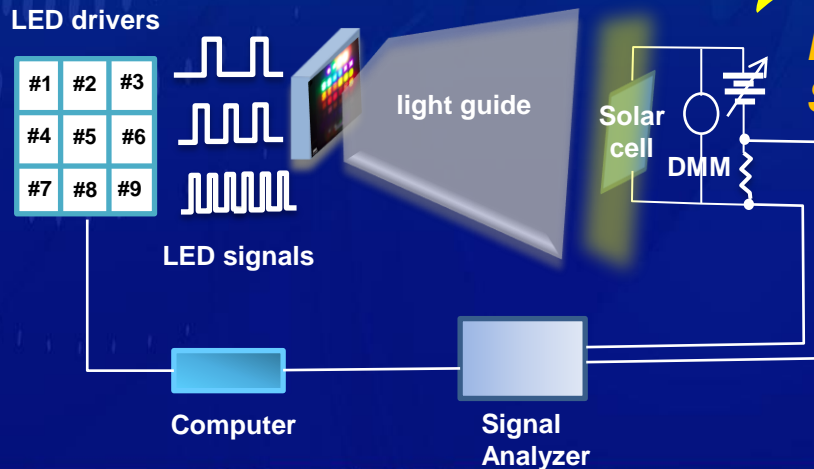
Solar Cell/Module Characterizations

Developing, utilizing, and combining aspects of two techniques for measuring a cell's absolute spectral responsivity (SR)

Monochromator-based SR System



LED-based SR System



I_{sc} for AM 1.5

Reference Cell Calibrations with SI-Traceability



Solar Photovoltaic Test Beds

PV performance and meteorological data from field-installed solar systems



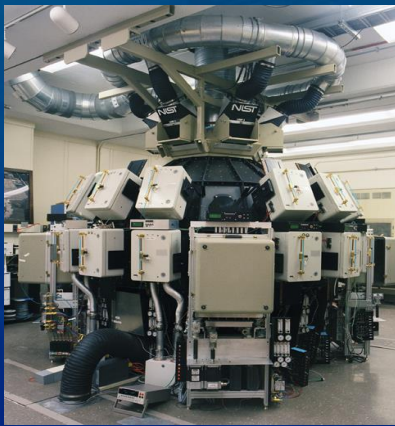
Characterize solar cells & modules => improve module ratings and computer models



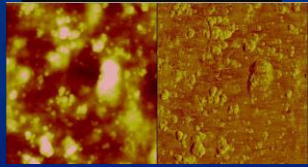
Measurement Science for Service Life Prediction of Polymers Used in PV Systems

NIST is developing and implementing measurement science for predicting the lifetime of polymeric materials utilized in PV applications.

- Engage industry partners and end-users.
- Fabricate a state-of-the-art PV accelerated weathering facility.
- Define, design, and expose PV materials, components and mini-modules.
- Characterize degradation mechanism under multiple simultaneous stresses.
- Develop and validate service life prediction models.



NIST SPHERE for Accelerated Weatherability Testing



Degradation Measurement and Failure Analysis



Linking Laboratory and Field Service Life Prediction Models

Total Effective Dosage Model

$$D_{total}(t) = \int_0^t \int_{\lambda_{min}}^{\lambda_{max}} E_o(\lambda, t) (1 - e^{-A(\lambda)}) \phi(\lambda) d\lambda dt$$

Cumulative Damage Prediction Model

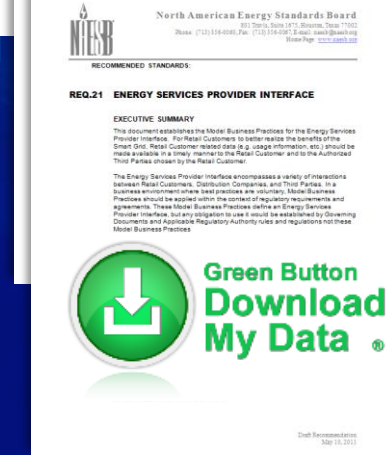
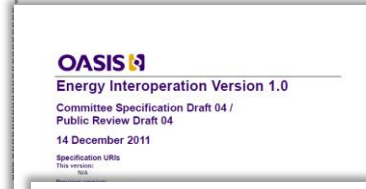
$$Damage_{CUM}(t) = \sum_{i=0}^t \Delta D(i)$$



Building to Smart Grid Integration

- Home and building energy management in the smart grid
- Interoperability standards for buildings communicating with the smart grid

Standard electric price, usage, weather signals
\$, kWh



Whole-Building Energy Modeling and Measurements

Reducing uncertainty in modeling tools and measurement techniques for making predictions on whole-home energy use



MONITORING SYSTEMS FOR HOME ENERGY USE FEEDBACK

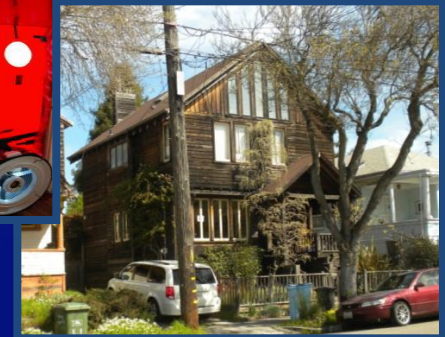
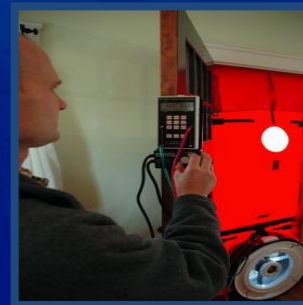
Identifying sources of measurement error
Developing a test method to evaluate accuracy and wireless communication

RETROFITS TO EXISTING HOMES

Quantifying variability of energy audits
Standardizing retrofit recommendations

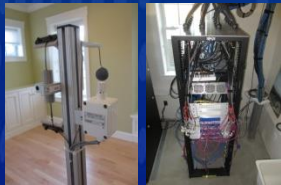
ENERGY MODELING

Sensitivity analyses of residential building energy simulations
Improving energy efficiency standards



Net-Zero Energy Residential Test Facility

- Demonstrate various technologies and operating strategies to achieve net-zero energy in a typical home
- Develop guidelines for performance measurement and operation of net-zero homes
- Provide “real-world” field data to improve models and test procedures
- LEED Platinum



Extensive Instrumentation

Automated Loads:

- Lights
- Electrical
- Hot Water
- Appliances



Solar Thermal Water Heating

Photovoltaics



3 HVAC System Options:

- Traditional
- High Velocity
- Multi-split

3 Ground Source Heat Pump Loops

Heat Recovery Ventilator



Net-Zero Energy Residential Test Facility

- Demonstrate net-zero energy
- Create test bed for in-situ measurements of components and systems
- Quantify impacts of embedded controls intelligence & building-to-grid interactions
- Compare actual installed performance to controlled laboratory measurements



LEED Platinum

engineering laboratory



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