



NIST Research Efforts Advancing Standards for :

- **Building Energy Efficiency**
- **Solar Energy Electrical Measurements and**
- **Smart Grid**

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Research Objective and Vision

- **Objective:**
Anticipates and meets measurement science and standards needs for technology-intensive manufacturing, construction, and cyber-physical systems, including the **Smart Grid Program Office**, in ways that enhance economic prosperity and improve the quality of life.
- **Vision:**
Be the source for:
 - **Solution-enabling measurement science , and**
 - **Technical contributions underpinning emerging standards, codes, and regulations used by the U.S. manufacturing, construction, and infrastructure industries to strengthen leadership in domestic and international markets.**



NIST R&D Role:

Measurement Science and Standards

- **Overview**
 - **Standards and Codes in the U.S.**
 - **Metrics & Tools for Sustainability**
- **Sustainable Buildings**
 - **materials, components, and systems**
 - **Energy-use reduction through in-situ performance measurements**
 - **Energy-use reduction through embedded intelligence in building controls**
 - **Emerging building energy technologies**



*High Efficiency HVAC
Systems and Controls*

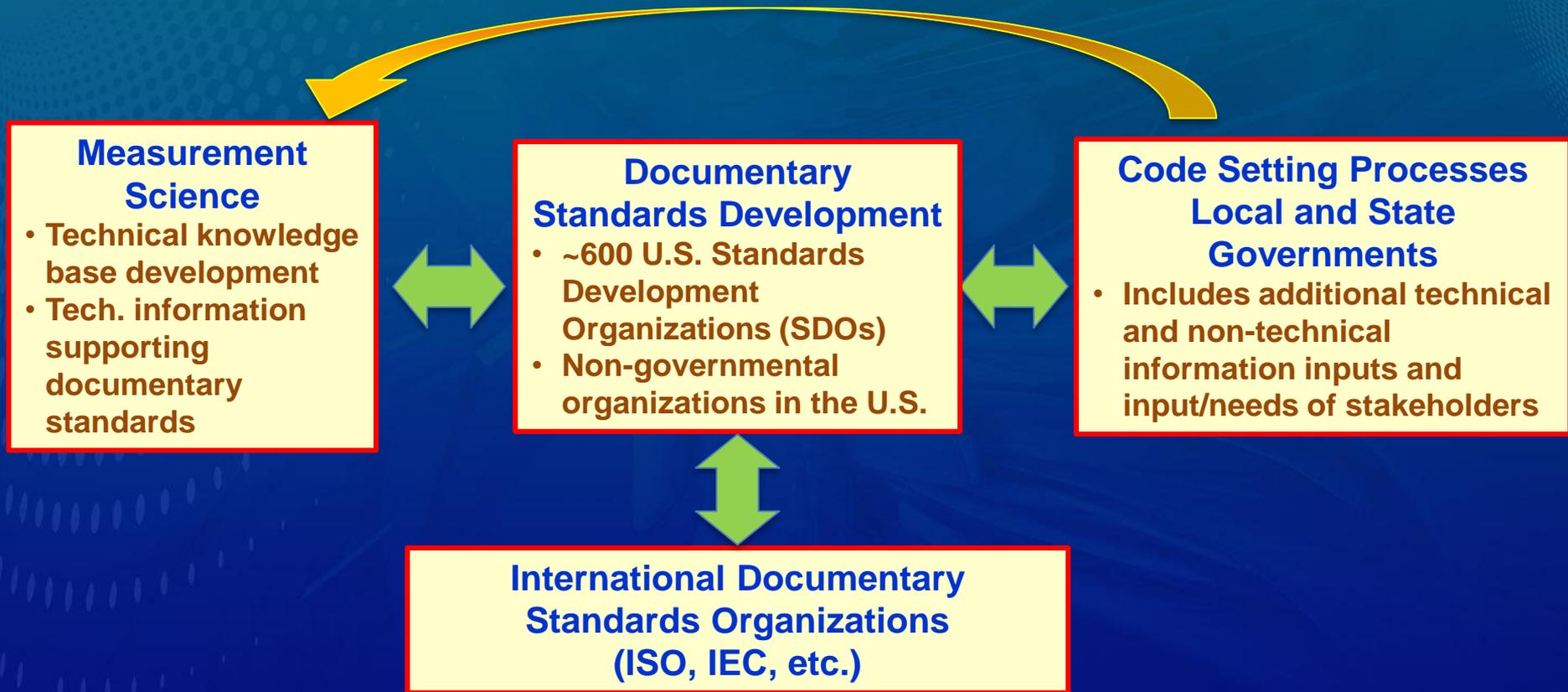


Fuel Cell Test Facility



NIST Measurement Science Research

Supporting U.S. Codes & Standards



U.S. Codes and Documentary Standards are Publically and Internationally Available



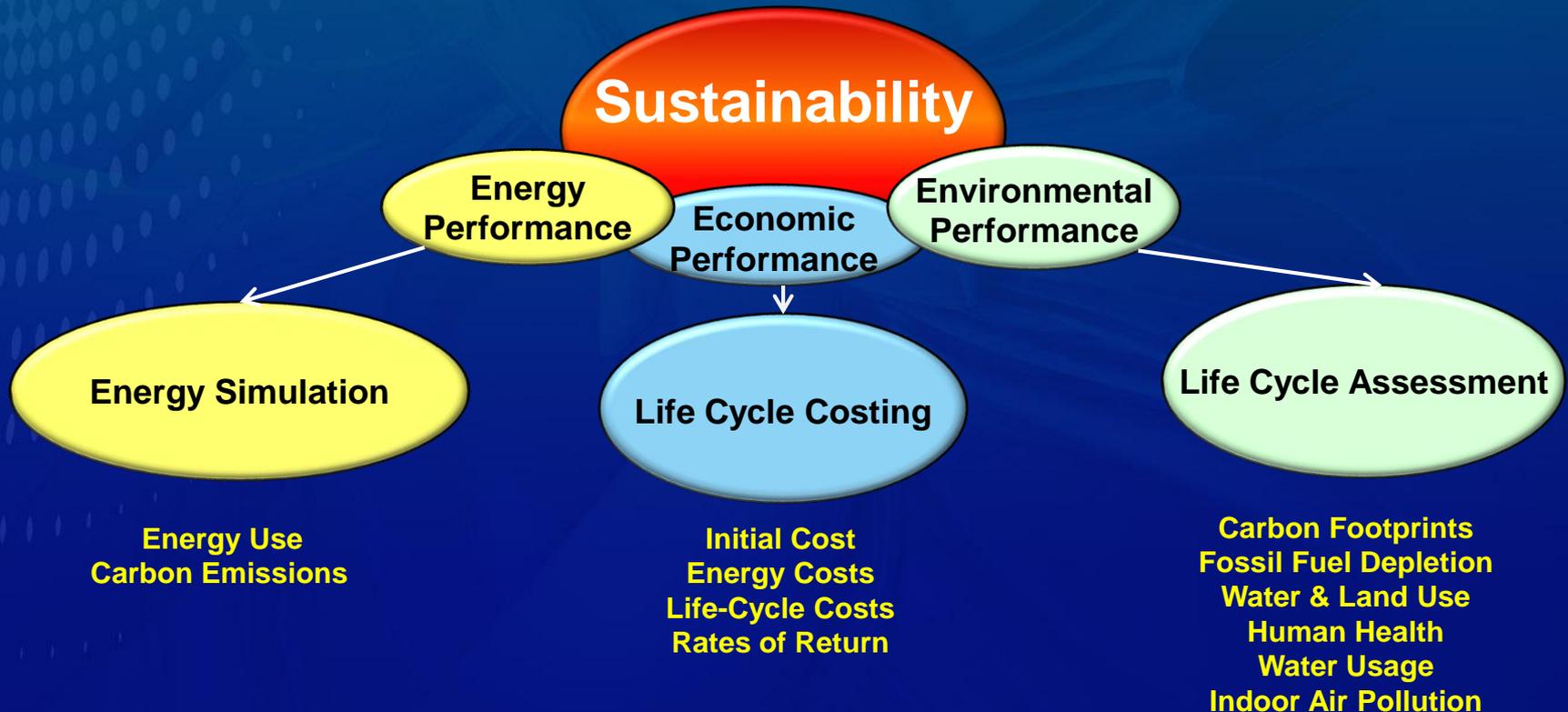
BUILDING ENERGY EFFICIENCY & SUSTAINABILITY



Metrics & Tools for Sustainable Buildings

A whole building sustainability measurement tool for adoption of

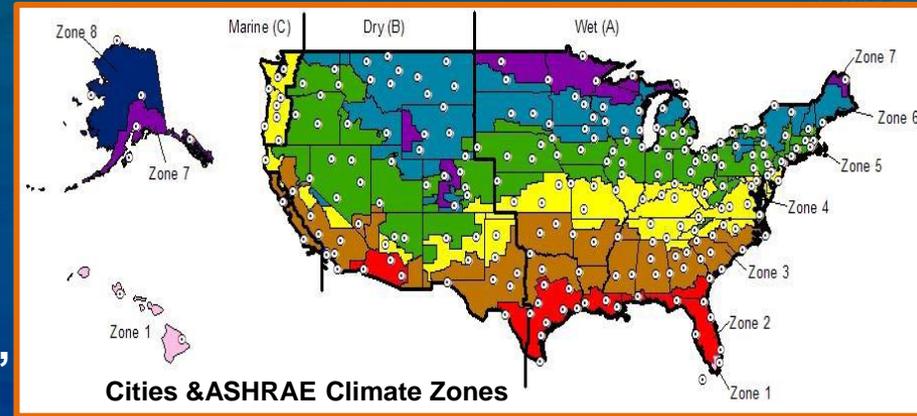
- More efficient and cost-effective energy codes
- More rigorous green building rating systems
- Science-based and cost-effective green building codes



Modeling Code Impact on Sustainability

BIRDS: Building Industry Reporting and Design for Sustainability

- Analyze the impacts adoption of newer, more efficient commercial building energy codes would have on building energy use, operational energy costs, building life-cycle costs, and energy-related carbon emissions
- Use ASHRAE 90.1-1999 (baseline year) to 90.1-2009 (Low Energy Case – LEC) to estimate commercial buildings performance in the U.S. by state



Total Change from Adoption of New Standards – 10 Year Study Period State of Alabama

| Metric | Unit | 2001 | 2004 | 2007 | LEC* |
|------------------|-----------------------------------|--------|---------|---------|---------|
| Energy Use | GWh | -48.9 | -518.4 | -631.6 | -1050.6 |
| Energy Cost | PV \$Million | -\$3.9 | -\$42.5 | -\$49.8 | -\$84.9 |
| Carbon Emissions | 1000 metric tons CO _{2e} | -41 | -458 | -528 | -909 |
| Life-Cycle Cost | PV \$Million | \$30.1 | -\$18.5 | -\$25.7 | -\$37.0 |

* LEC – Low Energy Case – ASHRAE 189.1-2009 (Am. Soc. of Heating, Refrigerating, and Air Conditioning Engineers)



Thermal Performance

Building Insulation Measurement Techniques

Develop measurement techniques, apparatus, and Standard Reference Materials to accurately measure and/or predict thermal properties of conventional and advanced insulation materials

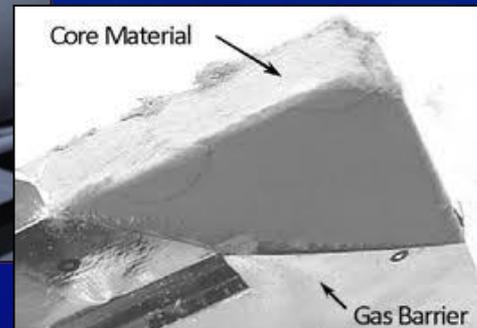
Aerogel insulation



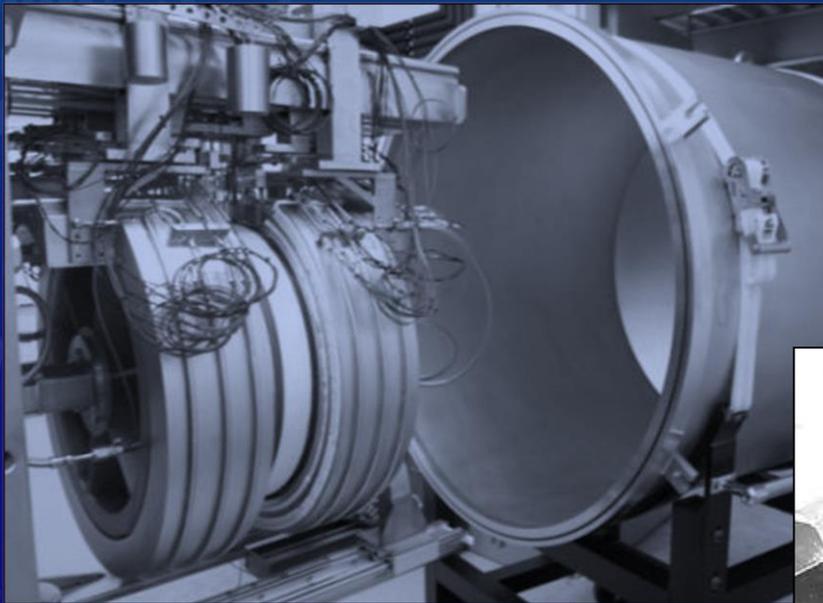
Phase Change Material (PCM)



Vacuum Panel Insulation (VIP)



NIST 500 mm Guarded-Hot-Plate Apparatus



PHOTOVOLTAIC CELL & ARRAY PERFORMANCE METRICS

- Advancing characterization methods for individual cells
- Improving panel materials failure mechanism models
- PV panel array testing methods



Photovoltaic Test Beds

Advancing Module Performance Methods



- PV performance combined with meteorological and solar irradiance data for solar panel systems
- Scales ranging from laboratory to field-installed single panels and arrays in roof and PV farm configurations



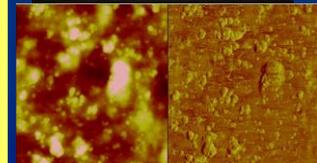
Advancing Service Life Prediction of Polymers Used in PV Systems

NIST is advancing the understanding of failure mechanisms of polymeric materials utilized in solar cell assemblies

- 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

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

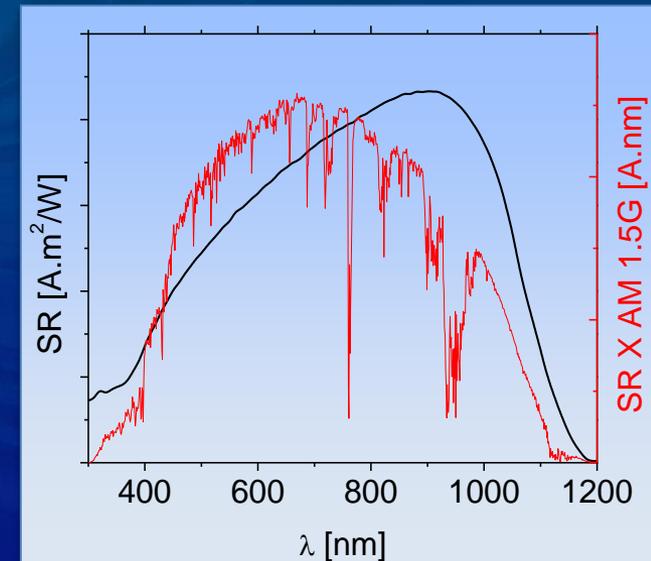
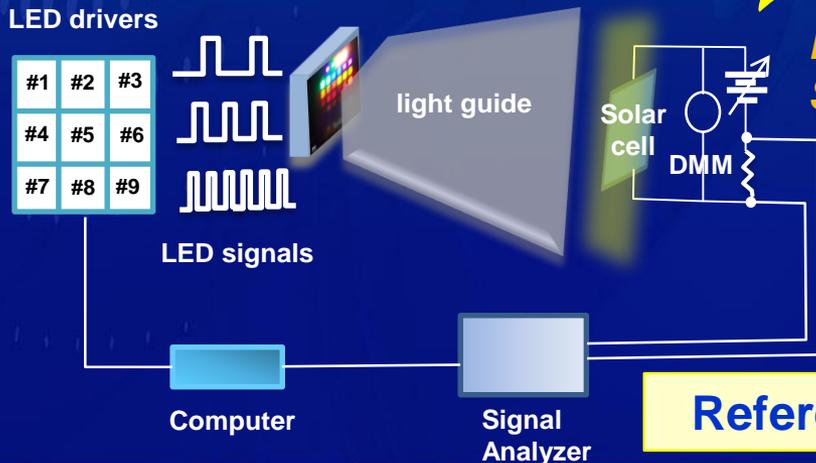
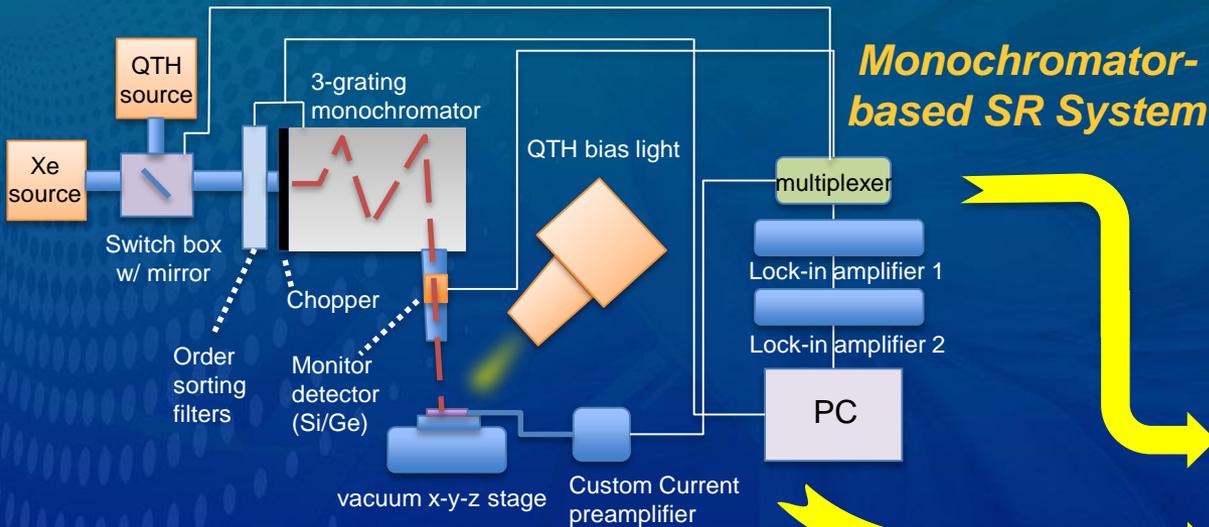
Cumulative Damage Prediction Model

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



Solar Cell/Module Characterizations

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



I_{sc} for Air Mass 1.5

Reference Cell Calibrations with SI-Traceability



Energy Efficiency in Buildings

Net-zero Building Performance Research

- Residential building test bed to test various high-efficiency and alternative energy systems, materials, and designs.
- 1st year goal: Demonstrate 1-year net-zero operation
 - Simulate a family of four living in an energy efficient home and monitor house performance
- Longer-Term Goals:
 - Testing of existing and advanced energy efficiency technologies
 - Develop test methods that better reflect how those technologies will perform in a real home, rather than a laboratory.
 - Lifetime performance characterization of building components and materials



Net-Zero Energy Residential Test Facility

- Demonstrate various technologies and operating strategies to achieve net-zero energy in a typical home
- Compare actual installed performance to controlled laboratory measurements
- Quantify impacts of embedded controls intelligence & building-to-grid interactions
- Develop guidelines for performance measurement and operation of net-zero homes
- Provide “real-world” field data to improve models and test procedures



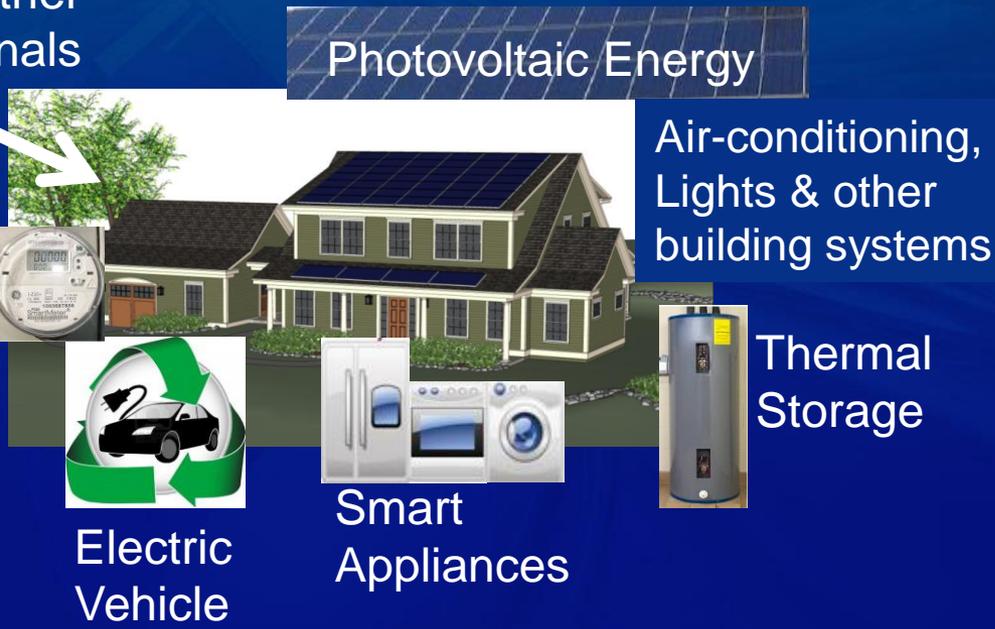
LEED Platinum



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



NET ZERO RESIDENTIAL RESEARCH FACILITY VIDEO



NIST Building Energy Efficiency Measurements & Performance Assessment Research Project Summary

- **Advanced Insulation Measurement Techniques**
- **Novel Working Fluids for High-Efficiency Air Conditioning & Refrigeration Equipment**
- **Fault Detection, Diagnosis, and Commissioning for Air Conditioners and Heat Pumps**
 - **Automatic Fault Detection and Diagnostics (FDD) Embedded in Commercial Buildings**
- **Whole-Building Energy Modeling and Measurements**
 - **Sensors for Improved Building Monitoring**
 - **Performance of Wireless Sensor Networks for Building Applications**
 - **Commissioning Building Systems for Improved Energy Performance**





Thank You for Your Attention

Questions and/or Comments

