

CHiPBS and the EEB HUB

A Brief Overview

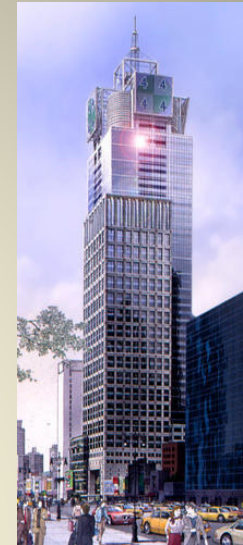
Central PA Chapter – AEE
January 24, 2013

Rick Hoover
Director, Industry Research Project Development
Penn State

Key

- CHiPBS
 - Center for High Performance Building Systems
 - Penn State, University Park
- EEB HUB
 - Energy Efficient Buildings HUB
 - Department of Energy
 - Philadelphia Navy Yard

Center for High Performance Building Systems (CHiPBS)

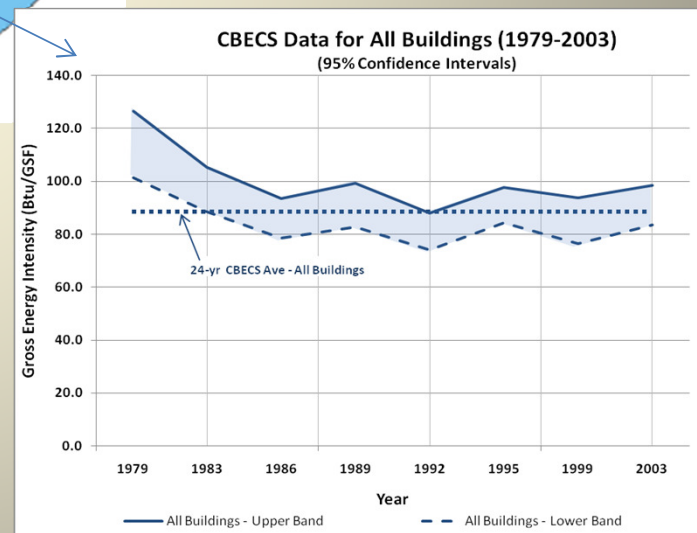
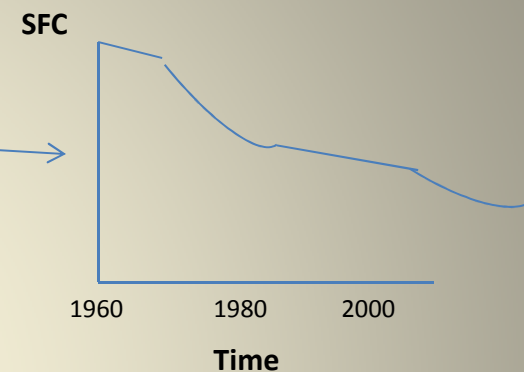
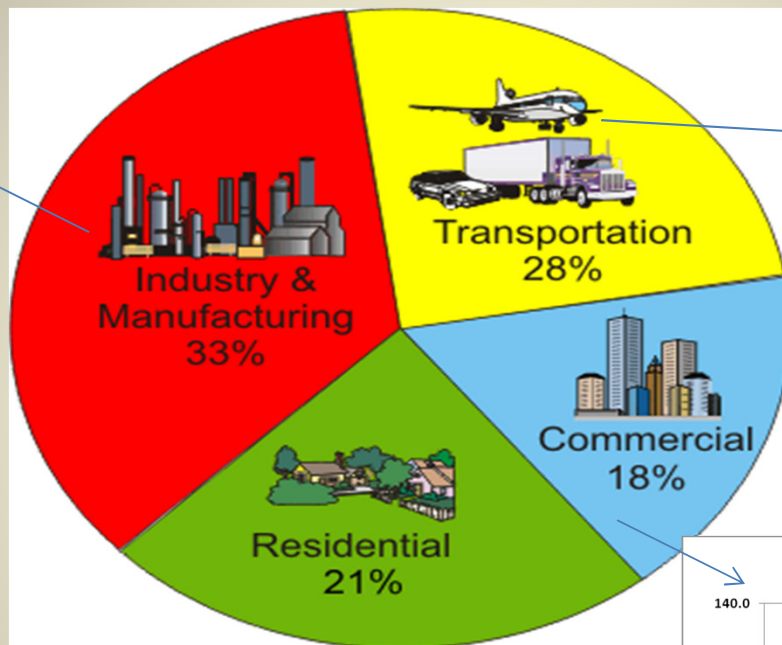
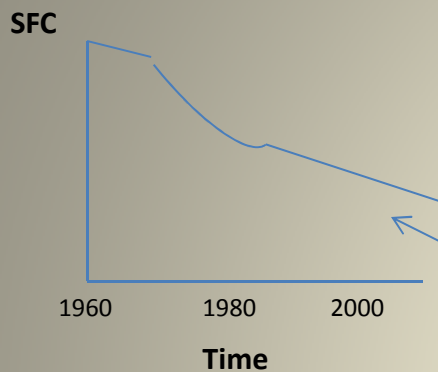


Mission: ***Establish PA building industry businesses as the world leaders in the development and implementation of high performance building technology, design practices and design tools – new and retrofit applications.***

CHiPBS is to be the technical leader and coordinating organization of a partnership among private firms, academia, and government agencies establishing processes, tools and component innovations necessary for ***Standard practice realization of high performance building systems – focus on retrofit applications***

Energy Use by Sector

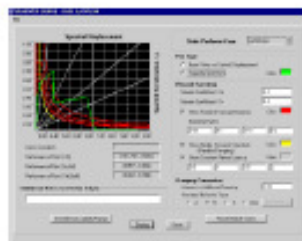
SFC = specific fuel consumption = unit desired result/fuel use, e.g. passenger mile/lbm primary fuel
manufactured units/lbm primary fuel



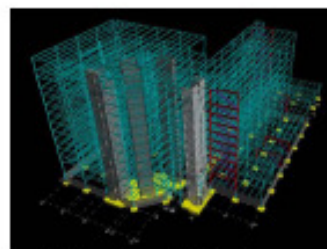
Transformative Research

Building system analysis and design software is currently at the level that structural analysis software was 30 years ago.

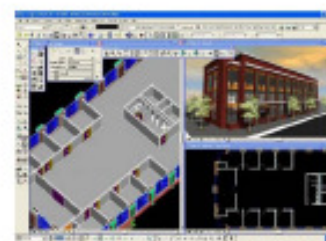
At present, building systems software tries to solve complex interacting-system problems with simplistic non-interoperable, unintegrated, and non-user friendly computational tools.



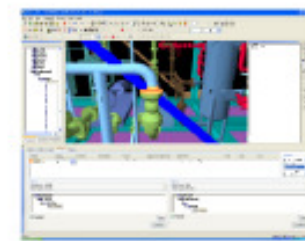
Nonlinear Analysis



Structural Design



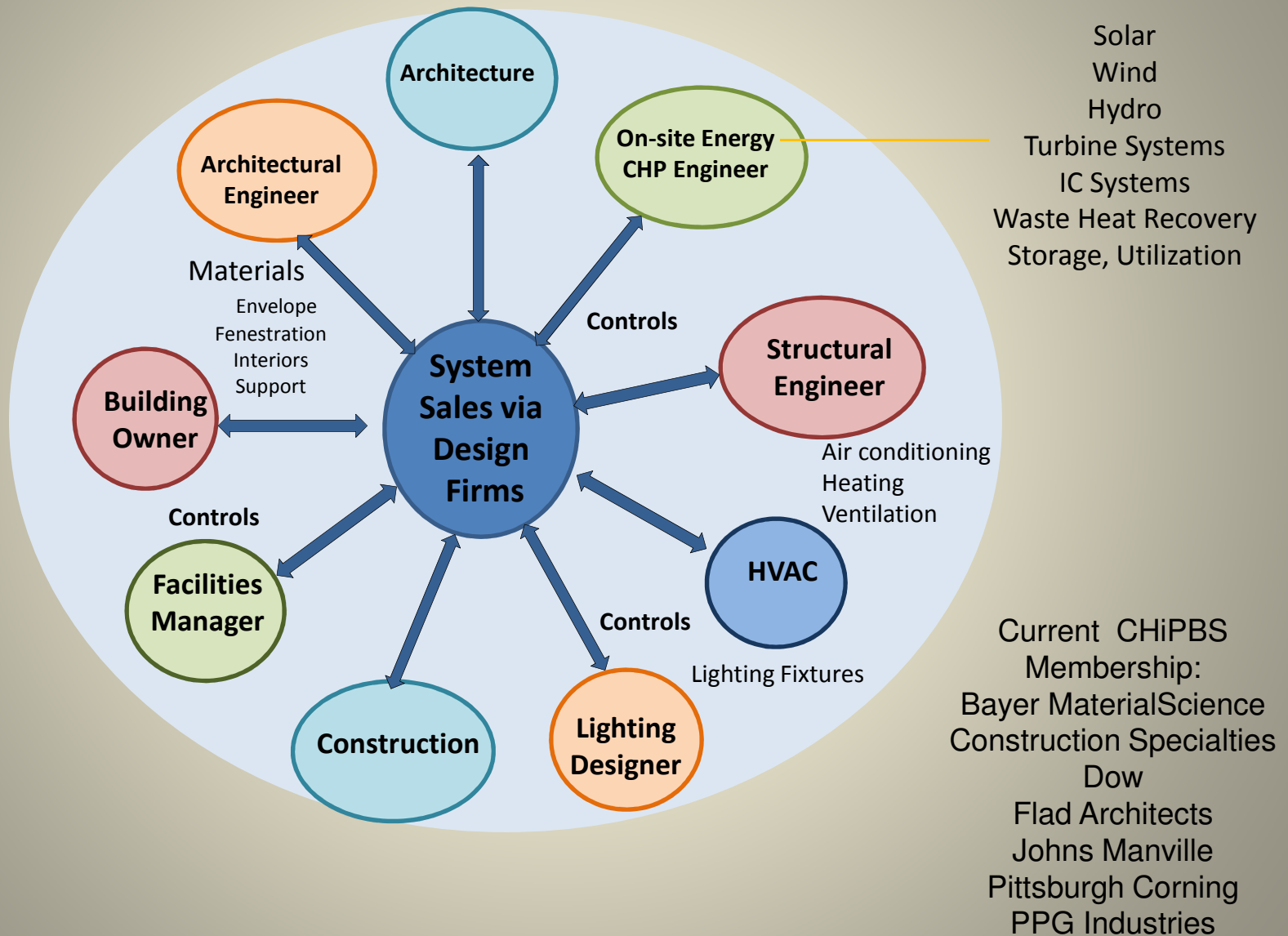
Building Information Model



Interference Detection

Science in Energy and Environmental Design (SEED)

CHiPBS Intends to Position PA Building Industry as Systems Solution Providers by Establishing a Virtual Vertically Integrated Industry from Dispersed Entities

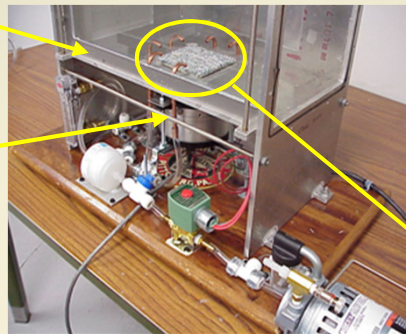


PSU Building Related Science Research

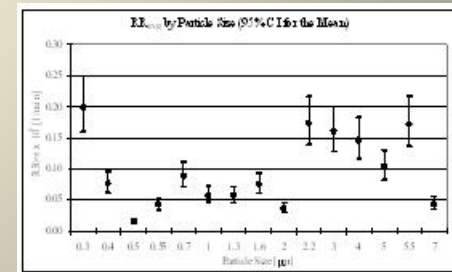
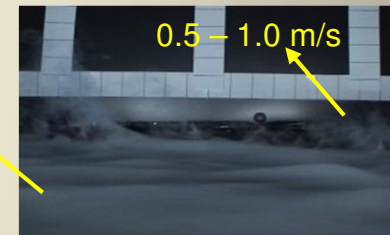
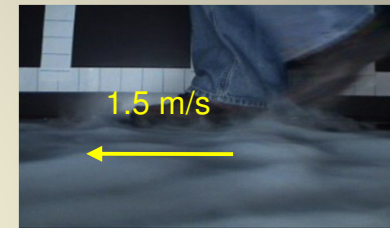
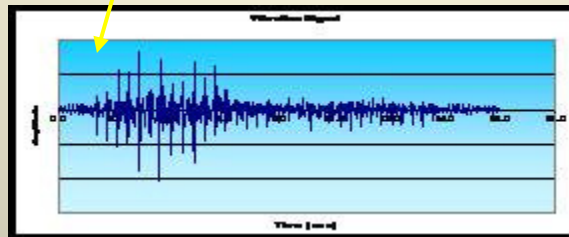
PSU World Class Indoor Aerosol Laboratory

Contaminant Carrying PM_{xx} Resuspension & Deposition Rate Determination

Computer Controlled Aerodynamic Swirl Disturbances Simulate Human Walking



- Computer controlled floor vibration due to human walking
- Measured and digitally recorded in the field

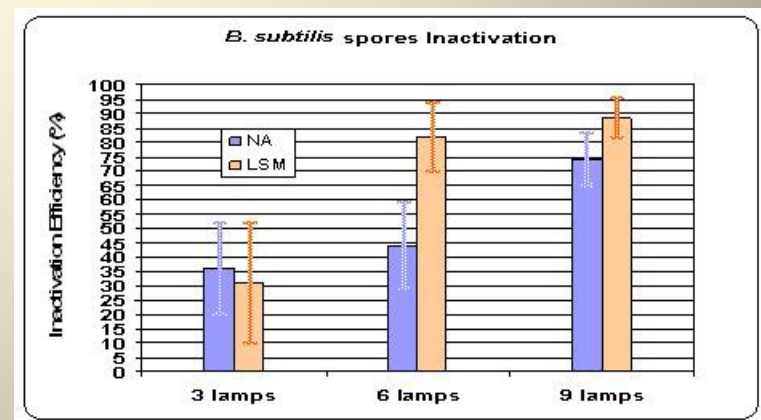
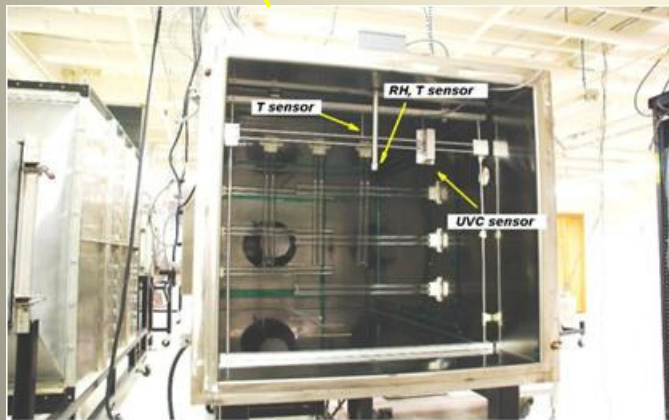


PSU World Class Indoor Filtration, UV and Catalytic Laboratory

Upstream Sections

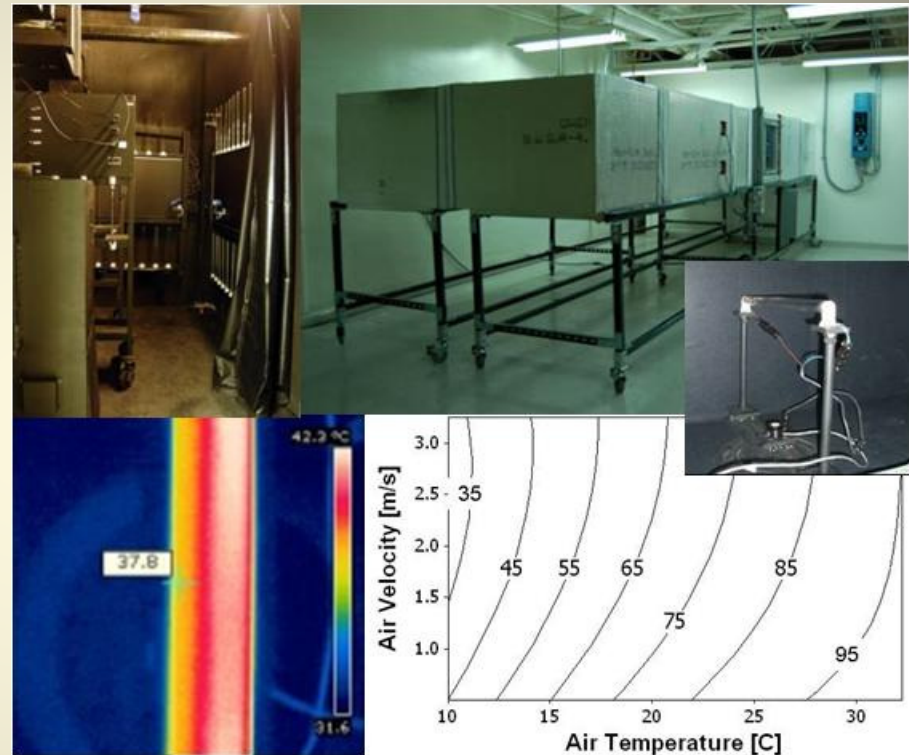


Upstream Sections



Ultraviolet Germicidal Irradiation (UVGI)

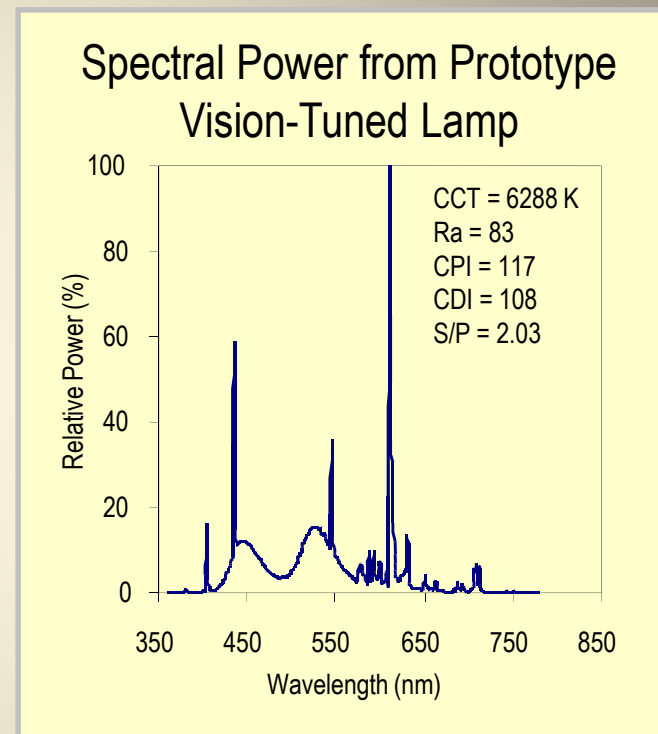
- UVC radiation from Hg lamps disinfects HVAC airstreams, prevents surface microbial growth
- Lamp age and operating conditions (air velocity and temperature) affect UVC output dramatically
- Little data, no models of lamp output vs. operating conditions exist
- Measure and model lamp and device characteristics to improve ability to predict UVGI system performance
- Lamp output may vary >50% over typical range of HVAC conditions
- Extending results to multi-lamp devices
- Used models in annual simulations of UVGI system performance



Sponsors: National Center for Energy Management and Building Technologies, ASHRAE

Low-Power Vision-Tuned Light Sources

- Outcomes
 - Develop new light source technologies for general illumination
 - Demonstrate that ENERGY USE and VISION can be concomitantly enhanced by tuning the output of light sources to coincide with the human visual response.
 - Past work using fluorescent lamp and phosphor technologies (coupled with vision science) demonstrated proof-of-concept.
 - Present work is using LED technologies.



Partners: California Energy Commission, GE Lighting, Litecontrol Corporation, Lumileds, DEED Program of the American Public Power Association, University of Nebraska-Lincoln, Penn State University

Lamp Spectral Power Distribution Effects on the Perception of Interior Space

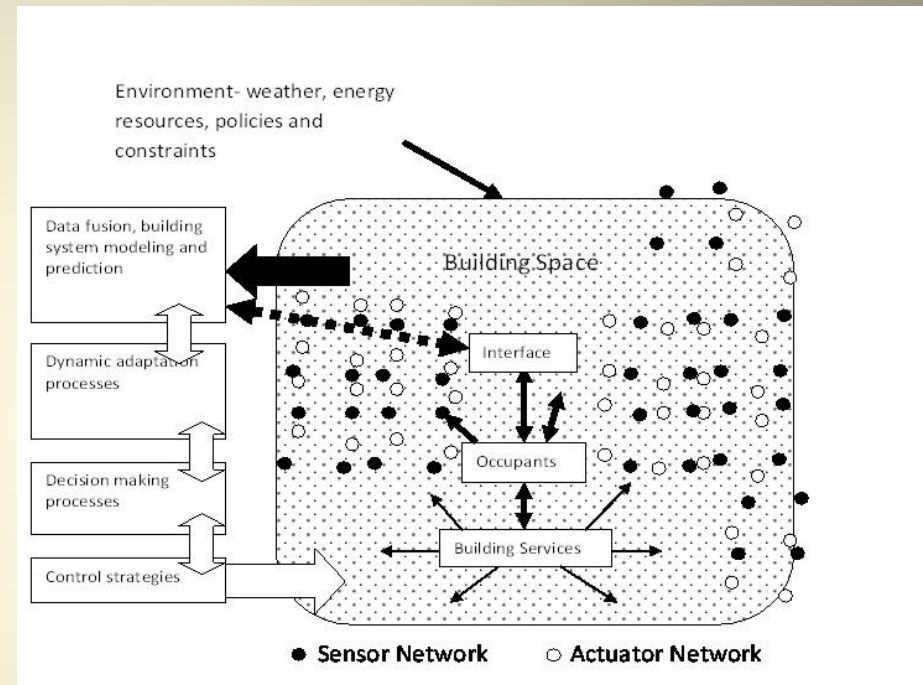
- Outcomes
 - Develop models of visual^e response that can be used by lamp manufacturers to create light sources tailored to human vision
 - Tune the spectral power distribution of interior lighting to optimize connected power, comfort, and performance.



Partners: University of Sheffield (UK), Project CANDLE (IALD Education Trust, Penn State University, US Department of Energy, Philips Lighting Company, Philips SSL Lighting Solutions, Cooper Lighting, Erco Lighting USA, Litecontrol Corporation, Lutron Electronics, Schuler Shook, Fisher Marantz Stone, Office for Visual Interaction, Naomi Miller Lighting Design, Horton Lees Brogden, Gabriel Mackinnon, Lighting Design Alliance, Randy Burkett Lighting Design, I2 Illuminations.

PSU Systems Integration and Optimization

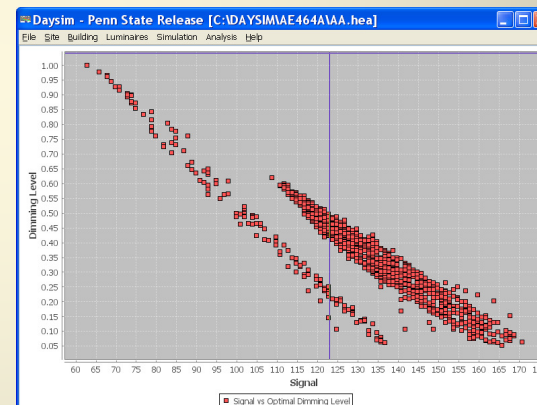
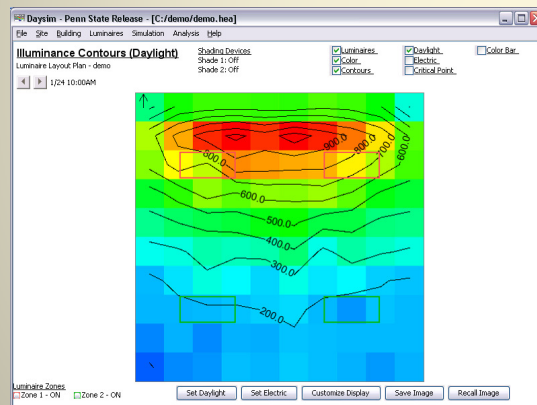
- Advanced Controls Research Facility MorningStar Home HyRES Laboratory System
 - To develop improved methods for designing, evaluating and operating optimization of building environmental control systems
 - To develop new techniques and strategies for effectively integrating building components and sub-systems to achieve energy efficiency and high performance



Recent PSU Daylighting Research

Minimizing Coupled Lighting and HVAC Loads via Simulation for Dynamic Control

- The Daysim software was significantly expanded to include modeling of operable shading devices and photosensor-based electric lighting control.
- Energy modeling of HVAC and lighting energy for buildings with translucent shades, variable window-to-wall ratio (WWR) and glazing.



Shades down
vs.
shades up

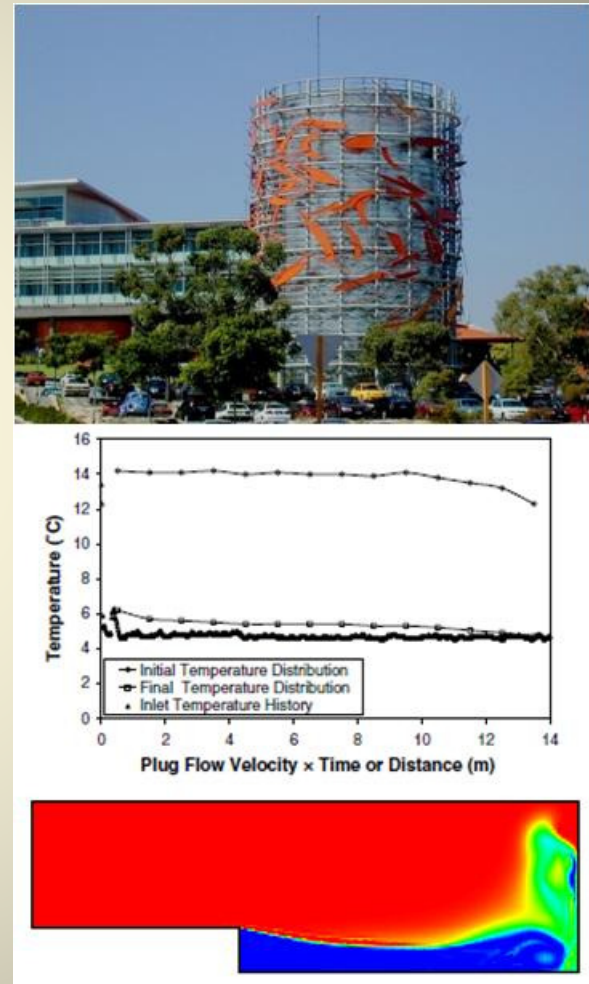
Energy Tables (KWh)

Controlled Zone: Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	85.0	73.92	81.31	73.92	85.0	0.0	0.0	85.0	77.61	85.0	81.31	55.44	783.55
Optimal	27.42	19.57	22.71	16.94	16.56	0.0	0.0	17.31	20.24	23.1	25.98	18.78	208.64
Algorithm	33.15	24.25	25.67	17.89	15.42	0.0	0.0	16.8	23.0	27.52	31.58	23.02	238.35
Savings	51.85	49.66	55.64	56.02	69.58	0.0	0.0	68.19	54.61	57.47	49.73	32.41	545.2

Chilled Water Thermal Energy Storage

- Large-scale thermal energy storage is a cost effective way to meet peak loads of district cooling systems
- Research at Penn State has included
 - Performance characterization of stratified tanks by field measurement and CFD
 - Evaluation of pumping strategies for systems with stratified tanks

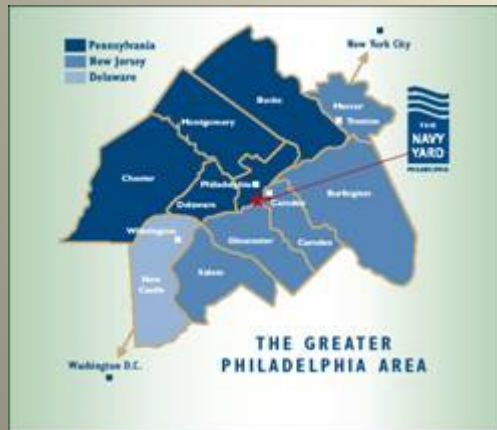


CHiPBS

- Member directed research focus
- Access to technology, software, training developed in the center
- Workshops, conferences, seminars
- Membership
 - \$3,000 / year Associate
 - \$10,000 / year Full

EEB HUB

Energy
Efficient
Buildings
Hub



Goal, Vision, and Mission

OVERALL GOAL:

Reduce annual energy use in the U.S. commercial buildings sector by 20 percent by 2020.

VISION:

Design, demonstrate and deploy market proven, system solutions in the Greater Philadelphia region enabling the building sector to accomplish ongoing energy efficiency as standard practice

MISSION:

Accomplish the goal through informed people, validated information, and proven technologies.

An Emergent Organization

- 22 initial performers
 - Research universities
 - DOE laboratories
 - Industrial firms
 - Economic development agencies
 - Community and technical colleges
- Not a closed consortium
- Dynamic association
- Driven by performance
- An emergent organization

EEB Hub Performers:

The Pennsylvania State University
Bayer MaterialScience
Ben Franklin Technology Partners of SE PA
Carnegie Mellon University
Collegiate Consortium
Delaware Valley Industrial Resource Center
Drexel University
IBM Corporation
Lawrence Livermore National Laboratory
Lutron Electronics, Inc.
Morgan State University
New Jersey Institute of Technology
Philadelphia Industrial Development Corporation
PPG Industries
Princeton University
Purdue University
Rutgers University
United Technologies Corporation
University of Pennsylvania
University of Pittsburgh
Virginia Tech
Wharton Small Business Development Center

The Navy Yard

- Redevelopment project of regional and national significance
- Test bed for research and demonstration
 - Independent unregulated micro-grid
 - Building energy efficiency
 - Distributed power production and management
- 270 buildings
 - Early 19th Century to the present
 - Most occupied and some awaiting redevelopment,
 - Mix of industrial, commercial and government uses
- Clean Energy Campus
 - Mid-Atlantic Clean Energy Applications Center
 - Northern Mid-Atlantic Solar Training Center
 - GridSTAR Smart Grid Training Center
 - Build America Residential Retrofit Center
 - Energy Efficient Buildings Hub



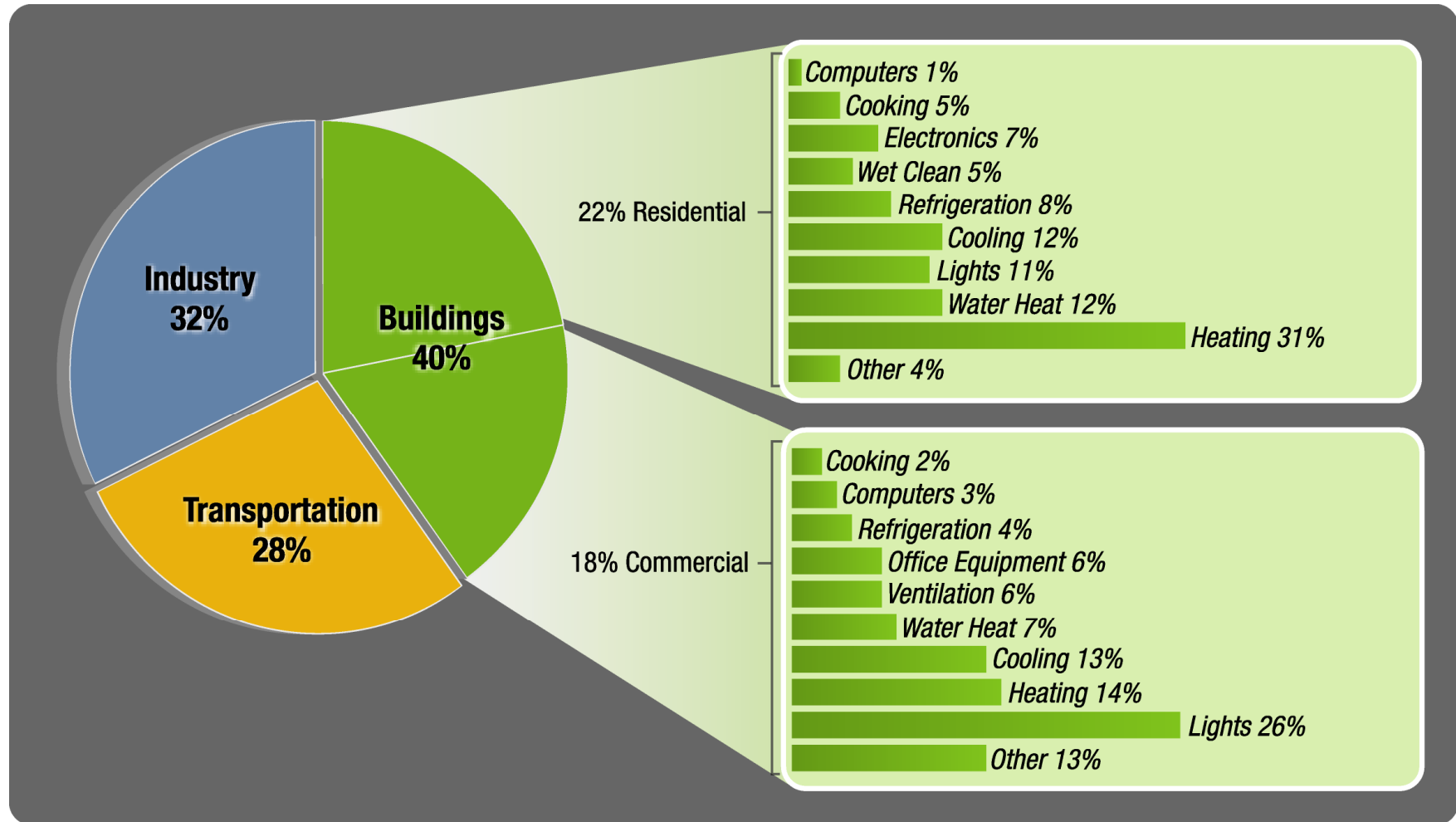
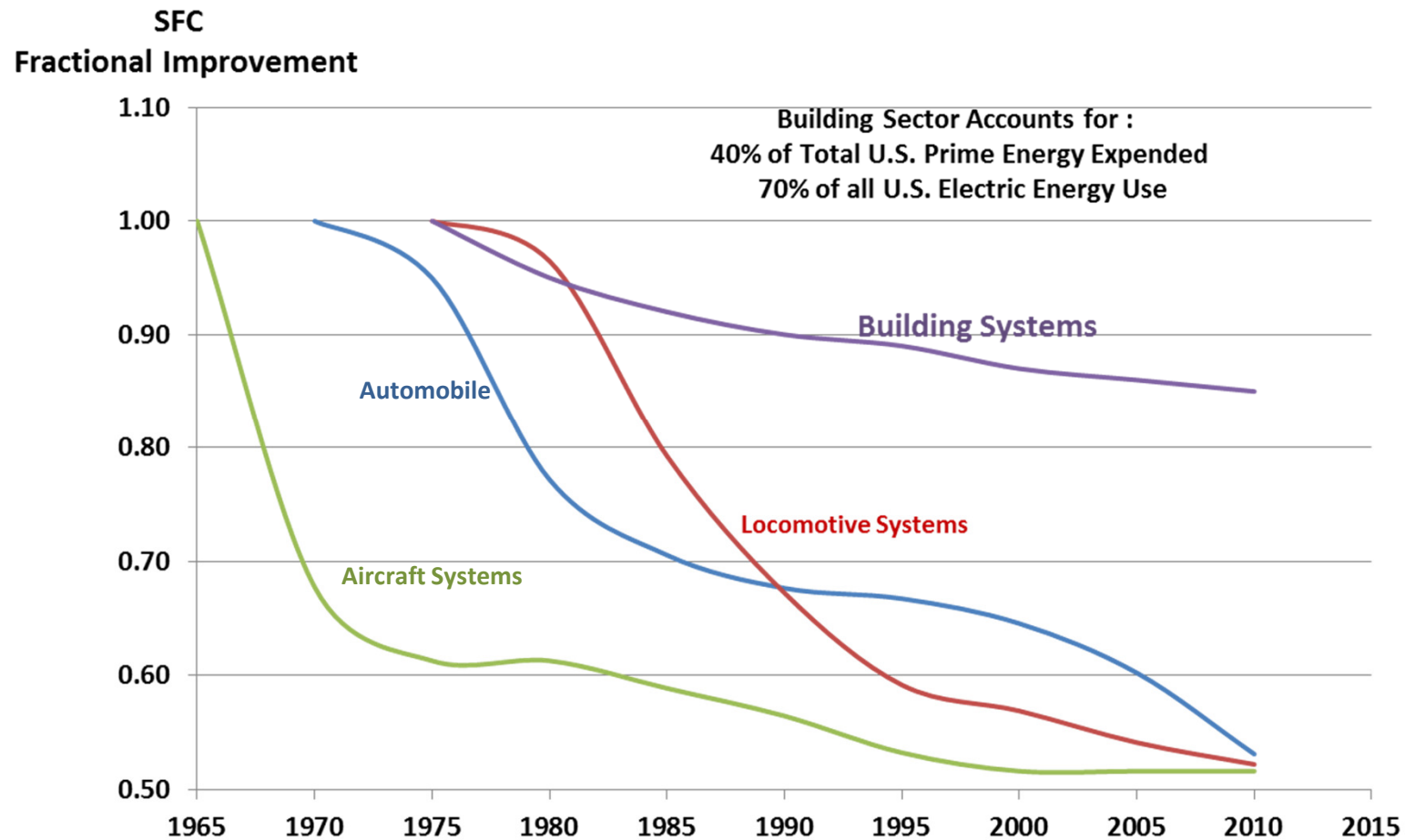
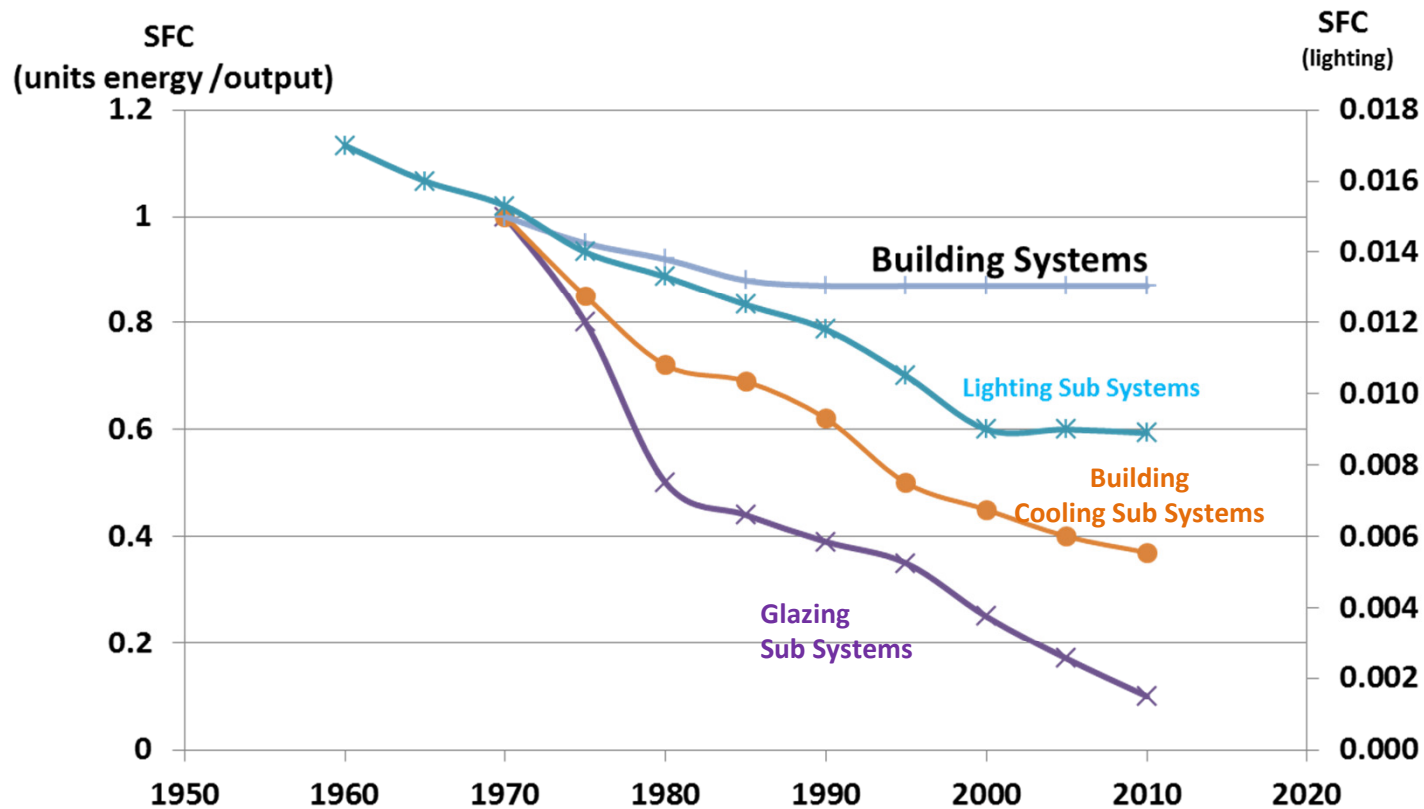


Figure prepared by National Renewable Energy Laboratory and the U.S. Department of Energy

Building Sector vs. Other Sectors



Energy Efficiency in Buildings



Building Sector Accounts for :
 40% of Total U.S. Prime Energy Expended
 70% of all U.S. Electric Energy Use

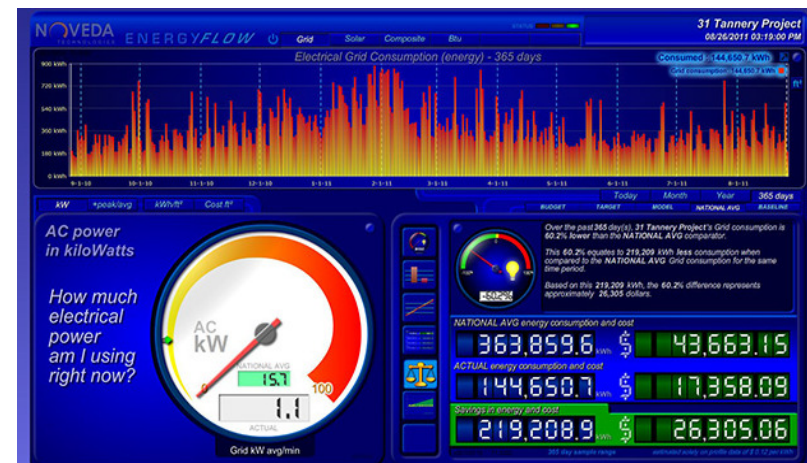
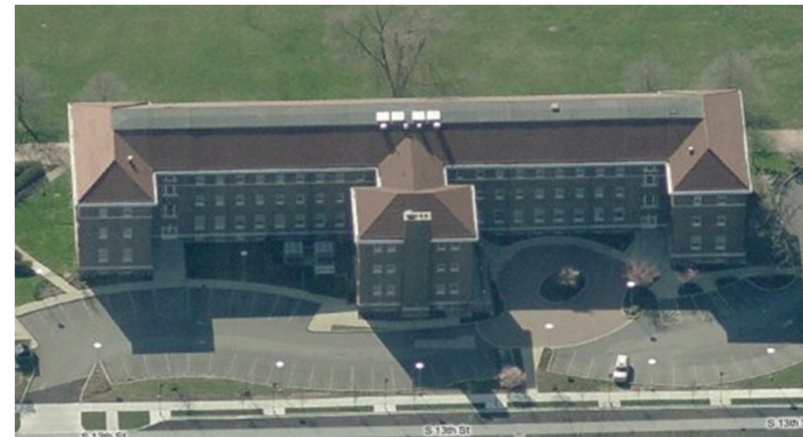
Building 101 Testbed

- Initially built in 1911 to serve as a U.S. Marine Corps barracks.
- Gross Building Floor Area is 75,156 ft² with 69,246 ft² of conditioned space.
- A three story commercial building that underwent a major renovation in 1999 to accommodate a single tenant. This renovation included adding a forced air heating and cooling system to the formerly hydronically heated barracks.
- Building 101 currently serves as a multi-tenant office building which is 60% occupied.



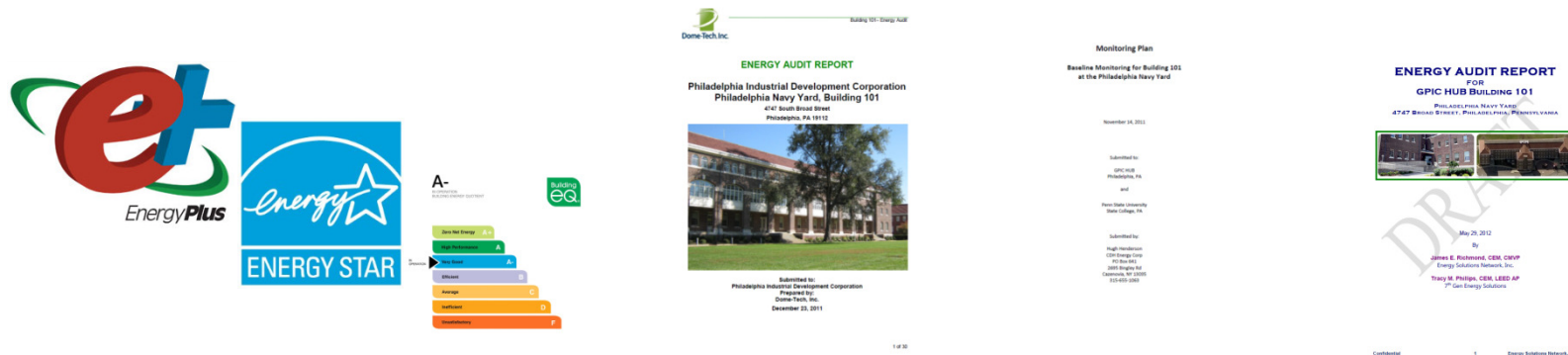
Building 101 Instrumentation Project

- More than 1500 data points every 60 seconds
 - One of the most highly instrumented commercial buildings in the country
- Information displayed on a public dashboard
- Test bed for assessing technologies and systems while holding constant for occupancy, weather and other factors

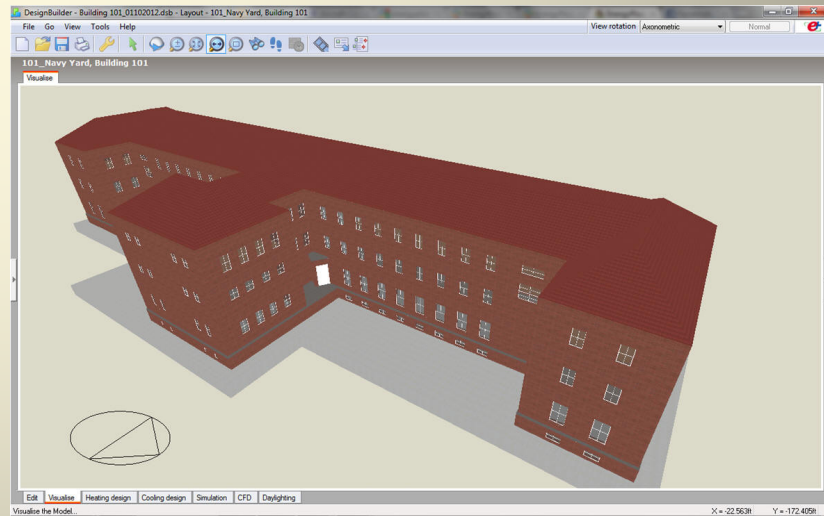


Building 101 Test Bed

The Monitoring Plan documents the measured data to be collected at Building 101 to establish energy, comfort, and indoor air quality (IAQ) baselines. The baselines will be used to calibrate and verify detailed simulation models of the building and its subsystems, benchmark energy auditing practices, develop inverse models, compare building labeling systems, and quantify the impact of any improvements.



Design Builder Model



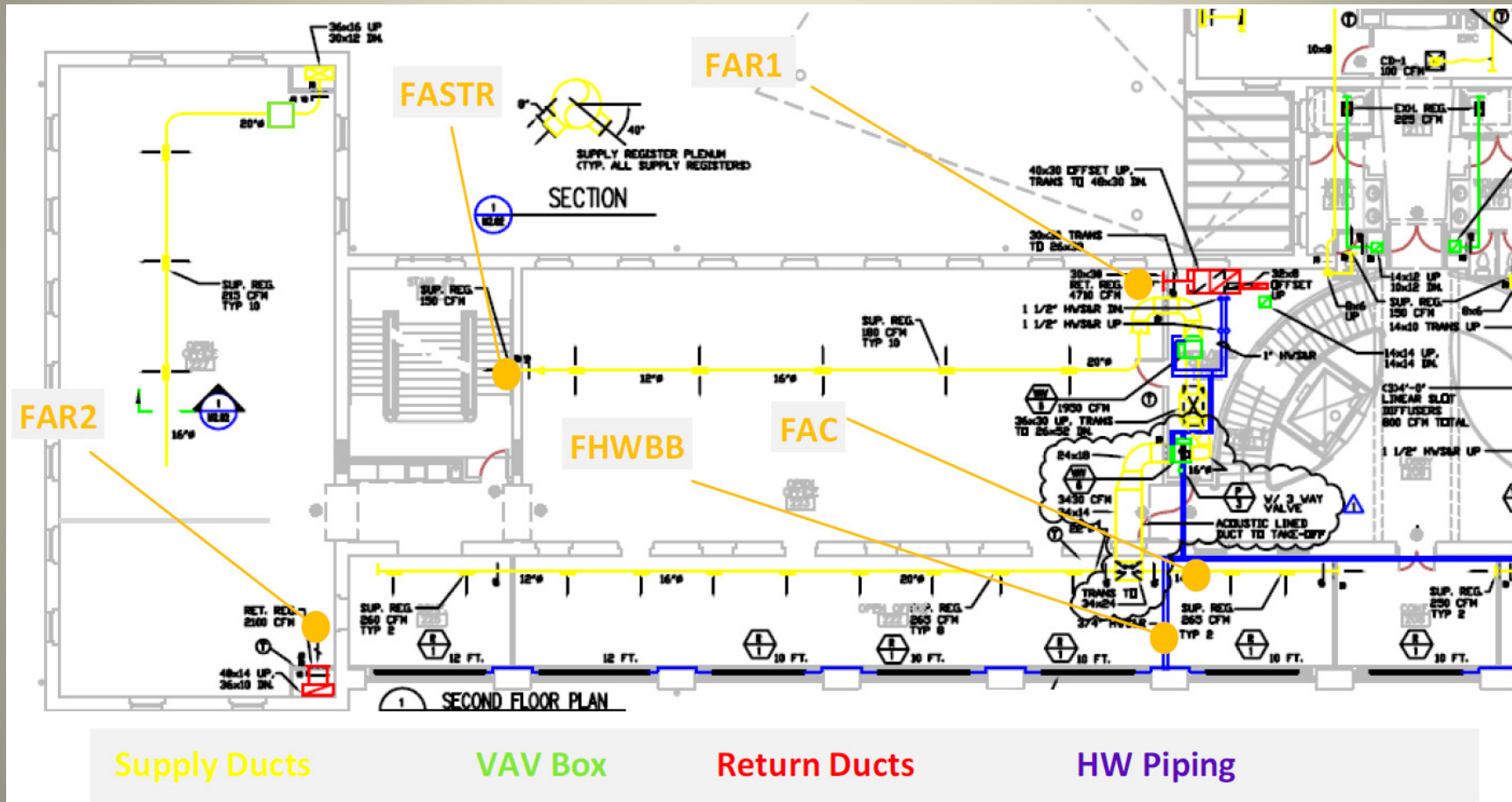
Instrumentation: Overall Building

- Total electricity and natural gas uses in the overall building,
- Heating and cooling capacity delivered by the HVAC equipment
- Local weather conditions near the building
- Ventilation flow rates provided to the building
- Overall air leakage rates for the building

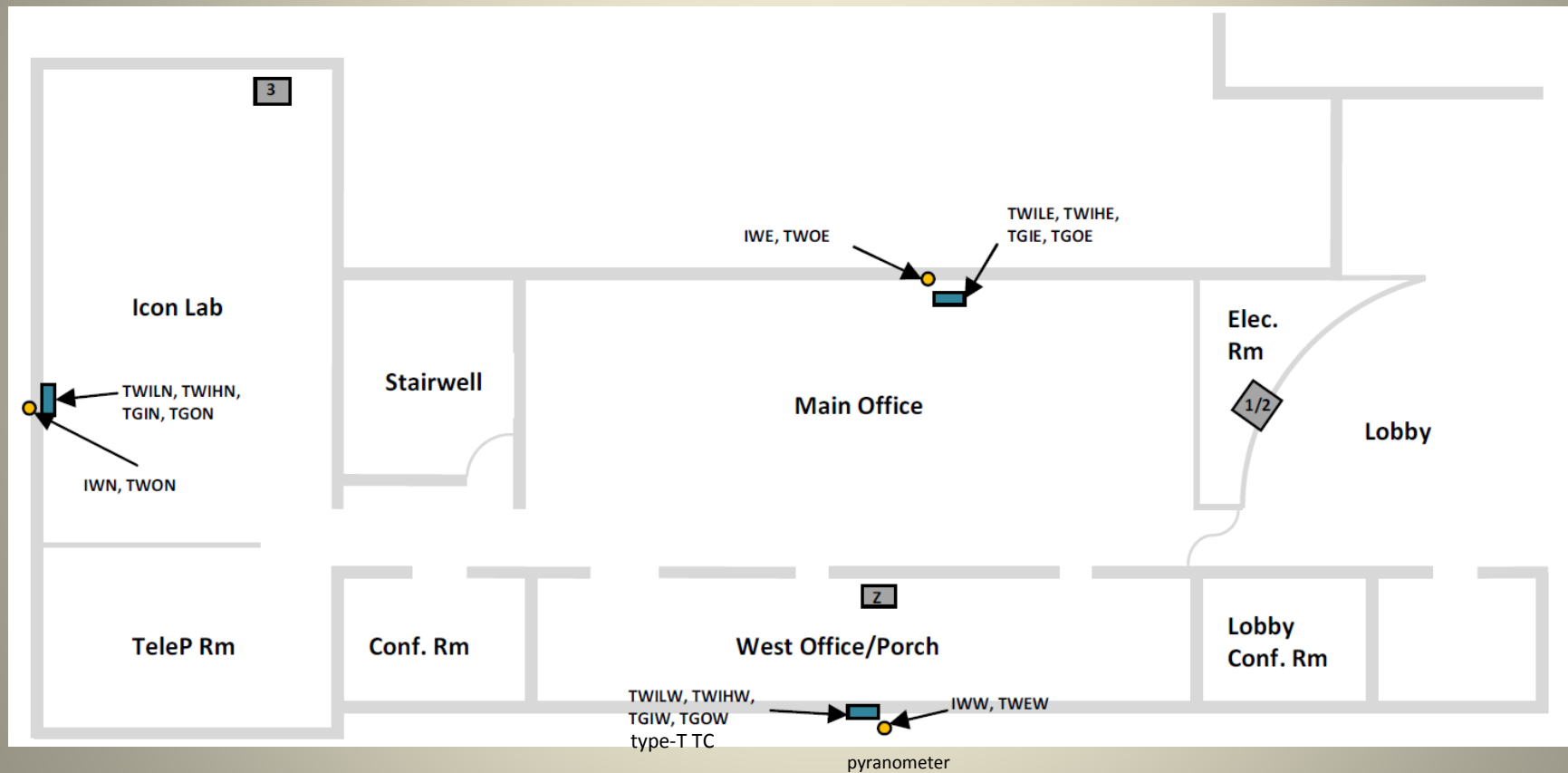
Instrumentation: EEB Hub Offices (2nd floor north wing)

- Operating conditions, heating and cooling inputs supplied by the Variable Air Volume (VAV) boxes
- Supply and return airflows, and pressure-induced air flows between this zone and other neighboring spaces and outdoors.
- Conduction losses across interior and exterior surfaces
- Solar gains into the space
- Plug loads and lighting
- Occupancy levels with automated real time measurements
- Temperature stratification
- IAQ parameters and environmental conditions at multiple locations in the space

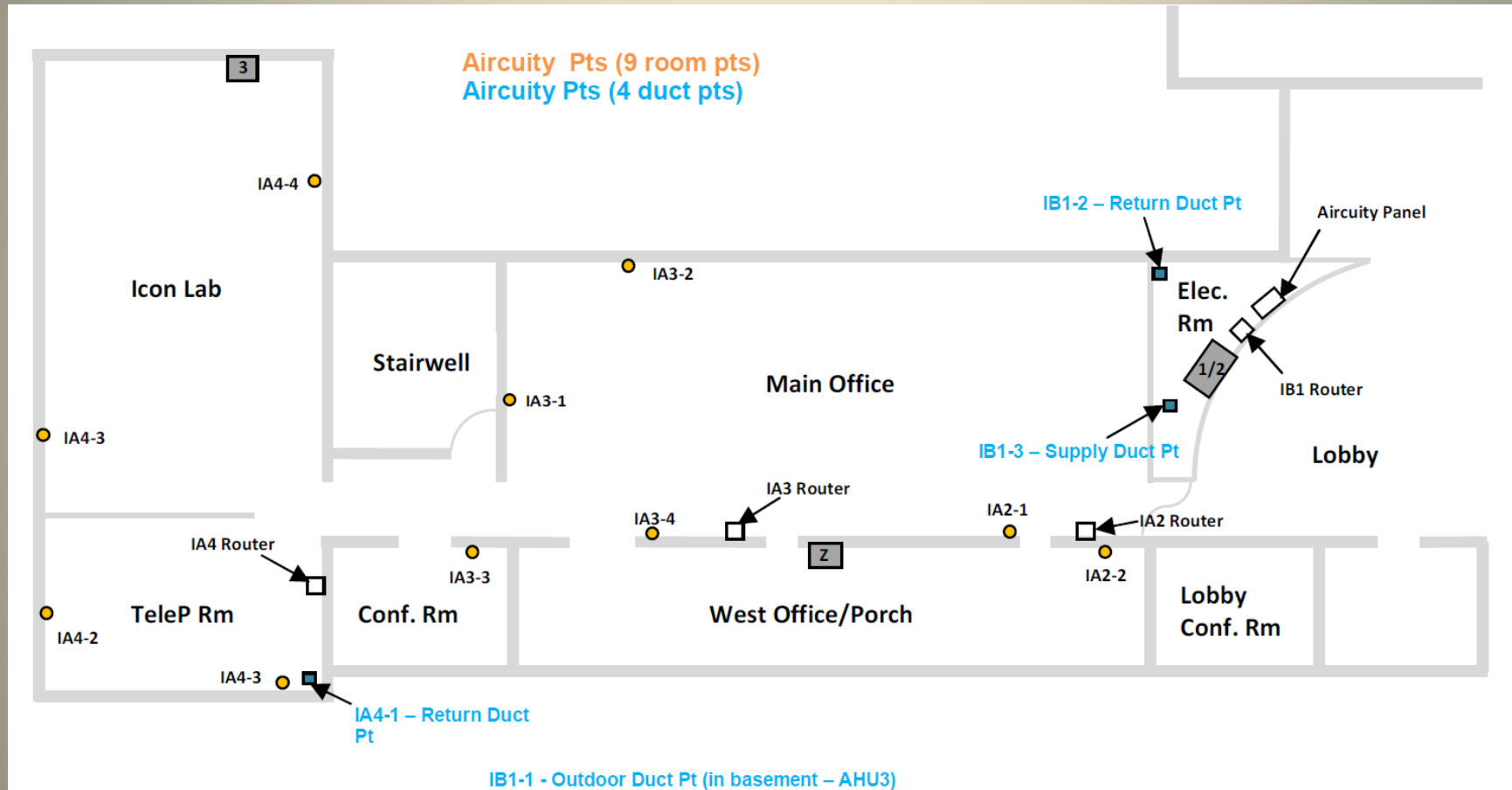
EEB Hub Offices Energy Measurement



Wall and Glazing Temperature and Solar Flux



EEB Hub Offices IEQ Measurement



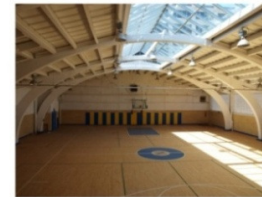
Building 661 Retrofit Project



EAST FACADE



S.W. CORNER



GYM INTERIOR



ROOF & PARKING LOT

Advanced Energy Retrofit
Living EEB Laboratory
Permanent EEB Hub HQ

Topic 2 / Metering, Sub-Metering for Inverse Modeling: A Potential Tool for Risk Reduction in Integrated Building Retrofit Planning

Ke Xu, Ph.D.

Payam Delgoshaei, Ph.D.

Scott Wagner

J. Freihaut, Ph.D. *

DOE Energy Efficient Buildings Hub

Philadelphia Navy Yard

Philadelphia, PA.

Penn State University

Department of Architectural Engineering

University Park, PA.



Seminar 10: Integrated Building Retrofits

ASHRAE Winter Conference

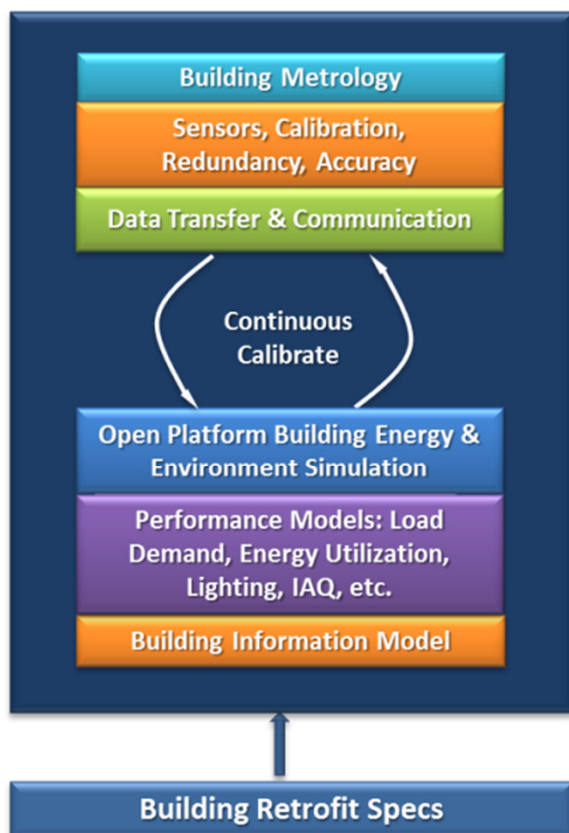
Jan. 26 – 30

Dallas, Texas

Data-based Continuous Improvement of Building Modeling



Inverse, Forward Design Models



Building 101 Testbed



800 60 second streaming data points

Load/demand parameters (temp, wind, humidity, incident solar irradiance, plug load, occupancy)

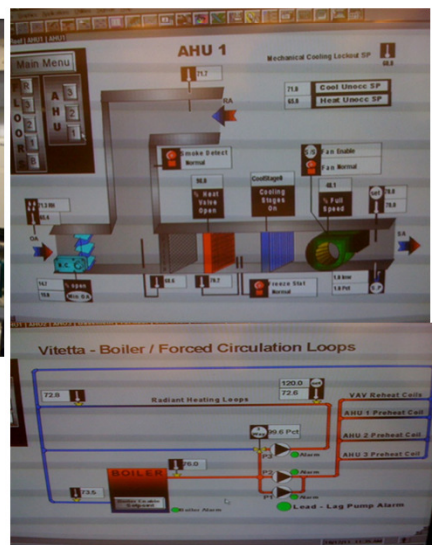
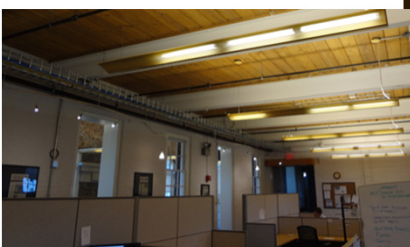
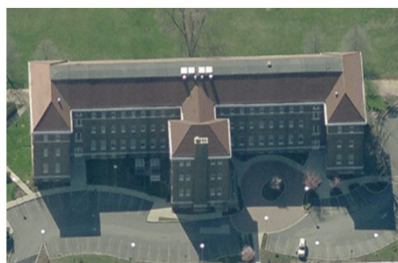
Indoor Environmental Quality: (CO₂, CO, particulates, humidity, VOCs)

Sub-metered Energy Use (HVAC equipment operation, heating / cooling distribution, lighting, plug load)

Introduction: Problem Statement

- **Q1**: Why is building energy use frequently different from model predictions established in design phase?
- **Q2**: *How does one calibrate a building energy model (BEM) before it can be used for ECMs evaluation or any model-based control and optimization?*
- **Q3**: How to build an “as-operated” BEM that accurately reflects the building actual operation (baseline) condition for an existing commercial building?

Case Study-Building I



- Located in Philadelphia Navy Yard;
- Originally Built in 1910s as a marine barrack, now a multi-tenant office building,
- Major renovation in 1999;
- 75,000 ft² GSF, 3 floors above ground, has an attic and a basement floor;
- 40W T-5 bi-axis fluorescent lamps;
- 3 VAV AHUs;
- DX Coils for Cooling;
- 1 Hot Water Boiler for Heating;
- 2 Water Heaters for DHW;
- Honeywell XL500 Control System for BAS;



Case Study-Building II and III

Building II: Malvern, PA;

Building III: Fort Washington, PA;

Two Buildings are 20 miles away from each other.

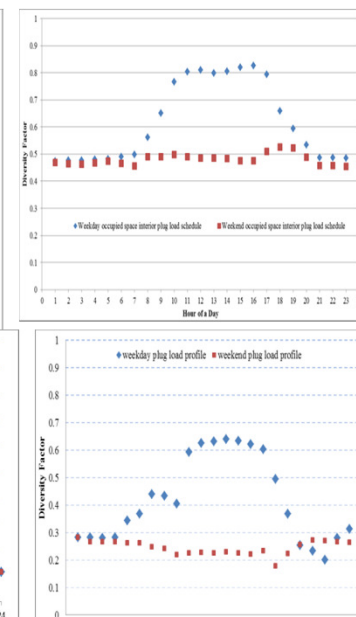
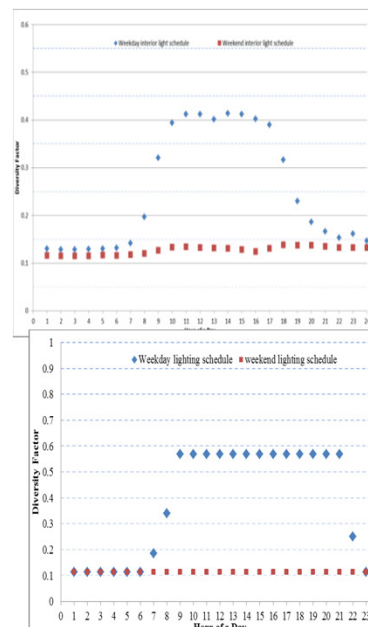
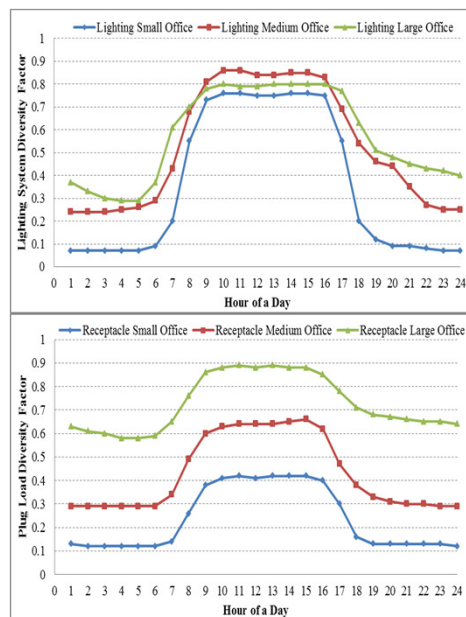
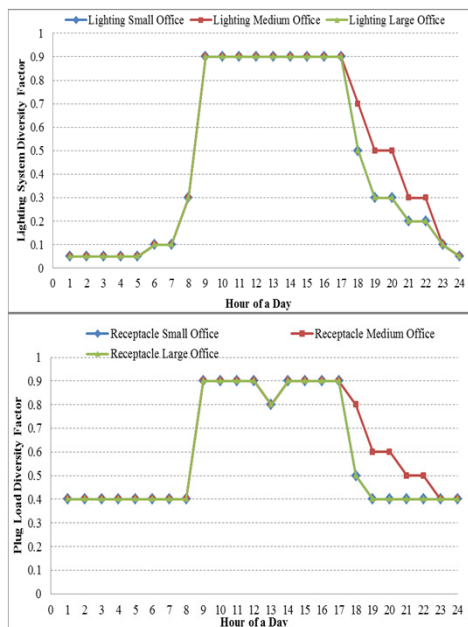


	Building II	Building III
Year Built	2004	2004
Number of Floors	3	3
Gross Floor Area (ft ²)	101,700	74,140
Building Envelope	Full-height glass curtain wall; insulated roof with dark colored surface	Pre-cast masonry curtain wall with double-pane tinted windows; insulated roof with light colored surface
Interior Lighting	2 by 4ft three T-8 32 W lamps for most spaces	2 by 4ft three T-8 32 W lamps for most spaces
Air System	3 VAV RTUs	2 VAV RTUs
Cooling System	3* 115 Ton DX Units	2* 115 Ton DX Units
Heating System	Electric resistance heating and reheating coils	Electric resistance heating and reheating coils
Terminal Units	Series Fan-Powered Terminal Box for perimeter zones and VAV Boxes for interior zones	Series Fan-Powered Terminal Box for perimeter zones and VAV Boxes for interior zones
Presence of Server/IT Rooms (Yes/No)	Yes	Yes
Tenant(s)	Bank, University Classrooms, Insurance Company, Dentist Office, Information Service Company	An Engineering Firm

Conclusions-Findings

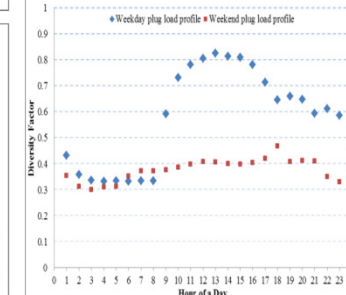
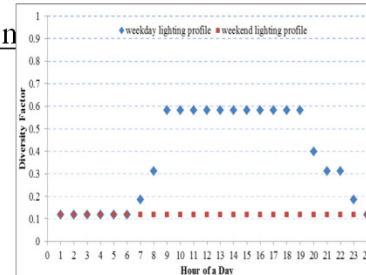
- Existing Literature

- Case Study Buildings



DOE Reference Building Model (adopts ASHRAE-Standard 90.1-2004 User's Manual)

ASHRAE RP-1093 (data collected in late 80s' and early 90s')



GridSTAR Center and Building to Grid Integration

GridSTAR

Grid Smart Training Application & Resource Center



GridStar Mission:

*Serve as an **education and research** resource for Smart Grid/Microgrid technologies*

Objectives

1. Build microgrid demonstration and research facility
2. Create web-resources for professionals on critical smart-grid topics
3. Facilitate workforce development and IBEW instructor training
4. Foster the integration of manufactures and technology providers in the development of smart grid solutions

GridSTAR

Grid Smart Training Application & Resource Center



Topical breadth + consumer / business focus

<http://www.gridstarcenter.psu.edu>

The screenshot shows the Penn State GridSTAR website. At the top left is the Penn State logo with the year 1855. To its right is a search bar with the text "Looking for something?" and a magnifying glass icon. Below the logo is the "GridSTAR" logo in large green and white letters, with the tagline "Grid Smart Training Application & Resource Center" underneath. A horizontal navigation bar contains links: Home, About GridSTAR, News & Events, Programs & Courses, Resources & Links, and Contact Us. On the left side, there is a vertical menu with icons and labels: Metering & Networks, Grid Management & Control, Smart Grid Economics, Cyber Security, Distributed Energy Production, Building Automation & Controls, and Vehicle to Grid Systems. The main content area features a large image of a silver Chevrolet Volt being charged at a station. Overlaid on this image is the text "Vehicle To Grid" in orange, followed by a paragraph: "A responsive and strategic infrastructure is needed to support the new age of electric vehicles". Below this text are two buttons: "More Info" and "View Courses". At the bottom of the main content area, there is a row of four sections: "Program Updates", "Featured Program", "Upcoming Courses", and "Smart Grid Videos", each with a right-pointing arrow icon.

PENNSTATE
1855

GridSTAR
Grid Smart Training Application & Resource Center

Looking for something? Search

Home About GridSTAR News & Events Programs & Courses Resources & Links Contact Us

Metering & Networks
Grid Management & Control
Smart Grid Economics
Cyber Security
Distributed Energy Production
Building Automation & Controls
Vehicle to Grid Systems

Vehicle To Grid

A responsive and strategic infrastructure is needed to support the new age of electric vehicles

More Info View Courses

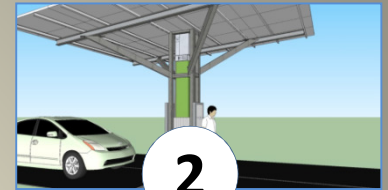
Program Updates Featured Program Upcoming Courses Smart Grid Videos

Plug & Play Microgrid

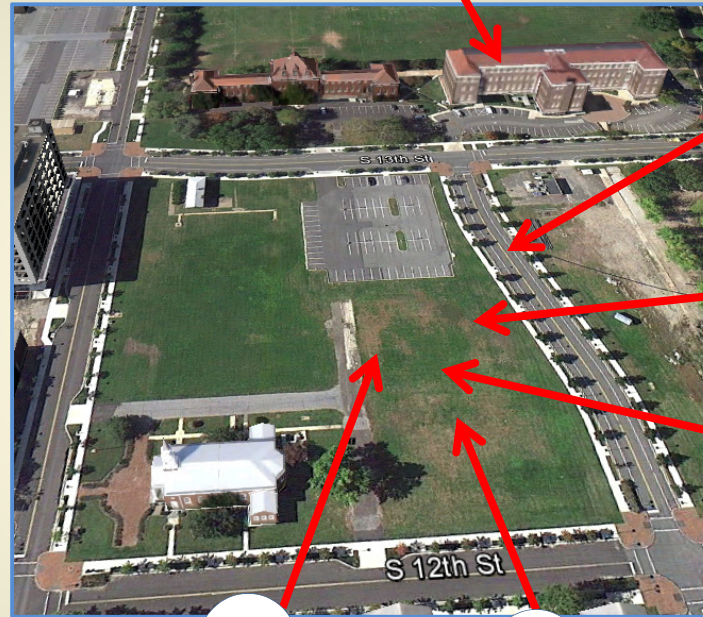
1. Building energy management systems and network operations center (BEMS) (B2G/DR/ADR)
2. Electric vehicle charging infrastructure(V2G)
3. Grid interactive smart home with energy storage, generation, and demand-response controls [2]
4. Solar PV training infrastructure (utility, commercial & residential)
5. Revenue grade smart metering infrastructure
6. Solar PV installation
7. Grid-interactive energy storage



1



2



3



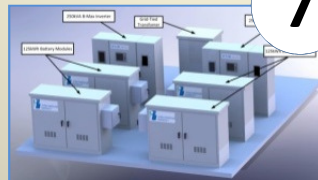
4



5



7



6



GridSTAR

Grid Smart Training Application & Resource Center

PENNSTATE
University
Park

THE
NAVY
YARD
PHILADELPHIA

Smart Grid House

- Hyper efficient modular construction
- Solar PV and Thermal systems integration
- Battery systems for security and demand response / load control
- Grid interactive lighting, electrical, and mechanical system controls
- Electric vehicle charging systems integration



GridSTAR

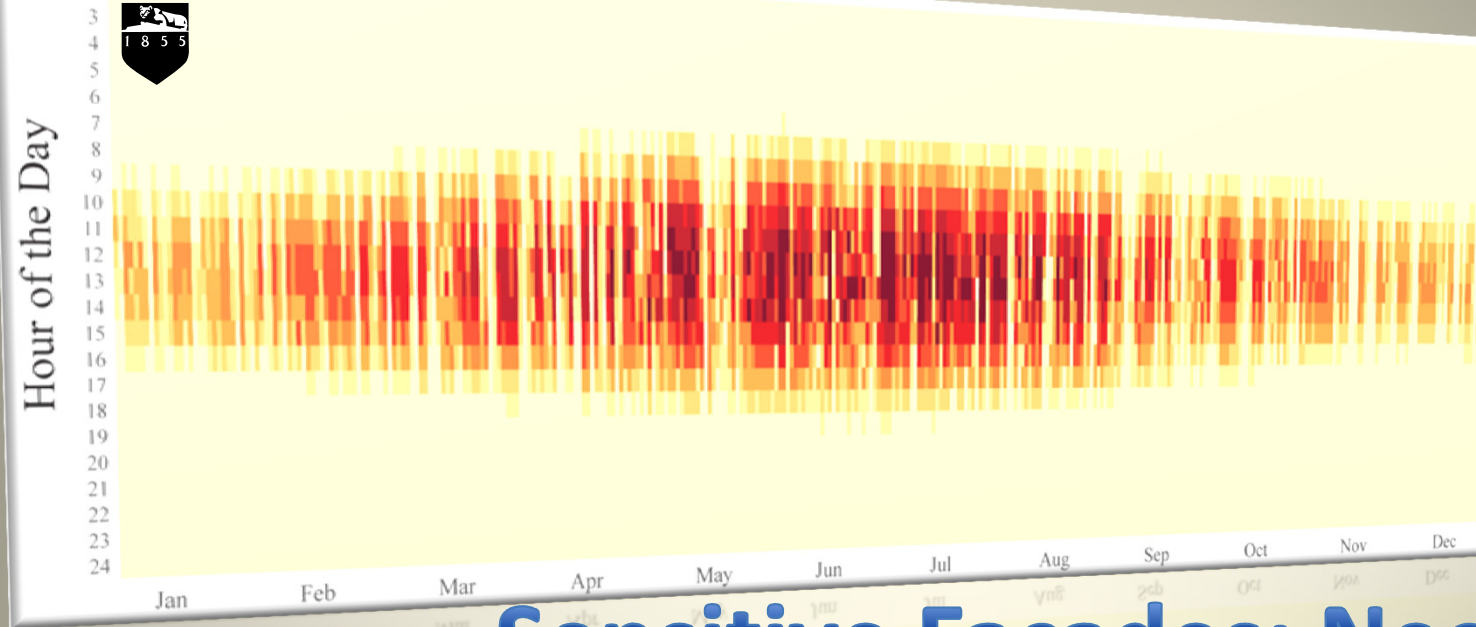
Grid Smart Training Application & Resource Center



Living Laboratories Built through EEB-Hub and Connected to GridSTAR

- Building 661
 - New home for EEB-Hub
 - Deep retrofit
 - Advanced technical systems
 - High-level instrumentation
- Building 7R
 - New building dedicated to education and training programs
 - Accessible building systems
 - Flexible training spaces
 - Distance education classrooms

PENNSTATE



Sensitive Façades: Necessary Innovations for Building Energy Management Systems

solarpower@psu.edu

JOHN AND WILLIE LEONE FAMILY DEPARTMENT OF

ENERGY AND MINERAL ENGINEERING

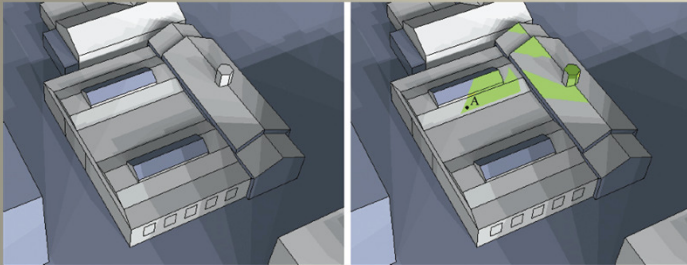
COLLEGE OF EARTH AND MINERAL SCIENCES

Jeffrey R. S. Brownson

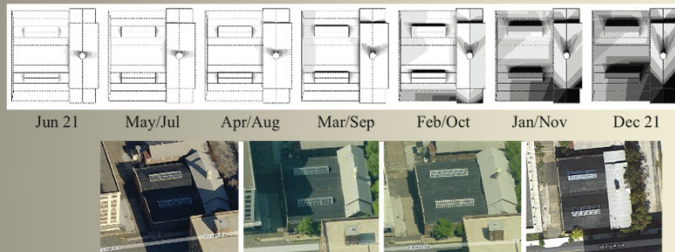
Dept. of Energy & Mineral Engineering

Dept. of Materials Science & Engineering

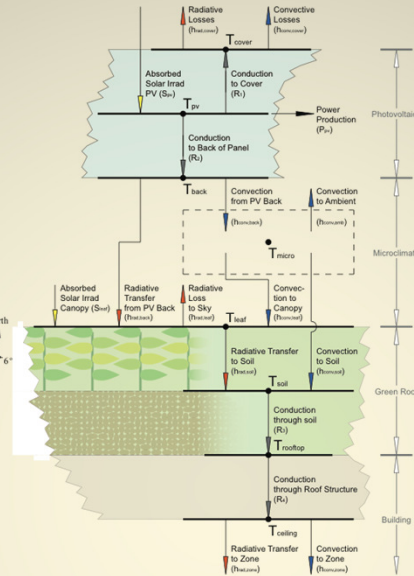
Brownson Team: Solar Systems Analysis



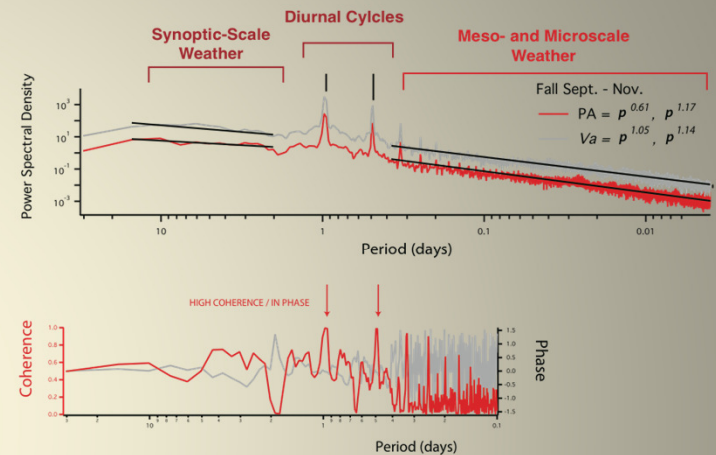
Building 661 - Roof Shading - Hours of Daily Direct Solar Irradiation



Urban Solar Analyst Development (Phil Navy Yard)



Green Roof Integrative Photovoltaics



Cospectrum Analyses of Irradiance (PA-VA)

Where to put Solar?

Geospatial assessment

How to cool Solar?

Microclimate simulations

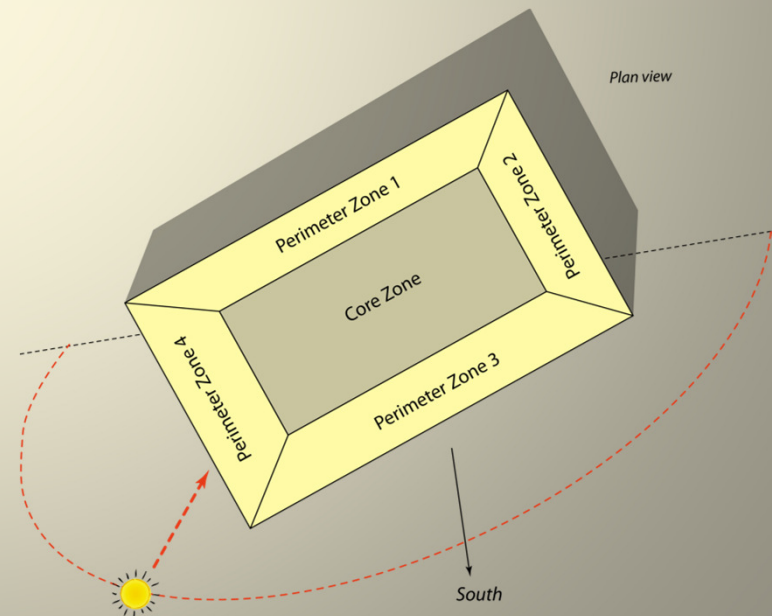
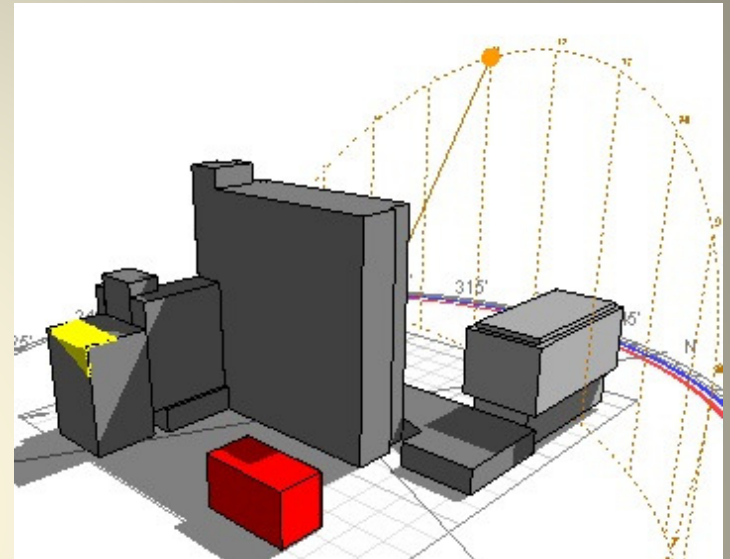
How to secure smooth power given the weather?

Covariance Spectral analysis and portfolio assessment

How to re-think Buildings as a large Solar Energy Conversion Systems!

Patterns in Buildings

- *Majority of energy exchange is through the façade/perimeter (55-80%)¹*
- And yet, external boundary conditions are not measured
- Outside air temperature is valued, rather than the *irradiation (W/m^2) driving the air temperature*
- The Sun is assumed to be good for *daylight* (illuminance is not irradiance)
- *Only windows are included* in radiative exchange
- *Major loss* of primary energy knowledge to adapt energy management with control systems



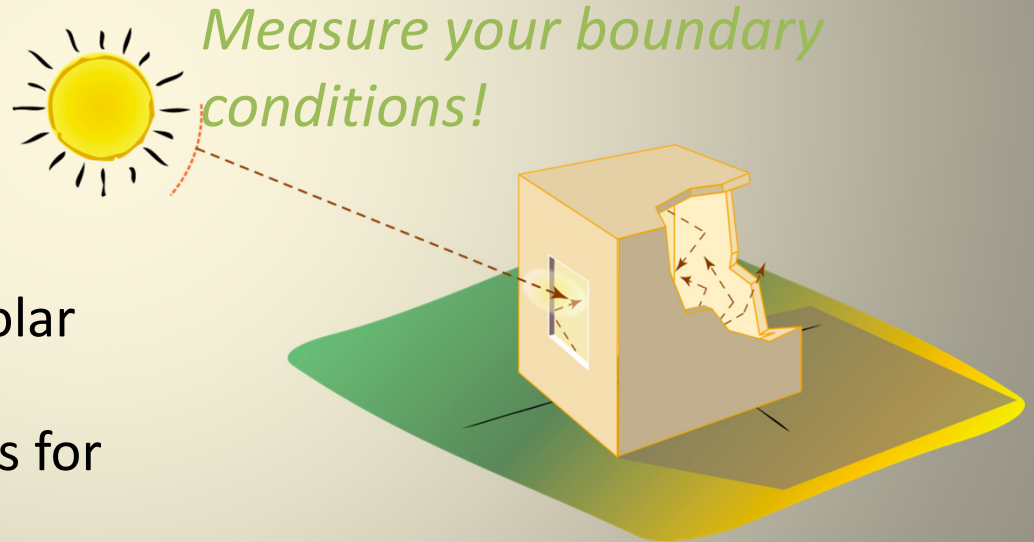
Patterns in Meteorology

- Typical Meteorological Years are not indicative of real weather data for short term use
- Time and Space are connected: remote measurements are dilated in time
- Translating horizontal irradiation to vertical surfaces has major issues for sub-hourly events
- The mid-latitudes have *FOUR characteristic fingerprints*, not one annual fingerprint, not 12 monthly fingerprints.



New Pattern Solution: Building as Solar Collector

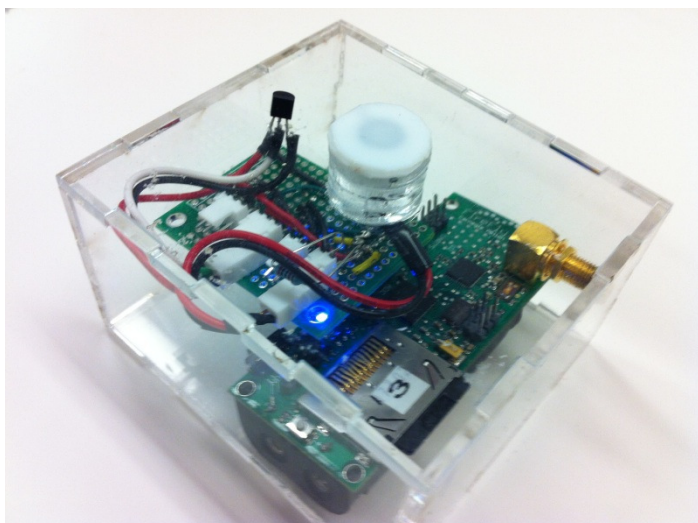
- Building Flux is highly susceptible to Radiative Transfer
- *Irradiation* (W/m^2) not *Illumination* (eyes)
- Each site is actually four fingerprints!*
- Vertical surfaces are to be measured, not estimated
- Walls are vertical flat plate solar thermal systems
- Windows are cavity collectors for perimeter zones
- Measure the system's energy flux!



*We call them “seasons” ...

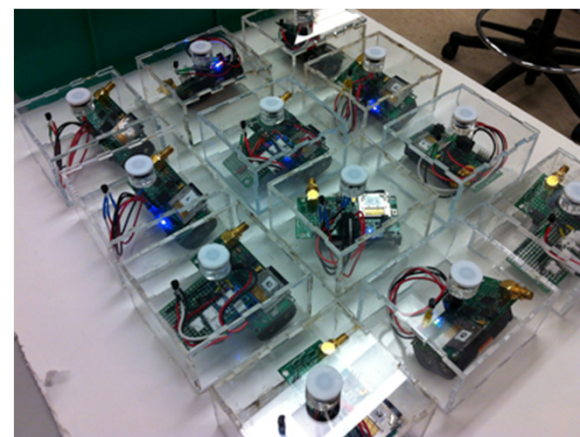
Energy Sensing for Active Response

Sensitive Façade Work at the Philadelphia Naval Yard



Components

- Firefly 2.2 Node
- Temperature Sensor
- Silicon Photodiode
- SD card
- Teflon Sheet



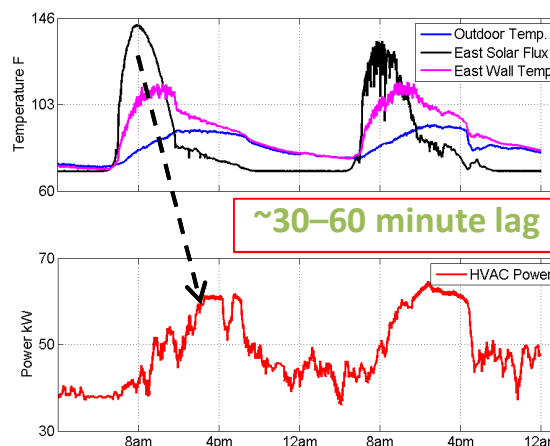
What to sense, how to sense, where to sense, how to share that data.

EEB Hub: Solar Skin Work
Penn State University
University of Pennsylvania
 (Rahul Mangharam)

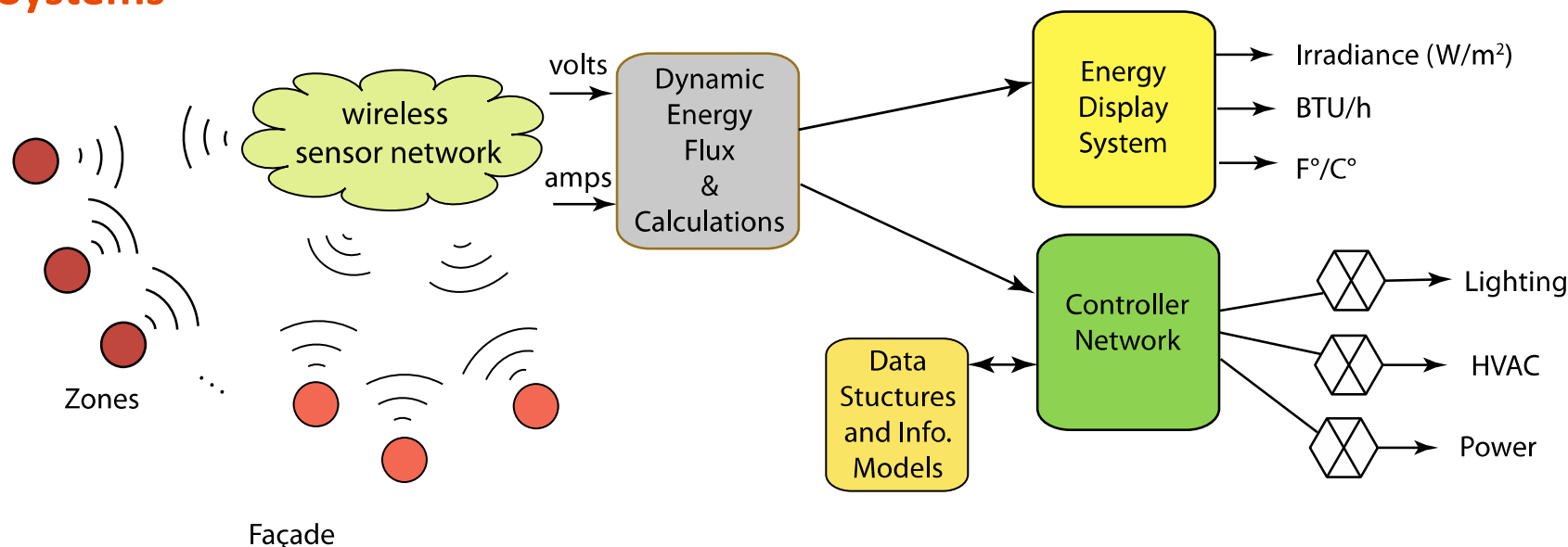
Outside Wall & Air Temperature and Solar Irradiance

HVAC Power Consumption

Real world external envelope measurements



Sensitive Façades within larger context: **Building Energy Management Systems**



Low-installed-cost temp/light “invisible” sensors, integrated into building components (e.g., window units)

Develop strategic sensor placement strategies to optimize costs

Deploy low cost Firefly irradiance and temperature façade sensors and sensor network
Real time conversion of sensor data to energy flux measurement for building components

Developing data structure communication and information model for control systems

Create distributed model predictive control algorithms

Distributed wireless control networks on low cost hardware

Fusion of sensor, scheduling, and wifi for automated occupancy model creation and prediction



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