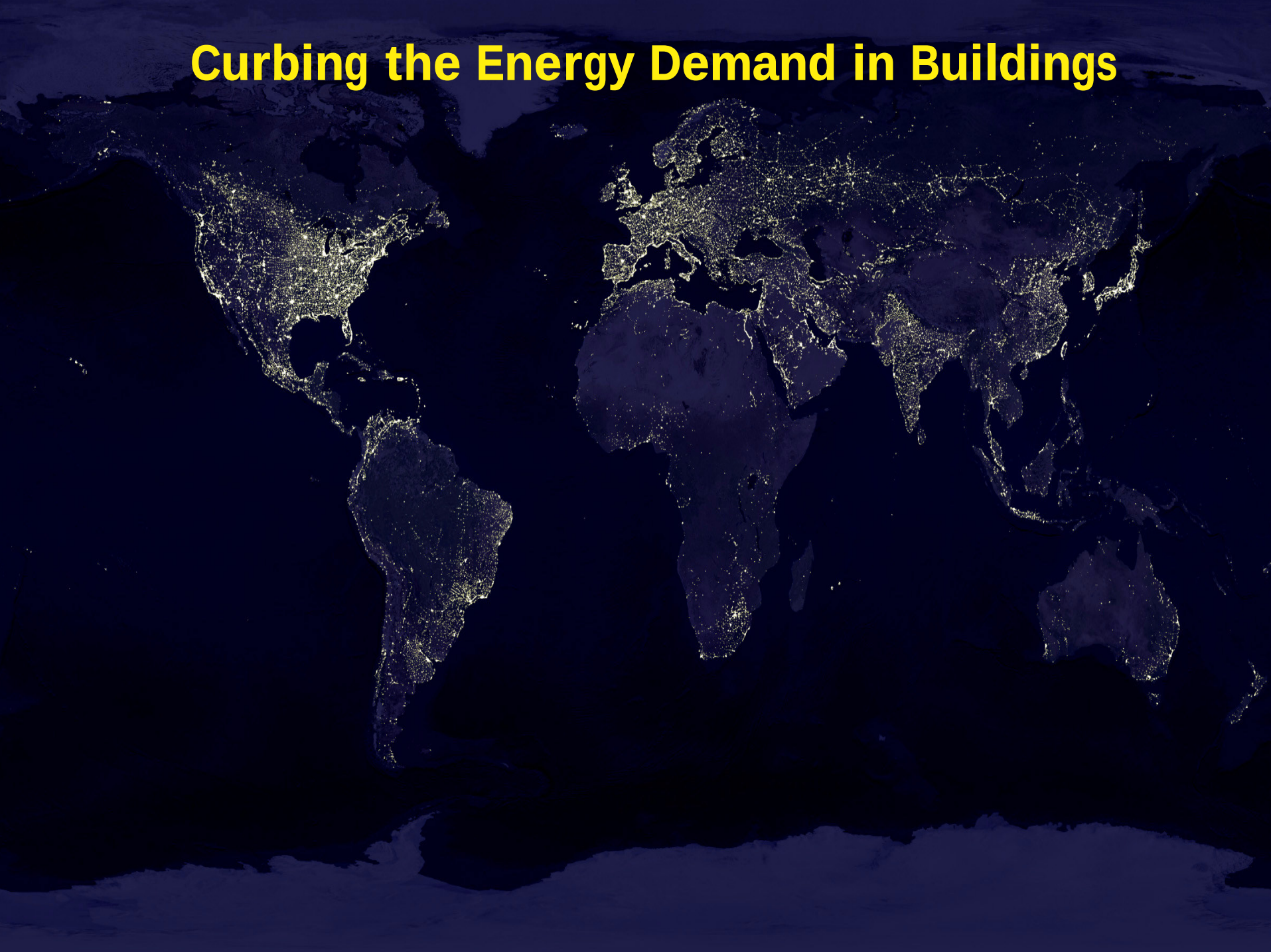
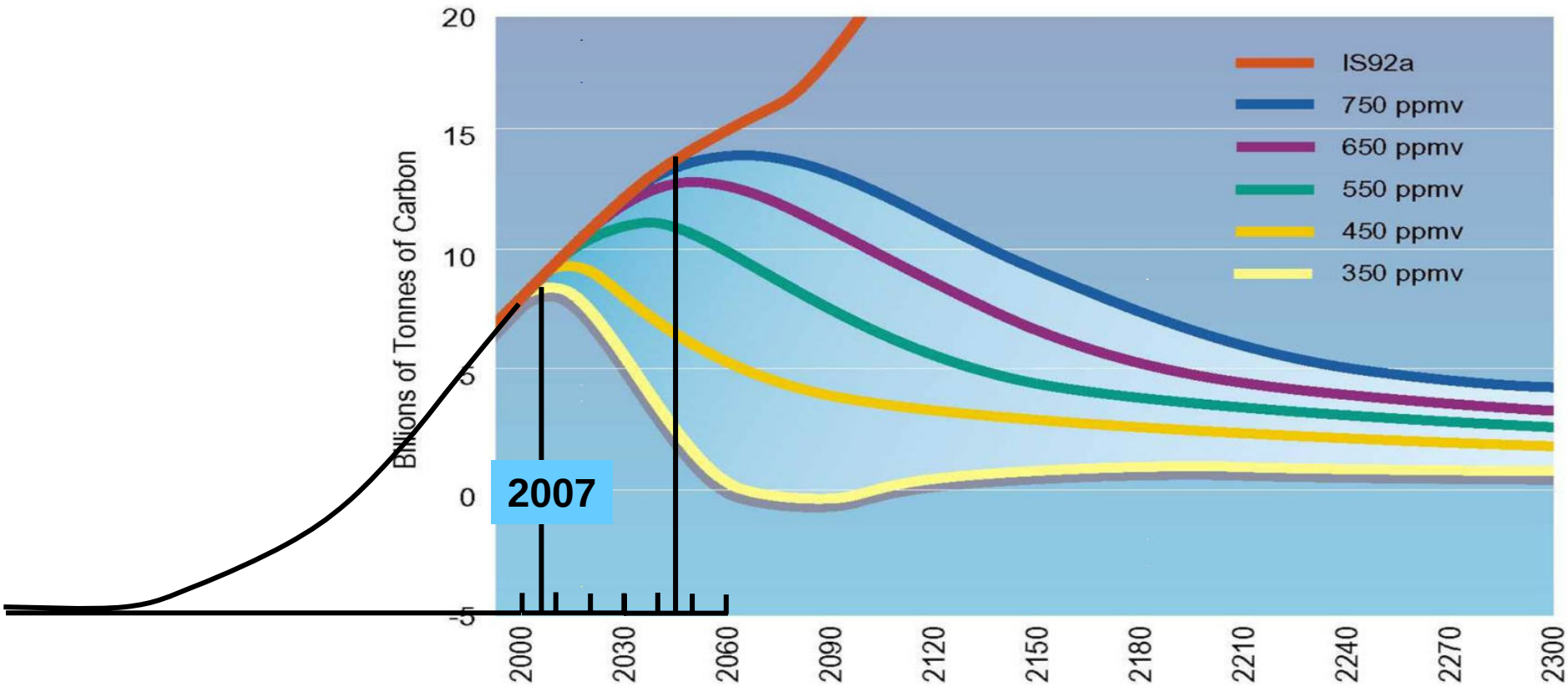
Curbing the Energy Demand in Buildings



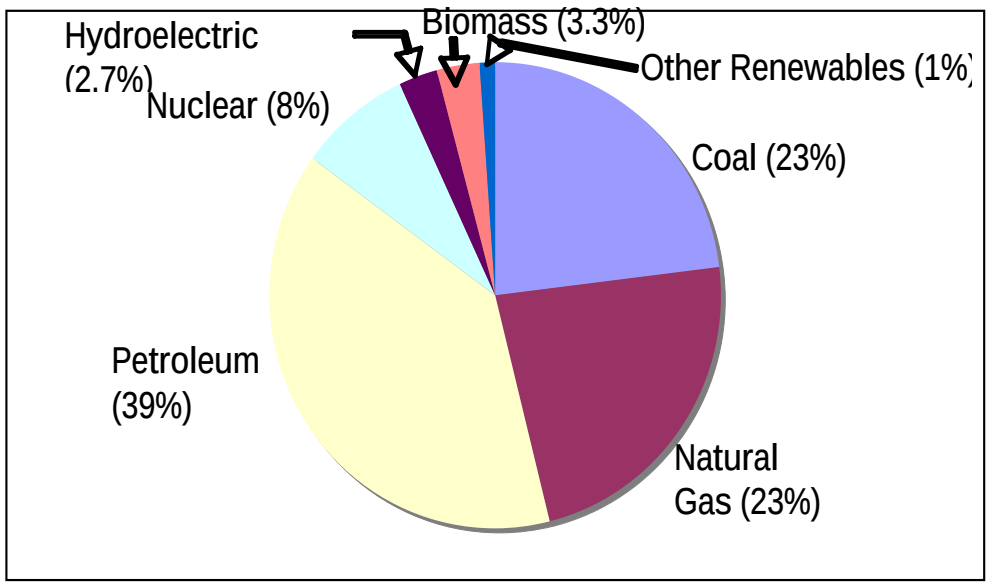
Emissions Trajectories for atmospheric CO_2 concentration ceilings



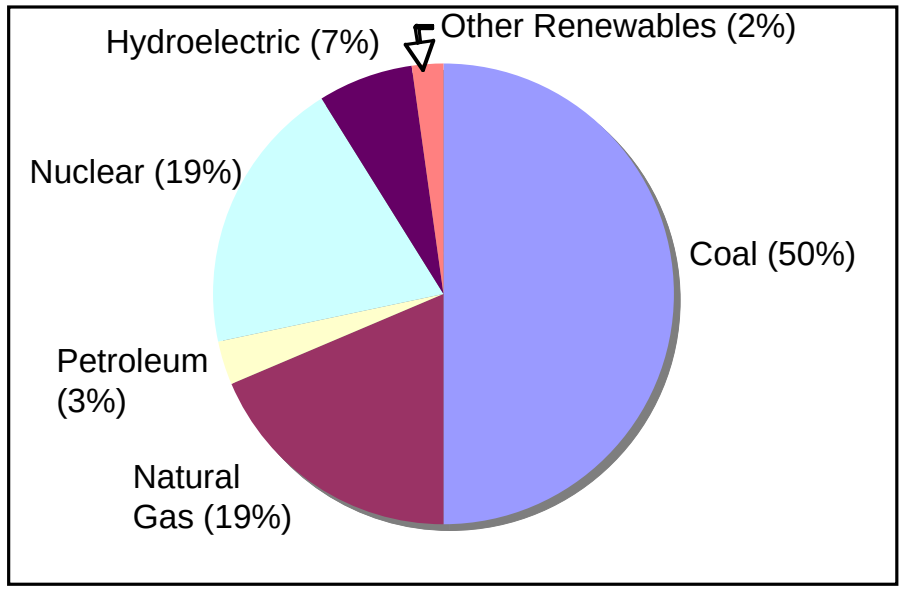
Source: Fourth Assessment of the Intergovernmental Panel on Climate Change; Summary for Policy Makers, February 2007.

Supply Side

Primary Energy (2005)



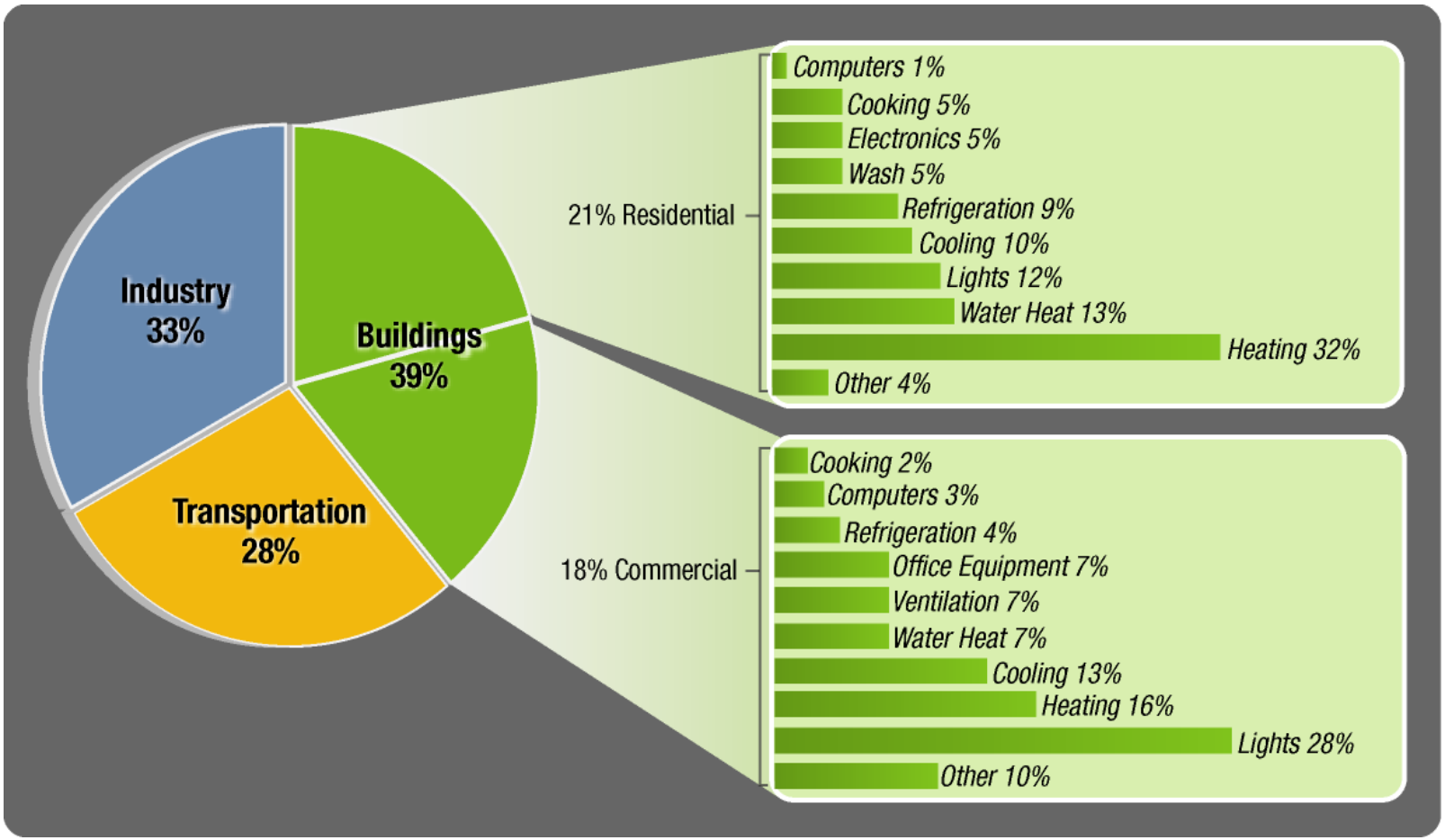
Electricity Generation (2005)



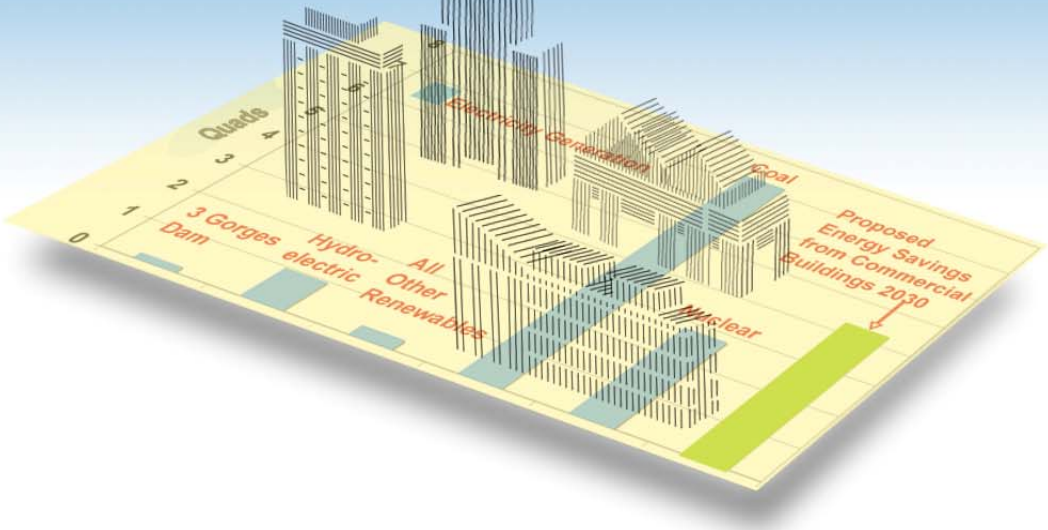
Demand Side: End Use Energy Consumption

Buildings consume 39% of total U.S. energy

- ***71% of electricity and 54% of natural gas***



High Performance Buildings Research & Implementation Center (HiPerBRIC)



National Lab-Industry-University Partnership

Arun Majumdar
Director, Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

United Technologies

February 28, 2008

Building Energy Demand Challenge

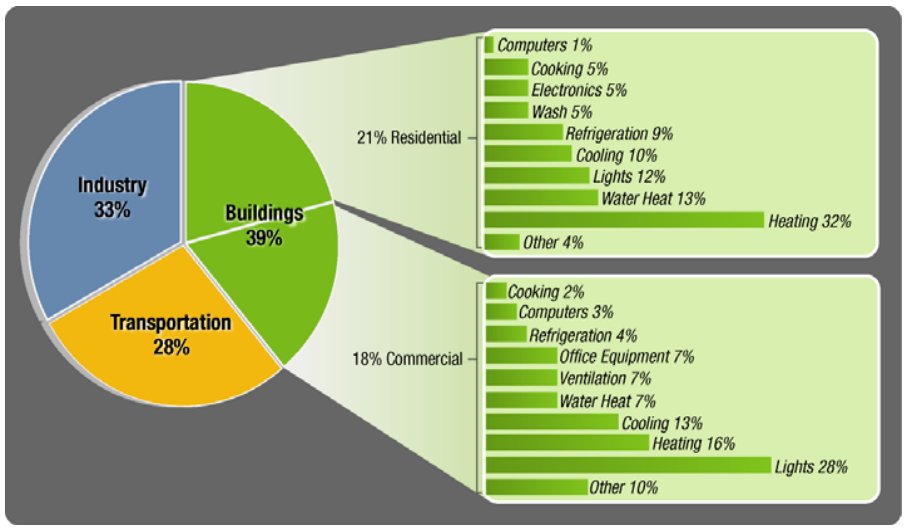
Buildings consume
- 39% of total U.S. energy
- 71% of U.S. electricity
- 54% of U.S. natural gas

Building produce 48% of U.S. Carbon emissions

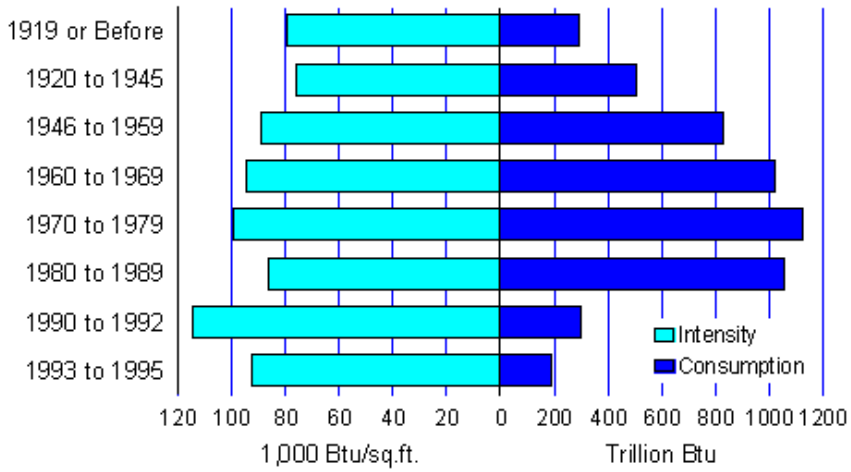
Commercial building annual energy bill: $120 billion

The *only* energy end-use sector showing growth in energy intensity
- 17% growth 1985 - 2000
- 1.7% growth projected through 2025

Energy Breakdown by Sector



Energy Intensity by Year Constructed



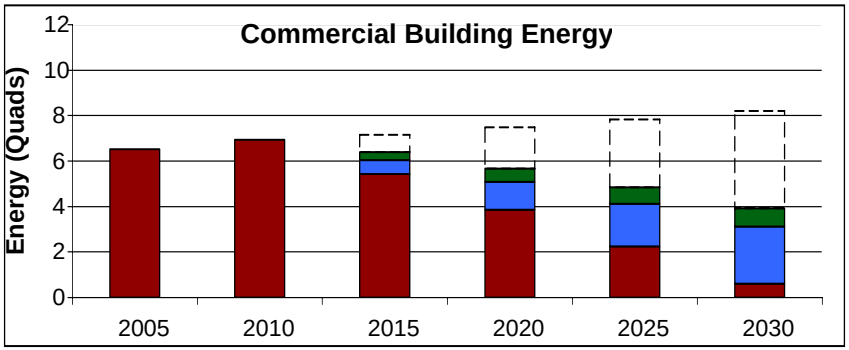
Energy Information Administration
1995 Commercial Buildings Energy Consumption Survey

Sources: Ryan and Nicholls 2004, USGBC, USDOE 2004

HiPerBRIC Vision

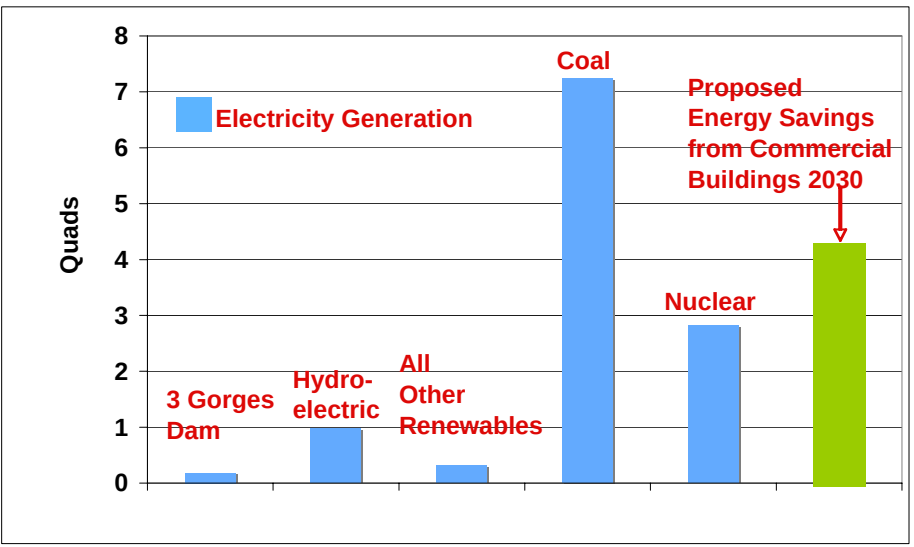
Enable transformation of U.S. Commercial buildings sector in 20 years, starting NOW

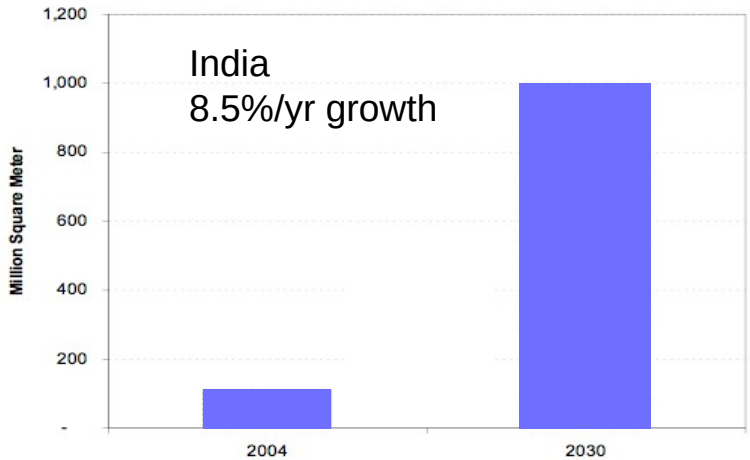
- Save >4 Quads of energy and reduce >400 million tons of CO_2 annually
  - Reduction in energy consumption: 90% in new buildings; >50% in retrofits
- Enhance health, comfort, safety/security and water usage while gaining energy efficiency



China

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.





Outcome & Milestone Roadmap

3 Years (2011)

- >50% reduction in energy consumption at the end of 3 years demonstrated in a “deep” retrofit with market-averaged payback
- Develop methods for scale-up with energy, health, comfort, and safety in mind
- Curriculum development tie-ins for training personnel
- Product communication protocols

5 years (2013)

- >70% reduction in energy consumption demonstrated in a “deep” retrofit with market-averaged payback
- >80% reduction in energy consumption demonstrated in a new building with cost of conserved carbon below onsite new clean generation
- Demonstrate fully automated self-tuning continuous energy minimization at test facility with designed comfort and indoor air quality
- Demonstrate moderate scale up
- Develop regional market transformation programs for buildings industry

2016 2018 2030

2011 2013

NOW

8 years (2016)

- Tens to Hundred deep retrofit with >50% reduction in energy consumption with market averaged payback
- Tens of new buildings with 90% reduction in energy consumption with market averaged payback

10 years (2018)

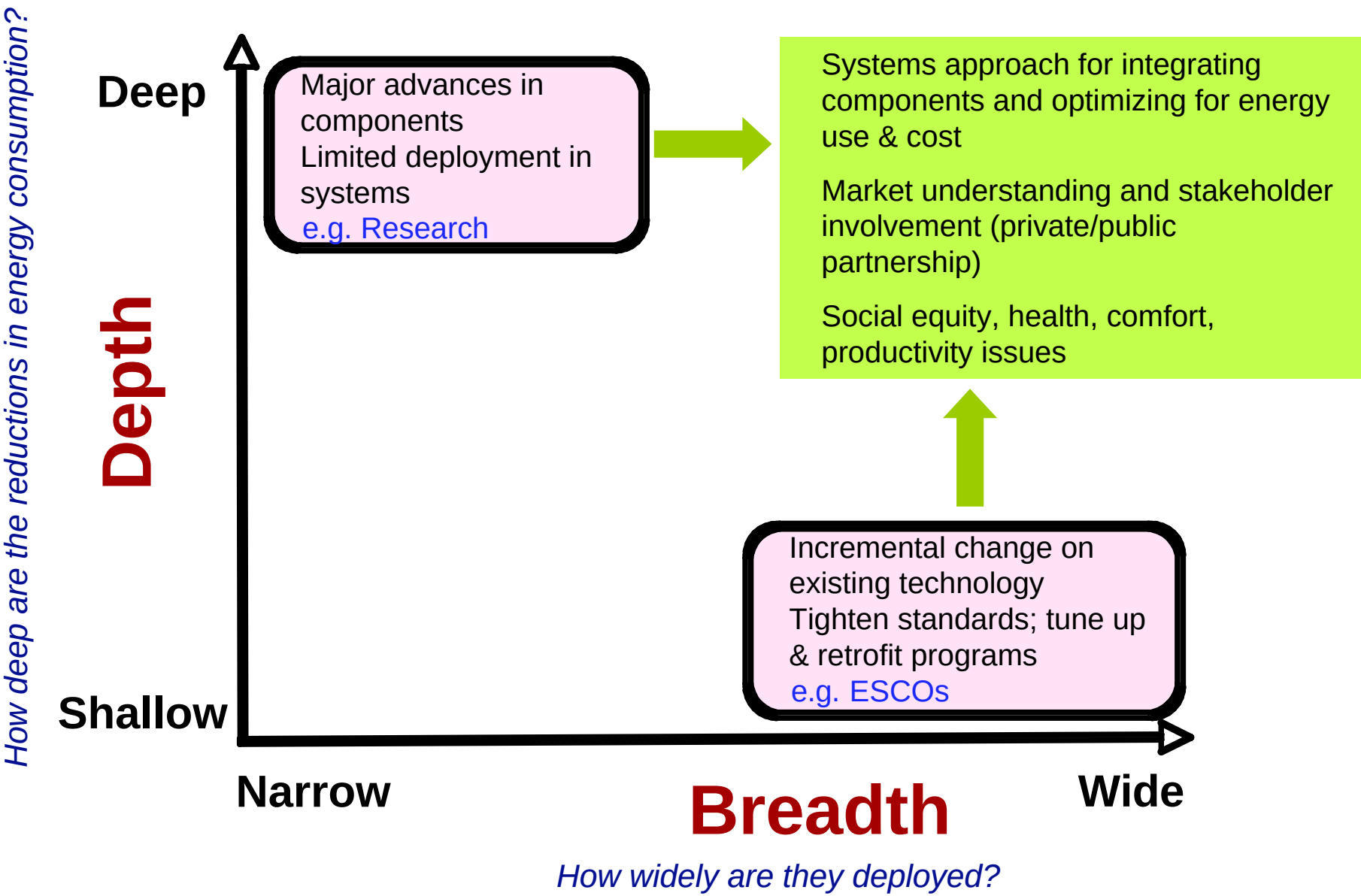
- >100 buildings being deep-retrofitted (>50% reduction) with market averaged payback time
  - Deploying fully automated self-tuning continuous energy minimization and indoor environment optimizing in retrofits and new buildings
  - Multiple service companies offering deep-retrofit capabilities with financing, remote monitoring, and performance guarantees
- Scale up for new buildings design and construction towards zero net energy and designed indoor environment and security with market averaged payback time
- Several dozen hardware and software products available from private sector enabled with BOP protocols, and plug-and-play capability

AIA Challenge & CPUC Goals

All new commercial buildings will be zero net energy

Technology Maturation; Implementation in Large Commercial Buildings; Domestic and International Scale up to Thousands of Buildings

Gaps & Opportunities

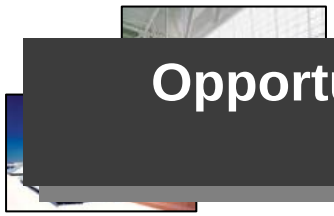


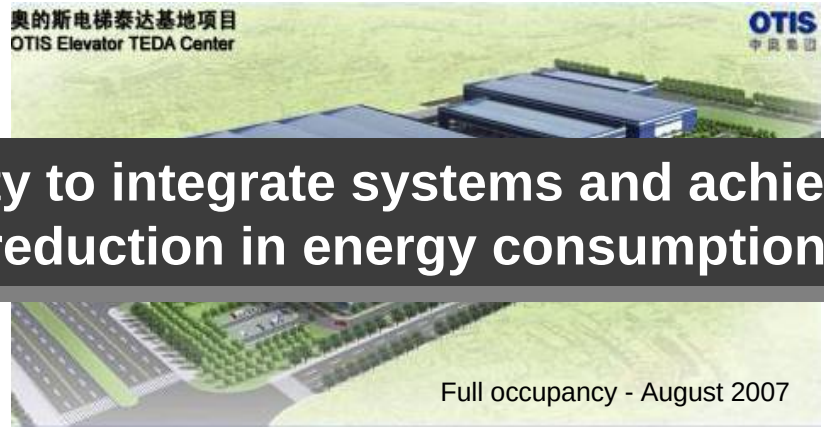
UTC Green Building ...Otis Elevator TEDA Center

25% Energy Reduction: Systems Engineering & Available Technology

another "one of a kind" new building with existing technology

Daylighting



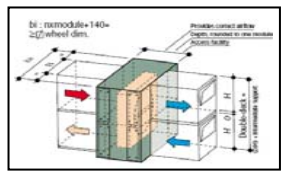


High Performance Equipment

Opportunity to integrate systems and achieve 70-80% reduction in energy consumption

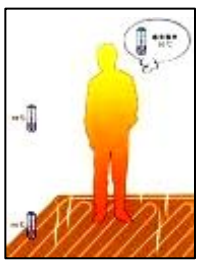
Shading

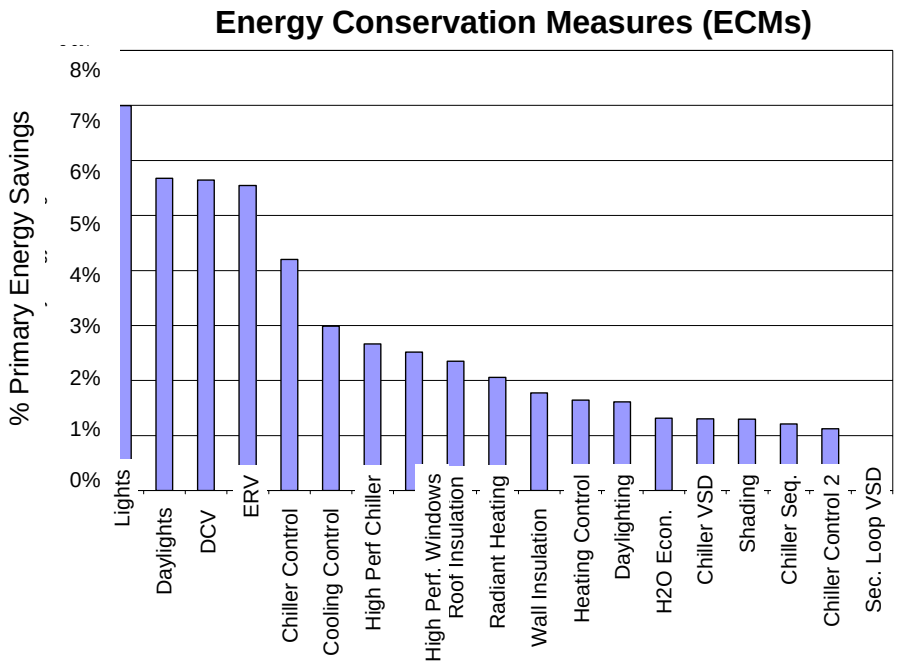
Energy Recovery Ventilation



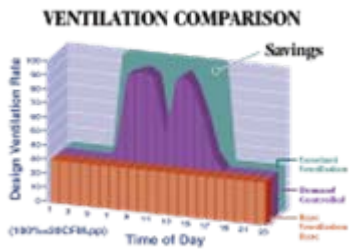
Heat Exchanger

Radiant Heating





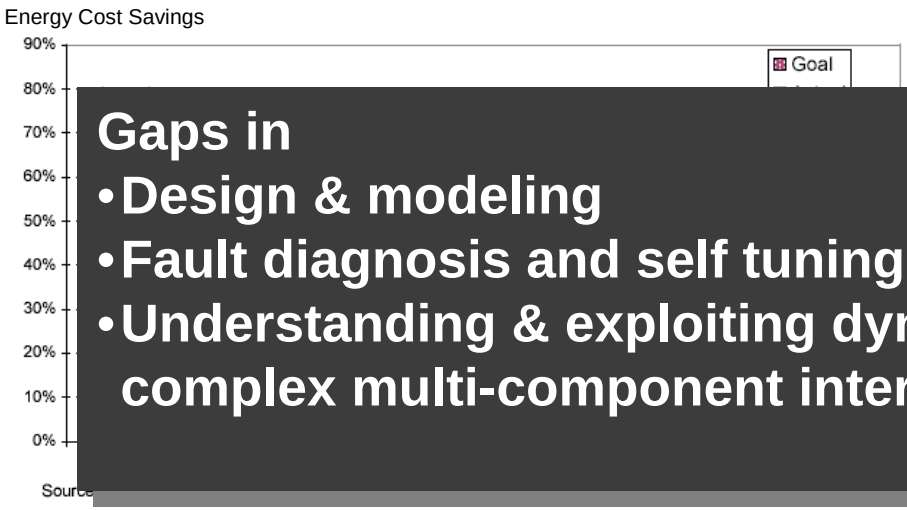
Demand Controlled Ventilation



Faults in *Operation* of Buildings

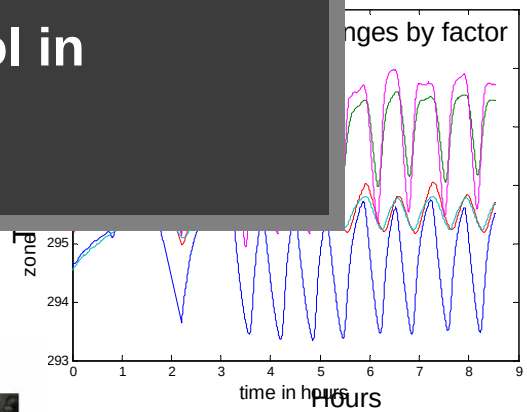
Gaps between predicted & actual performance

Models over-predict savings by ~20-30%

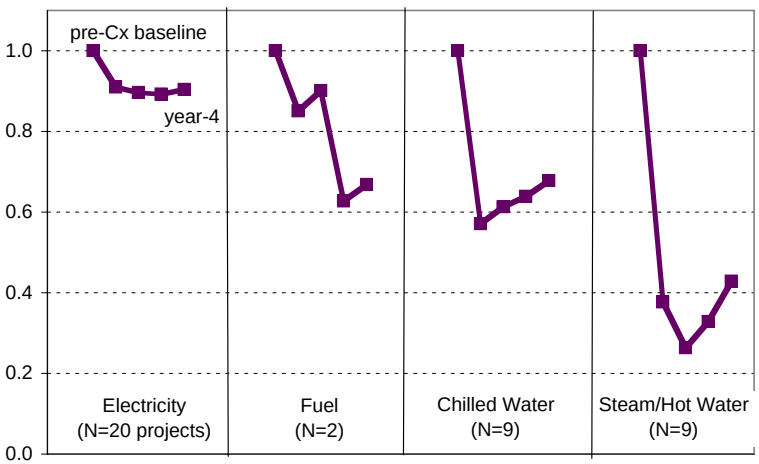


Gaps in

- **Design & modeling**
- **Fault diagnosis and self tuning**
- **Understanding & exploiting dynamics and control in complex multi-component interacting systems**



Façade Damage



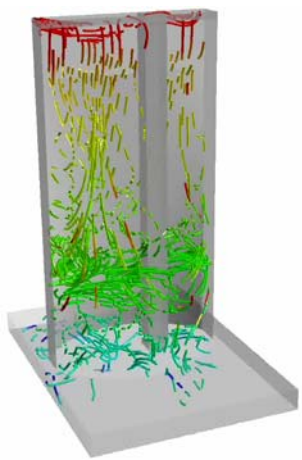
Markers indicate Years following Retro-commissioning (4 years per project)

Many of these faults are invisible.

Source: "The Cost Effectiveness of Commercial Buildings Commissioning," LBNL, 2005.

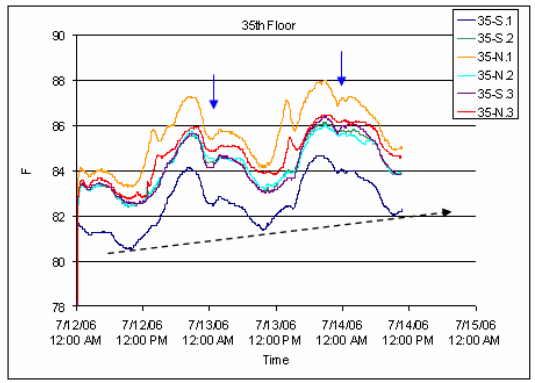
Building Energy and Comfort Implications

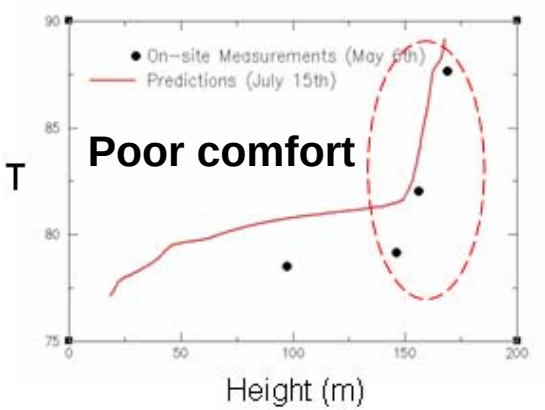
Building dynamics and complexity arising from interactions

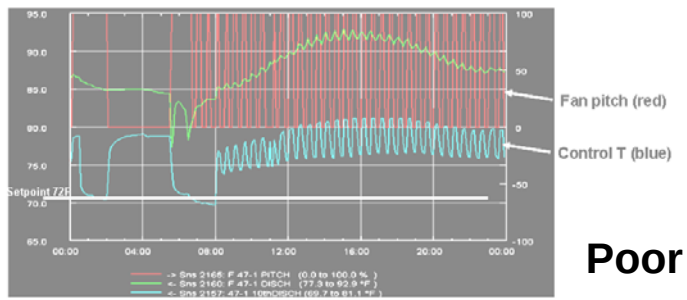


- ***30% energy increase over benchmark***
- ***Poor comfort (100F+ at top floors)***

Building thermals & airflow coupling

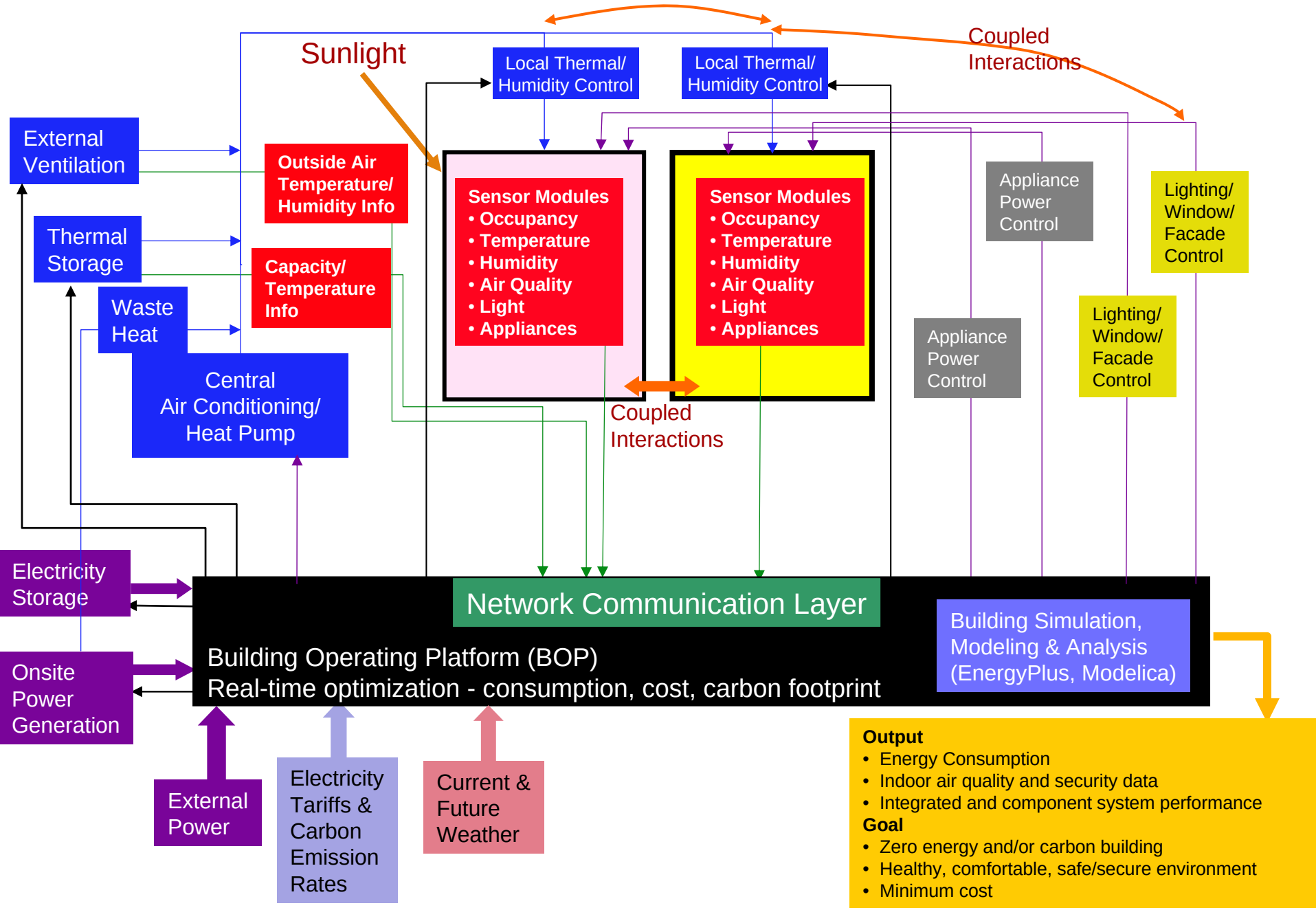






Poor controls performance

Technical Scope

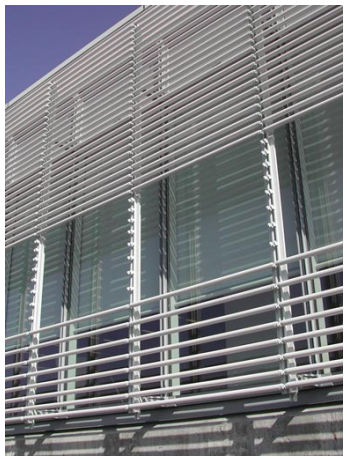


Experience with New York Times HQ

Just a start

“one of a kind” new building without system integration

- Construction complete, occupied June 2007
- Automated shading and daylight dimming installed and working
- Extensive monitoring planned
- Challenge: Adoption by others…



Modeling Daylight Distribution

Experimental Validation

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Dimmable; Addressable; Affordable

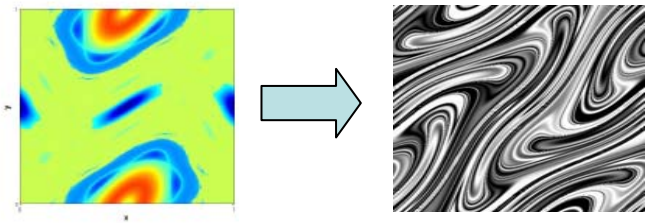
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

October Workshop: Enabling Technology

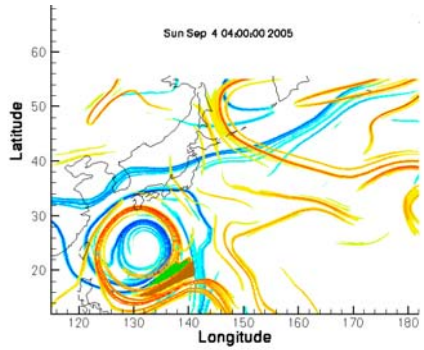
LBNL, UTRC, UC Santa Barbara, UC Berkeley, Stanford, UIUC

Numerical Methods for Analysis of Mixing

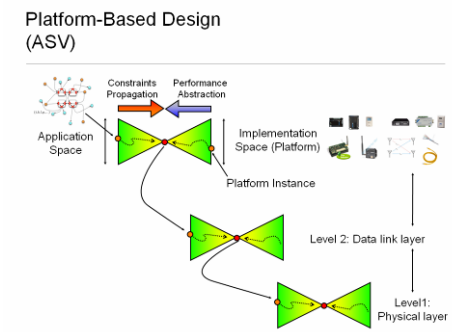
Safe and Immune Buildings



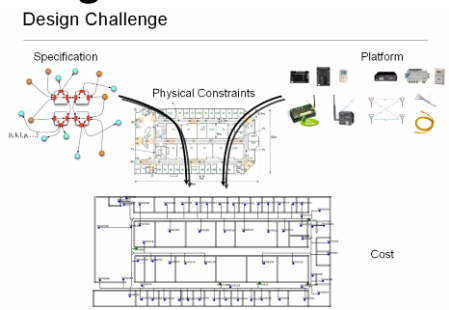
Control of Mixing



Net Zero Energy Buildings

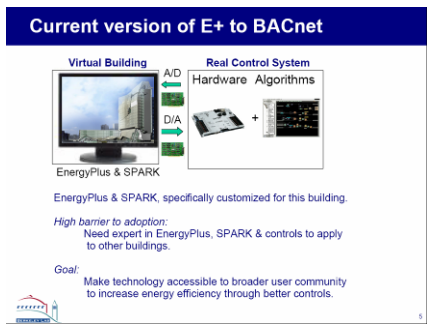


System Level Design: Platform Based Design



Building Network Synthesis: Platform Based Design

Energy Efficient Retrofits of Existing Buildings



Control Oriented Modeling and Design

Wireless Enabled Visibility of Energy Use

HiPerBRIC Role & Differentiation: Systems of Systems

"Prius of Buildings: Exploiting the Interfaces between Sub-systems"

Buildings Design & Energy Analysis

HVAC

Natural Ventilation, Indoor Environment

Windows & Lighting

Networks, Communications

Building Materials

Sensors, Controls

Domestic/International Policies, Regulation, Standards, Markets

Power Delivery & Demand Response

Demonstrations

Integration & Building Operating Platform (BOP) Team

Major Project Themes

1. **Monitoring & Diagnostics**
   - **Open-platform sensor communication and information management infrastructure for monitoring & analyzing occupancy, lighting, indoor environment, energy/mass flow and diagnosing faults in HVAC, lighting and other delivery systems**

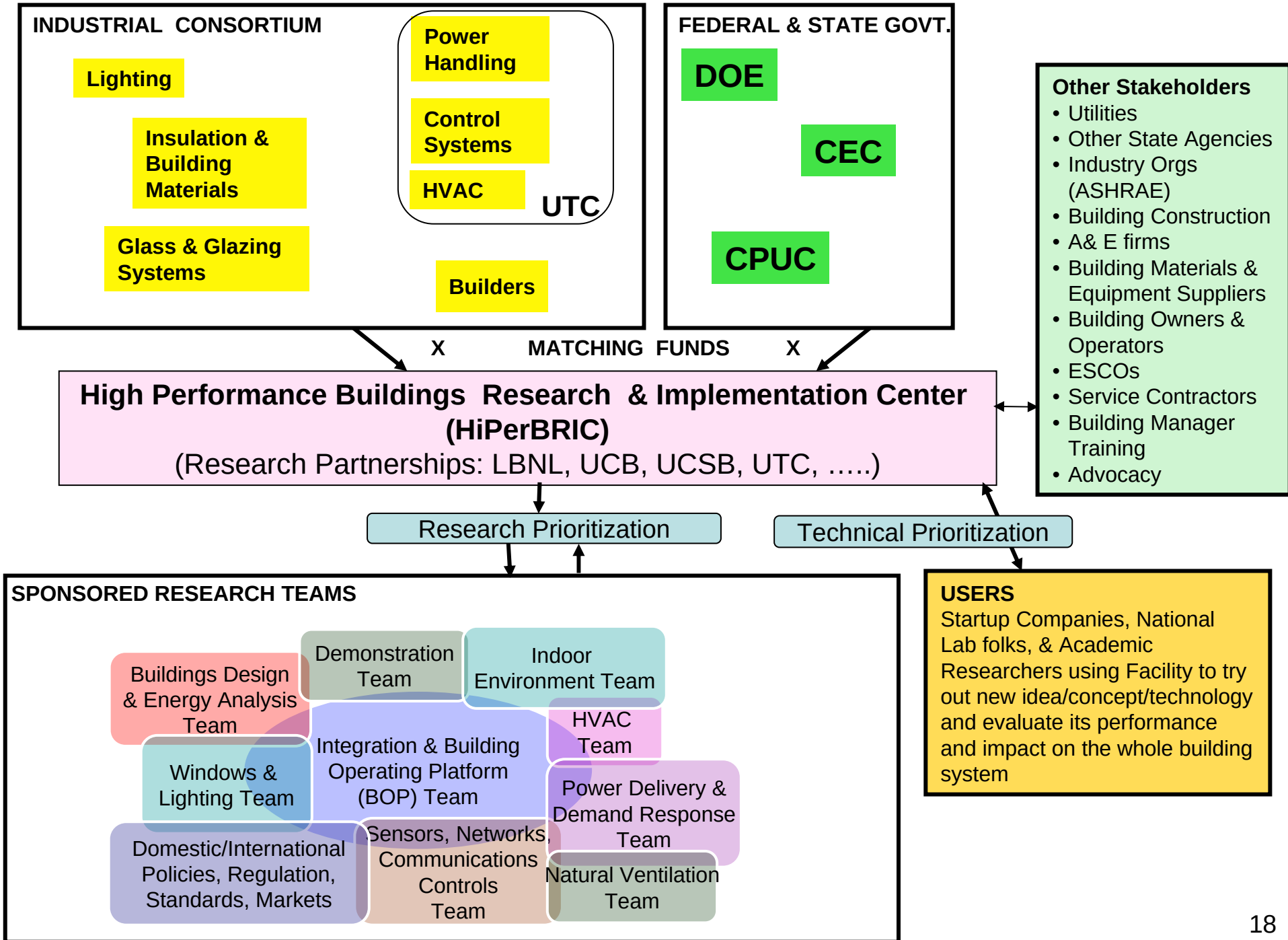
2. **Building Operating Platform (BOP)**
   - **Open-platform intelligent system that coordinates monitoring/diagnostics, energy modeling and analysis, and feedback control systems, while exploiting interfaces between sub-systems in real-time to minimize energy consumption, carbon footprint, and cost** ("Linux" for Buildings)

3. **System Design Tools**
   - **Buildings SPICE: Tool for architects to design buildings with embedded engineering, materials/component selection, and energy systems simulation and optimization. Such a tool will allow system-level analysis to identify components and integration strategies to reduce energy consumption.** (Leverage EnergyPlus)

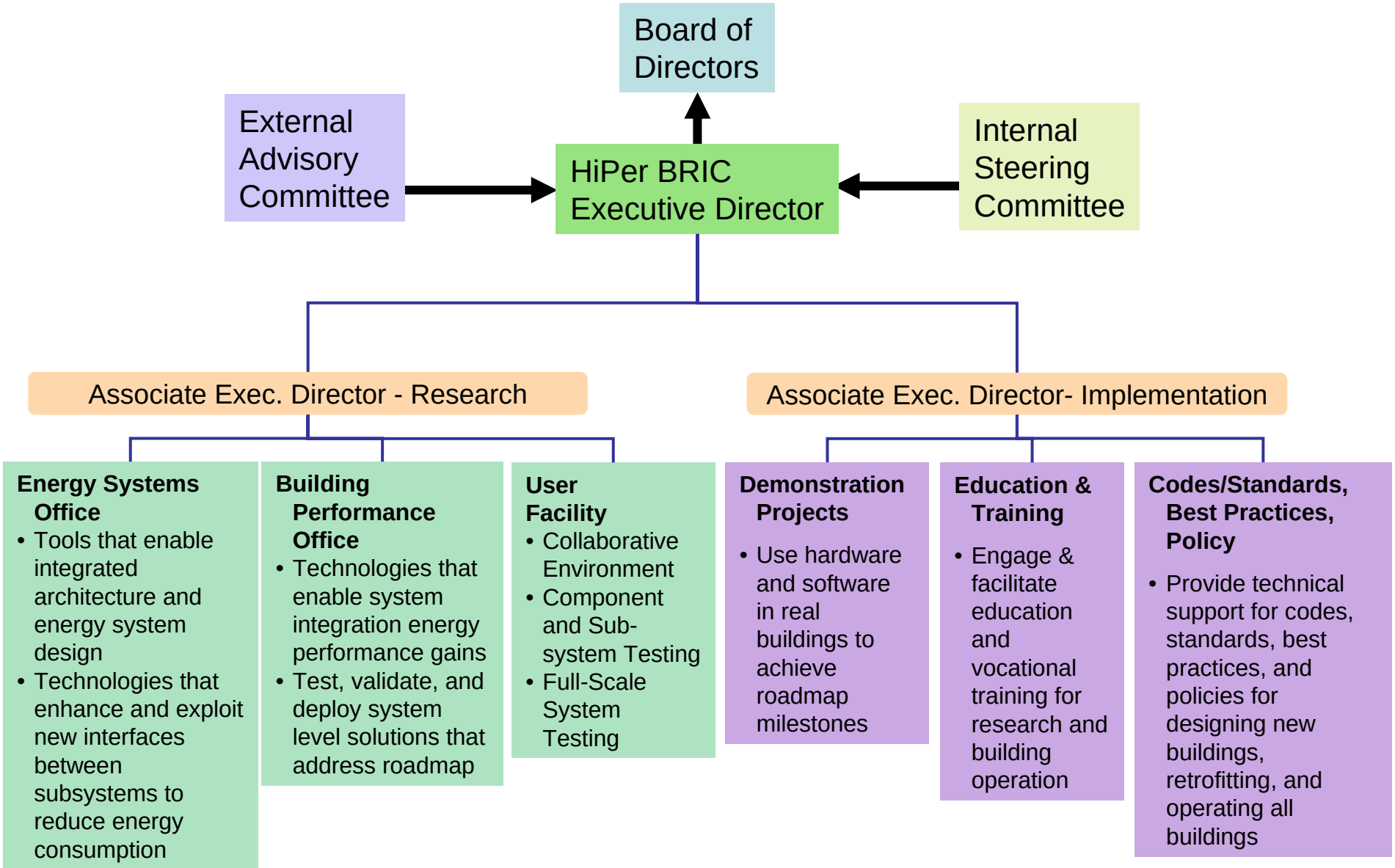
4. **Integration-Enabled Component Development**
   - **Development of buildings components (materials, power delivery, HVAC, etc..) with hardware and software interfaces that allow plug-and-play integration with other components and with BOP**

5. **National Test Facility**
   - **A experimental facility to validate Buildings SPICE models and evaluate & tune performance of BOP, monitoring/diagnostics, and components/sub-systems**

6. **Economics & Policy**
   - **Economic analysis to identify technologies that reduce payback time (<5 years) while reducing energy consumption and improving indoor environment**
   - **National standard for measured building performance with corrections based on climate and other environmental conditions**
   - **Economic incentives for beating standard**


INDUSTRIAL CONSORTIUM
Lighting
Insulation & Building Materials
Glass & Glazing Systems
Power Handling
Control Systems
HVAC
UTC
Builders
FEDERAL & STATE GOVT.
DOE
CEC
CPUC
Other Stakeholders
• Utilities
• Other State Agencies
• Industry Orgs (ASHRAE)
• Building Construction
• A& E firms
• Building Materials & Equipment Suppliers
• Building Owners & Operators
• ESCOs
• Service Contractors
• Building Manager Training
• Advocacy
X
MATCHING FUNDS
X
High Performance Buildings Research & Implementation Center (HiPerBRIC)
(Research Partnerships: LBNL, UCB, UCSB, UTC, ...)
Research Prioritization
Technical Prioritization
SPONSORED RESEARCH TEAMS
Buildings Design & Energy Analysis Team
Demonstration Team
Indoor Environment Team
HVAC Team
Integration & Building Operating Platform (BOP) Team
Windows & Lighting Team
Power Delivery & Demand Response Team
Domestic/International Policies, Regulation, Standards, Markets
Sensors, Networks, Communications Controls Team
Natural Ventilation Team
USERS
Startup Companies, National Lab folks, & Academic Researchers using Facility to try out new idea/concept/technology and evaluate its performance and impact on the whole building system

HiPerBRIC Organization and Structure



HiPerBRIC Value and Differentiation

- **Open Development**
  - Open development of pre-competitive platform, best practices, test and validation results - “Linux” approach
- **Strategic**
  - Form a National Labs-Industry-Academia partnership that engages relevant stakeholders to provide the broad and deep R&D base needed to enable market transformation
- **Technology**
  - Focus on a systems approach to identify, develop and mature new enabling hardware and software technology to facilitate commercialization and market adoption
- **National Test Facility**
  - Create a unique facility (physical infrastructure and virtual presence) to evaluate, validate and mature new technologies in real buildings
  - Enable commercialization, education, and training
- **People**
  - Recruit and train a new generation of scientists, engineers, architects, and building industry professionals educated in systems approach to energy efficiency
- **Jobs**
  - Create job growth through revitalizing the US commercial buildings industry, including suppliers, builders, building operators, architects