Energy Efficient Buildings

A Systems Approach

R&D Directions

Clas A. Jacobson
Chief Scientist, Controls, UTC
860.830.4151, JacobsCA@utrc.utc.com

Satish Narayanan
Project Leader, Integrated Buildings, UTRC
860.610.7412, NarayanS@utrc.utc.com

Kevin Otto
President, Robust Systems & Solutions
617.319.2777, otto@robuststrategy.com

Smart and Efficient Energy Council
(SEEC'2009)

ARTIST Meeting

Trento, Italy

October 8, 2009

United Technologies Research Center

Key Points

•Energy efficient buildings. Achieving >50% over current standards (ASHRAE 90.1) is possible; proof points occur for all sizes and climates; buildings designed using climate responsive design principles.

•Market conditions – currently driven by labeling and increasingly by regulatory pressures (carbon cost not sufficient to drive market: findings through UTC led WBCSD study).

•What is hard? Delivery process handoffs are a problem and are where there is a loss of potential for energy savings in design, construction and operation.

•What are R&D areas?

- •Address Productivity – need design tools (configuration exploration, specification of equipment and controls, automated implementation) – for automation on all parts of delivery chain.
- •Address Risk. Need calibrated models (experimental facilities) and ability to calculate, track and manipulate uncertainty (DFSS).
- •Address Operations – need to understand sensing requirements, failure modes and FDIA.

Outline

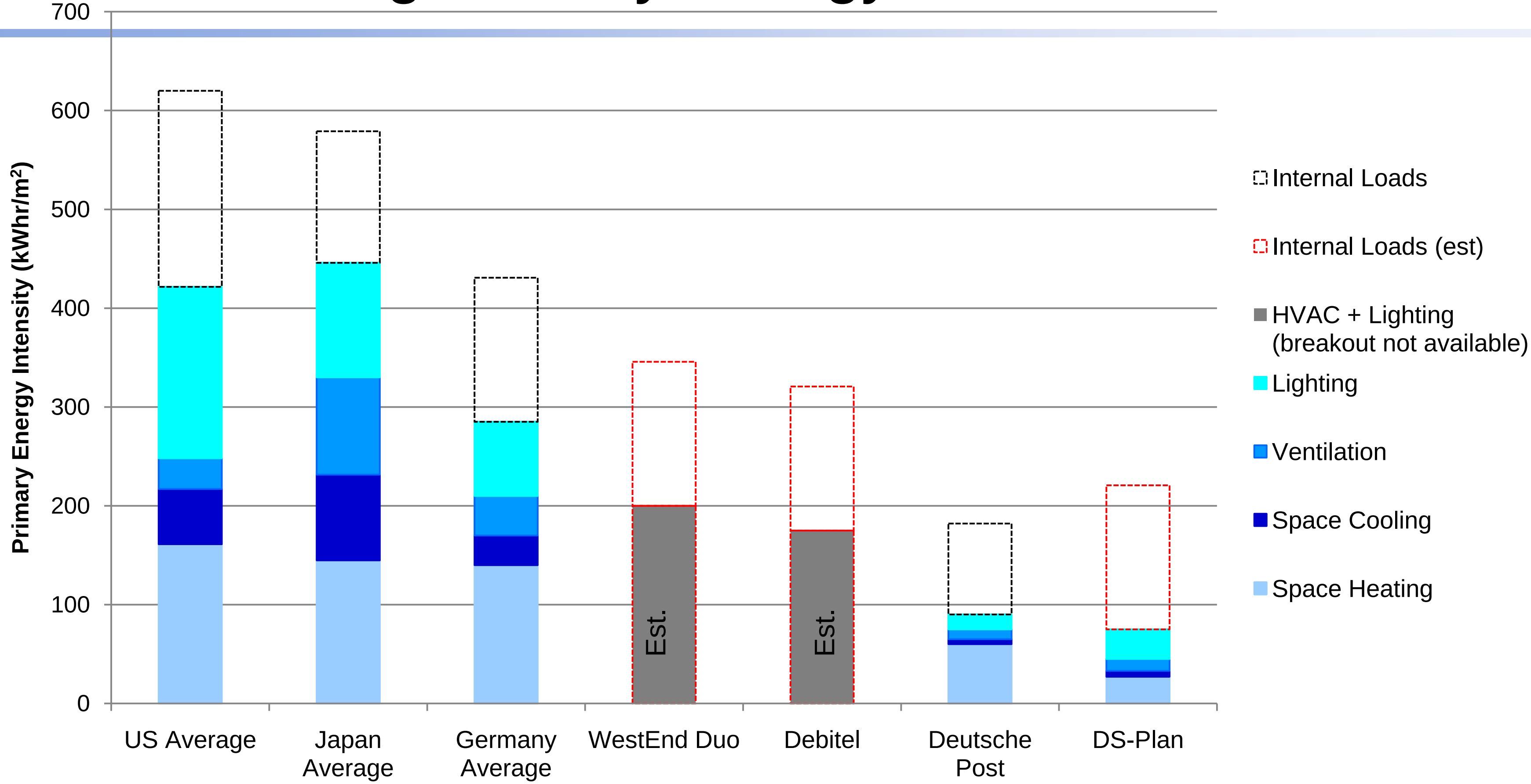
Energy Efficient Buildings

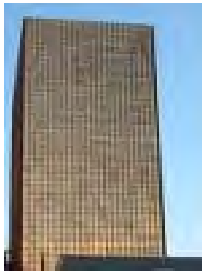
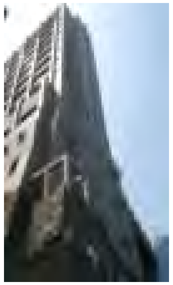
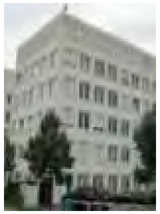
Market Conditions

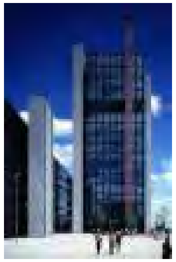
What is hard?

R&D

Office Building Primary Energy Intensities



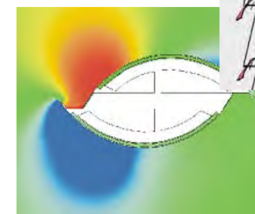


HIGHLY EFFICIENT BUILDINGS EXIST

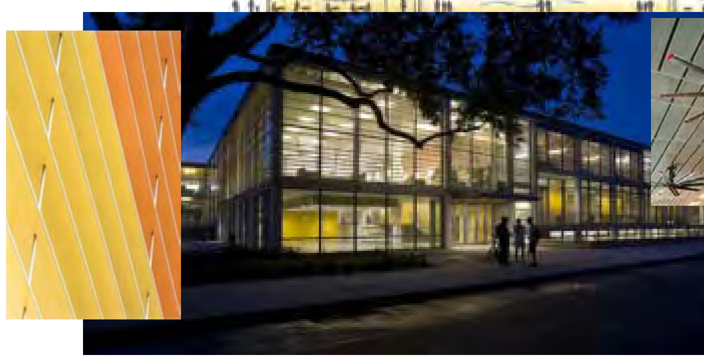
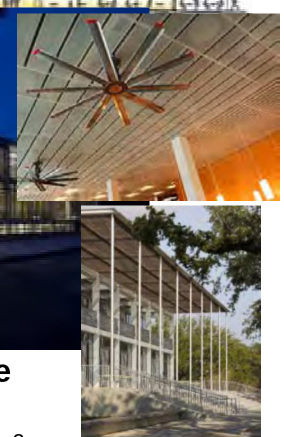
Energy Retrofit
10-30% Reduction


Cityfront Sheraton
Chicago IL
1.2M ft^2, 300 kWhr/m^2
5753 HDD, 3391 CDD
VS chiller, VFD fans, VFD pumps
Condensing boilers & DHW

Very Low Energy
>50% Reduction




Bonn Germany
1M ft^2, 75 kWhr/m^2
6331 HDD, 1820 CDD
No fans or Ducts
Slab cooling
Façade preheat
Night cool

LEED Design
20-50% Reduction

Tulane Lavin Bernie
New Orleans LA
150K ft^2, 150 kWhr/m^2
1513 HDD, 6910 CDD
Porous Radiant Ceiling, Humidity Control
Zoning, Efficient Lighting, Shading

- Different types of equipment for space conditioning & ventilation
- Increasing design integration of subsystems & control

Outline

Energy Efficient Buildings

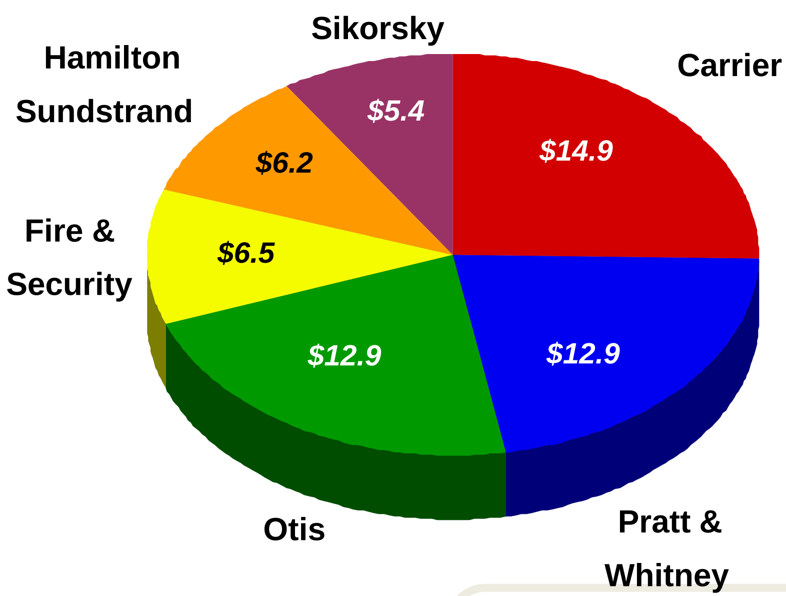
Market Conditions

What is hard?

R&D

UNITED TECHNOLOGIES (UTC)

2008 Revenue - $59 billion



commercial power solutions

aerospace systems

United Technologies

commercial building systems

UTC SUSTAINABILITY ROADMAP

Operations

- UTC establishes first set of EH&S goals (1991)
- Otis opens TEDA facility, the world's first green elevator factory, in China (2007)
- Pratt & Whitney breaks ground on an engine overhaul facility, targeted to meet LEED platinum standards, in Shanghai (2007)
- UTC launches 2010 EH&S goals, which include absolute metrics and a new goal on greenhouse gas emissions (2007)

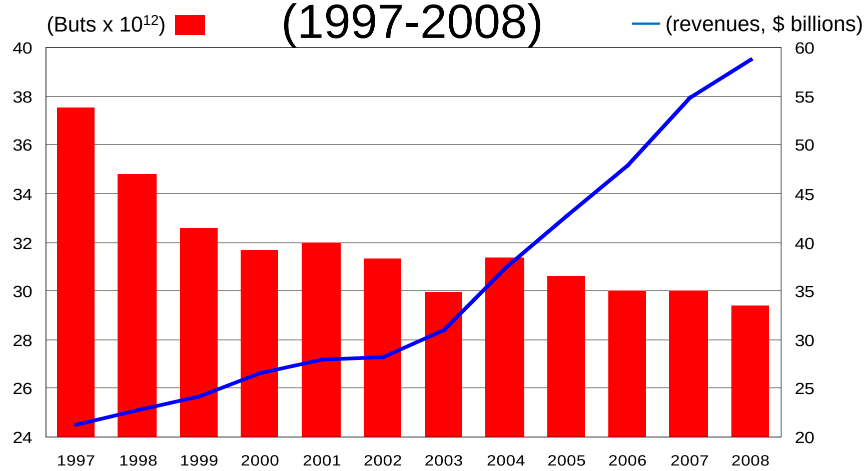
Products

- Carrier introduces Evergreen® chiller (1996)
- Otis launches the Gen2™ elevator system (2000)
- UTC launches the PureComfort® cooling, heating and power system (2003)
- Pratt & Whitney launches EcoPower® engine wash (2004)
- UTC launches the PureCycle® geothermal power system (2007)
- UTC Power introduces 400 kW PureCell® system (2008)
- Pratt & Whitney flight tests PurePower™ PW1000G engine with Geared Turbofan technology (2008)

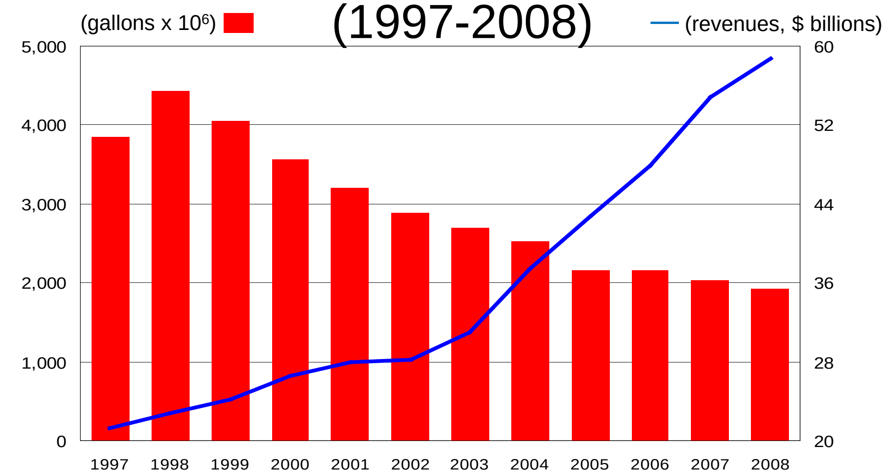
Advocacy

- U.S. Green Building Council (1993)
- Pew Center on Global Climate Change (1998)
- Dow Jones Sustainability Index (1999-2009)
- Global 100 Most Sustainable Corporations in the World. (2005-2009)
- World Business Council for Sustainable Development's Energy Efficiency in Buildings project (2006-2009)

Energy use (1997-2008)



Water use (1997-2008)



UTC Sustainable Product Launches

Otis Elevator

UTC Power

2007 recipient

Purecycle® Geothermal Power System

UTC Power

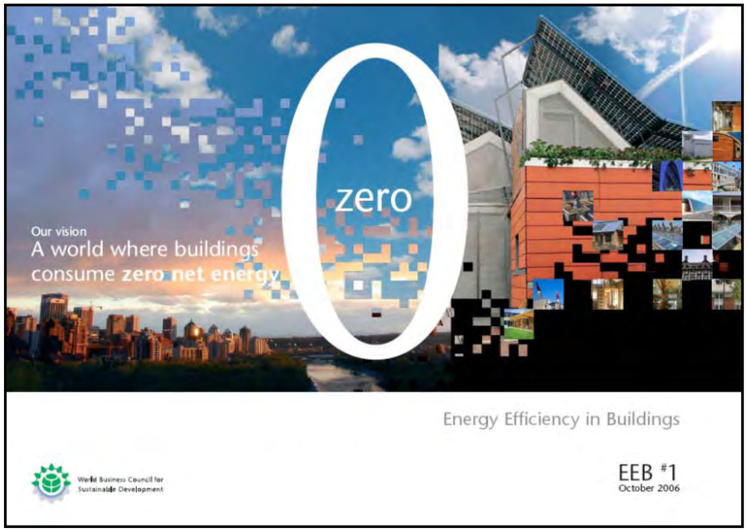
Combined Heat Power (CHP) system

Pratt & Whitney

Geared Turbofan™ Engine

WBCSD EEB PROJECT

A world where buildings consume zero net energy



Energy efficiency first

From the business voice

Launch and lead sector transformation

Contribution to "sustainable" buildings

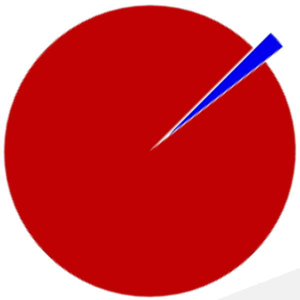
Communicate openly with markets

LAFARGE
World Business Council for Sustainable Development
United Technologies

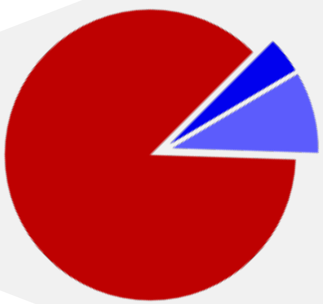
ArcelorMittal
DUPONT The miracles of science
BOSCH
SKANSKA
ACTELIOS GRUPPOFALCK
PHILIPS

CEMEX
THE KANSAI ELECTRIC POWER CO.,INC.
GDF SUEZ
TEPCO
EDF
SONAE SIERRA

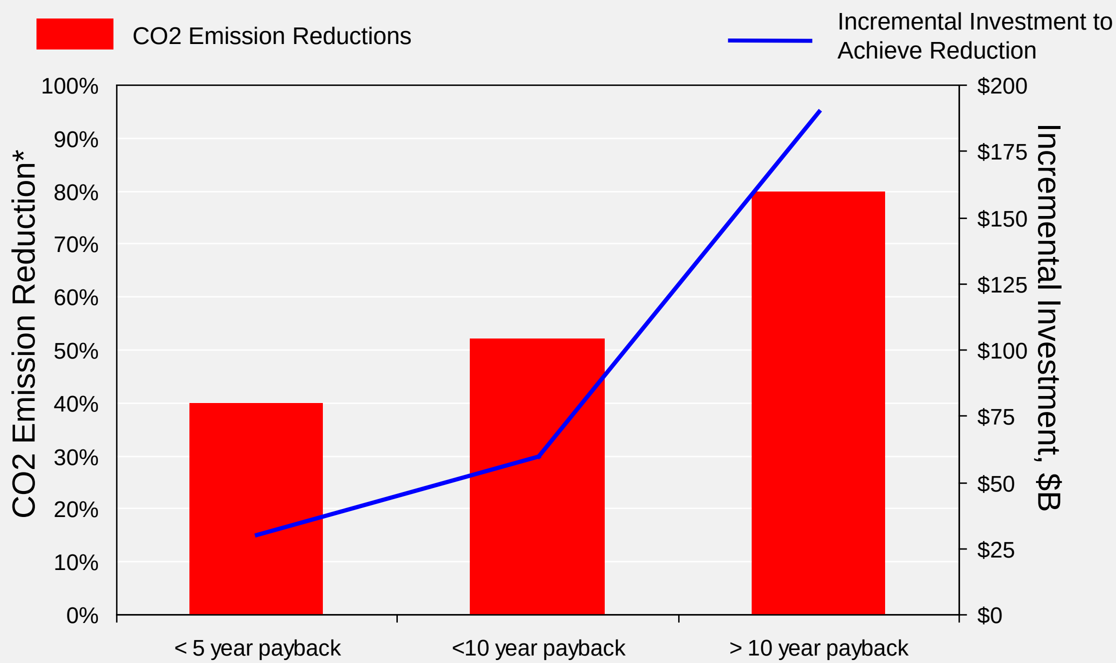
ECONOMIC ASSESSMENT – US ONLY

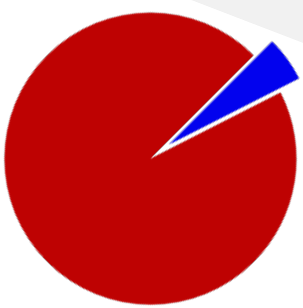


Auto Safety Regulations
2% First Cost Premium



Required Building Efficiency Investments
3% Total Cost Premium
13% First Cost Premium





Building Fire Safety Regulations
5% First Cost Premium

*reflects scale up of buildings contribution to IEA Blue Map scenario, 2050

RECOMMENDATIONS

Create and enforce building energy efficiency codes and labeling standards

- Extend current codes and tighten over time
- Display energy performance labels
- Conduct energy inspections and audits

Incentivize energy-efficient investments

- Establish tax incentives, subsidies and creative financial models to lower first-cost hurdles

Encourage integrated design approaches and innovations

- Improve contractual terms to promote integrated design teams
- Incentivize integrated team formation

Fund energy savings technology development programs

- Accelerate rates of efficiency improvement for energy technologies
- Improve building control systems to fully exploit energy saving opportunities

Develop workforce capacity for energy saving

- Create and prioritize training and vocational programs
- Develop “system integrator” profession

Mobilize for an energy-aware culture

- Promote behavior change and improve understanding across the sector
- Businesses and governments lead by acting on their building portfolios

Outline

Energy Efficient Buildings

Market Conditions

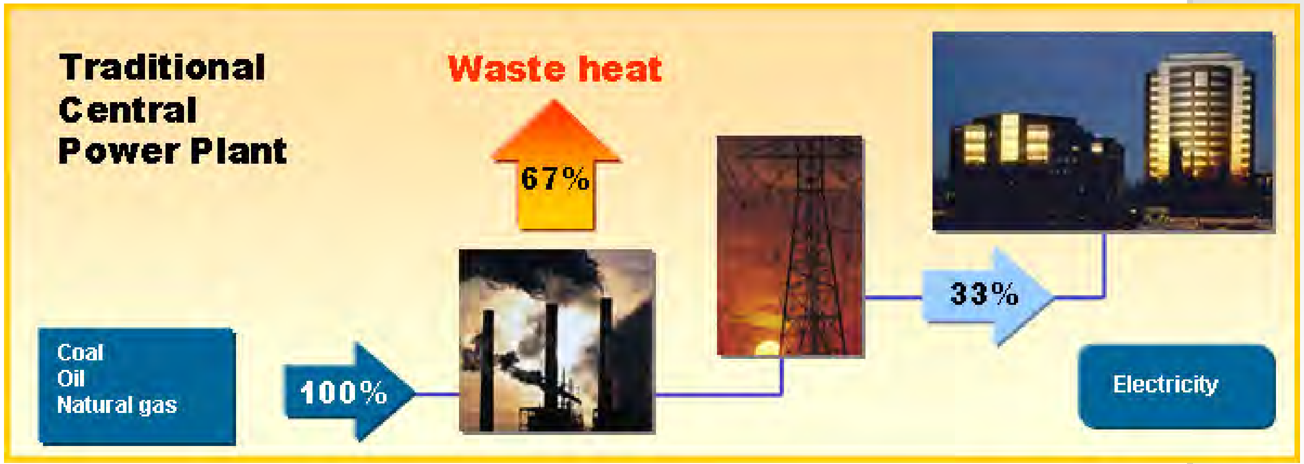
What is hard?

R&D

Combined Cooling, Heating & Power

PureComfort™ Integrated Energy Solutions

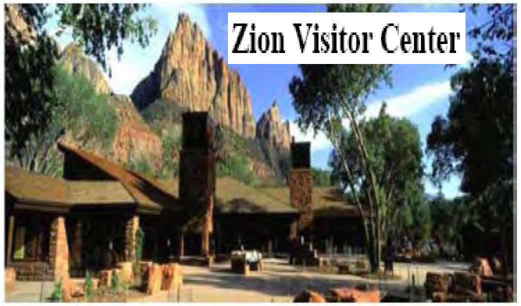
UTC Power
A United Technologies Company



HIGH PERFORMANCE BUILDINGS: REALITY

Design Intent: 66% (ASHRAE 90.1);
Measured 44%

Actual energy performance lower than predictions



Design Intent: 80% (ASHRAE 90.1);
Measured 67%

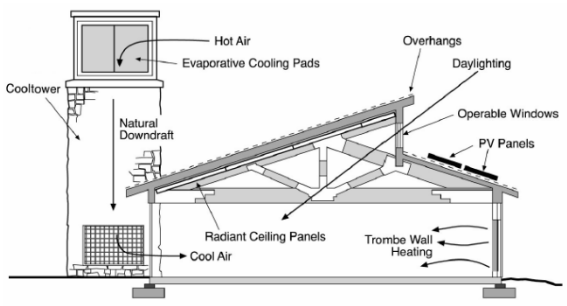


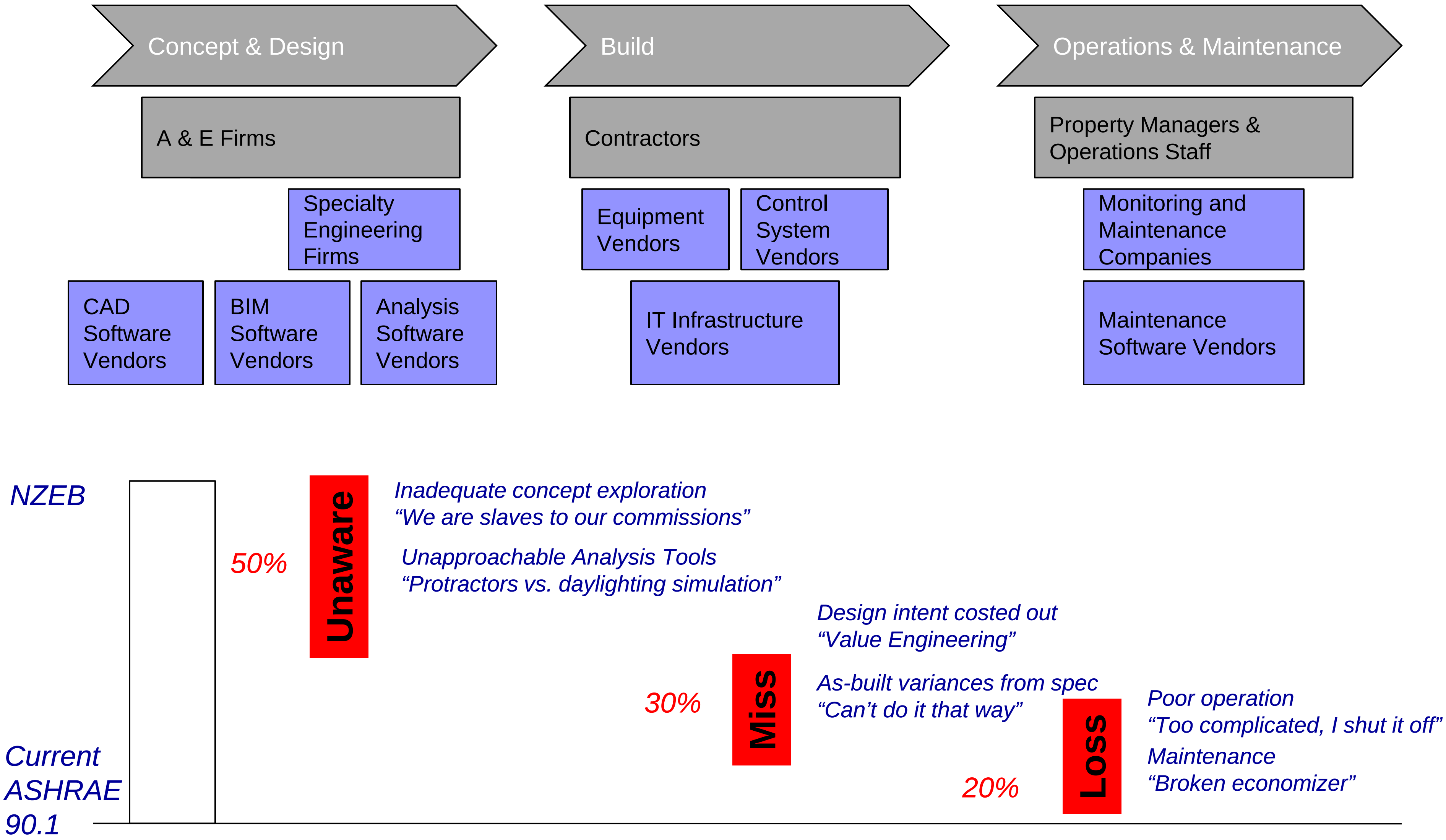
Figure 3-28 Illustration of how the cooltowers work at the Zion Visitor Center

Source: Lessons Learned from Case Studies of Six High-Performance Buildings, P. Torcellini, S. Pless, M. Deru, B. Griffith, N. Long, R. Judkoff, 2006, NREL Technical Report.

Failure Modes Arising from Detrimental Sub-system Interactions

- Changes made to envelope to improve structural integrity diminished integrity of thermal envelope
- Adverse system effects due to coupling of modified sub-systems:
  - changes in orientation and increased glass on façade affects solar heat gain
  - indoor spaces relocated relative to cooling plant affects distribution system energy
- Lack of visibility of equipment status/operation, large uncertainty in loads leads to excess energy use

ENERGY IMPACT IN DESIGN-BUILD PROCESS



Outline

Energy Efficient Buildings

Market Conditions

What is hard?

R&D

FROM R&D TO COMMERCIALIZATION

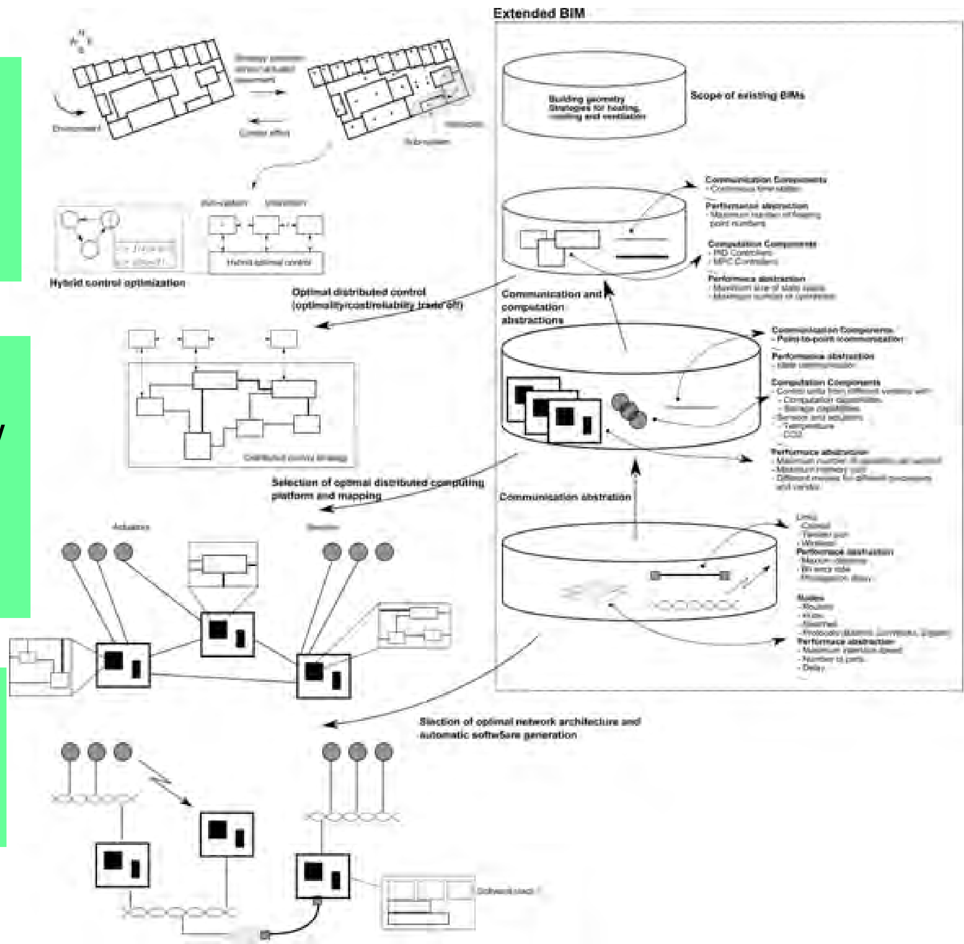
Barriers	Enablers
Lack of process and tools for system analysis and design	Computational science, physics-based modeling, methodology, tools and training for Integrated design
Lack of a demonstration capability for technology maturation	Full scale demonstrations facilities and concentration of talent
Lack of tools for on-going auditing, commissioning & operations	Methodology, tools and training for building operations (e.g. computational/IT/controls advances)
Lack of a long reach and broad scope in technology and business model exploration	Pre-competitive collaboration among industry, national labs and universities

Basic Science To Enable Energy Savings

Architecture & Envelope Optimization: *Whole building simulation, uncertainty analysis, and definition of abstraction layers*

Mechanical Systems Specifications & Supervisory Control: *Multi-scale (zone-room) modeling, computation and hybrid system optimization*

Rapid and Robust Implementation: *Network design and data assimilation*



Requirements & Architecture Exploration: BIM and Tool Chains for Integrated Mechanical and Control Design

Integrated Design: Decentralized Control Design & Analysis for Robust Operation

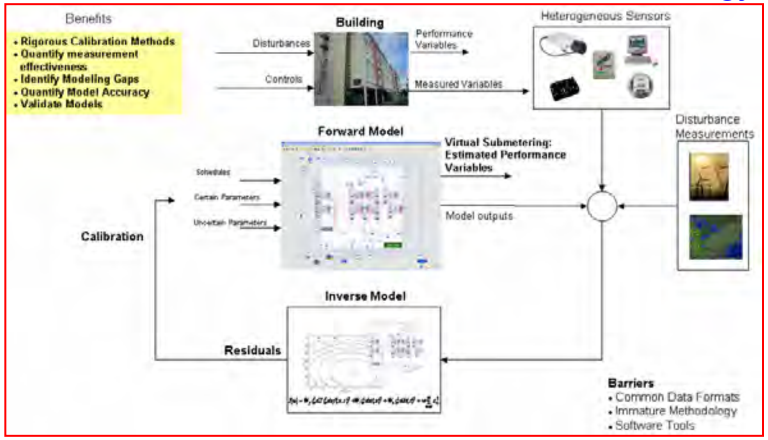
Implementation: IT enabling continuous commissioning and occupancy and plug load estimation for detailed energy management

Needs for Basic Science and Measurement for Energy Efficient Buildings

DOE Projects: Merced Campus

Technology Maturation and Demonstration at University of California - Merced

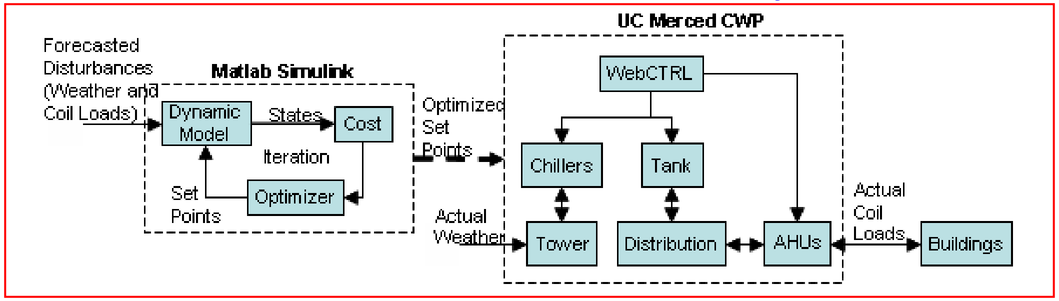
Real-time Visualization of Model-based Energy Performance



Integrated Energy Information Systems
Approx. 20% total building energy ↓

U.S. Department of Energy
Energy Efficiency and Renewable Energy

Model Predictive Control of HVAC systems



Integrated Cooling & Thermal Storage
Approx. 20% total building energy ↓

United Technologies Research Center

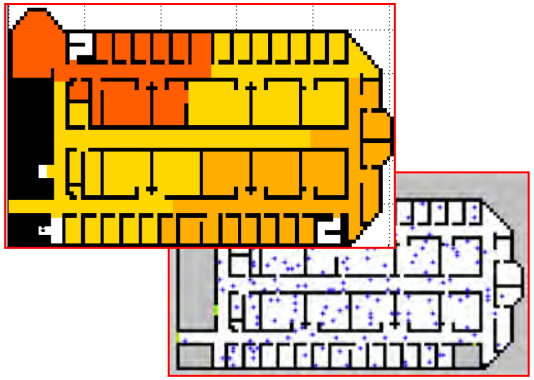
Berkeley Lab

Berkeley University of California

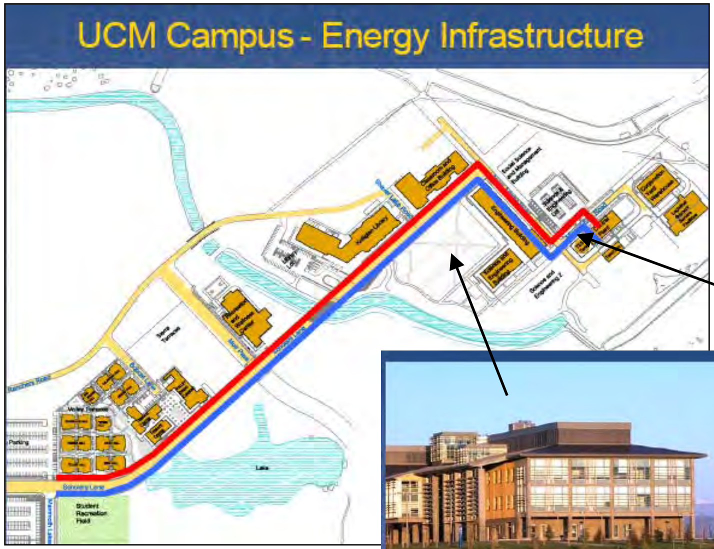
UCSB

UC Merced

Occupancy-based energy management



Integrated Security & HVAC Systems
Approx. 20% HVAC system energy ↓




Science & Engineering – 205,000 sq ft


Central Plant – 25,000 sq ft