USEA / USAID Global Energy Efficiency Workshop

Technology Overview: Energy Efficient Buildings

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Johnson Controls

Agenda for Today's Discussion

- Introduction to Johnson Controls Viewpoint
- Commercial Building Energy Use & Impact
- A "Whole Systems" Approach to Building Efficiency
- HVAC Systems Overview
- ENERGY STAR Standards
- Case study: Empire State Building
- Case study: Johnson Controls HQ Campus
- Case study: IDeAS Net Zero Energy Building

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3 Global Businesses Focused on Sustainability

140,000 Employees | **Fortune 100** | **Multi-Industry Company**

Building Efficiency
Creating quality indoor environments that are comfortable, safe, energy efficient, and sustainable

Power Solutions
Providing the highest quality, lowest cost automotive batteries to power vehicles of today and tomorrow

Automotive Experience
Delivering world-class technologies that differentiate vehicle interiors and increase consumer demand

- *200 million vehicles*
- *12 million homes*
- *1 million commercial buildings*

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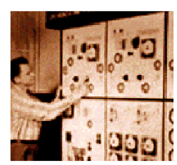
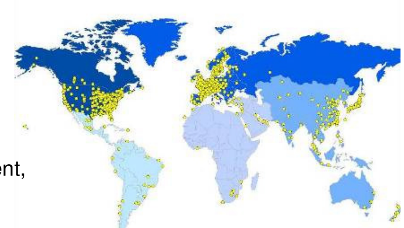
Johnson Controls & Energy Efficiency, since 1885

140,000 Employees | **Fortune 100** | **Multi-Industry Company**



- Founded in **1885** by Warren Johnson, inventor of the first electric room thermostat
- Over 40,000 employees dedicated to **building efficiency** in 500+ locations in 125 countries
- 13,000 **HVAC technicians,** 12,000 **facility mgrs**
- Over **1.4B sq ft** of space under direct management, with services provided to a further **20B sq ft**
- Largest ESCO in North America with over **$4.5 billion** of active cost savings guarantees



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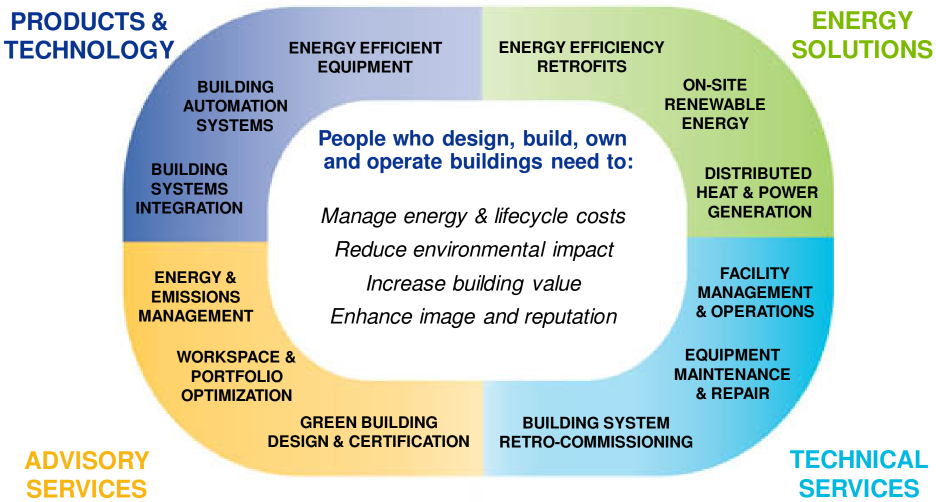
Our Building Efficiency businesses



Integrated technology and services for sustainable, energy efficient buildings

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Who are our customers?

Residential — Mid Market — Complex

6

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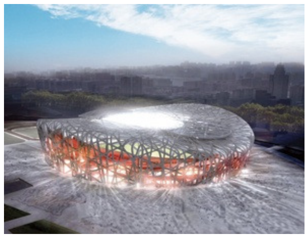
Who are our customers?



Beijing National Stadium

Integrated Design Associates

Empire State Building

Qatar Cool

Shanghai World Financial Center

Burj Khalifa

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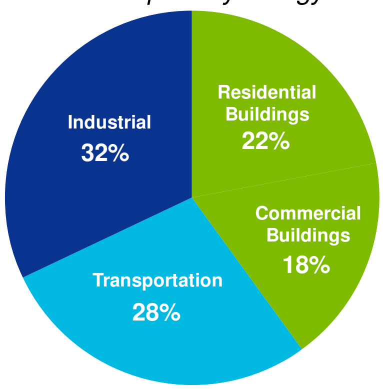
Buildings have a major energy & environmental impact

Buildings use 40% of U.S. primary energy



- **Building sector represents 40% of the world's energy consumption**
- **1/3rd of energy-related global GHG emissions (~8 gigatons/year)**
- **Buildings responsible for 30% of raw materials use, 25% of solid waste, 25% water use, and 12% of land use.**
- **Existing building retrofits are a critical part of the climate solution**
- **Energy consumption in building stock (both new and existing) could be cut by 30-50% by 2020**

9 Sources: International Energy Agency; U.S. Energy Information Administration (2009) *Annual Energy Review*; U.S. Dept of Energy (2009) *Building Energy Data Book*; World Resources Institute; United Nationa Environment Program –Sustainable Buildings & Climate Initiative

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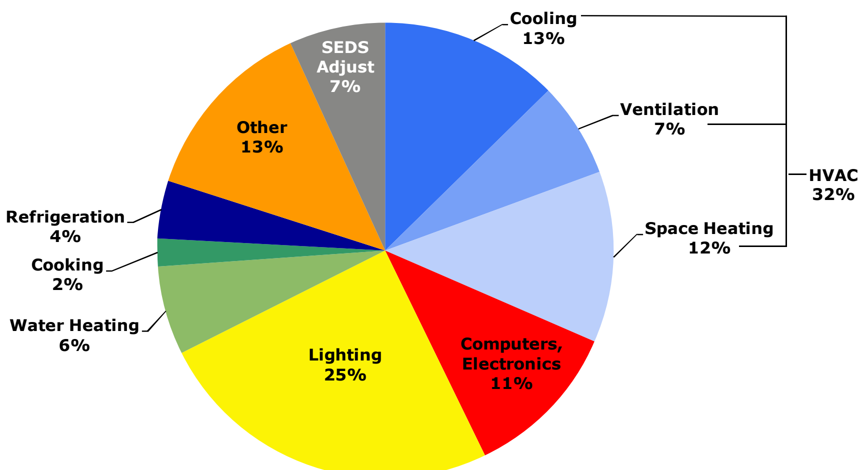
Average U.S. End Use Energy Split in Commercial Buildings



10 Source: U.S. DOE (2009) Building Energy Data Book - Table 3.1.4

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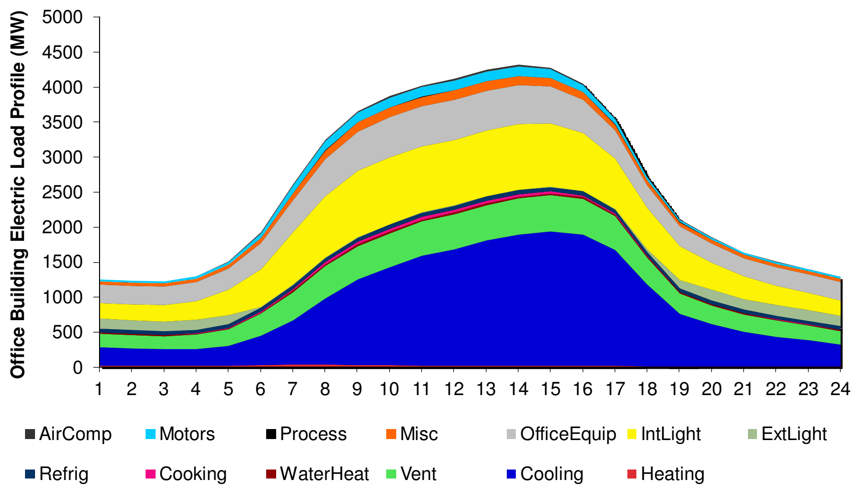
Load varies throughout the day and the seasons



 Source: CA Commercial Energy End Use Consumption Survey

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Traditional solutions to meet growing energy needs

Create new energy supply

Build new power plants

Build new transmission and distribution infrastructure

Discover new energy reserves

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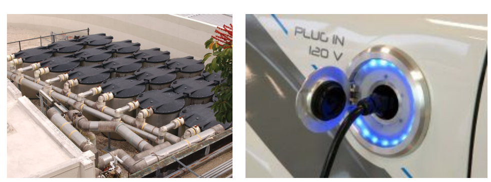
A cheaper and more expedient path to more energy services

Invest in demand side energy resources

Energy Efficiency

Demand Response

Onsite Renewable Energy



Distributed Energy Storage

14 This "soft path" approach popularized in Lovins , A.B. (1976) "Energy Strategy: The Road Not Taken?" Foreign Affairs

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Energy efficiency should not be confused with conservation

Energy Efficiency:	Energy Conservation:
Achieving the same ends (but often more or better) with less primary energy	Using less energy in order to reduce cost or the impact on the environment
Wringing more work from our energy by intelligently substituting good design, improved equipment, and attention for joules	Doing less, worse, or without—curtailment, discomfort, self-sacrifice, or privation

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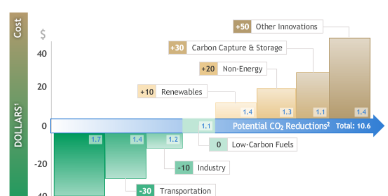
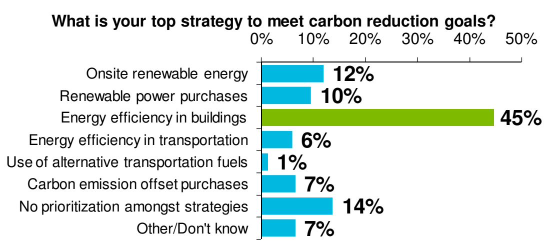
Energy efficiency is the "dark horse" of clean energy

- The largest, **cheapest**, safest, and fastest energy option
- Currently the **fastest-growing** new "energy source" (~2.5-3.5%/yr) in the U.S.
- Gains in real GDP per unit of primary energy vs. 1975 provides over **twice the energy services as oil**
- Also the **least visible**, least understood, and most neglected



Source: NRDC summary of McKinsey & Co. (2007) analysis



Source: Johnson Controls, IFMA (2009) "Energy Efficiency Indicator Survey"

 Sources: McKinsey & Co (2007); JCI/IFMA (2009)

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Work backwards from end-use "energy services"

Hot showers, cold beer, light, mobility, torque…

… not barrels of oil, kWh of electricity, etc.

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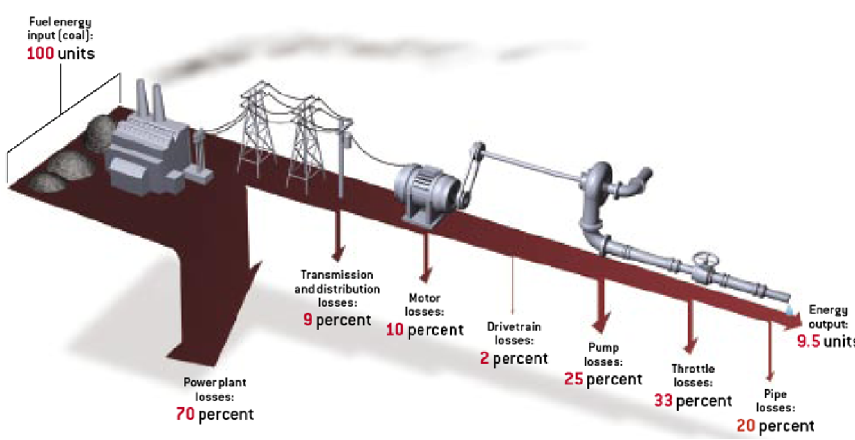
Why focus on end-use savings first?



Savings *downstream* results in 10x energy saved at the power plant
Also makes upstream equipment smaller, simpler, cheaper

 Source: Rocky Mountain Institute

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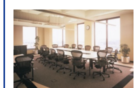
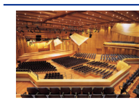
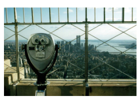
Buildings provide a variety of end-use services

 Illumination	 Thermal Comfort	 Air Quality
 Mobility & Access	 Commun-ication	 Physical Space
 Physical Security	 Fire Safety	 Water Delivery
 Acoustics	 Mechanical Work	 Sanitation
 Views	 Design Aesthetic	 Food Prep, Preservation

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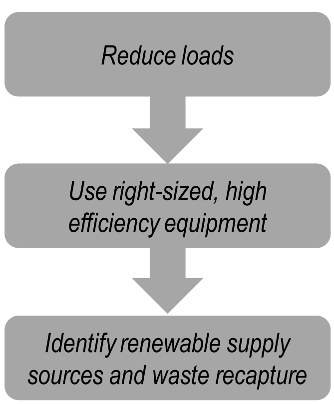
Whole systems design: the right steps in the right order

In Priority Order:



1. Demand elimination (substitution)
2. Demand reduction
3. Demand shaping
4. Modular/variable speed equipment
5. Highest efficiency equipment
6. Renewable energy supply
7. Waste stream reuse

 Attribution: Rocky Mountain Institute; Jason Denner

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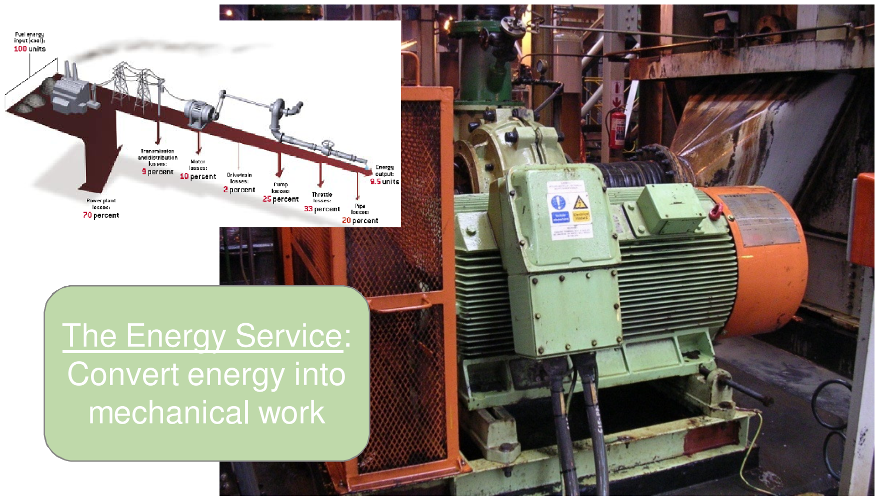
Returning to our drive power services example



The Energy Service: Convert energy into mechanical work

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The right steps in the right order

Reduce loads	• Can process demand for driverpower be eliminated?	▪ Natural ventilation ▪ Use gravity/convection for transport
	• Can process demand for drivepower be reduced?	▪ Reduce friction (big, straight pipes) ▪ Reduce flow rate or distance traveled
	• Can variation in process demand be optimized?	▪ Add storage buffer ▪ Process control load leveling control
Right-sized, high efficiency equipment	• What is optimal drive power configuration/sequencing?	▪ Multiplex ▪ Variable speed drives
	• What is the best device / drive to specify?	▪ Centrifugal, reciprocating pumps ▪ Best in class efficiency at full/part loads
Identify renewable and waste recapture	• What is the best energy source for this application?	▪ Electricity, steam, fuel engine, compressed air
	• What byproducts created can be reused nearby?	▪ Waste heat, pressure from reduction valves, warmed cooling water

 Source: Jason Denner Point 360; RMI; JCI

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Heating, Ventilation, and Cooling (HVAC) Services

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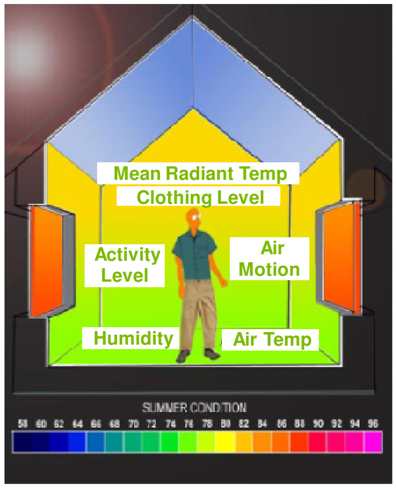
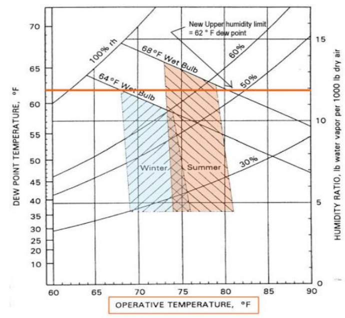
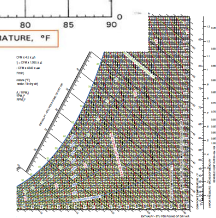
The six factors of human thermal comfort



Comfort Zones



Psychrometric Chart



25 Source: Johnson Controls “Building Environments”

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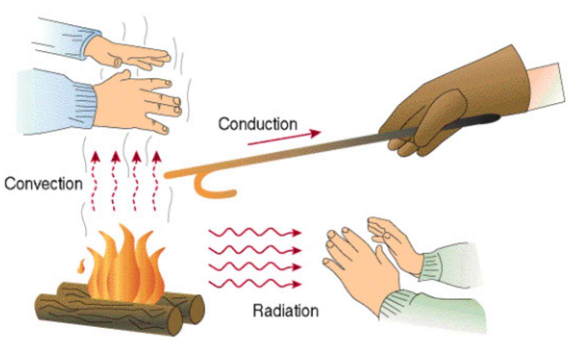
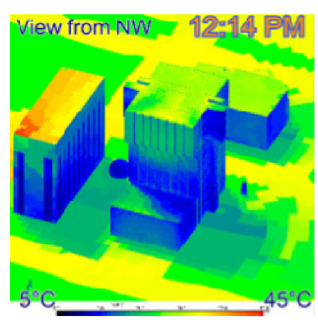
How do buildings gain heat? Lose heat?

Conduction **Convection** **Radiation**





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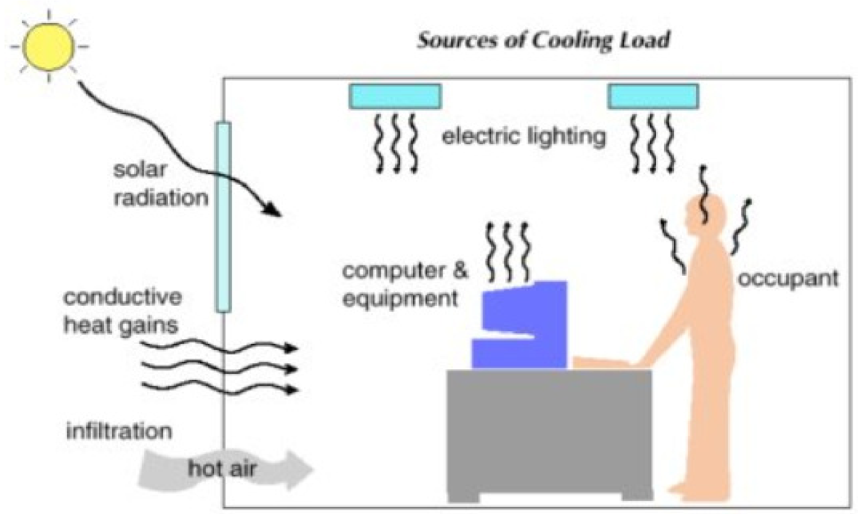
External loads and internal loads



 Source: BC Hydro

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Cooling - Right Steps in the Right Order:

reduce cooling demand

1. Eliminate requirement to cool entire space equally
2. Expand the comfort envelope
3. Minimize sources of heat and humidity gains
4. Optimize balance-of-plant (pumps, piping loops, etc.)

select cooling approach

5. Apply *passive* cooling techniques
6. Consider *active* non-refrigerative cooling techniques
7. Use super-efficient *refrigerative* technology (COP > 5.8)
8. Optimize automation controls and operation
9. Capture beneficial by-products

 Source: Jason Denner Point 360; RMI; JCI

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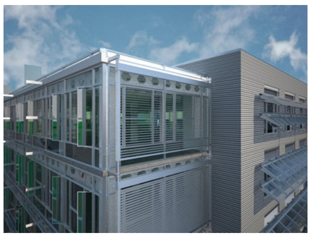
What are the methods of rejecting heat from a building?

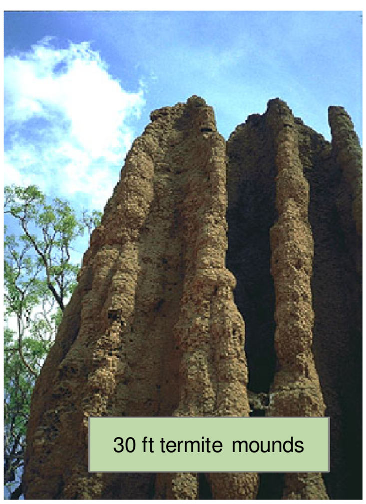
Passive cooling

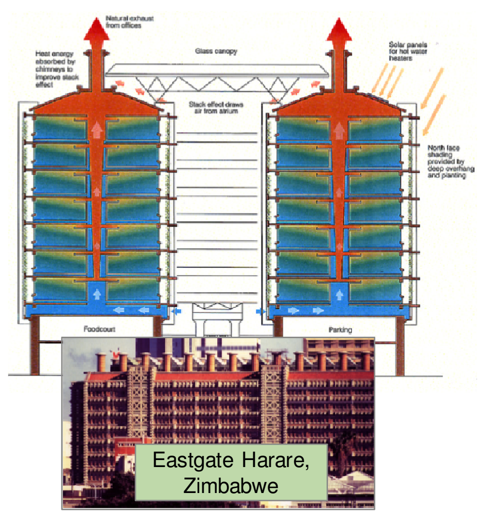


Active – Non refrigerative

Active cooling – refrigerative

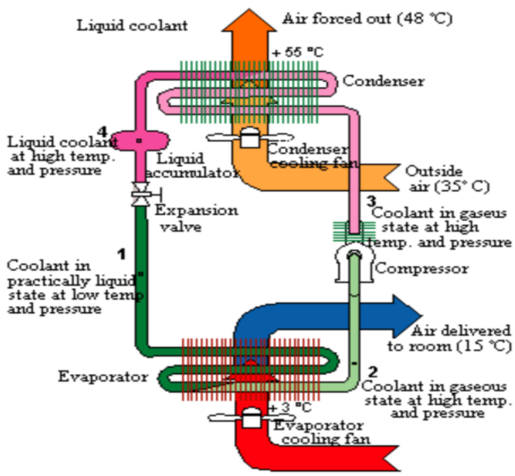
Passive displacement ventilation – “Biomimicry”



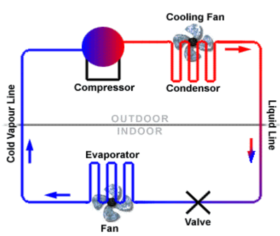


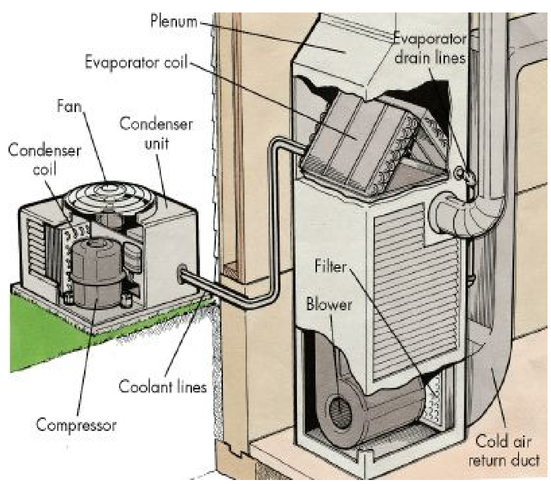
 Source: Wikimedia.org Commons

How active refrigeration works



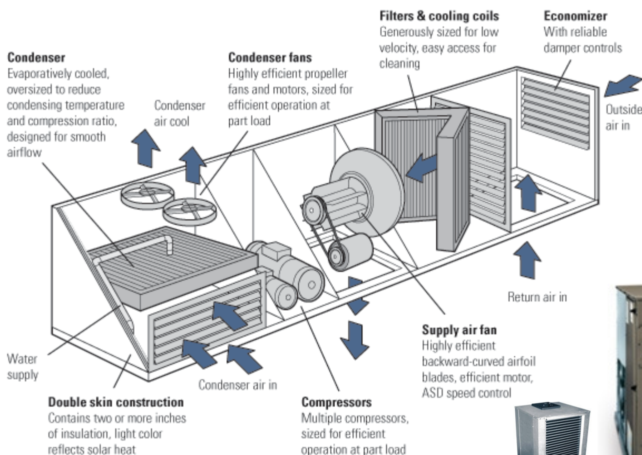
Active Cooling – Split Systems





 Source: De Klein (2009); ASHRAE; Johnson Controls

Active Cooling – Rooftop Package Units & Heatpumps



 Source: E Source; Johnson Controls

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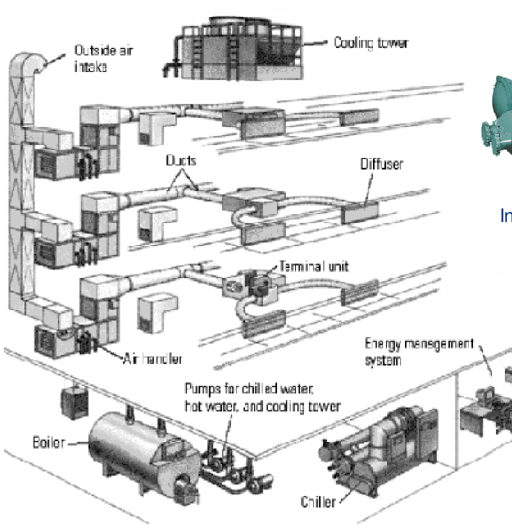
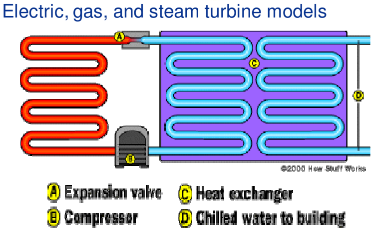
Active Cooling – Chilled Water Systems



HFC-134a refrigerant for zero ozone depletion potential (ODP) and low global warming potential (GWP)

Integral variable speed drive compressor

Electric, gas, and steam turbine models



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Air Distribution and Secondary Systems

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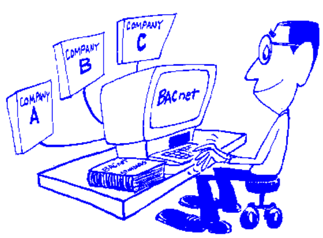
Sensors and Control Systems

- Control system maintains setpoints, schedules, and adaptive tuning to prolong equipment life, reduce maintenance and save energy.
- Control, meter and monitor HVAC, security, lighting, energy, water, irrigation, etc
- Wireless technology reduces wiring material consumption and cost
- Ready access portal gives more control to users and tenants

Building Automation System (BAS)



 Source: ASHRAE

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Metrics: Energy Efficiency Ratio (EER)

Used to define the cooling efficiency of unitary air-conditioning and heat-pump systems under peak day conditions (95° F outdoor temp).

The higher the EER the more efficient is the system.

$$EER = Ec / Pa$$

where
EER = energy efficient ratio (Btu/h/Watt)
Ec = net cooling capacity (Btu/h)
Pa = applied energy (Watt)

Typically includes the energy requirement of auxiliary systems such as the indoor and outdoor fans

Metrics: Seasonal Energy Efficiency Ratio (SEER)

Used to define the average annual cooling efficiency of an air-conditioning or heat-pump system over typical cooling season

$$SEER = Ec / Pa$$

where
SEER = seasonal energy efficiency ratio (Btu/Wh)
Ec = cooling output for typical season (Btu/season)
Pa = applied energy (Wh/season)

SEERs usually 0.5-1.0 higher than corresponding EERs

ENERGY STAR qualified central AC must have a SEER of at least 14

 Source: Air Conditioning, Heating, and Refrigeration Institute (AHRI)

Metrics: Coefficient of Performance (COP)

Basic dimensionless parameter used to report the efficiency of refrigerant based systems

Ratio between useful energy acquired and energy applied and can be expressed as:

$$COP = Eu / Ea$$

where

COP = coefficient of performance
Eu = useful energy acquired (Btu in imperial units)
Ea = energy applied (Btu in imperial units)

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Metrics: kW/Ton

Common term used for large commercial and industrial air-conditioning, heat pump and refrigeration systems.

Ratio of the rate of energy consumption in kW to the rate of heat removal in tons at the rated condition.

The lower the kW/ton the more efficient the system.

$$kW/ton = Pc / Er$$

where
Pc = energy consumption (kW)
Er = heat removed (ton)

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Some benchmarks for reference

	Standard	Better	Best
Site kBtu/ft^2/yr	≥100	40-60	‹10-20
= kWh/ft^2/yr	25	15	2-4
Lighting W/ft^2	1.5-2	1.1	0.1-0.3
Plug Load W/ft^2	5-8	1-2	0.2
Glazing Btu/ft^2/°F/hr	0.6	0.3	0.05-0.13
Glazing T_{vis}/SC	1.0	1.2	› 2.0
Perimeter htg	extensive	medium	none
Roof, α, ε	0.8, 0.2	0.4, 0.4	0.08, 0.97
Cooling ft^2/ton	250 - 350	500-600	1,-1,200+
Cooling System kW/ton	2.0	1.5	≤0.7
Relative Capital Cost	1.0	1.03	0.95

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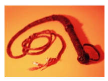
What is driving increases in building performance?



Codes and Standards

- International Energy Conservation Code (IECC)
- EU Energy Performance in Buildings Directive
- Japan 2008 Revised Energy Conservation Law
- IIEC Indian Energy Efficiency Building Code
- China 2006 Building Energy Code

Voluntary Ratings & Certification Systems

- ENERGY STAR
- Leadership in Energy & Environmental Design (LEED)
- Green Globes
- BREEAM
- Green Star
- & more

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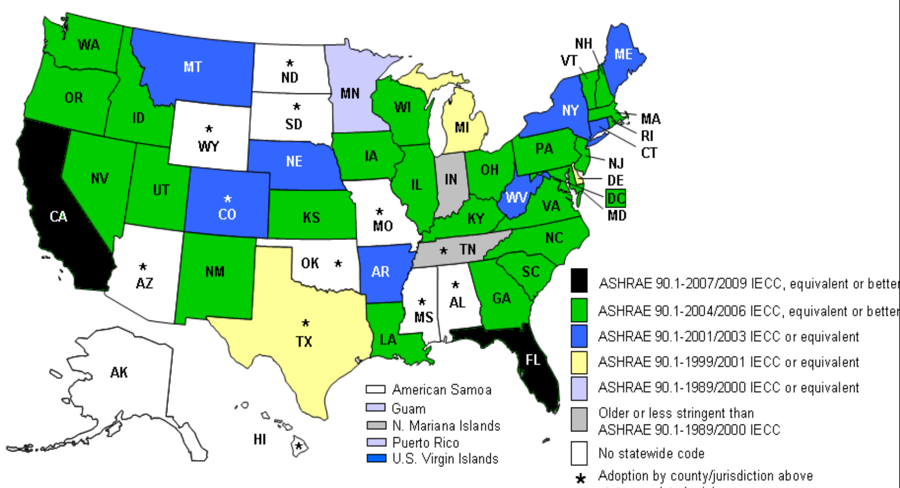
Commercial Building Energy Codes in the U.S.



44 Source: U.S. DOE (2009) Building Energy Data Book - Table 7.3.2

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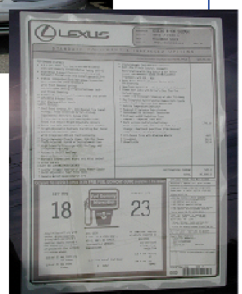
ENERGY STAR Performance Benchmarking



Fuel Efficiency

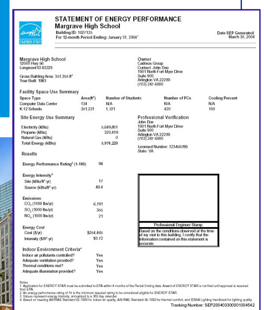
MPG

Is 18 MPG high or low for an automobile?

Is 90 kBtu/SF/YR high or low for a building?

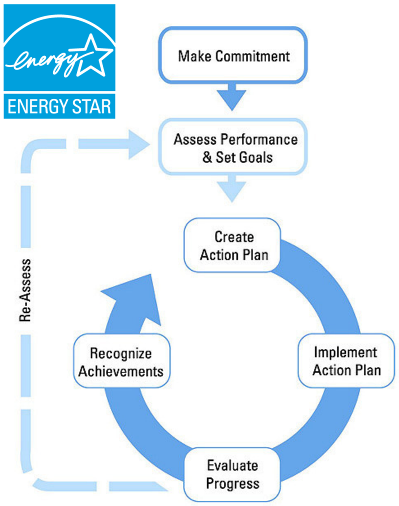
Building Energy Performance

kBtu/sf/yr



 Source: U.S. Environmental Protection Agency

The ENERGY STAR Benchmarking Process



Step 1: Join ENERGY STAR

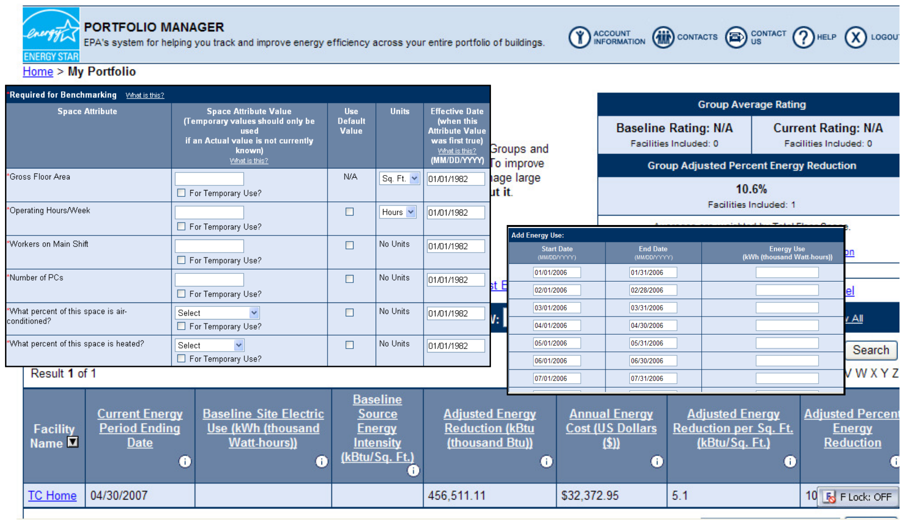
Step 2: Measure Your Energy Use
Use **Portfolio Manager** tool to enter your monthly energy use

Step 3: Develop and Implement Plan
Learn about energy-efficiency opportunities, work with service companies to implement plan.

Step 4: Earn Recognition
Recognition as a leader in reducing energy consumption, cost stewardship, and environmental sustainability.

 Source: U.S. Environmental Protection Agency

Use of PORTFOLIO MANAGER Tool



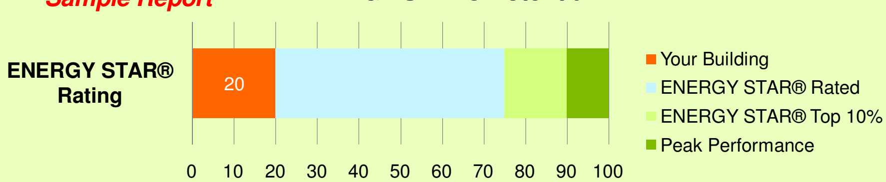
47 Source: U.S. Environmental Protection Agency

The ENERGY STAR rating system

- Compares building to statistically representative models
- 50 represents the score for an average building
- 100 is the highest achievable score a building can achieve.
- To obtain ENERGY STAR status your building must have a rating of at least 75.

Money Isn't All You're Saving

Sample Report **ENERGY STAR® Potential**



To become an ENERGY STAR® building you have to improve your rating by 55 points.
In terms of energy efficiency, 80% of similar buildings outperform your building.

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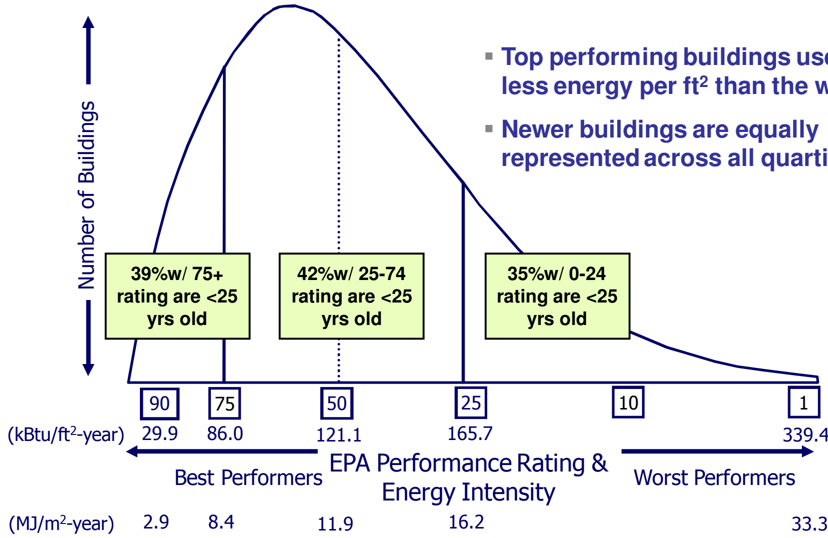
The ENERGY STAR distribution curve

- Top performing buildings use 3-4x less energy per ft² than the worst.
- Newer buildings are equally represented across all quartiles.



 Based on a sample of 4,000 buildings nationwide; Source: U.S. Environmental Protection Agency; US DOE Commercial Building Energy Consumption Survey

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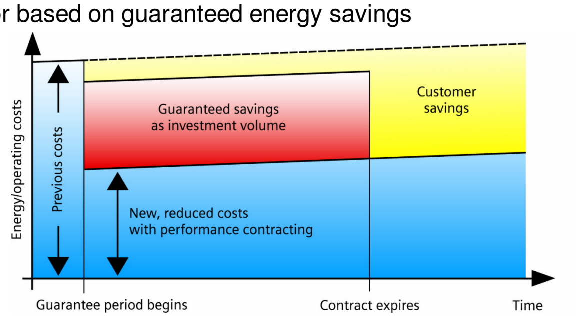
IN 1931 IT BECAME THE WORLD'S TALLEST BUILDING.

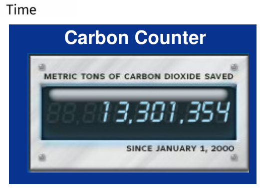
NOW IT WILL BECOME ONE OF THE MOST ENERGY EFFICIENT

Whole building retrofits through performance contracting

a proven model for financing large-scale energy efficiency retrofit projects in the public sector based on guaranteed energy savings



- Johnson Controls is the largest ESCO in North America, with **$4.7 billion** active cost saving guarantees
- Since 2000, the we've delivered verified energy savings resulting in **13.3 million tons** of avoided GHG emissions



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Case Study:

Sustainable Renovation of Empire State Building

102 stories, 2.8 million square feet

$11 million annual energy costs

Peak electric demand of 9.5 MW
(3.8 W/sq ft including HVAC)

88 kBtu / sq ft / year in office space

CO_2 footprint of 25,000 tons per yr
(9 tons/1000 sq ft)

Vision Leaderships + Distinguished Team of Partners

Owner's goals:

1) **Reduce carbon footprint**
2) **Demonstrate business case w/ transparency**
3) **Create replicable model for holistic retrofits**

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Jones Lang LaSalle
Real value in a changing world

Clinton Foundation | Clinton Climate Initiative

Rocky Mountain Institute

"Addressing these investments correctly will create a competitive advantage for ownership through lower costs and better work environment for tenants…

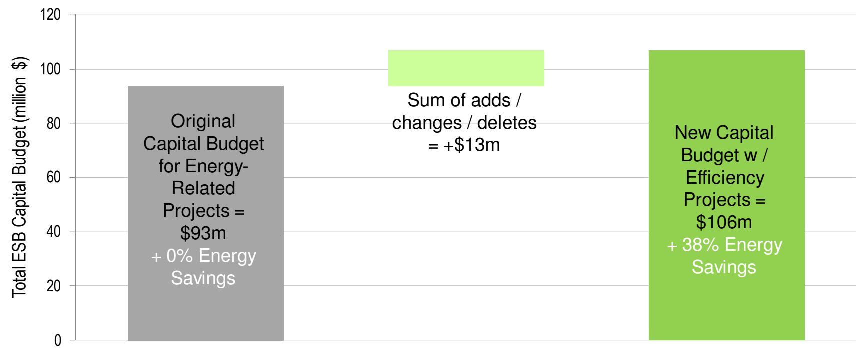
…Succeeding in these efforts will make a replicable model real for others to follow."

- Anthony E. Malkin

Demonstrating the Business Case

With a $500 million capital improvement program underway, ownership decided to re-evaluate certain projects with cost-effective energy efficiency and sustainability opportunities in mind.

Capital Budget Adjustments for Energy Efficiency Projects



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Creating a Replicable Model and Process

Demonstrate how to cost-effectively retrofit a large multi-tenant office building to inspire others to embark on integrated retrofits.

1 Identify opportunities

- 60+ energy efficiency ideas were narrowed to 17 implementable projects
- Team estimated theoretical minimum energy use
- Developed eQUEST energy model

2 Evaluate measures

- Net present value
- Greenhouse gas savings
- Dollar to metric ton of carbon reduced
- Calculated for each measure

3 Create packages

- Maximize net present value
- Balance net present value and CO_2 savings
- Maximize CO_2 savings for a zero net present value
- Maximize CO_2 savings

4 Model iteratively

- Iterative energy and financial modeling process to identify final eighht recommendations

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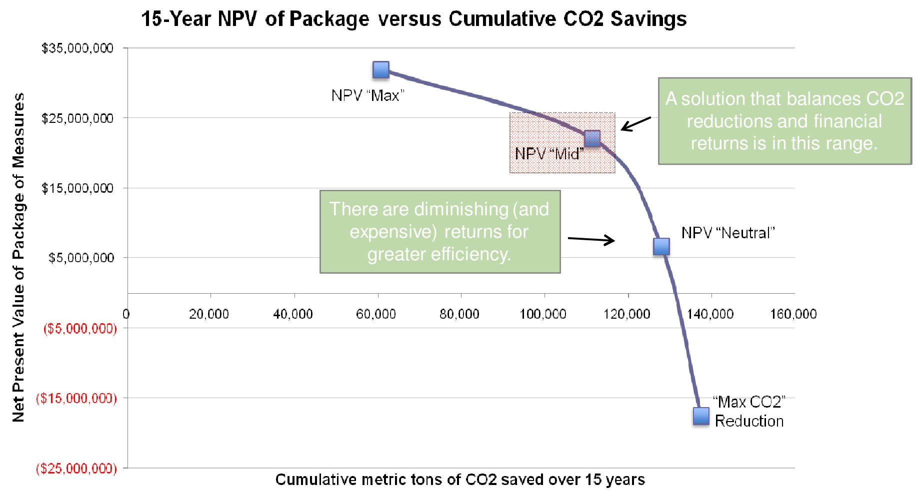
Balancing financial and carbon impacts



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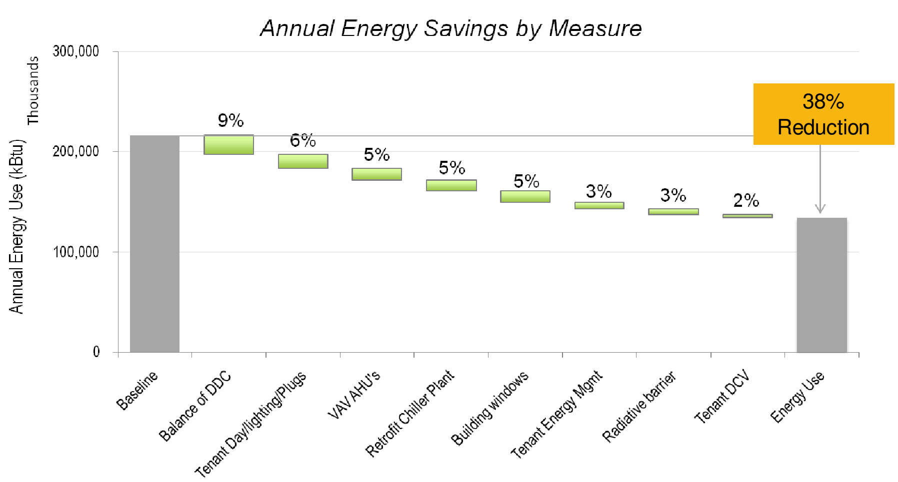
A package of 8 interactive measures result in 38% savings



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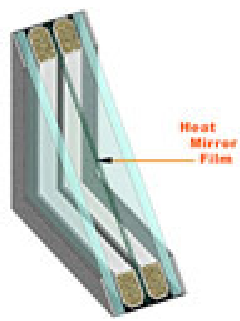
Eight Interactive Measures

WINDOWS: Remanufacture existing insulated glass units (IGU) within the Empire State Building's approximately 6,500 double-hung windows to include suspended coated film and gas fill.



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Eight Interactive Measures

RADIATIVE BARRIER: Install more than six-thousand insulated reflective barriers behind radiator units located on the perimeter of the building.

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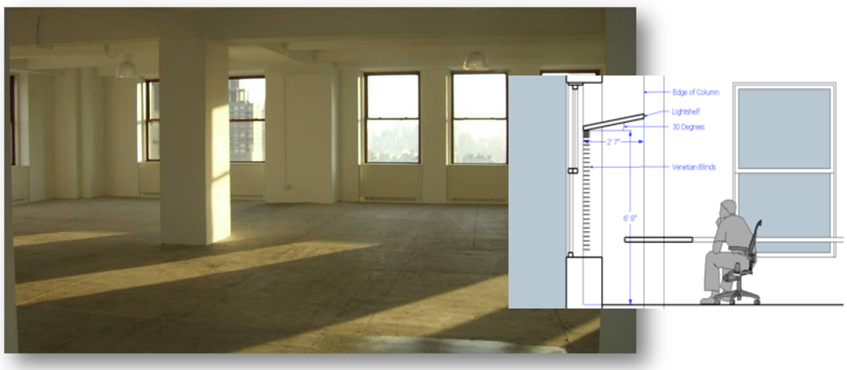
Eight Interactive Measures

TENANT DAYLIGHTING / LIGHTING / PLUGS: Reducing lighting power density in tenant spaces, installing dimmable ballasts and photosensors for perimeter spaces, and providing occupants with a plug load occupancy sensor for their personal workstation.



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Eight Interactive Measures

CHILLER PLANT RETROFIT: Retrofit of four industrial electric chillers plus upgrades to controls, variable speed drives, and primary loop bypasses.

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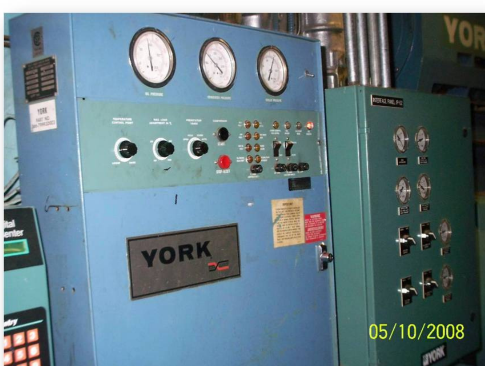
Eight Interactive Measures

VAV AIR HANDLING UNITS: Replace existing constant volume units with variable air volume units using a new air handling layout (two floor-mounted units per floor instead of four ceiling-hung units).

Eight Interactive Measures

DDC CONTROLS: Upgrading the existing control systems to become *one of the largest wireless networks ever installed*. Real-time *facilities performance index monitoring* used for continuous commissioning of HVAC systems.



Eight Interactive Measures

DEMAND CONTROL VENTILATION: Installation of CO_2 sensors for control of outside air introduction to chiller water and DX Air Handling Units.

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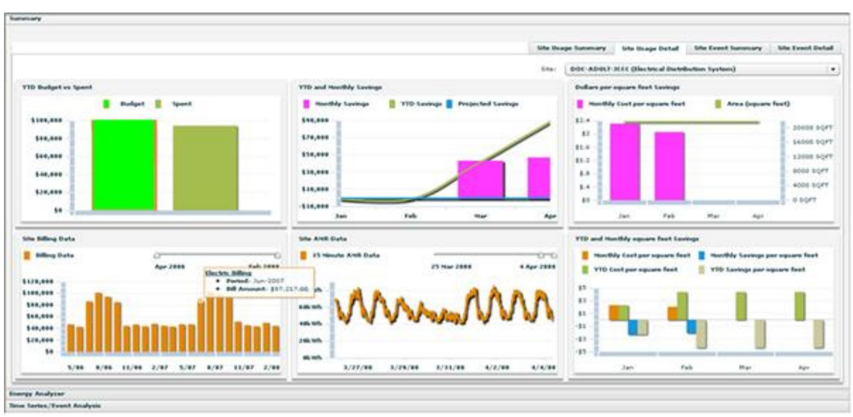
Eight Interactive Measures

TENANT ENERGY MANAGEMENT: Provide tenants with information feedback on energy consumption, benchmarking, as well as sustainability tips and interactive guidance from an energy engineer through a web-based portal.



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Expected Results

$4.4 million
annual energy cost savings

Top 10%
of commercial buildings in efficiency

38%
energy reduced annually

3.1 years
payback incremental cost

105,000
metric tons carbon emissions saved over next 15 years

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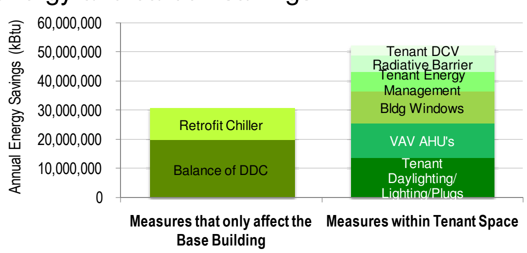
Lessons Learned from Empire State Building project

For maximum cost-effective energy and carbon savings:

1) Can't overlook tenant spaces:
   a) Phasing over time;
   b) Enabling technology for information feedback;
   c) Lease structures to align incentives



2) Take the right steps in the right order for holistic integrated design

3) Align with capital plan to match with renovation cycles

Reduce Loads → Upgrade Systems → Monitoring & Controls

- Widows
- Insulation
- Daylighting
- Green pre-builts
- Occupancy/photo sensors - lighting and plug loads

- Chiller plant retrofit,
- VSDs
- VAV air handlers

- Direct digital controls
- Demand-controlled ventilation
- Tenant energy mgmt system

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Case Study:

Johnson Controls Global Headquarters

34 acre site, 500,000 sf total building footprint

Targeting

- 4 LEED-NC v2.2 Platinum buildings
- 1 LEED-EBOM v2.0 Platinum building
- >90th percentile EnergyStar ratings

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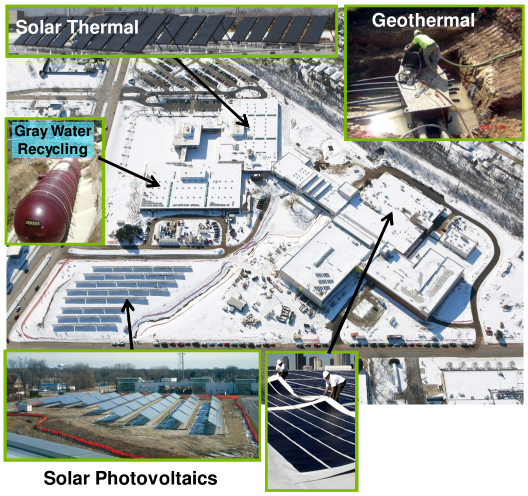
Integrated Green Design Showcase



Solar Photovoltaics

- Targeting highest concentration of **LEED Platinum** certified buildings (4 NC, 1 EB) in world
- >90th %^{tile} **Energy Star** ratings
- 272 wells for ground-source heat pumps reduce energy by 29%
- Extensive daylight harvesting and shade control
- 385 kW combined ground and roof mounted photovoltaic arrays (Wisconsin's largest PV system)
- 1,330 sf solar thermal collectors used to heat hot water in building
- BMS integration to IT monitoring system in data center

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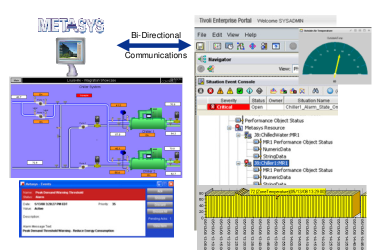
Advanced HVAC/Controls

- Under floor air distribution system that can be easily reconfigured
- Daylight harvesting and shade controls
- Personal environment modules
- Semi-automated demand response
- BMS ↔ IT asset mgmt system integration in data center
- BMS ↔ Work order management system



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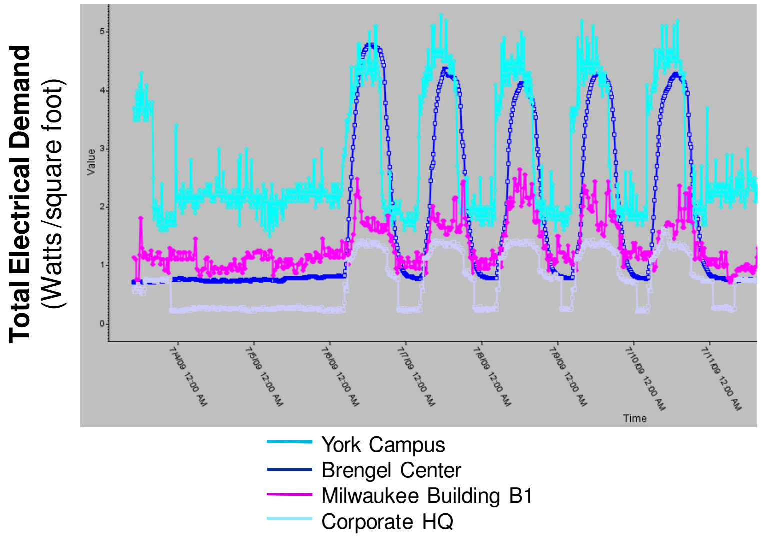
Actual performance compared to other facilities



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Case Study:
Integrated Design Associates (IDeAS) Building

Commercial office building renovation in San Jose, CA

Geothermal heat pump with floor-based radiant heating and cooling and dedicated high efficiency outdoor air ventilation unit

PV-integrated membrane roofing

High efficiency windows and lighting with dimming control

40% better than 2005 California Title 24 energy requirements

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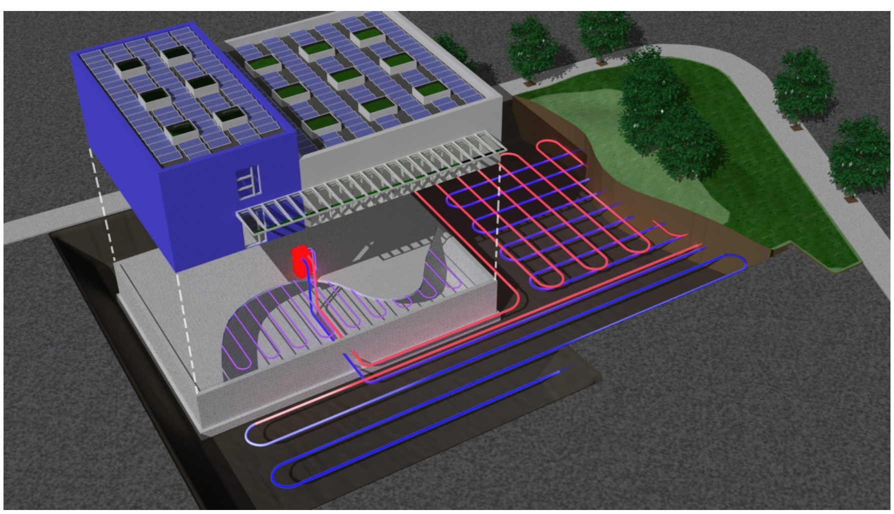
IDeAS Net Zero Energy Building



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IDeAS Net Zero Energy Building

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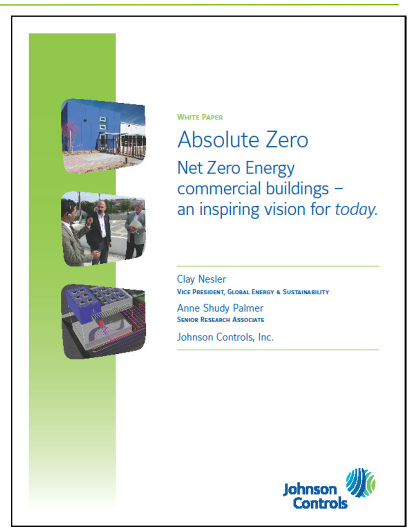
Movement toward Net Zero Energy Buildings

- There are 8 documented net-zero commercial buildings in the U.S.
- There are several more throughout the rest of the world
- We expect that number to grow significantly over the next few years
- Europe's recast Energy Performance in Buildings Directive requires all new construction to be NZE by 2019
- The technology is there, design processes have been identified
- What it takes is a motivated owner – someone who wants to get it done



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Questions ?

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