Industry Integration Trends for the future Office Building

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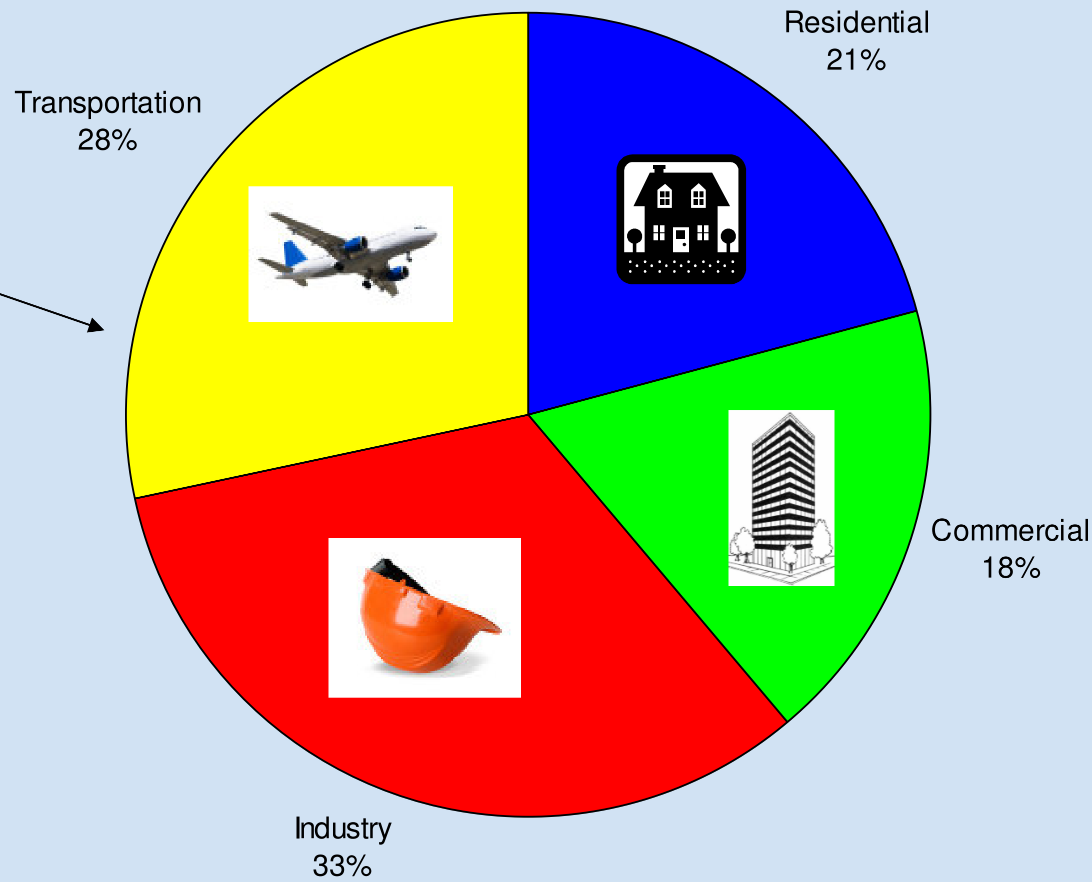
Presentation Overview

- Introduction to the Office Market and HVAC Industry
- Current Market Approach
- Current Metrics and Code Requirements
- Future Market Trends

U.S. Building Energy Consumption

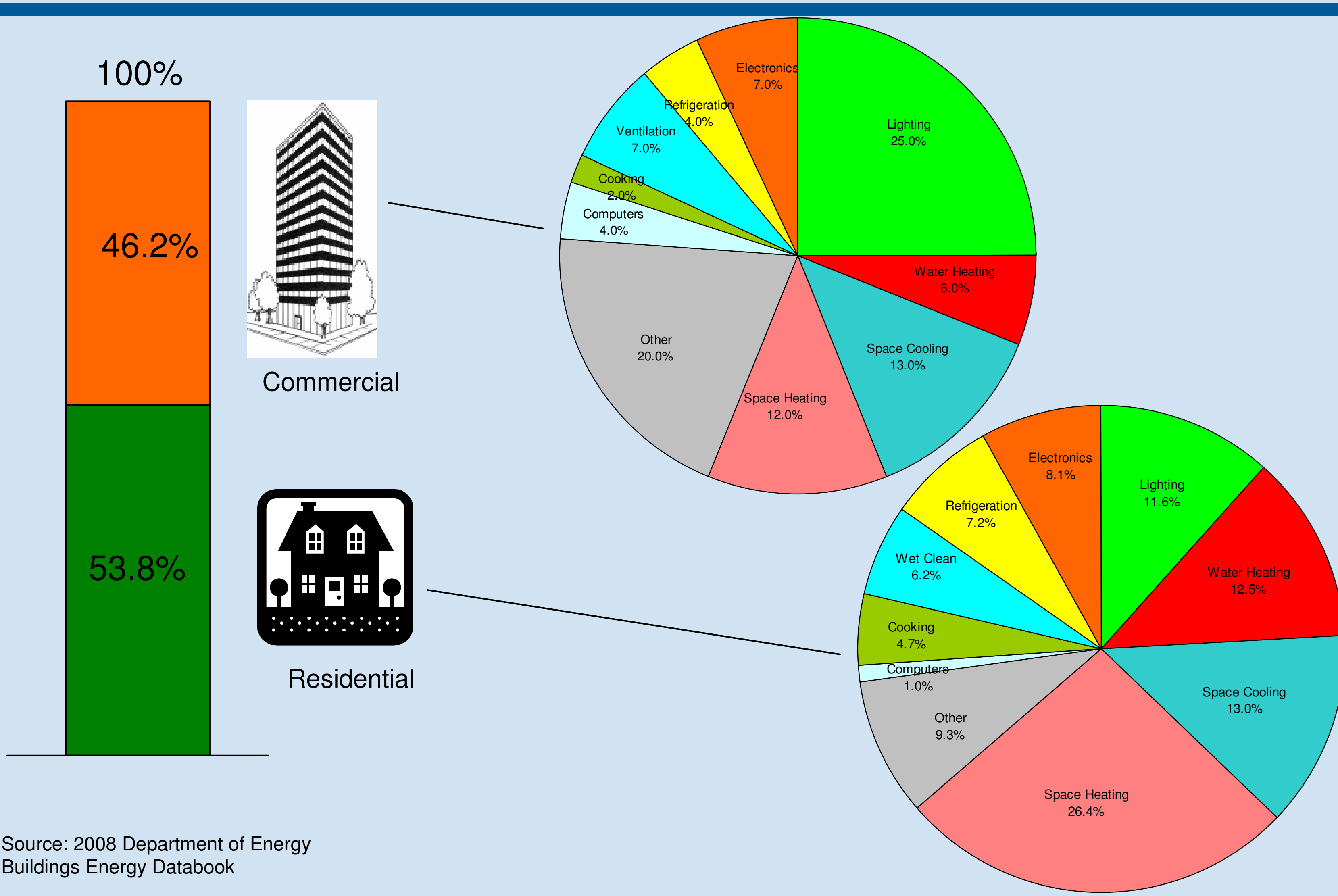
Total Consumption

Year	Quads
1980	57.9
1990	76.1
2000	97.2
2006	99.5
2010	103.3
2015	107.3
2020	110.8
2025	114.5
2030	118.0



Source: 2008 Department of Energy
Buildings Energy Databook

U.S. Building Energy Consumption (2006)



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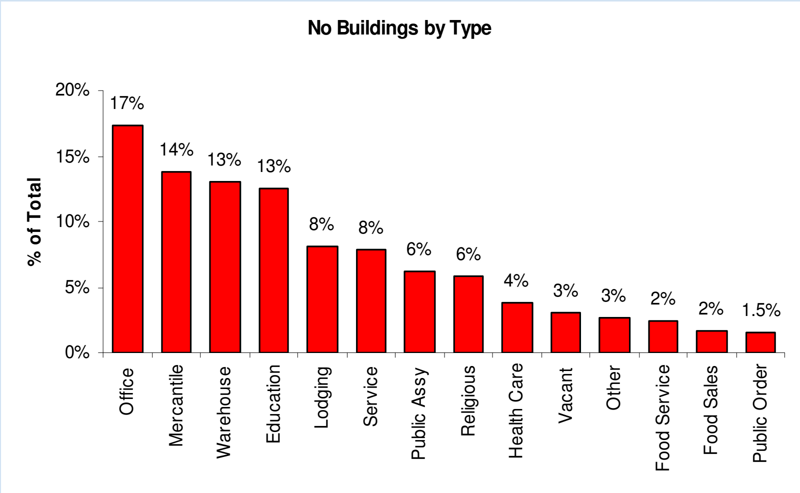
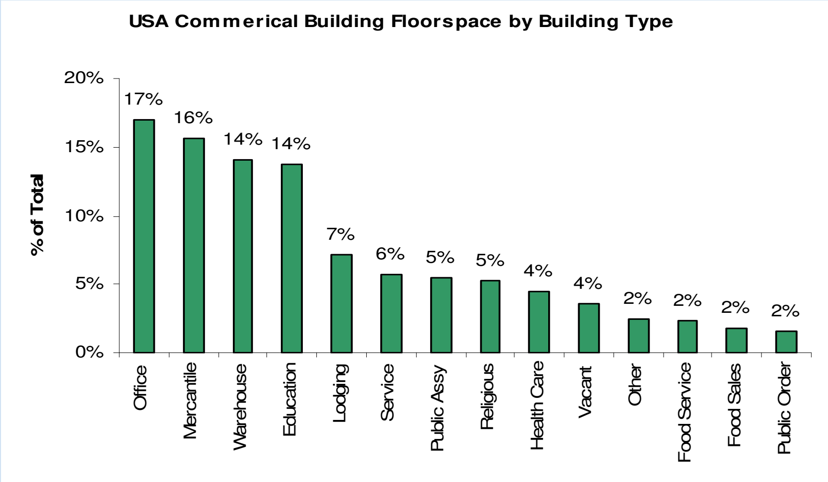
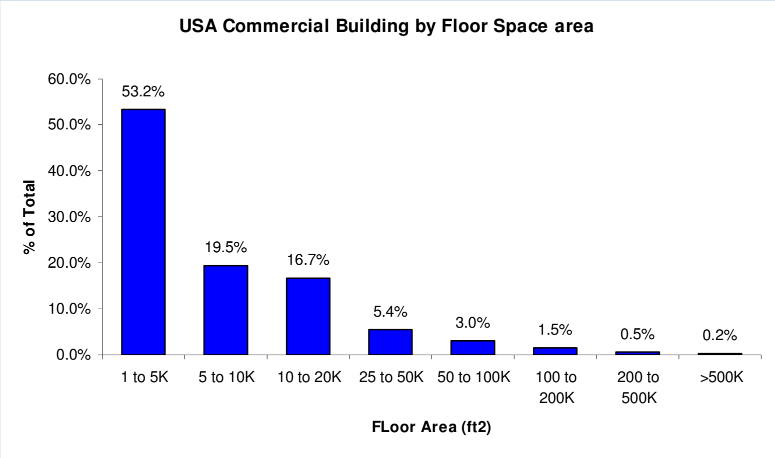
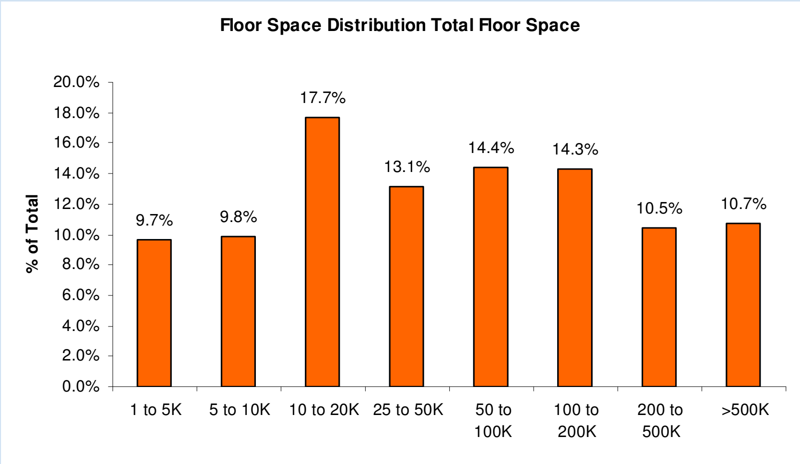
Commercial Building Breakdown









From 2003 Commercial Buildings
Energy Consumption Survey

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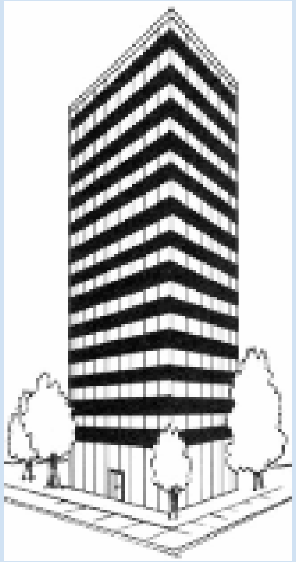
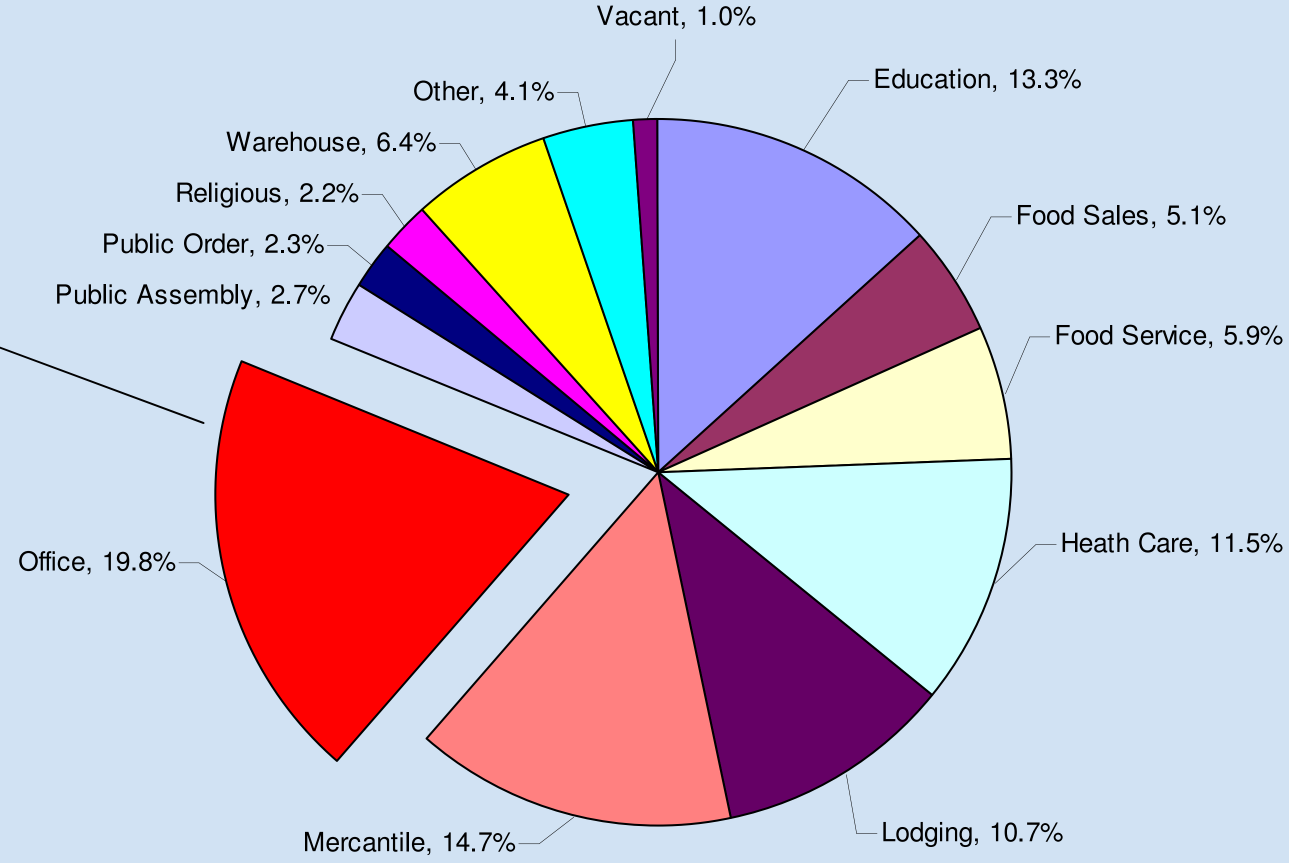
Commercial Building Energy Use

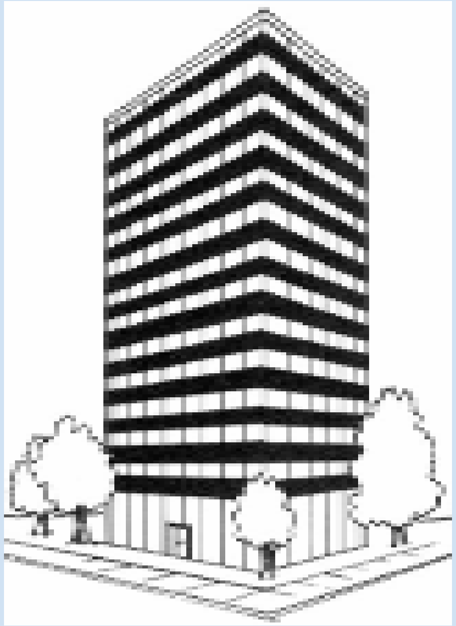


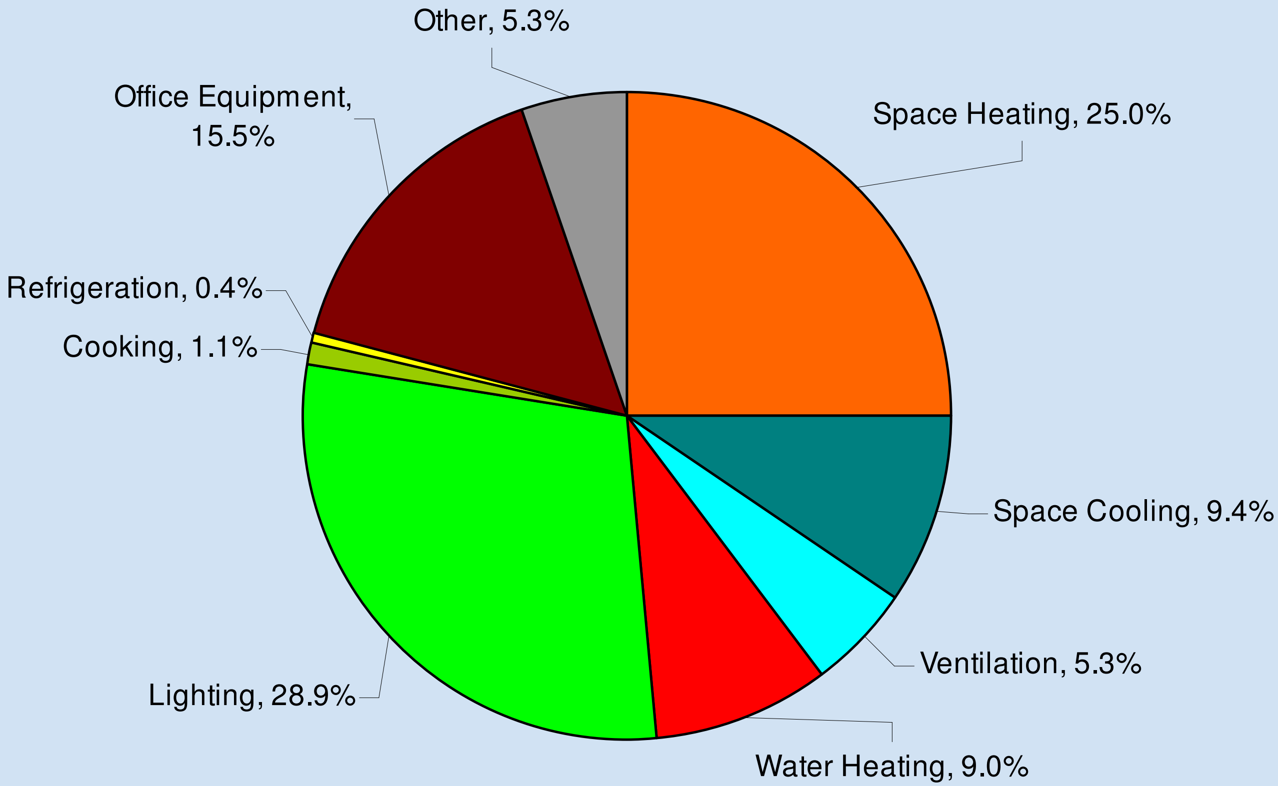
Commercial Office Building



Source: 2008 Department of Energy Buildings Energy Databook

Commercial Office Building Energy Use





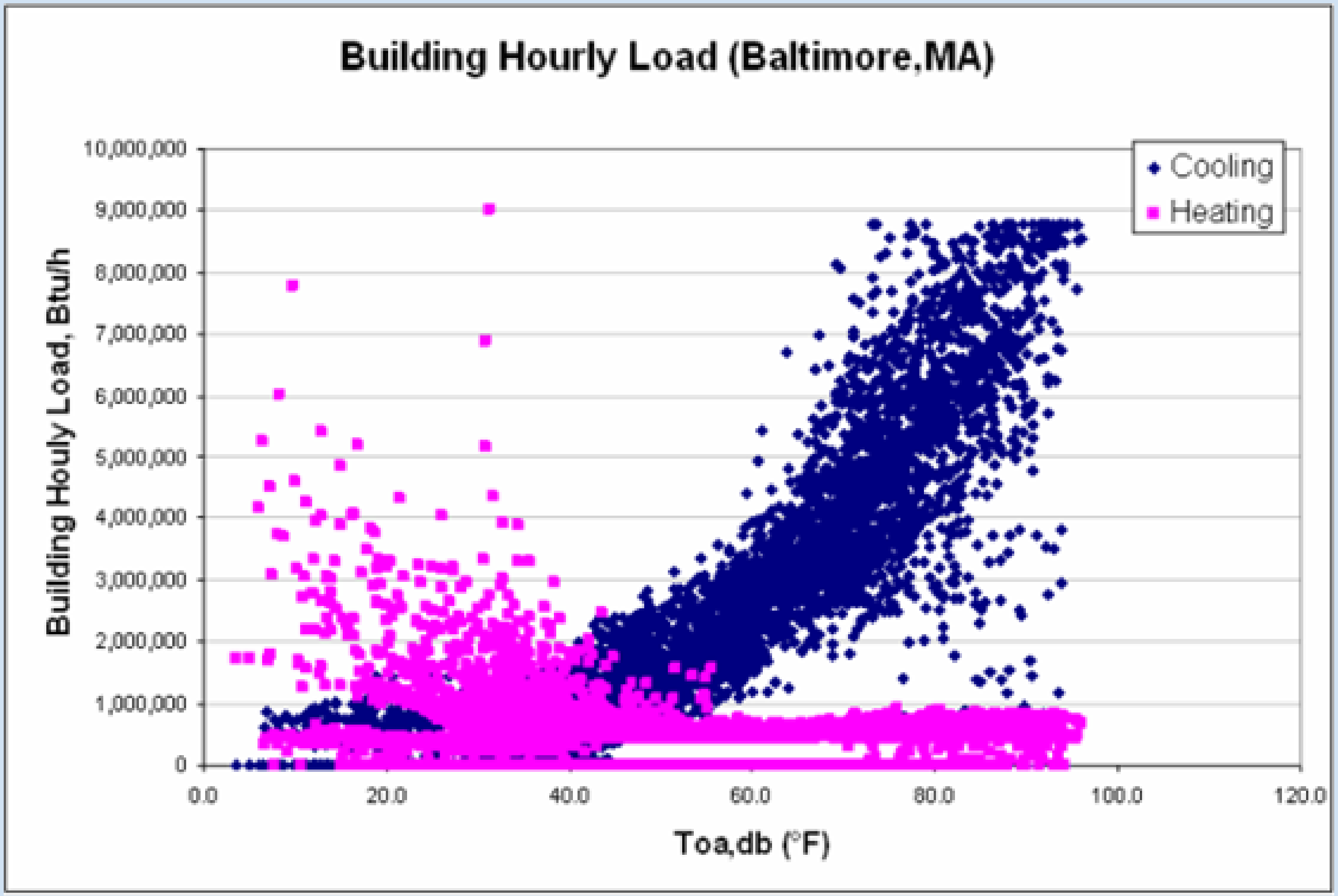
Source: 2008 Department of Energy Buildings Energy Databook

Typical Office HVAC Systems

Typical Office Building	Large (≥25,000 ft2)	Small (< 25,000 ft2)
Stock Floor Area (billion ft2)	8.22	4.29
Shell		
Percent Glass	40 - 50	15 - 20
Window R value	1.39 - 1.71	1.34 - 1.99
Window Shading Coefficient	0.69 - 0.80	0.71 - 0.82
Wall R Value	2.5 - 6.0	3.9 - 6.3
Roof R Value	9.1 - 12.6	10.5 - 13.3
Wall Material	masonry	masonry
Roof Material	built-up	built-up
Occupancy		
Average Occupancy (SF/person)	390 - 460	420-470
Weedkday Hours (hrs/day)	12	11
Weekend Hours (hrs/day)	5	4
Equipment		
Average Power Density (watts/ft2	1	1
Occupied Hours (hrs/yr)	3,580	3,360
Lighting		
Average Power Density (watts/ft2	1.3 - 1.8	1.7 - 2.2
Full Lighting hours (hrs/yr)	4,190	3,340
System and Plant		
System and Distribution	Constant Volume or VAV w/reheat	Packaged Single Zone or packaged VAV
Heating Plant	Gas Boiler	Gas furnace
Cooling Plant	Hermetic Centrifugal Chiller	Direct Expansion
Service Water Heater	Gas Boiler	Gas Water Heater

Source: 2008 Department of Energy
Buildings Energy Databook

Typical Office HVAC System Load Profile

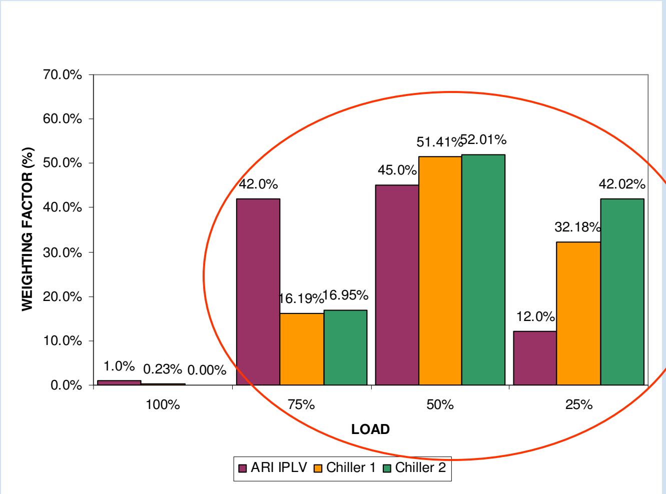


Data based on ASHRAE 90.1 benchmark large office building

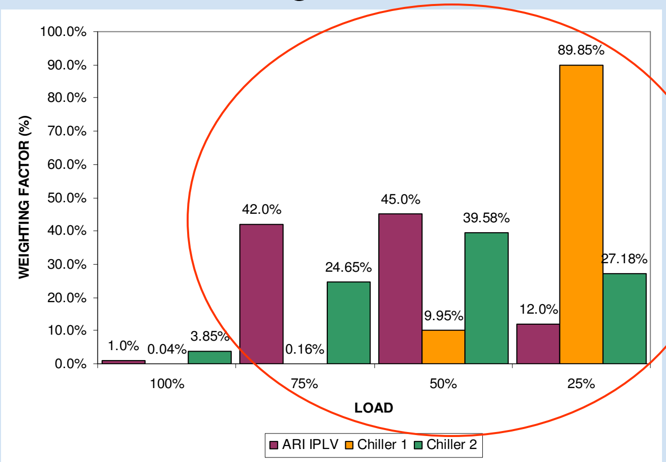
Actual Building Load Results

- With building automation systems we are now able to measure actual building data.
- The charts show data from two actual office buildings with multiple chillers
- Actual recorded data was compared to the ARI IPLV rating at the 4 categories
  - 100% - 100 to 97% load
  - 75% - 96 to 62.5% load
  - 50% - 62.5% to 37.5% load
  - 25% - 37.5% to 0% load
- As you can see **most of the operation is at part load** and even the ARI weighting factors are conservative

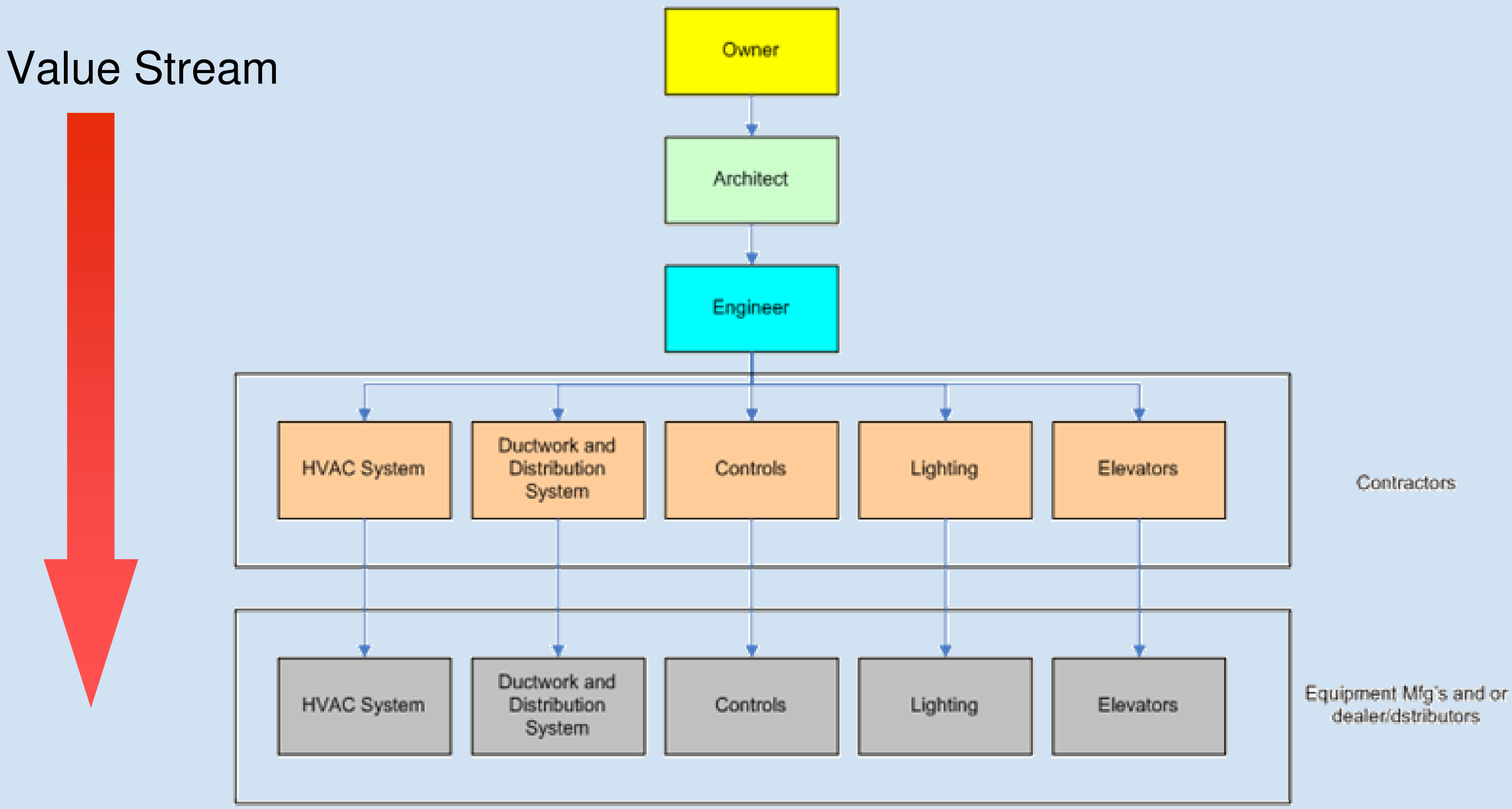
Kansas City Office



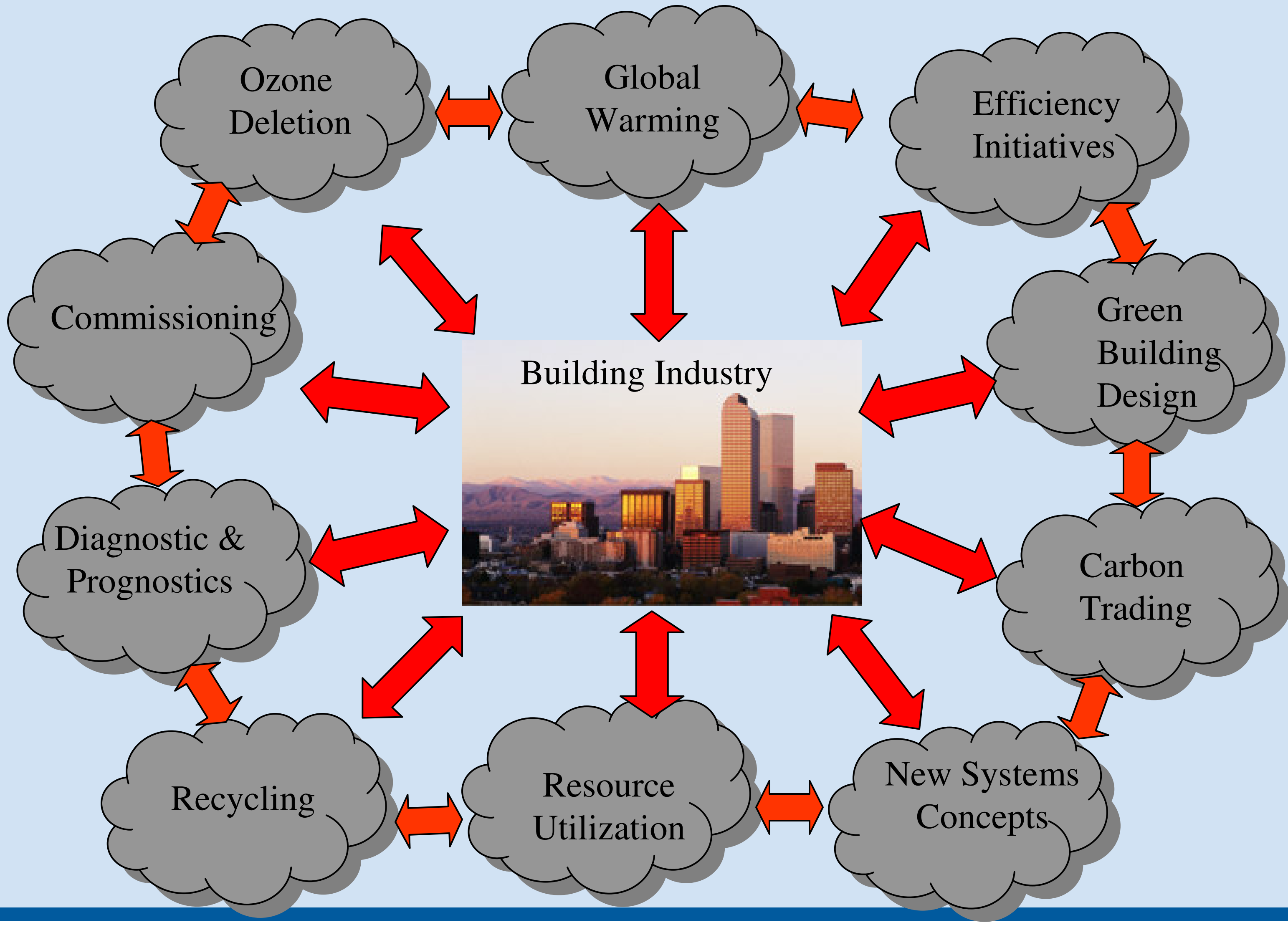
Chicago Office



Current Value Stream



New Building Industry Influences



Codes/Standards and Guidelines

- The typical approach to meeting the demands on the building industry and office building have been through codes and standards including the following;

  - **Minimum Efficiency Building Code**
    - US Energy Policy Act – Updated every few years
    - ASHRAE 90.1 and the IECC Code – Updated every 3 years

  - **Tier II and III Standards and Guidelines**
    - ASHRAE 189.1 – New High Performance Green Building Standard
    - ASHRAE Advanced Energy Design Guides (ie Small Office Building)
    - CEE Efficiency Requirements
    - EnergyStar
    - New Building Institute
    - LEED building rating system
    - FEMP

Other than the LEED rating system most are focused on component efficiencies with the emphasis at full load

Codes and Standards Trends

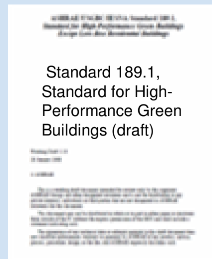
- **Existing Standards**
  - Standards groups are continuing to push towards improved component efficiencies but with refrigerant changes and approaching technological limits it is becoming increasingly more difficult and costly
  - Standards are trying to expand to cover other energy uses including industrial, plug loads, water and transportation

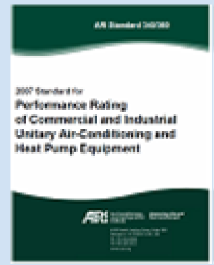
- **New Trends Start to emerge**
  - Continuing on the above path will eventually lead to equipment state of the art. New approaches are emerging to capture all of the energy use and intensity to allow systematic reduction of them in all aspects of building systems.

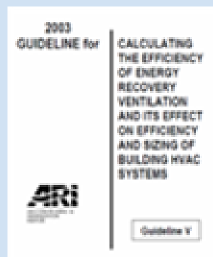
Efficiency Standard Progression

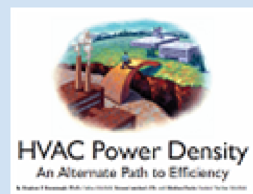
	Option	Example Metric
current	HVAC Unit Full Load Efficiency Metrics	EER, watts/cfm COP, % Eff
	HVAC Full and Part Load Efficiency Metrics	IPLV SEER, IEER, HSPF
	Hybrid System Combined Efficiencies	CEF, System EER
	Overall Annualized Efficiency Relative to a Base	Building % Energy Savings
future	Overall Building Ratings	Energy intensity building rating

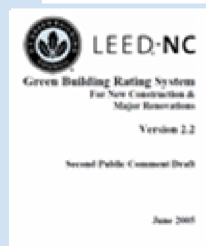
Example Standard(s)

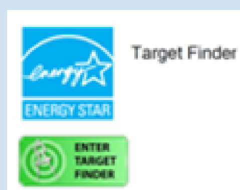


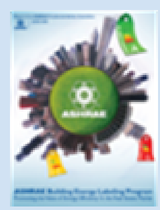












ASHRAE 90.1 Efforts

- ASHRAE Standard 90.1-2010 is committed to a reduction of 30% from the 2004 version of the standard

- Addenda already nearing completion that recognize the value of capturing the part load contribution
  - Addendum m-Chiller efficiencies
  - Addendum g – New packaged unit efficiencies
  - Addendum s-The new IEER part load metric for packaged units

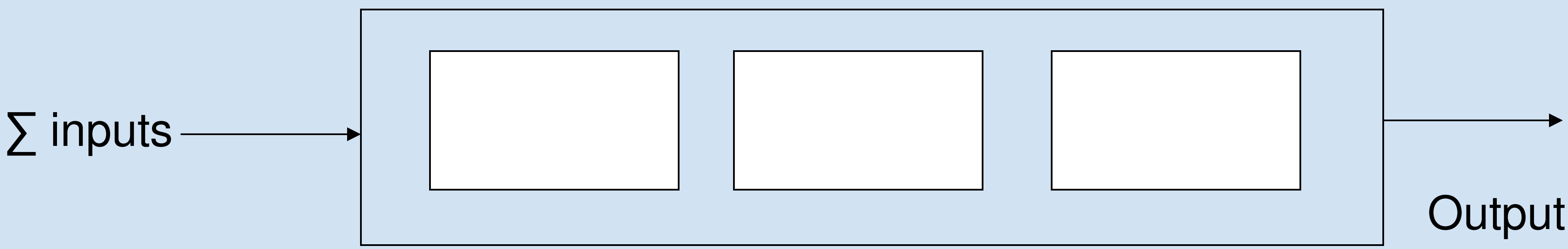
- There is a defined project to develop a methodology and metrics for system efficiency and a modeling capability being developed by PNNL to assist this process.

The Basic Approach to System Efficiency

Efficiency = output/input

So, another way of looking at this is

Efficiency = ∑ outputs/ ∑ inputs



System Level Efficiency Example

Stephen P. Kavanaugh, Ph.D., Fellow ASHRAE;

Score Sheet for HVAC SYSTEM Efficiency

University of Alabama - Mechanical Engineering

System Description: Air Cooled Screw Chiller with FPVAV

HVAC Item #		Value	kW	Ton	hp/ton	Std. 90.1 hp/1000cfm
1	Chiller/Compressor: kW/Ton ---->	1.26	1.26	1.00	1.52	
2	Supply Air Handling Unit Total Fan Pressur	4.4	0.35	-0.10	0.40	0.99
	Motor Eff (%) ---->	85				
	Fan Eff. (%) ---->	70				
	Airflow in cfm/ton ---->	400				
3	Return Fan Pressure: Inches of Water ----	1.4	0.11	-0.03	0.13	0.31
	Motor Eff (%) ---->	85				
	Fan Eff. (%) ---->	70				
	Exhaust Air Percent of Return Air (%) ---->	20				
4	Chilled Water Pump Head - Ft. of Water ----	110	0.09	-0.03	0.10	
	Motor Eff (%) ---->	85				
	Pump Eff. (%) ---->	65				
	Chilled Water Flow in gpm/ton ---->	2.4				
5	Condenser Pump Head - Ft. of Water ----	0	0.00		0.00	
	Motor Eff (%) ---->	90				
	Pump Eff. (%) ---->	70				
	Condenser Water Flow in gpm/ton ---->	3				
6	Cooling Tower or Condenser Fan kW/Ton----	0.000	0.00		0.00	
7	Zone FCU or VAV Terminal Fans kW/ton ---->	0.180	0.18	-0.05	0.16	0.39
		Σ=	1.99	0.80		1.70
		kW/Ton=	2.49			
		EER =	4.8			
		COP =	1.41			

NOTES

Enter values fo items in yellow cells that apply to system

Not all systems will contain all seven HVAC items.

The required power input is computed in Column D. Column E includes the base output (1 ton) and indoor fan and chilled water pump heat penalties (in tons).

Column F converts values to motor hp/ton. Column G computes the value of hp/1000 cfm that is used in ASHRAE Standard 90.1-2004 to limit fan power. The Standard limits fan power to 1.5 hp/1000 cfm for AHUs > 20,000 cfm and 1.7 hp/1000 cfm for AHUs < 20,000 cfm for VAV systems

For CAV systems limits are 1.1 hp/1000 cfm and 1.2 hp/cfm.

Return fan heat in % exhausted air is not included in fan heat penalty.

For primary-secondary, add pump heads.

kW/ton values from generic manufacurer data, use actual values if known

kW/ton values from generic manufacurer data, use actual values if known

Eg.: A fan for a 3-ton unit draws 0.5 kW, kW/Ton=0.5 kW ÷ 3 tons = 0.167

Summation in "Ton" column includes fan, pump, and motor heat deductions.

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ASHRAE Building Energy Labeling

- The purpose of the label is to:
  - Provide a meaningful summary of a commercial building's energy performance with a comparison to ASHRAE/IESNA Standard 90.1 that can be disclosed or presented to parties engaged in real estate transactions.
  - Provide an energy efficiency rating that facilitates the comparison of buildings' performance.
  - Provide an energy efficiency rating based on a building's design and its estimated energy consumption.
  - Provide an energy efficiency rating for a building's actual energy consumption and operation.
  - Provide meaningful indicators of the building's impact on the environment such that the greenhouse gas emissions can be estimated.
  - Document major energy efficiency features and characteristics of the building.
  - Evaluate the building's design intent to meet or exceed minimum indoor environmental criteria for health.
  - Provide recommendations for energy efficiency improvements.

- These metrics will be used to guide the development of the ASHRAE Building Energy Label.

ASHRAE Building Energy Labeling

BUILDING ENERGY CERTIFICATE

BUILDING INFORMATION

Building Type: ______ Size: ______ Year of Construction: ______

Address: ______

Owner Contact Information: ______

Asset Rating for Design Specifications	Operational Performance Rating for Building as Used
50 (on a scale of 1-100) This building is **Asset Rated** as: **AVERAGE** For the Year of **2003**	**50** (on a scale of 1-100) This building is **Performance Rated** as: **AVERAGE** For the Year of **2007**
Method Used: EPA ENERGY STAR Target Finder	Method Used: EPA ENERGY STAR Portfolio Manager
Estimated Annual Site Energy Usage: ______ [kBtu]	Actual Annual Site Energy Usage: ______ [kBtu]
Estimated Annual Energy Cost: ______ [$]	Actual Annual Energy Cost: ______ [$]
Estimated Annual Carbon Emissions: ______ [tons CO2]	Approximate Annual Carbon Emissions: ______ [tons CO2]

ENERGY DESIGN FEATURE

Check all that apply:

- ❑ Designed to meet minimum state energy code: ______
- ❑ Designed to meet ASHRAE AEDG for building type: ______
- ❑ Designed for USGBC LEED rating. Rating ______ EA Points ______
- ❑ Designed for Green Globes. Rating: ______
- ❑ Designed to Earn the ENERGY STAR
- ❑ Designed to meet a new construction program (specify) ______

List Top Five Energy Efficiency Design Features:

1. ______
2. ______
3. ______
4. ______
5. ______

- ❑ This building design has been benchmarked to ASHRAE/IESNA Standard 90.1 following the procedures in Informative Appendix G. This building design achieves a __% improvement over the baseline.

OPERATIONAL FEATURES

Check all that apply:

- ❑ This building earned the ENERGY STAR Label for these years (list): ______
- ❑ Building systems that were commissioned or re-commissioned: Specify system and year ______
- ❑ This building meets EPA's ENERGY STAR indoor environmental quality assessment requirements including temperature and humidity, illumination, outside air ventilation, and control of indoor air pollutants
- ❑ This building has had the following energy efficiency improvements since construction:

  Item: ______ Date: ______

  Item: ______ Date: ______
- ❑ Recommendations for Energy Efficiency Improvements attached.

BUILDING ENERGY CERTIFICATE INPUT DATA & PERFORMANCE DETAILS

BUILDING INFORMATION

Building Type: ______ Size: ______ Year of Construction: ______

Address: ______

Owner Contact Information: ______

Professional Engineer

Name: ______

State License No.: ______

Signature ______

Stamp of Licensed Professional Engineer

Energy Modeling Software Used to Calculate Design Energy Usage:

Date of ENERGY STAR Statement of Energy Performance:

Name of Qualified Energy Modeler

Name: ______

Signature ______

Building Owner Acceptance

Name: ______

Signature ______

Estimated Building Design Energy Use, by End Use:

kBTU/sf/yr	
Heating	
Air-Conditioning	
Ventilation	
Lighting	
Domestic Water	
Misc Equipment	
(Other)	
(Other)	
TOTAL:	

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Future Building Design Trends

Move to Integrated Design Methodology

Future Design Process

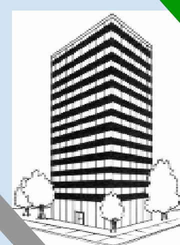
Establish Order of Priorities
- Energy Modeling
- Performance Targets
- Low **Ex**ergy Systems
- Renewable Energy Sources

Microclimate Considerations
- Displacement ventilation
- IAQ, Comfort

Passive Designs
- High Mass Buildings
- Free cooling

Active Systems
- Combined Heat/Power
- Hybrid Systems

Commissioning
- Startup
- Continuous



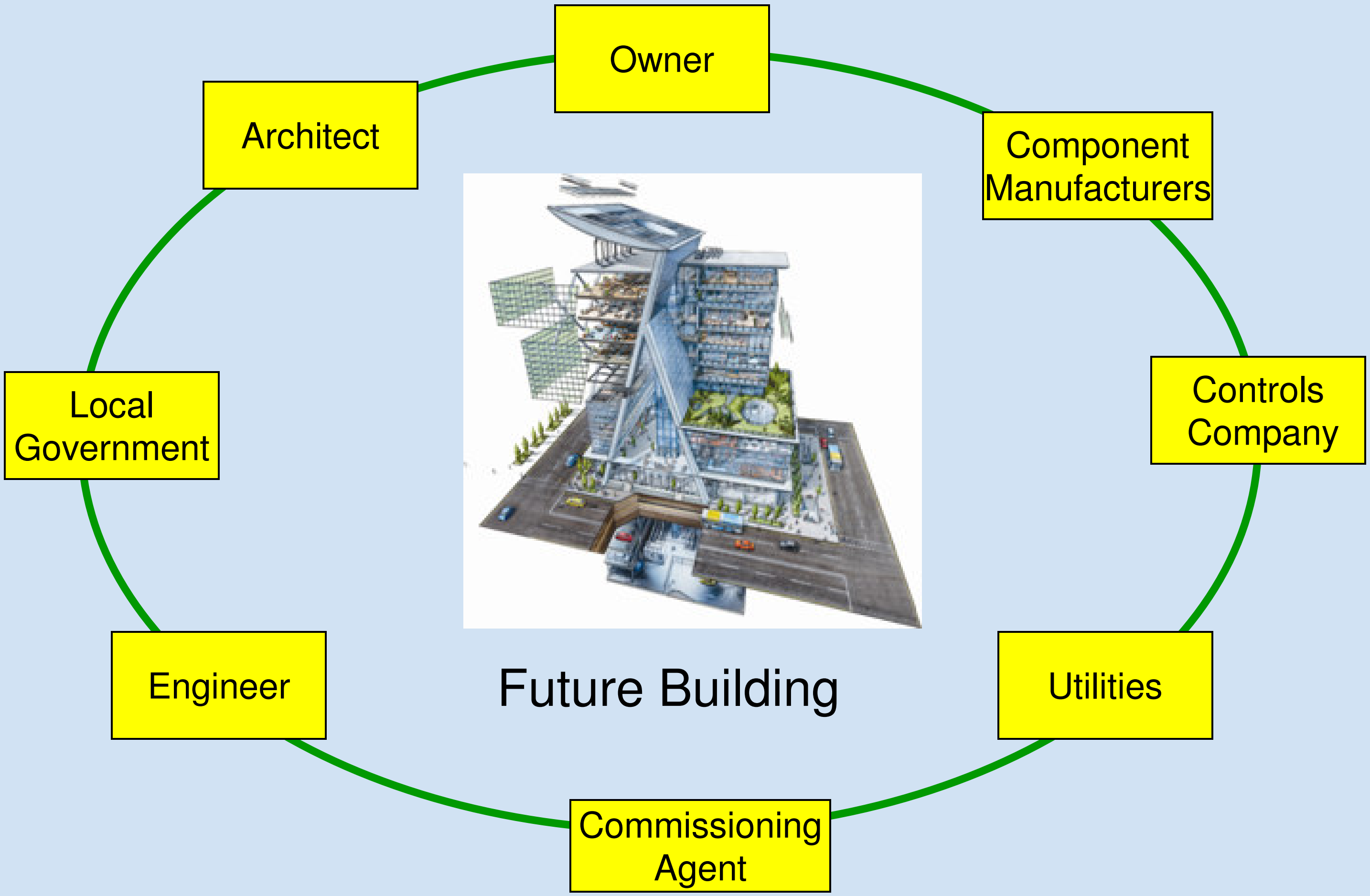
Building
Design Process

Conventional Design Process

Active Systems
Selected to meet
specifications

Design Process

- For future buildings it will take a team effort and use of advanced modeling tools to make significant energy reductions



Post Design Phase

- Recent studies have shown that buildings often do not operate as they were intended
- To obtain the design energy savings we must also do the following;
  - Properly commission the building
  - Maintain the building and equipment
  - Adapt as the building use changes
  - Make the occupants aware of the energy use

Results from a DOE commissioned Tiax study on existing building energy losses

Fault	AEC [quads[2]]
Duct Leakage	0.30
HVAC Left on When Space Unoccupied	0.20
Lights Left on When Space Unoccupied	0.18
Airflow Not Balanced	0.070
Improper Refrigerant Charge	0.070
Dampers not Working Properly	0.055
Insufficient Evaporator Airflow	0.035
Improper Controls Setup / Commissioning	0.023
Control Component Failure or Degradation	0.023
Software Programming Errors	0.012
Improper Controls Hardware Installation	0.010
Air-Cooled Condenser Fouling	0.008
Valve Leakage	0.007
TOTAL	1.0

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UTC Experience

- In United Technologies we set aggressive goals to reduce energy, water, and waste.
- This was done thru analysis of existing resource, modeling and then implementing changes to reduce demand.
- This was often done with existing equipment.

Our performance:

	Energy (BTUs)	Water (gal.)	Air Emissions (lbs.)	Waste (lbs.) Recycled	Waste (lbs.) Non-Recycled
Normalized	56%	72%	69%	52%	66%
Absolute	19%	49%	44%	13%	39%

- We have seen other studies in the industry with similar results

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Questions