Building Energy Efficiency: The Opportunities

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Iowa Energy Center

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redefining innovation

Outline

- Brief Introduction to Iowa Energy Center
- Why Building Energy Efficiency is Important
- Strategies and Steps to Improve Building Energy Efficiency
  - Know your building’s energy performance through building energy benchmarking
  - Analyze opportunities through an energy audit
  - Explore building energy improvement options
  - Monitor results
- High Performance Building Case Studies

About the Iowa Energy Center

- A public, non-profit organization
- Was created by the Iowa General Assembly and signed into law in 1990
- Has a mission to serve Iowans through reliable, objective tools, and information
- Is administered through Iowa State University
- Has a 13-member Advisory Council representing key constituencies and stakeholders (as described in the 1990 Energy Efficiency Act)

Iowa Energy Center - Our Mission

- Advance Iowa's energy efficiency and renewable energy use through transformative research, education, and demonstration
  - Strive to increase energy efficiency in all areas of Iowa's energy use
  - Serve as a model for state efforts on energy efficiency and renewable energy
  - Conduct and sponsor research on energy efficiency and conservation, as well as alternative energy based on renewable resources
  - Assist Iowans in assessing energy-related technologies
  - Support educational and demonstration programs

Iowa Energy Center - Key Program Areas

- **Energy Efficiency**
  - Building
  - Industrial
  - Agricultural
  - Transportation
- **Renewable Energy**
  - Biorenewable
  - Solar
  - Wind
- **Grants and Funding**
  - IEC Sponsored Grants
  - Alternate Energy Revolving Loan Program
  - Scholarships
- **Outreach**
  - Learning Institute for training and education
  - Communications and Marketing

Iowa Energy Center - Key Facilities

- Energy Resource Station (ERS)

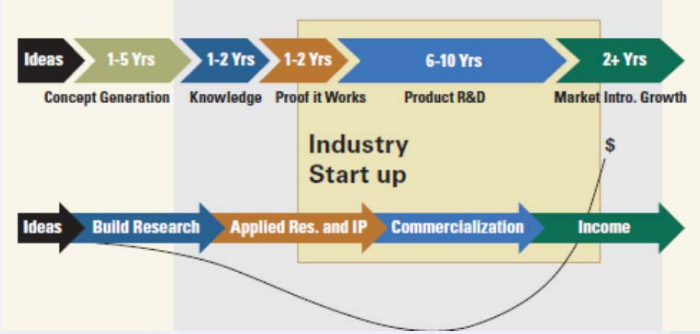
- Biomass Energy CONversion Facility (BECON)

Iowa Energy Center - Energy Resource Station

- Research, testing and demonstration facility
- Provide practical information to building owners and EE professionals
- Unique lab-grade facility with side-by-side system testing capability
- 4 matched pairs of test rooms and over 1,200 control and monitoring points
- Nationally and internationally known

Iowa Energy Center - Biomass Energy Conversion Facility

- Demonstrations of **pilot-scale** biomass conversion systems
- Provides credible, firsthand information on biomass technologies
- Open to researchers from all of Iowa's universities, colleges and community colleges, and private nonprofit organizations and their research partners from the private sector



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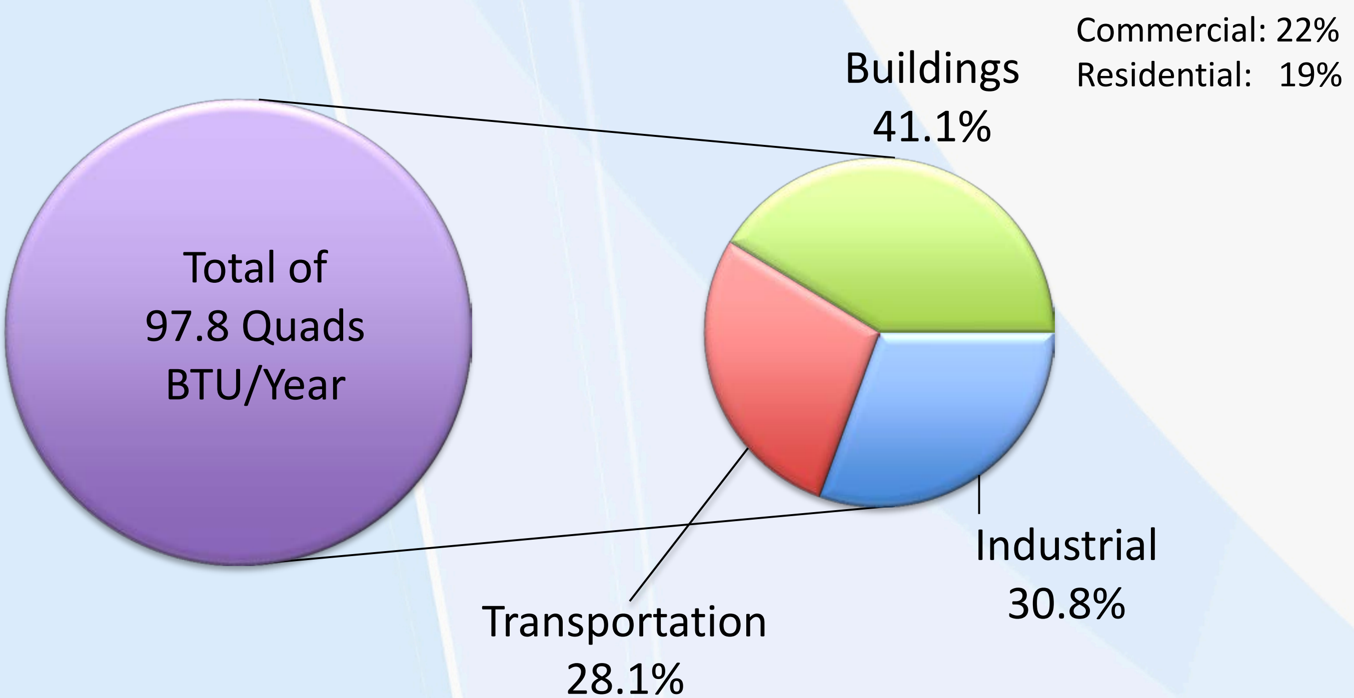
Why Building Energy Efficiency is Important

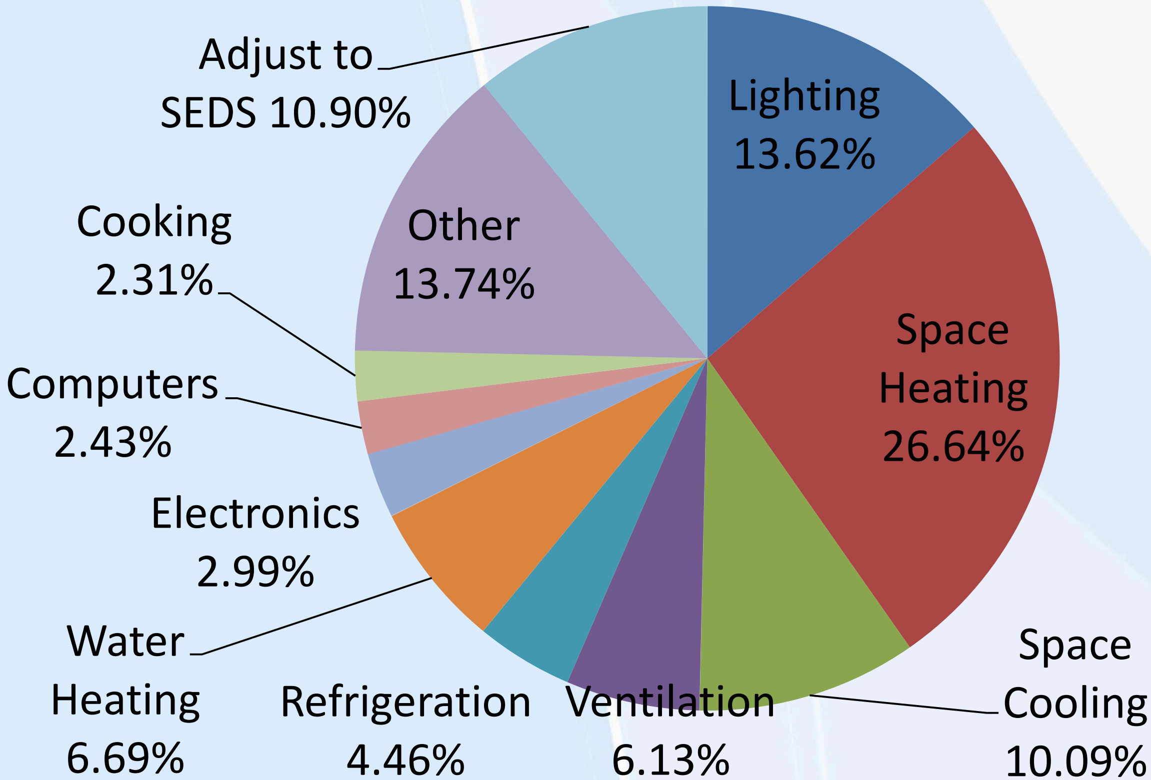
2010 U.S. Primary Energy Consumption*



*Based on the 2011 Building Energy Data Book by the Department of Energy; 1 Quads = 1 000 000 000 000 000.

Why Building Energy Efficiency is Important

- 2010 Commercial Building Site-Energy End-Use Type Splits*



*Based on the 2011 Building Energy Data Book by the Department of Energy. SEDS: State Energy Data System

Why Building Energy Efficiency is Important

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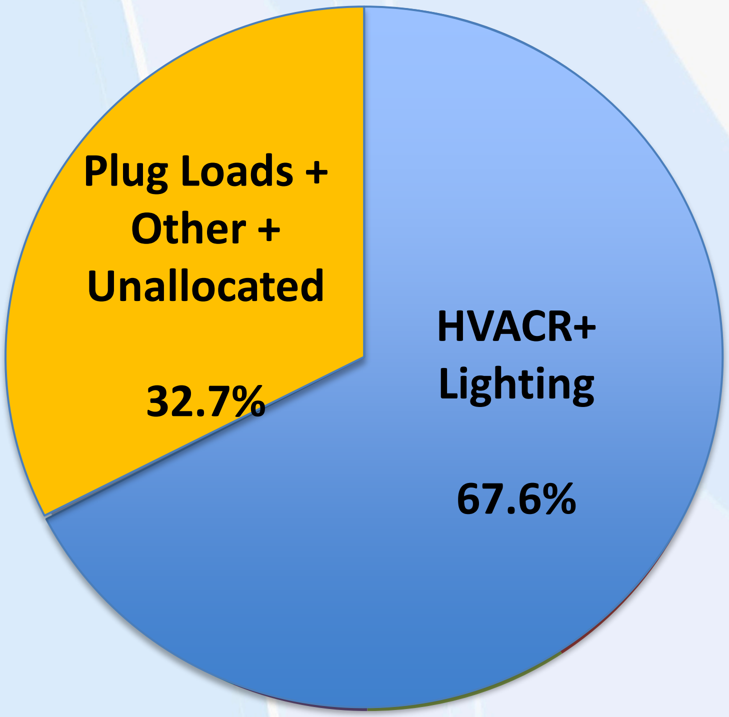
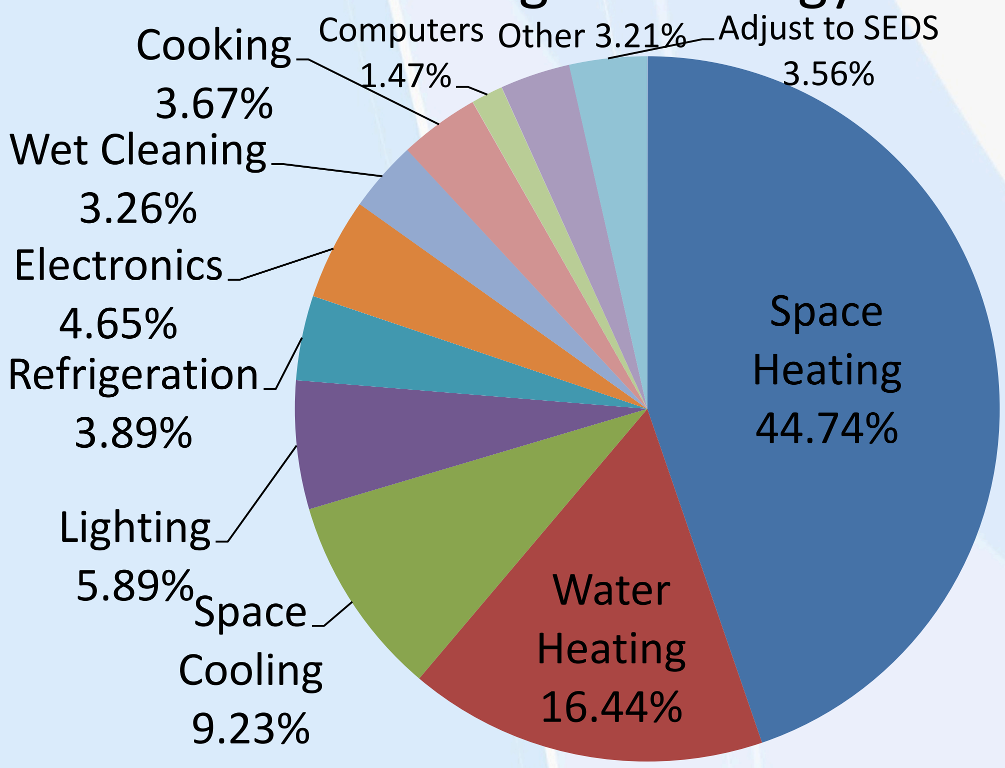


*Based on the 2011 Building Energy Data Book by the Department of Energy

Why Building Energy Efficiency is Important

- 2010 Residential Building Site-Energy End-Use Type Splits*



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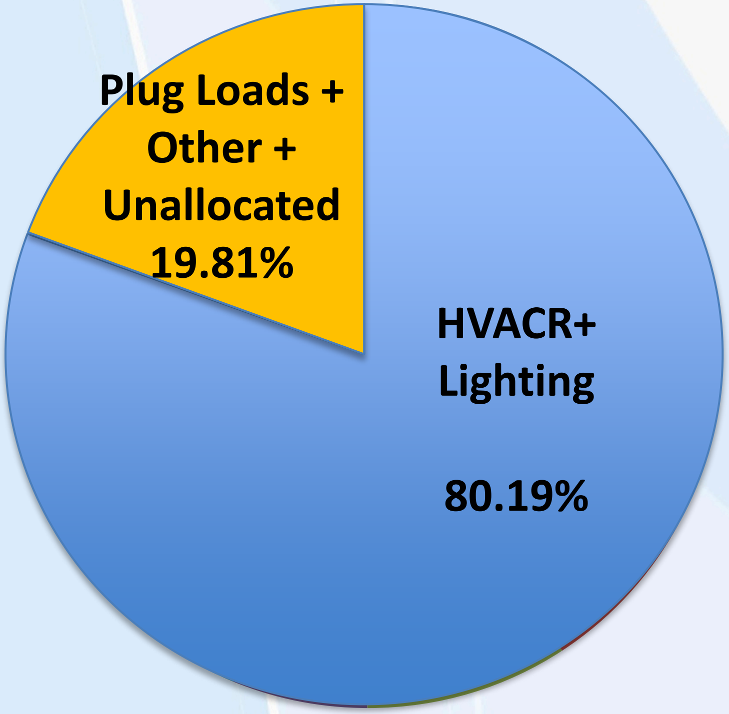
Why Building Energy Efficiency is Important

- 2010 Residential Building Site-Energy End-Use Type Splits*



*Based on the 2011 Building Energy Data Book by the Department of Energy

Strategies to Reduce Building Energy Use and Cost

- **Reduce Energy Demand: plug loads, load shifting and peak load reduction**
- **Improve Building Energy Efficiency: operations & management; energy audit and retro-commissioning**
- Use Renewable Energy Source: wind, solar, biomass
- Financial Incentive opportunities: tax credits, utility rebates

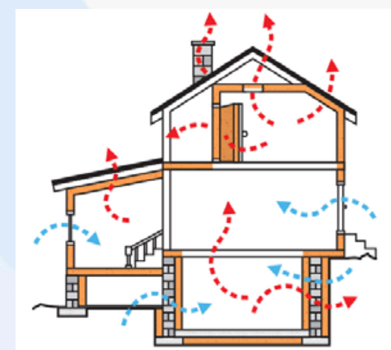
Strategies to Reduce Building Energy Use and Cost

- Commercial Buildings: How Much Energy Can be Saved by Doing What*?
  - 7%~28% by implementing no cost or low-cost energy efficient measures through changes in building <u>operations and management</u> (O&M)
  - 9.4%~25% by <u>retrofitting lighting</u>
  - <u>7.3%~22.9% by calibrating HVAC control devices, improve control sequences, and monitoring energy use</u>
  - <u>3.5%~15.9% through replacing old HVAC equipment with new energy efficient units</u>
  - 3.5%~15.2% by <u>changing occupant behavior</u>

*Based on BOMA International BEEP 2006 report

Strategies to Reduce Building Energy Use and Cost

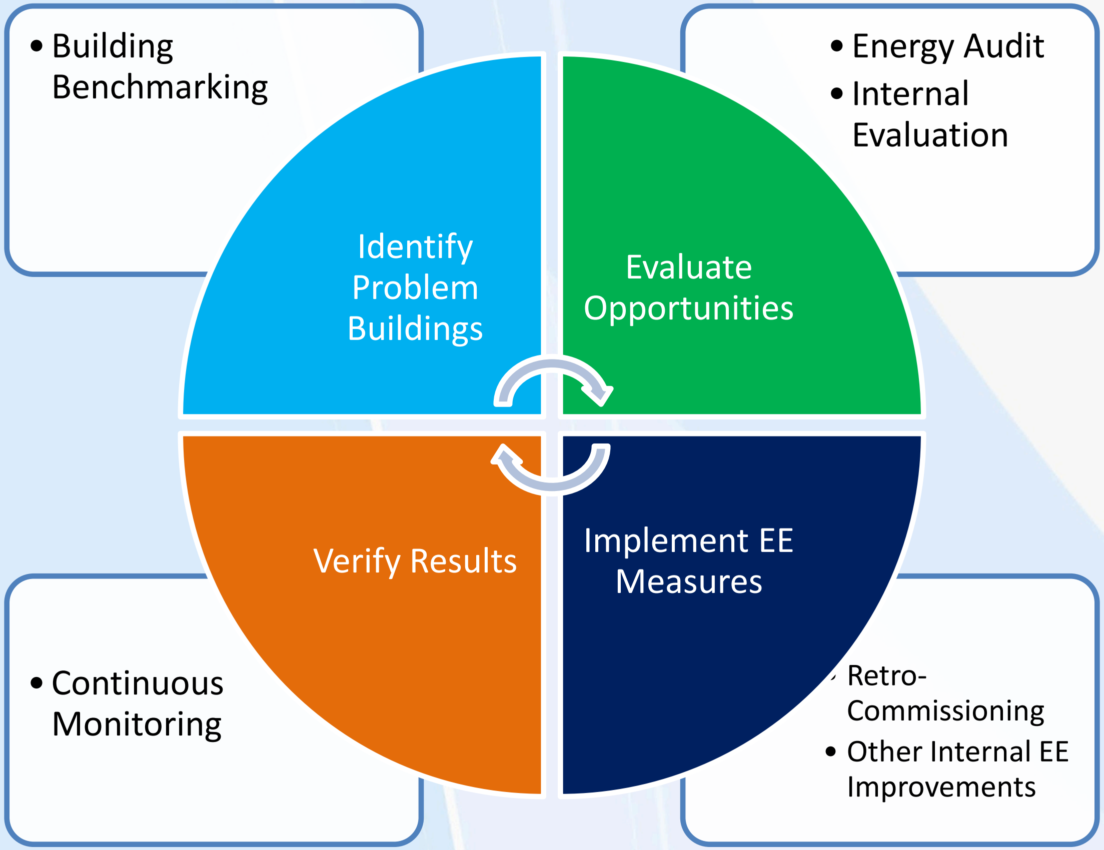
- Residential Buildings:
  - Fix air leak and improve insulation (building envelop and HVAC system)
  - Replacing old appliances and HVAC equipment with new energy efficient units
  - Retrofitting lighting
  - Changing occupant behavior



Steps to Take

- Step1: Know Your Building's Energy Performance through Building Energy Benchmarking
- Step 2: Analyze Opportunities through an Energy Audit
- Step 3: Implement Building Energy Improvements
- Step 4: Monitor Results

Steps to Take



Step 1: Know Your Building's Energy Performance EUI & ECI

- Two Key Building Performance Indicators
- Energy Utilization Index (EUI)
  - Unit energy use for buildings in BTU/sq. ft. - year
- Energy Cost Index (ECI)
  - Unit cost of energy for buildings in $/sq. ft. - year

*BTU = British Thermal Unit; 1 BTU ~= 0.293 Watt-Hour

Step 1: Know Your Building's Energy Performance
EUI & ECI

Gross Office Building Area: **12500 sq. ft.**

MONTH	Electricity		Natural Gas		Total	
	Cost $	Office Bldg Total KWH	Energy Therms	Cost $	Energy kBTU	Cost $
January	608.8979	12835.4	427	397.11	86507.2202	1006.007898
February	533.8115	9923.2	91	90.47	42967.8816	624.281456
March	389.1015	6779	101	91.43	33236.727	480.5315275
April	299.5248	4955.8	50	45.5	21914.1454	345.0247663
May	509.1813	5520	10	17.92	19839.76	527.1013084
June	529.8775	5728.7	5	14.12	20052.0531	543.9974705
July	575.858	6367.8	5	14.49	22233.3014	590.3479565
August	496.5895	5614	5	14.26	19660.582	510.8494889
September	226.5405	3734.8	4	13.38	13146.8724	239.9205187
October	394.9498	6555.8	5	14.21	22874.9454	409.1598217
November	516.2209	9379.5	64	61.3	38412.2335	577.5209352
December	547.3023	10953.7	121	111.33	49484.9781	658.632338
Total					390330.7001	6513.375486
Average					**31.23** EUI (kBTU/s.q ft. - year)	**0.52** ECI ($/sq. ft. - year)

* 1 KWH = 3.412 kBTU; 1 Therm = 100 kBTU

Step 1: Know Your Building's Energy Performance
EUI & ECI

- EUI = 31.2 BTU/sq. ft. - year
- ECI = $0.52/sq. ft. - year

So what?

Is this building very energy efficient?

Step 1: Know Your Building's Energy Performance
Building Energy Benchmarking

- Building Energy Benchmarking and Benefits
  - Building Energy Benchmarking
    - Estimate of building energy performance based on monthly energy use and basic building information
    - How did your building compare with similar buildings?
    - Compared to self, within a portfolio, or nationally?
    - Compare to an energy code-compliant building?
  - Benefits
    - Identify buildings with high Return On Investment (ROI) potential in EE projects
    - Respond to rising energy costs
    - Enhance your company's image and attract satisfied tenants
    - Improve the marketability of your property and increase real estate value

Step 1: Know Your Building's Energy Performance
Building Energy Benchmarking

The financial value of benchmarking can be expressed in terms that are meaningful to each building sector. A savings of 2.4% for three consecutive years is equivalent to the following:

For a 500,000 square foot office building:
Cumulative energy cost savings of $120,000
Increase in asset value of over $1 million

For a medium box retailer with 500 stores:
Cumulative energy cost savings of $2.5 million
Increase in sales of 0.89%

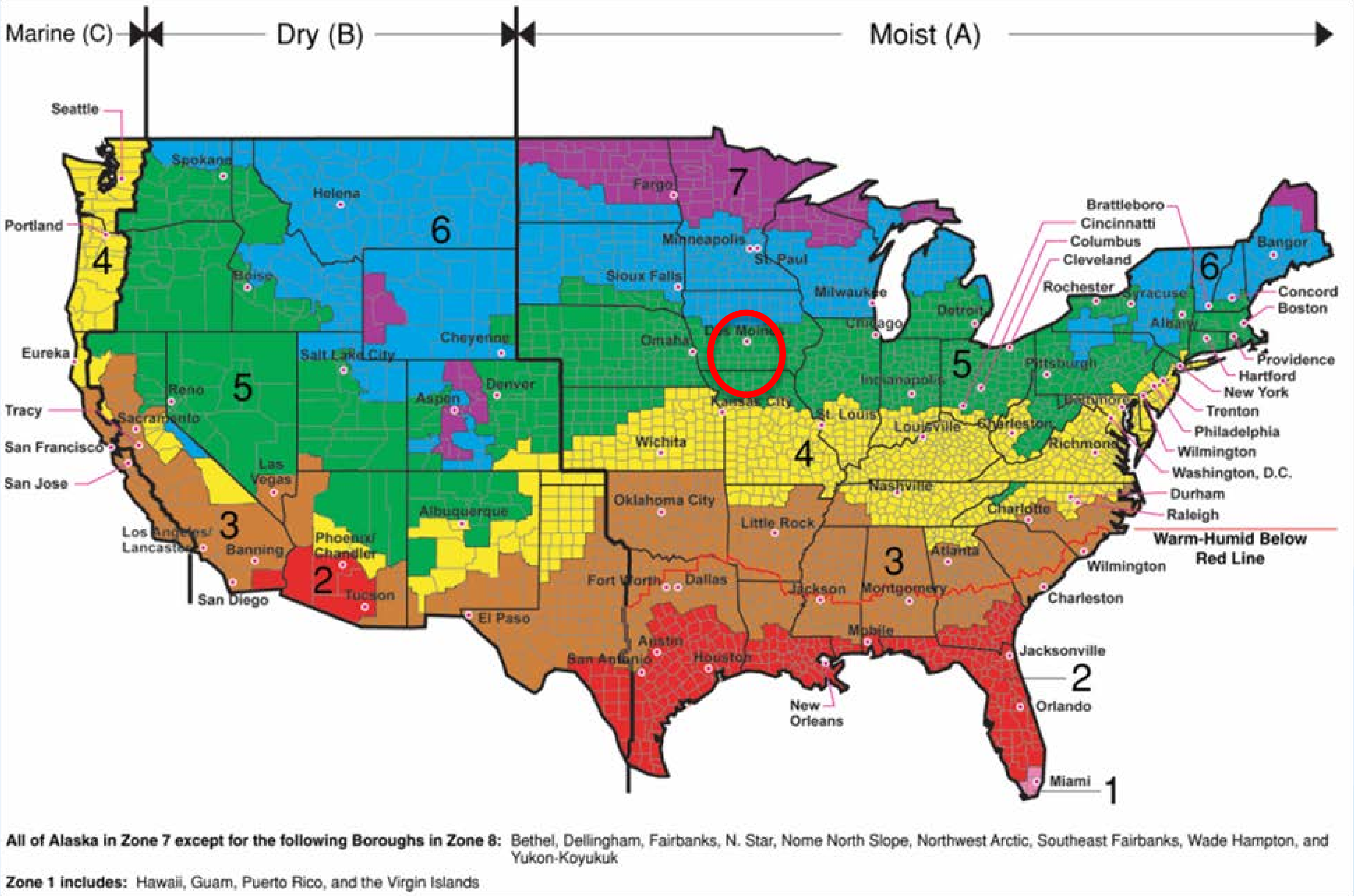
For a full service hotel chain with 100 properties:
Cumulative energy cost savings of $4.1 million
Increase in revenue per available room of $1.41

For an 800,000 square foot school district:
Cumulative energy cost savings of $140,000
Salary of 1.2 full time teachers each year

*EPA: “Benchmarking and Energy Savings” 2012

Step 1: Know Your Building's Energy Performance
Building Energy Benchmarking

U.S. Climate Zone Map



Step 1: Know Your Building's Energy Performance
Building Energy Benchmarking

DOE Commercial Building Benchmarks –
New Construction

EUIs (kBtu/sq. ft-yr)

October 2009

City	Chicago	Denver	Minneapolis
Climate Zone	5A	5B	6A
Large Office	43	36	46
Medium Office	48	41	54
Small Office	51	45	57
Warehouse	24	23	29
Stand-alone Retail	81	69	93
Strip Mall	85	72	99
Primary School	65	58	75
Secondary School	76	64	89
Supermarket	195	179	208
Quick Service Restaurant	657	604	713
Full Service Restaurant	527	481	570
Hospital	148	130	153
Outpatient Facility	271	271	280
Small Hotel	80	74	87
Large Hotel	138	131	150
Mid-Rise Apartment	47	41	54

Step 1: Know Your Building's Energy Performance Energy Star Portfolio Manager

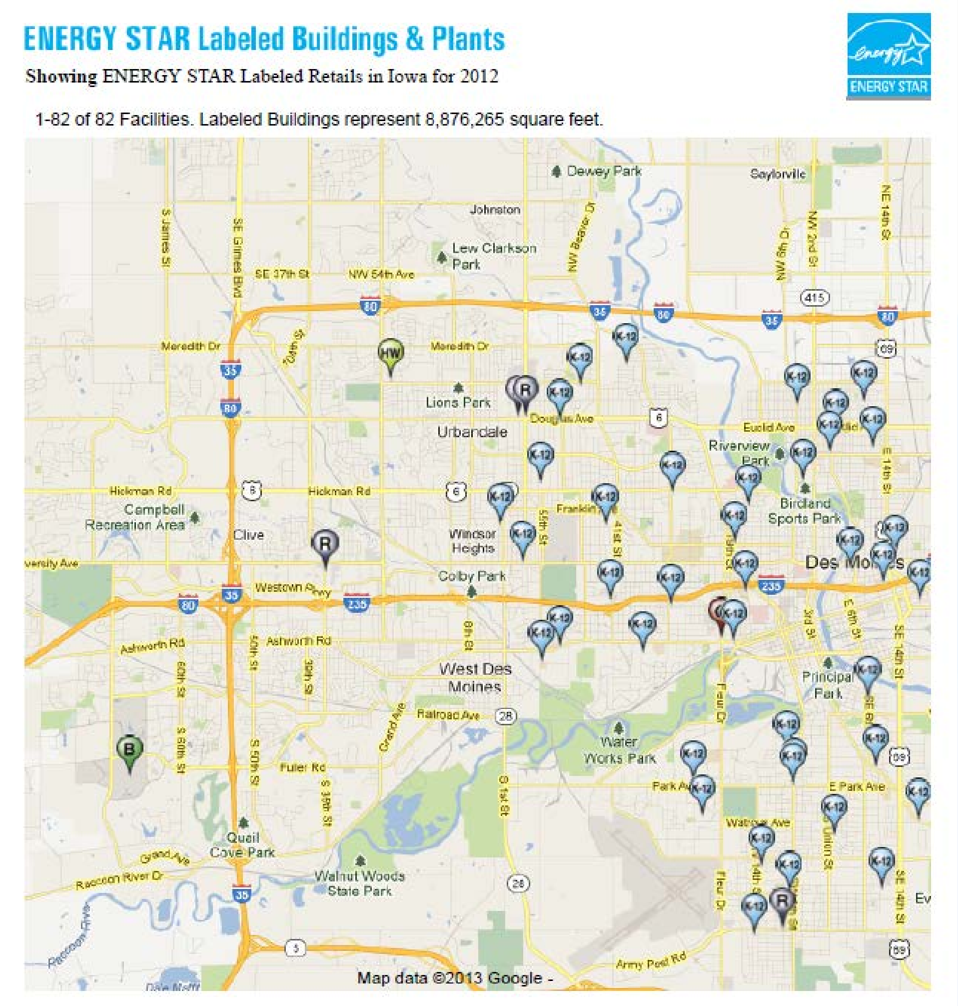
- Benchmarking Systems 1: EPA's **Energy Star Portfolio Manager**
  - Based on national survey 2003 CBECS database by EIA (Energy Information Administration)
  - Provides a comparison for 15 commercial building types
  - Scaled in 1 – 100 relative to similar buildings nationwide (highest number is the most energy efficient building)
  - Building rating above **75** may receive Energy Star plaque
  - Target finder to set building energy design goal
  - No cost to users
  - http://www.energystar.gov/index.cfm?c=business.bus_index&s=m

Step 1: Know Your Building's Energy Performance
Energy Star Portfolio Manager

➢ Required Data

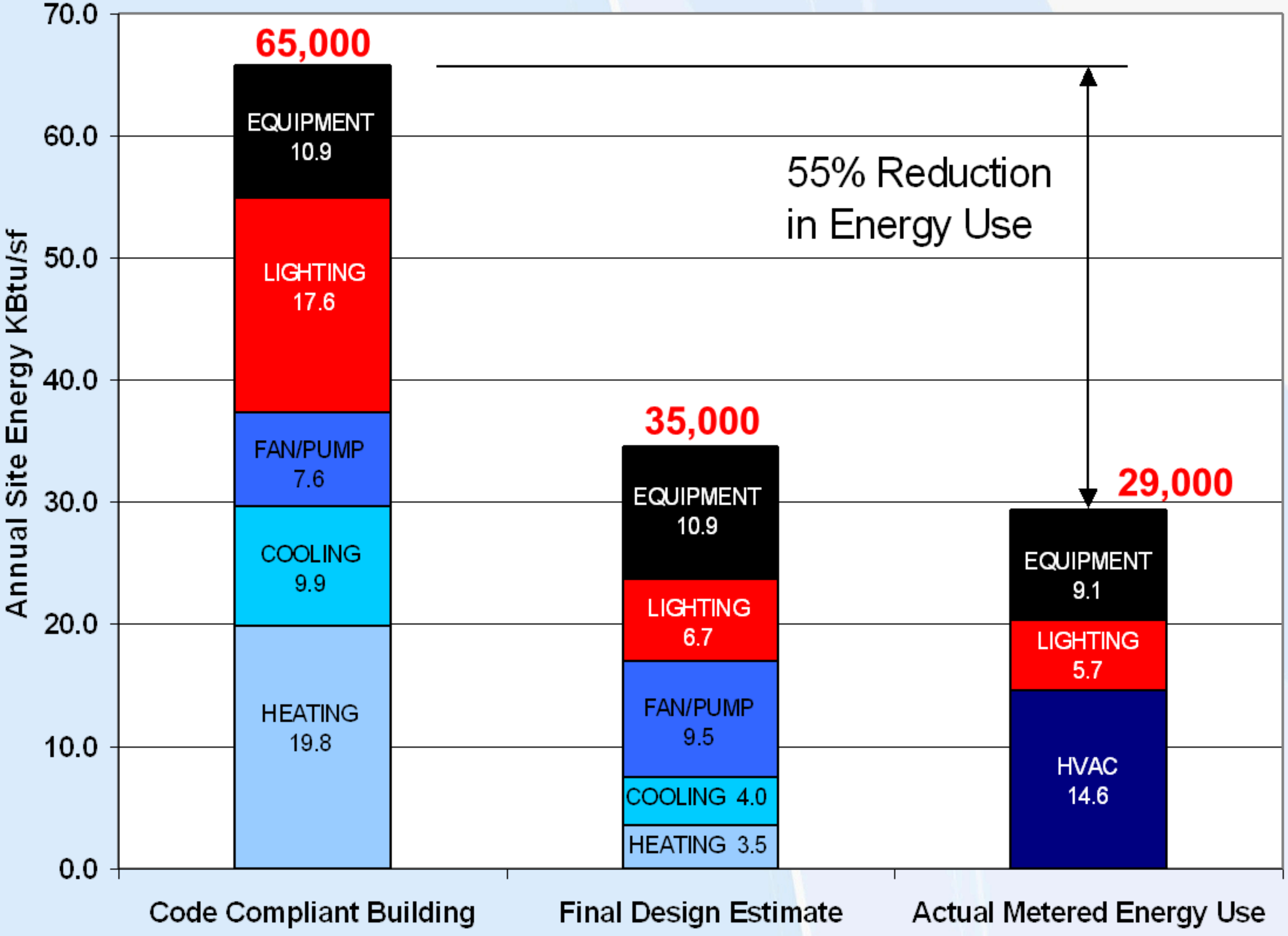
• **Portfolio Manager username and password.** • **The building street address, year built, and contact information.** • **The building gross floor area and key operating characteristics for each major space type. Use this worksheet to collect this information before logging in to Portfolio Manager.** • **12 consecutive months of utility bills for all fuel types used in the building.**	**K-12 School** **Required:** _______ **Gross floor area (SF)** _______ **# of personal computers** _______ **# of walk-in refrigeration/freezer units** _______ **High school - yes or no** _______ **Open weekends – yes or no** _______ **On-site cooking – yes or no** _______ **Percent of floor area that is cooled in 10% increments (10%, 20%, 30%, etc.)** _______ **Percent of floor area that is heated in 10% increments (10%, 20%, 30%, etc.)** **Optional:** _______ **Months of use** _______ **School District**

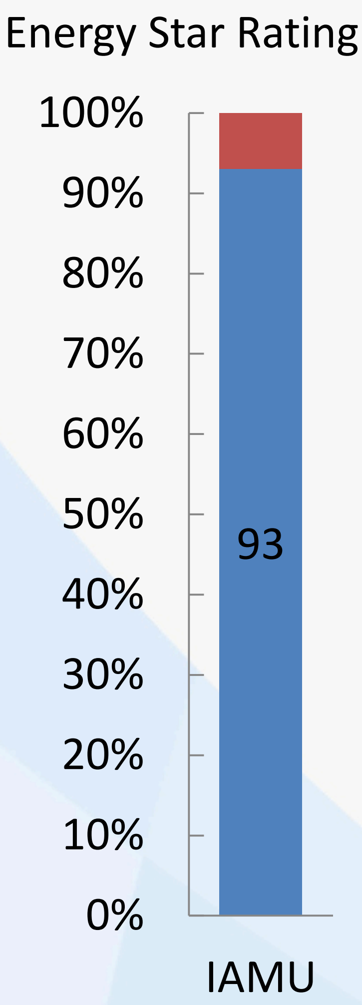
Step 1: Know Your Building's Energy Performance
Energy Star Portfolio Manager



B: Bank
HW: House of Worship
K-12: K-12 Schools
O: Office
R: Retail
W: Warehouse

Step 1: Know Your Building's Energy Performance
Energy Star Portfolio Manager





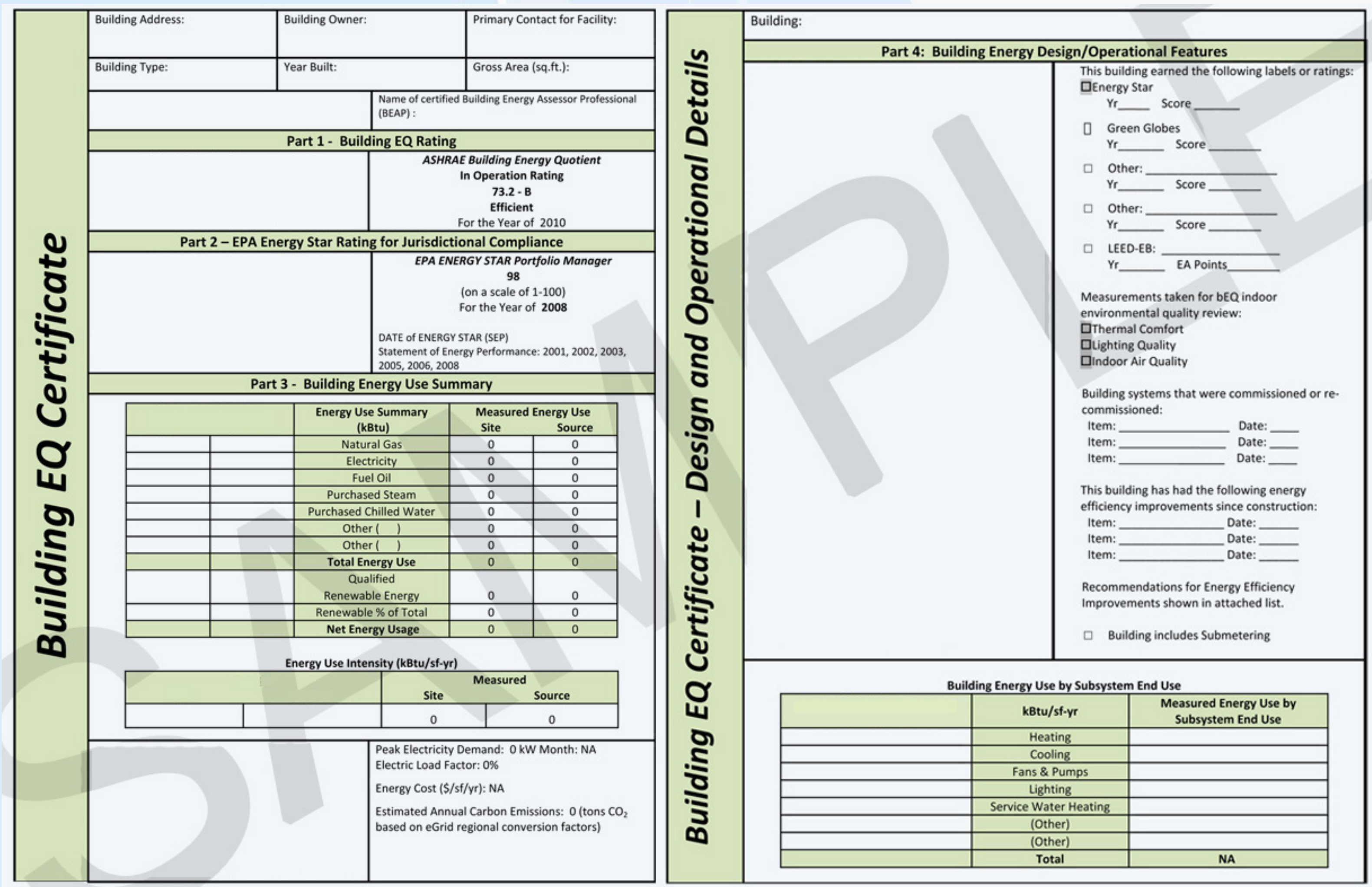
Step 1: Know Your Building's Energy Performance ASHRAE Building Energy Quotient

- Benchmarking Systems 2: **ASHRAE Building Energy Quotient**
  - ASHRAE’s Building Energy Labeling Program, ratings for both design and operation
  - Requires more detailed information than just the monthly utility bill
  - Requires ASHRAE Level 1 energy audit done by a ASHRAE-certified Building Energy Assessment Professional (BEAP)
  - Provides a little more detailed opportunity analysis/suggestions: envelop, lighting/day lighting, HVAC, utility/operation, other
  - Energy end use breakdown
  - The registration fee for bEQ is $500. Energy audit fee separate
  - http://buildingenergyquotient.org/

Step 1: Know Your Building's Energy Performance ASHRAE Building Energy Quotient

- Required Data and Worksheet
  - Form 1 – Building Characteristics
  - Form 2 – Energy Calculations for In Operation Rating
  - Form 3 – Building Indoor Environmental Quality (IEQ) Screening Information
  - Form 4 – Suggestions for Additional Energy Savings
  - Form 5 – Energy End Use Breakdown
  - Electric Metered Data Worksheet
  - Natural Gas Metered Data Worksheet
  - Other Energy Metered Data Worksheet

Step 1: Know Your Building's Energy Performance
ASHRAE Building Energy Quotient



Building EQ Certificate

Building Address:	Building Owner:	Primary Contact for Facility:
Building Type:	Year Built:	Gross Area (sq.ft.):

Name of certified Building Energy Assessor Professional (BEAP) :

Part 1 - Building EQ Rating

ASHRAE Building Energy Quotient
In Operation Rating
73.2 - B
Efficient
For the Year of 2010

Part 2 – EPA Energy Star Rating for Jurisdictional Compliance

EPA ENERGY STAR Portfolio Manager
98
(on a scale of 1-100)
For the Year of **2008**

DATE of ENERGY STAR (SEP)
Statement of Energy Performance: 2001, 2002, 2003, 2005, 2006, 2008

Part 3 - Building Energy Use Summary

		Energy Use Summary (kBtu)	Measured Energy Use Site	Measured Energy Use Source
		Natural Gas	0	0
		Electricity	0	0
		Fuel Oil	0	0
		Purchased Steam	0	0
		Purchased Chilled Water	0	0
		Other ( )	0	0
		Other ( )	0	0
		Total Energy Use	0	0
		Qualified Renewable Energy	0	0
		Renewable % of Total	0	0
		Net Energy Usage	0	0

Energy Use Intensity (kBtu/sf-yr)

		Measured Site	Measured Source
		0	0

Peak Electricity Demand: 0 kW Month: NA
Electric Load Factor: 0%

Energy Cost ($/sf/yr): NA

Estimated Annual Carbon Emissions: 0 (tons CO_2 based on eGrid regional conversion factors)

Building EQ Certificate – Design and Operational Details

Building:

Part 4: Building Energy Design/Operational Features

This building earned the following labels or ratings:
- ☐ Energy Star Yr_____ Score _______
- ☐ Green Globes Yr_______ Score ________
- ☐ Other: ________________ Yr_______ Score ________
- ☐ Other: ________________ Yr_______ Score ________
- ☐ LEED-EB: ________________ Yr_______ EA Points________

Measurements taken for bEQ indoor environmental quality review:
- ☐ Thermal Comfort
- ☐ Lighting Quality
- ☐ Indoor Air Quality

Building systems that were commissioned or re-commissioned:
Item: _______________ Date: ____
Item: _______________ Date: ____
Item: _______________ Date: ____

This building has had the following energy efficiency improvements since construction:
Item: ______________ Date: ______
Item: ______________ Date: ______
Item: ______________ Date: ______

Recommendations for Energy Efficiency Improvements shown in attached list.

☐ Building includes Submetering

Building Energy Use by Subsystem End Use

	kBtu/sf-yr	Measured Energy Use by Subsystem End Use
	Heating	
	Cooling	
	Fans & Pumps	
	Lighting	
	Service Water Heating	
	(Other)	
	(Other)	
	Total	**NA**

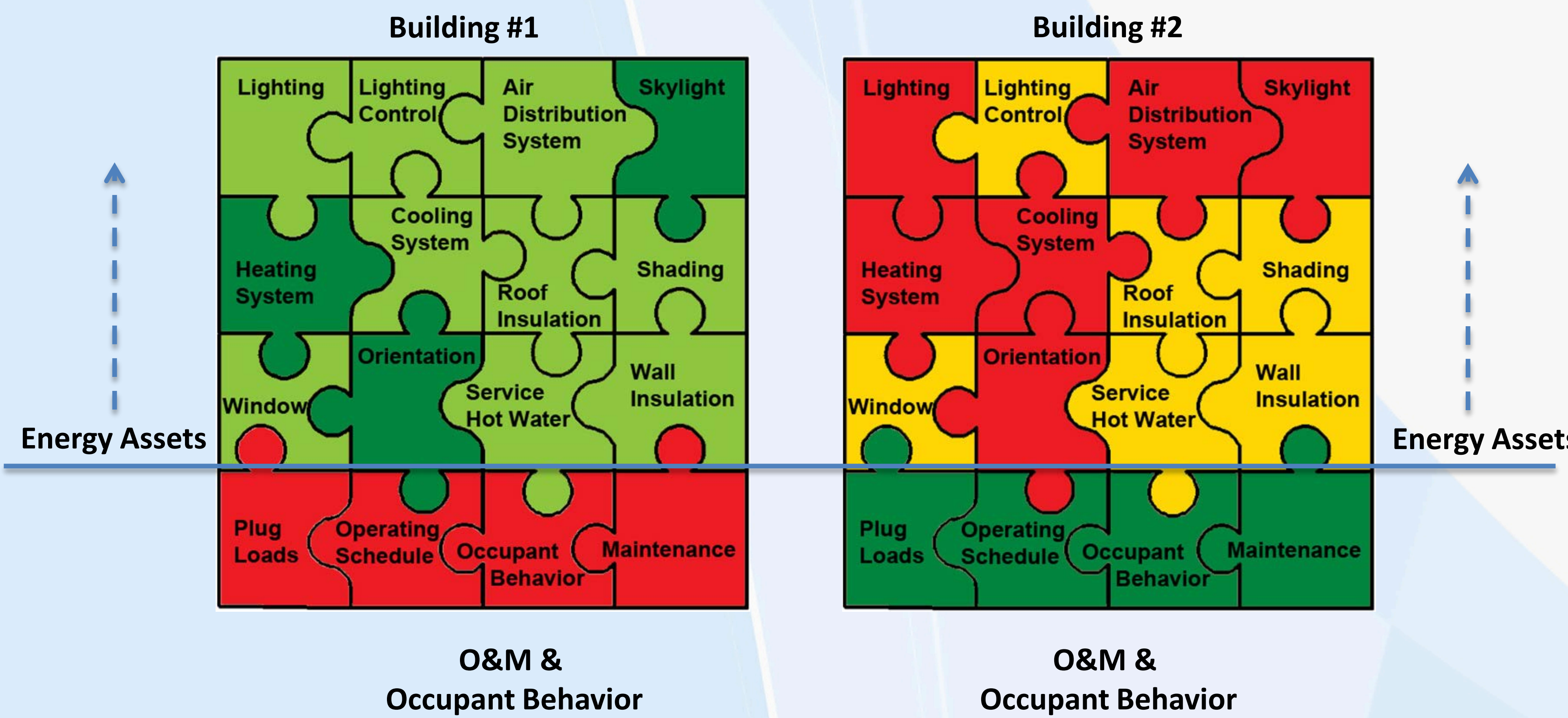
Step 1: Know Your Building's Energy Performance
ASHRAE Building Energy Quotient

Step 1: Know Your Building's Energy Performance
Commercial Building Energy Asset Score

- Benchmarking Systems 3: U.S. Department of Energy **Commercial Building Energy Asset Score**
  - Still being developed by the Building Technologies Office (BTO)
  - Uses a national standardized web-based modeling tool (EnergyPlus simulation engine) to obtain benchmark EUIs
  - Phase I and II provides a comparison for 11 building types
  - Scale 1 - 100 (higher number is better)
  - Exclude O&M and occupant behavior impact
  - No cost to users
  - http://www1.eere.energy.gov/buildings/commercial/assetscore.html

Step 1: Know Your Building's Energy Performance
Commercial Building Energy Asset Score

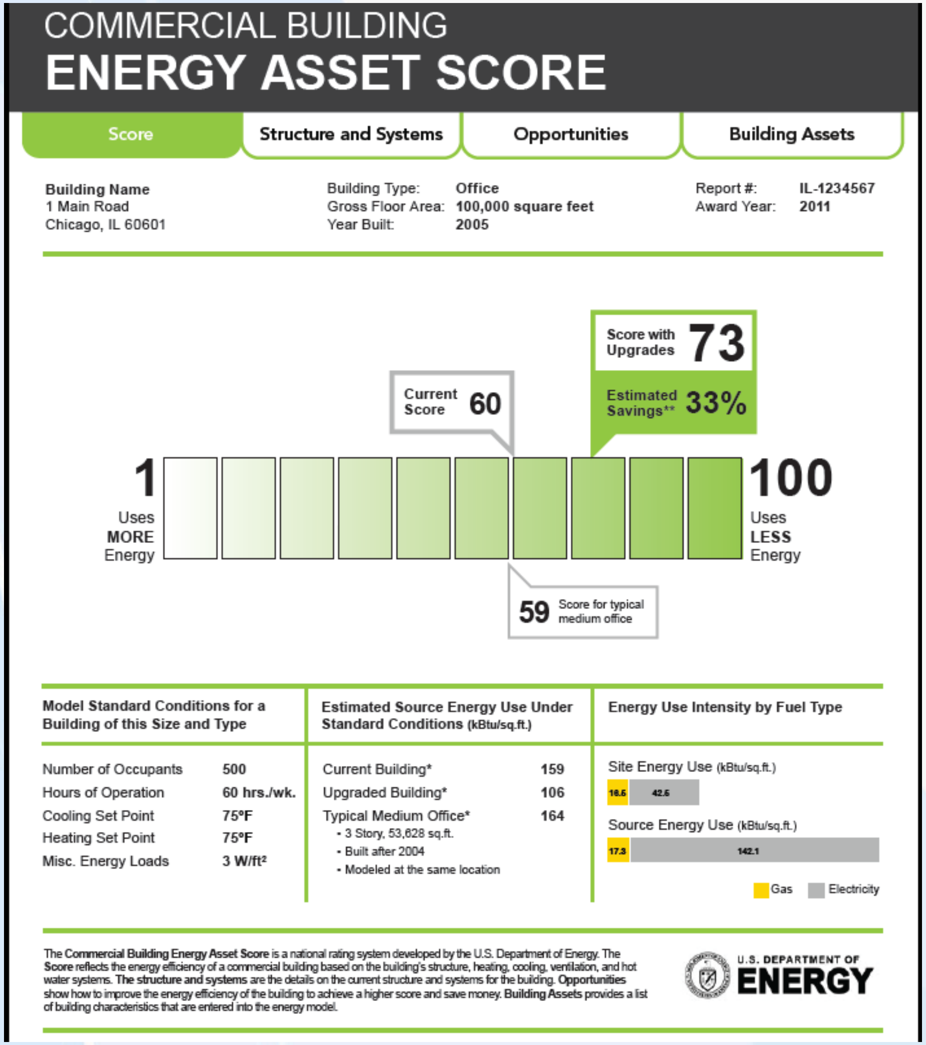
- Energy Assets vs. Building Energy Performance



Step 1: Know Your Building's Energy Performance
Commercial Building Energy Asset Score

Score:

Highlights a building’s as-built efficiency and its potential efficiency



Step 1: Know Your Building's Energy Performance Commercial Building Energy Asset Score

Structure and Systems:

Provides insight into the performance potential of individual energy systems

COMMERCIAL BUILDING
ENERGY ASSET SCORE

Score | **Structure and Systems** | Opportunities | Building Assets

Example Building 1 Main Road Chicago, IL 60601	Building Type: **Office** Gross Floor Area: **100,000 ft²** Year Built: **2005**	Report #: **IL-1234567** Score Date: **07/2011**

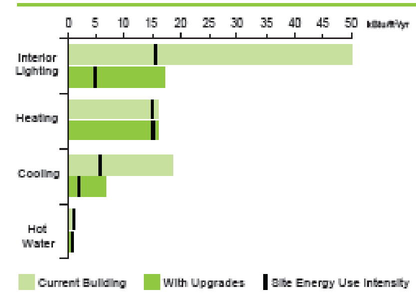
ABOUT THE BUILDING ENVELOPE

	Current Building	With Upgrades	Reference Value[1]	Ranking[2]	EEM Identified[3]
Roof U-Value (Btu/ft² h °F)	0.056	0.033	0.027 - 0.065	Good	✔
Floor U-Value (Btu/ft² h °F)	0.052	—	0.033 - 0.087	Good	
Walls U-Value (Btu/ft² h °F)	0.077*	—	0.064 - 0.123	Good	
Windows U-Value (Btu/ft² h °F)	0.68	0.30	0.35 - 0.67	Fair	✔
Walls + Windows U-Value (Btu/ft² h °F)	0.38	0.19	0.13 - 0.29	Fair	
Window Solar Heat Gain Coefficient	0.60	—	0.40 - 0.49	Fair	

ABOUT THE BUILDING SYSTEMS

	Current Building	With Upgrades	Reference Value	Ranking	EEM Identified
Interior Lighting[4] (kBtu/ft²)	50.40	30.00	21.99 - 38.74	Fair	✔
Heating[5]	0.32	—	0.11 - 0.18	Superior	
Cooling[5]	0.50*	1.10	0.46 - 1.32	Good	✔
Overall HVAC Systems[5]	0.46	0.80	0.31 - 0.97	Good	
Hot Water[5]	0.65	0.71	0.70 - 0.76	Fair	✔

SOURCE ENERGY USE INTENSITY BY END USE



	Current Building (kBtu/ft²/yr)		With Upgrades (kBtu/ft²/yr)	
	Source	Site	Source	Site
Interior Lighting	50.4	15.1	16.7	5.0
Heating	15.7	15.0	15.7	15.0
Cooling	18.7	5.6	6.7	2.0
Hot Water	1.6	1.5	1.0	1.0

Step 1: Know Your Building's Energy Performance Commercial Building Energy Asset Score

Opportunities

Identifies short-term and long-term capital investment opportunities

COMMERCIAL BUILDING
ENERGY ASSET SCORE

Score | Structure and Systems | **Opportunities** | Building Assets

Example Building
1 Main Road
Chicago, IL 60601

Building Type: **Office**
Gross Floor Area: **100,000 ft²**
Year Built: **2005**

Report #: **IL-1234567**
Score Date: **07/2011**

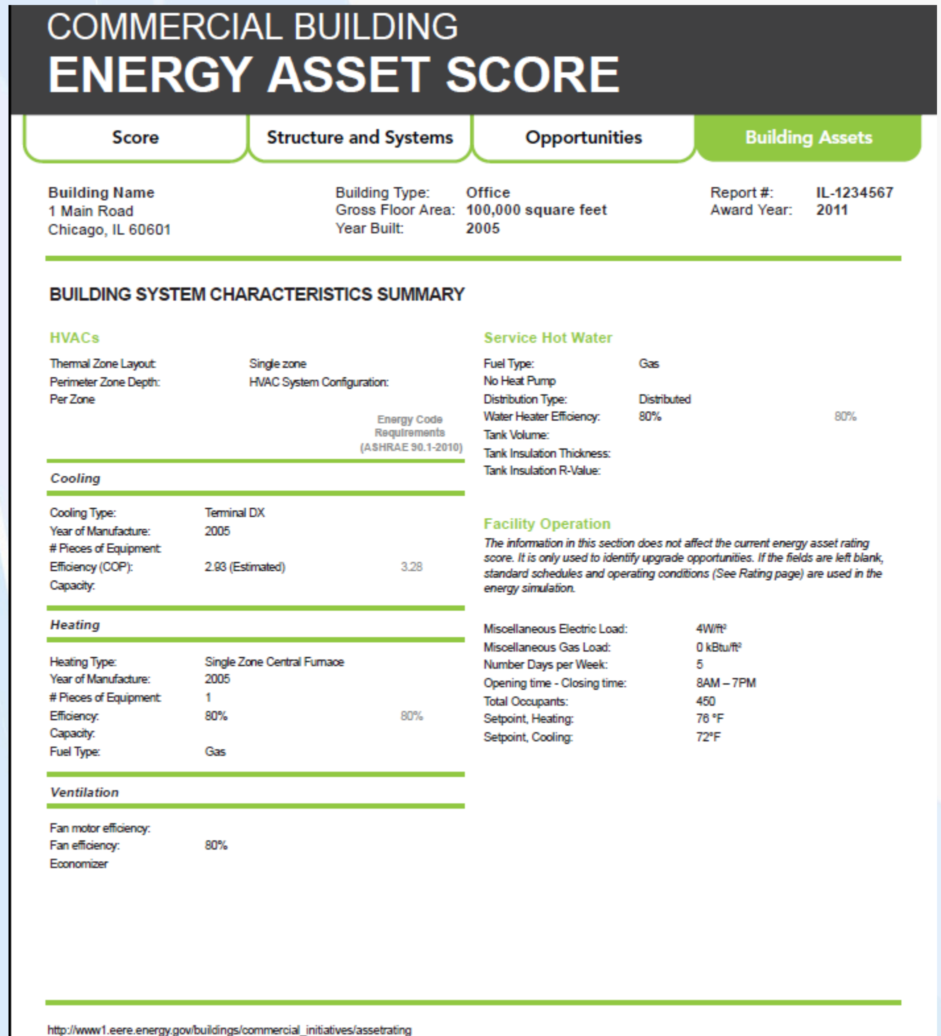
COST EFFECTIVE UPGRADE OPPORTUNITIES[1]

	Energy Savings[2]	Payback
Building Envelope		
• Add Roof Insulation in "Example Building"	5 - 10%	15 - 25 yrs
• Upgrade Windows in "Example Building" with High Performance Double Pane Windows	5 - 10%	10 - 15 yrs
Interior Lighting		
• Upgrade T8 Fluorescent Lighting in "Example Building" to High Efficacy T8 Fluorescent Lighting	10 - 15%	1.5 - 5 yrs
HVAC Systems		
• Upgrade Cooling System in "Example Building" with High Efficiency Terminal Electric DX	10 -15%	5 - 10 yrs
Hot Water Systems		
• Upgrade Service Hot Water System in "Example Building" with Improved System Efficiency	0 - 5%	< 1.5 yrs

Step 1: Know Your Building's Energy Performance
Commercial Building Energy Asset Score

Building Assets:

Describes the inputs used to generate the score and report



COMMERCIAL BUILDING
ENERGY ASSET SCORE

Score | Structure and Systems | Opportunities | **Building Assets**

Building Name
1 Main Road
Chicago, IL 60601

Building Type: Office
Gross Floor Area: 100,000 square feet
Year Built: 2005

Report #: IL-1234567
Award Year: 2011

BUILDING SYSTEM CHARACTERISTICS SUMMARY

HVACs

Thermal Zone Layout: Single zone
Perimeter Zone Depth: HVAC System Configuration:
Per Zone

Energy Code Requirements (ASHRAE 90.1-2010)

Cooling

Cooling Type:	Terminal DX	
Year of Manufacture:	2005	
# Pieces of Equipment:		
Efficiency (COP):	2.93 (Estimated)	3.28
Capacity:		

Heating

Heating Type:	Single Zone Central Furnace	
Year of Manufacture:	2005	
# Pieces of Equipment:	1	
Efficiency:	80%	80%
Capacity:		
Fuel Type:	Gas	

Ventilation

Fan motor efficiency:	
Fan efficiency:	80%
Economizer	

Service Hot Water

Fuel Type:	Gas	
No Heat Pump		
Distribution Type:	Distributed	
Water Heater Efficiency:	80%	80%
Tank Volume:		
Tank Insulation Thickness:		
Tank Insulation R-Value:		

Facility Operation

The information in this section does not affect the current energy asset rating score. It is only used to identify upgrade opportunities. If the fields are left blank, standard schedules and operating conditions (See Rating page) are used in the energy simulation.

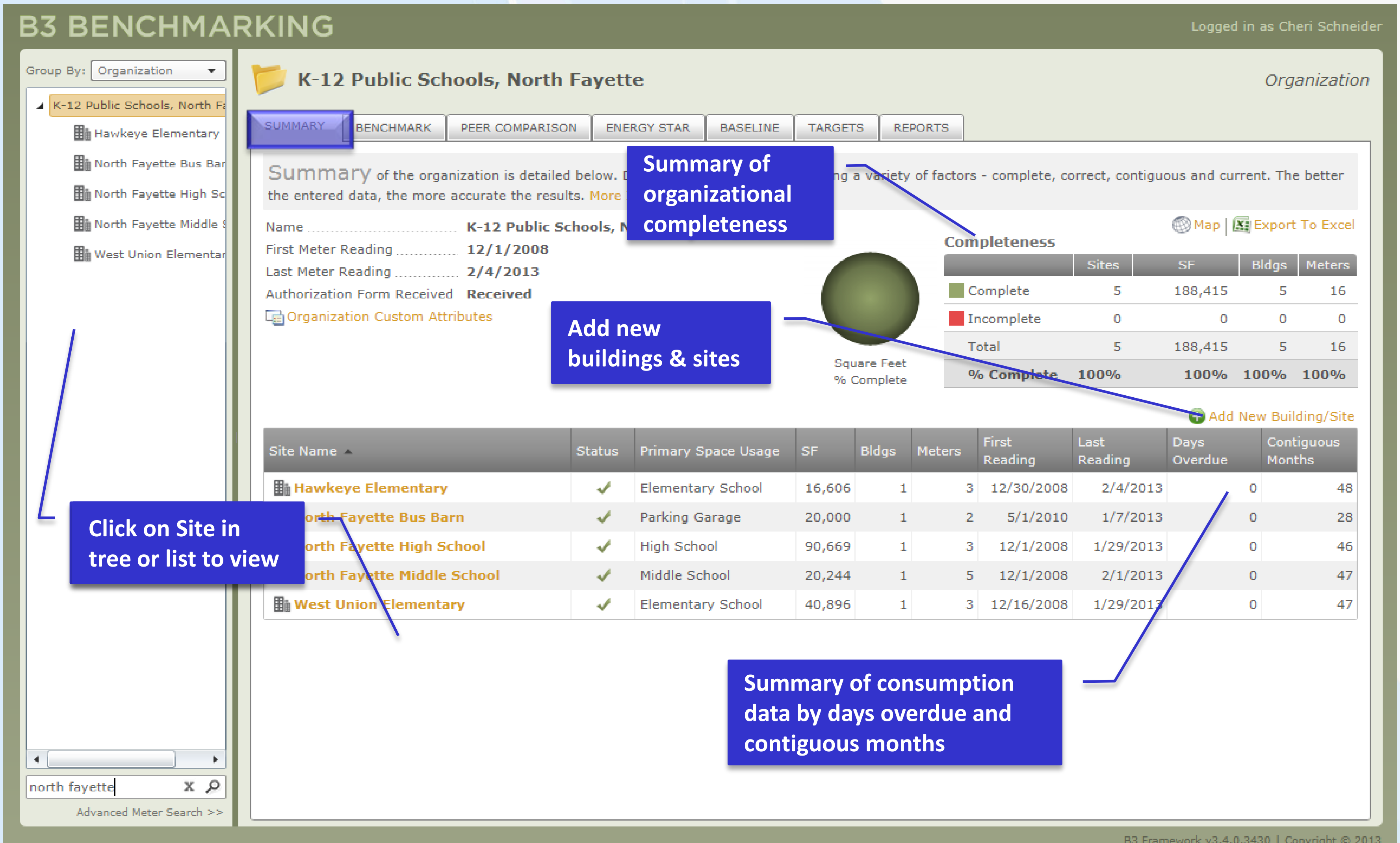
Miscellaneous Electric Load:	4W/ft²
Miscellaneous Gas Load:	0 kBtu/ft²
Number Days per Week:	5
Opening time - Closing time:	8AM – 7PM
Total Occupants:	450
Setpoint, Heating:	76 °F
Setpoint, Cooling:	72°F

http://www1.eere.energy.gov/buildings/commercial_initiatives/assetrating

Step 1: Know Your Building's Energy Performance
Iowa Public Building Benchmarking System

- Benchmarking Systems 4: **Iowa Public Building Benchmarking System**
  - Web-based platform by the Weidt Group, uses DOE2 simulation engine to obtain benchmark EUIs based on 2009 IECC (current Iowa Building Energy Code)
  - For Iowa public buildings (now have 1200+ buildings)
  - Also includes Energy Star rating (if applicable) and peer rating
  - Currently recruiting up to 800 new buildings
  - Free for phase 1 and phase 2 project participants
  - http://www.iowaenergycenter.org/; https://ia.b3benchmarking.com/

Step 1: Know Your Building's Energy Performance
Iowa Public Building Benchmarking System



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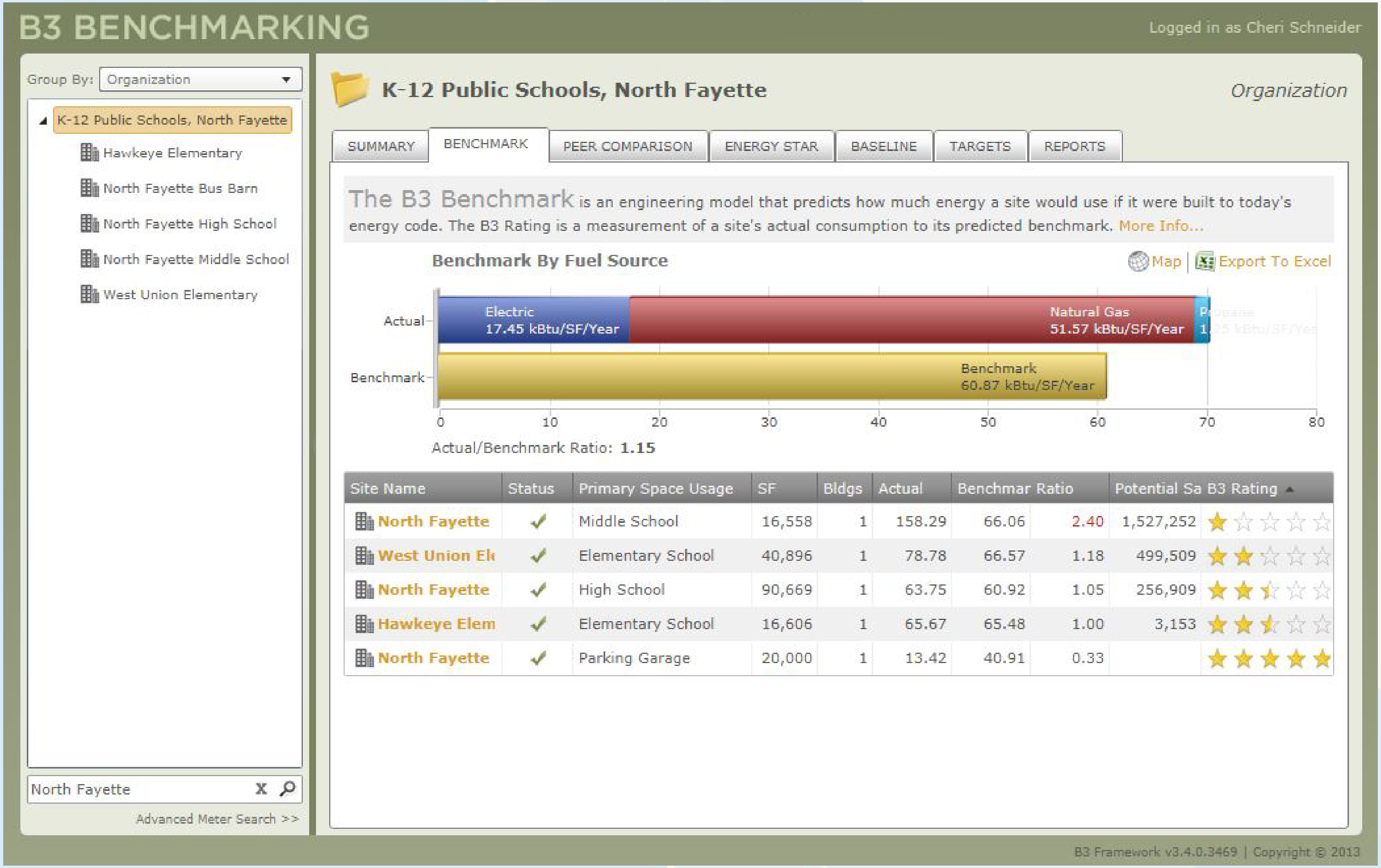

Site Name	Status	Primary Space Usage	SF	Bldgs	Actual	Benchmar	Ratio	Potential Sa	B3 Rating
North Fayette	✓	Middle School	16,558	1	158.29	66.06	2.40	1,527,252	★☆☆☆☆
West Union El	✓	Elementary School	40,896	1	78.78	66.57	1.18	499,509	★★☆☆☆
North Fayette	✓	High School	90,669	1	63.75	60.92	1.05	256,909	★★½☆☆
Hawkeye Elem	✓	Elementary School	16,606	1	65.67	65.48	1.00	3,153	★★½☆☆
North Fayette	✓	Parking Garage	20,000	1	13.42	40.91	0.33		★★★★★

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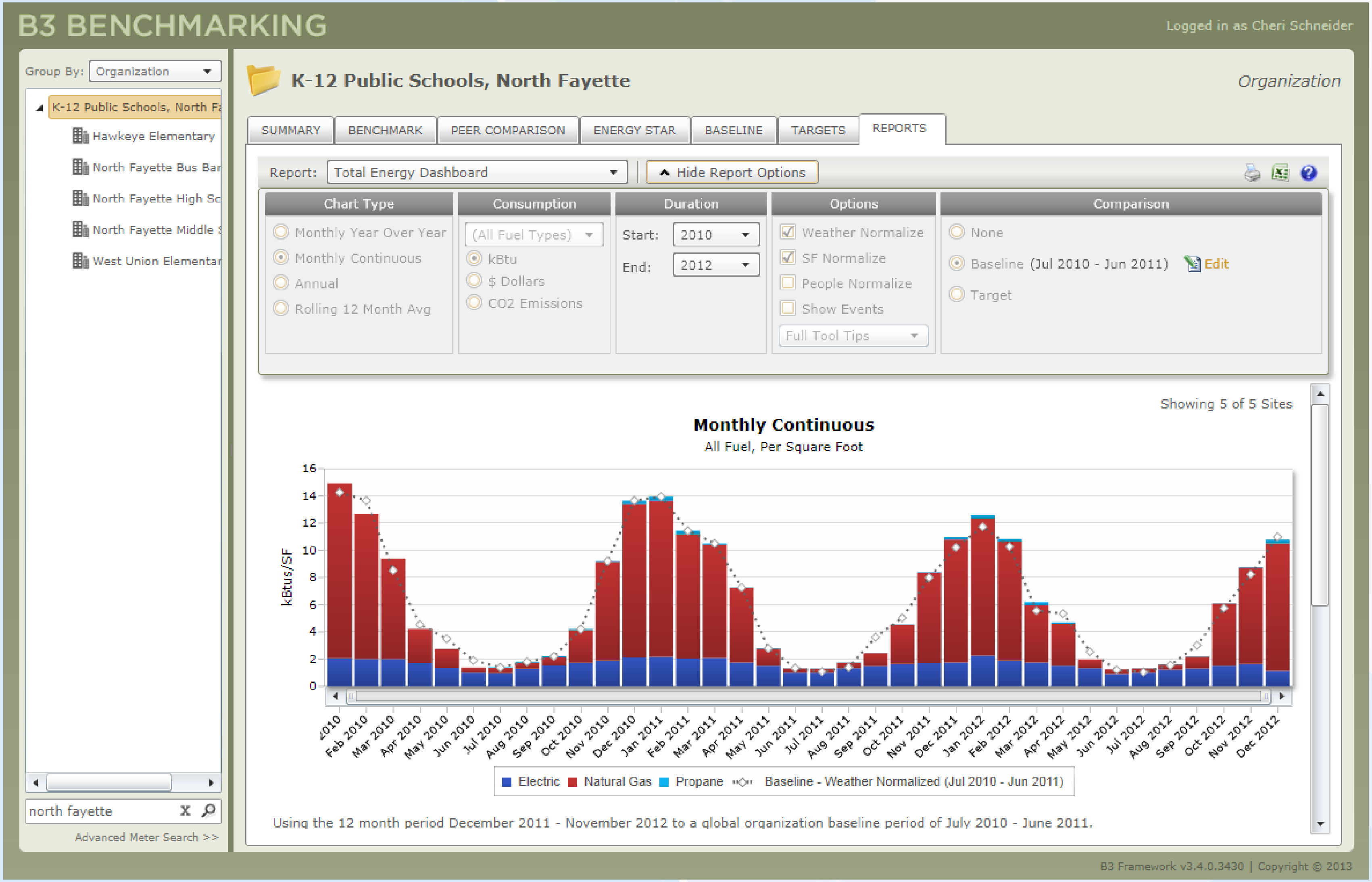

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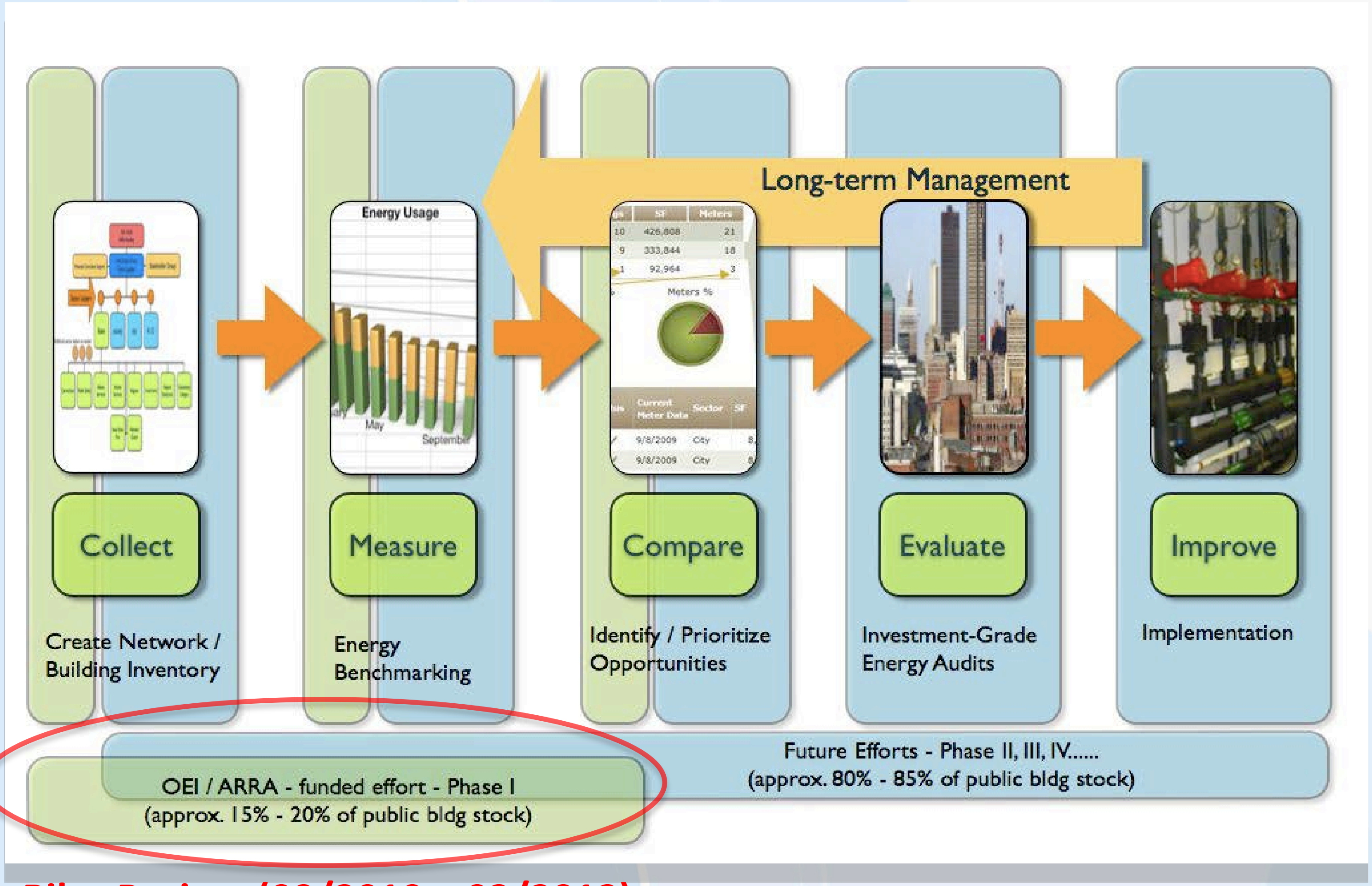
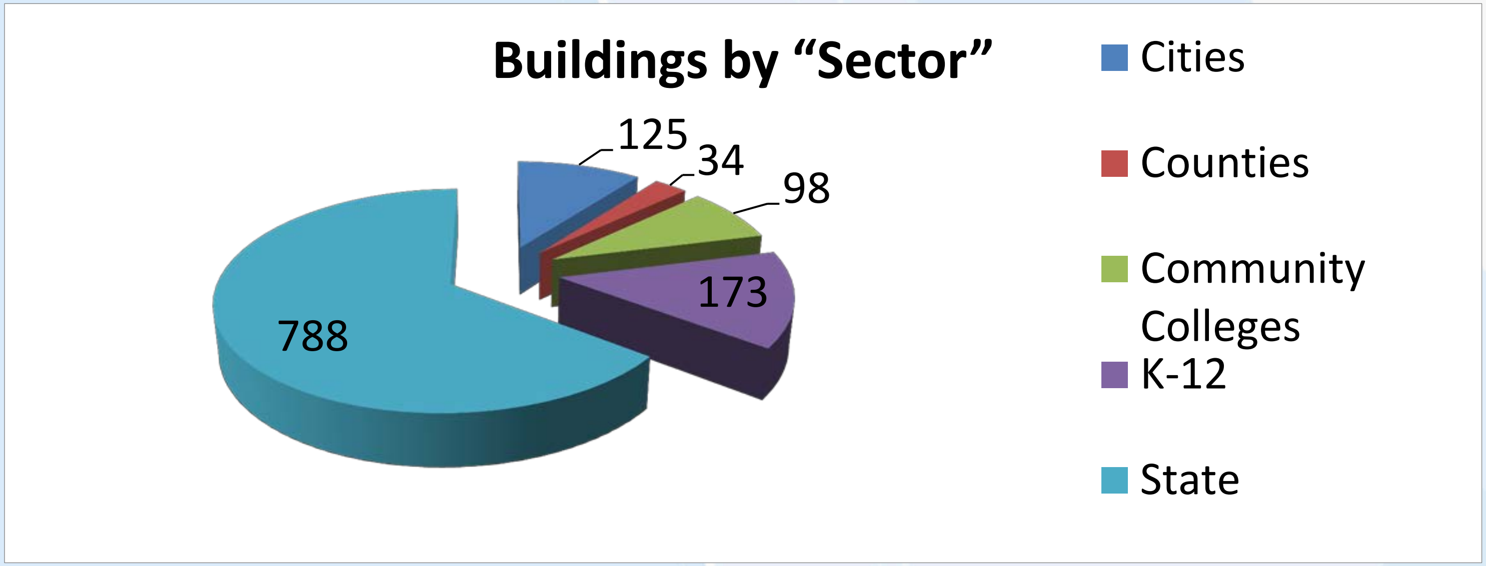


Pilot Project (09/2010 ~ 03/2012)

Step 1: Know Your Building's Energy Performance Iowa Public Building Benchmarking System

- Phase 1: Pilot Project
  - 53 organizations
  - 49 utilities (IOUs, Municipal Utilities, RECs, etc.)
  - 1,218 buildings (original goal: 1,000 buildings)



Step 1: Know Your Building's Energy Performance Iowa Public Building Benchmarking System

- Phase 1:

Sector	Floor Area (SF)	Number of Sites	Number of Buildings	Average Benchmarking Ratio*
City	3053750	123	125	**1.81**
Community Colleges	2457257	52	98	**0.82**
County	706447	32	34	**1.59**
K-12 Public Schools	12682273	183	173	**0.9**
State	13710149	239	788	**1.44**
Total	32609876	629	1218	**1.32**

*Benchmarking Ratios of 1 or less are buildings closest to meeting code
*Benchmarking Ratios of 1 or more have more opportunity to make energy efficiency improvements

Step 1: Know Your Building's Energy Performance Iowa Public Building Benchmarking System

- Phase 2: Integrating Benchmarking into EE Process
  - Project timeline: 1/15/2013 ~ 09/31/2014
  - Establish a model to integrate benchmarking platform into building energy efficiency improvement process
  - Add additional 800 buildings
  - Select 5 “showcase” buildings with 20% energy savings potential as case studies and monitor results using the platform
  - Automate data import from major utilities
  - B3 system function enhancement

Step 2: Analyze Opportunities

- Your Building Needs Improvement, Where To Start?
- Setting Goals
  - 10%, 20%, or 30% compared with historical EUI?
  - LEED for existing buildings? (O&M certification requires a minimum of 69 on ENERGY STAR rating)
  - Benchmarking ratio below 1.0?
- Needs Strong Management Support

Step 2: Analyze Opportunities

- Analyze How and Where Did Energy Go - Prioritize
  - Sub-Metering
  - Energy Audits
    - Level 1: Walk-through analysis
    - Level 2: Energy survey and analysis
    - Level 3: Detailed analysis of capital-intensive modifications
    - Utility programs – no cost or low-cost for qualified customers

Step 2: Analyze Opportunities
Sub-Metering

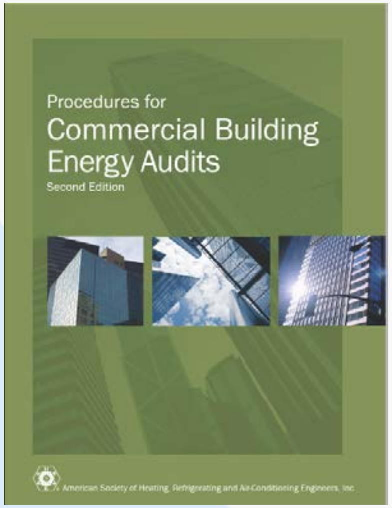
- Sub-Metering
  - Install a separate meter in each building in a campus environment, or install a separate meter in each sub-system in a building
  - Benefits: business perspective and engineering perspective
  - Barriers: current offerings not cost-effective, more features than needed or low cost but not robust

DOE’s “Submeter Challenge”

- Challenge manufactures of electric meters to develop low-cost panel-level wireless electric meters. Target price: $150/meter
- Program will launch in May, 2013

Step 2: Analyze Opportunities
Energy Audit

- Energy Audit
  - No national standard. Different companies have their own procedures
  - ASHRAE recommended procedure published in 2011
  - DOE Advanced Energy Retrofit Guide



http://www1.eere.energy.gov/buildings/commercial/aerg.html

ASHRAR Standard Project Committee SPC 211P was created in 2012 to write the first “Standard for Commercial Building Energy Audits”

Step 2: Analyze Opportunities Energy Audit

- Energy Audit – Level 1, 2, 3 Process Comparisons

Process	Level 1	Level 2	level 3
Conduct PEA	*	*	*
Conduct walk-through survey	*	*	*
Identify low-cost/no-cost recommendations	*	*	*
Identify capital improvements	*	*	*
Review ME design and condition and O&M		*	*
Measure key parameters		*	*
Analyze capital measures		*	*
Meet with owner/operators to review recommendations		*	*
Conduct additional testing monitoring			*
Peform detailed system modeling			*
Provide schematic layouts for recommendations			*

Step 2: Analyze Opportunities
Energy Audit

- Energy Audit – Level 1, 2, 3 Report Comparisons

Report	Level 1	Level 2	level 3
Estimate savings from utility rate change	*	*	*
Compare EUI to EUIs of similar sites	*	*	*
Summarize utility data	*	*	*
Estimate savings if EUI were to meet target	*	*	*
Estimate low-cost/no-cost savings		*	*
Calculate detailed end-use breakdown		*	*
Estimate capital project costs and savings		*	*
Complete building description and equipment inventory		*	*
Document general description of considered measures		*	*
Recommend measurement and verification (M&V) method		*	*
Perfrom financial analysis of recommended EEMs		*	*
Write detailed description of recommended measures			*
Compile detailed EEM cost estimates			*

Step 2: Analyze Opportunities Energy Audit

- An Energy Audit Level 2 Example

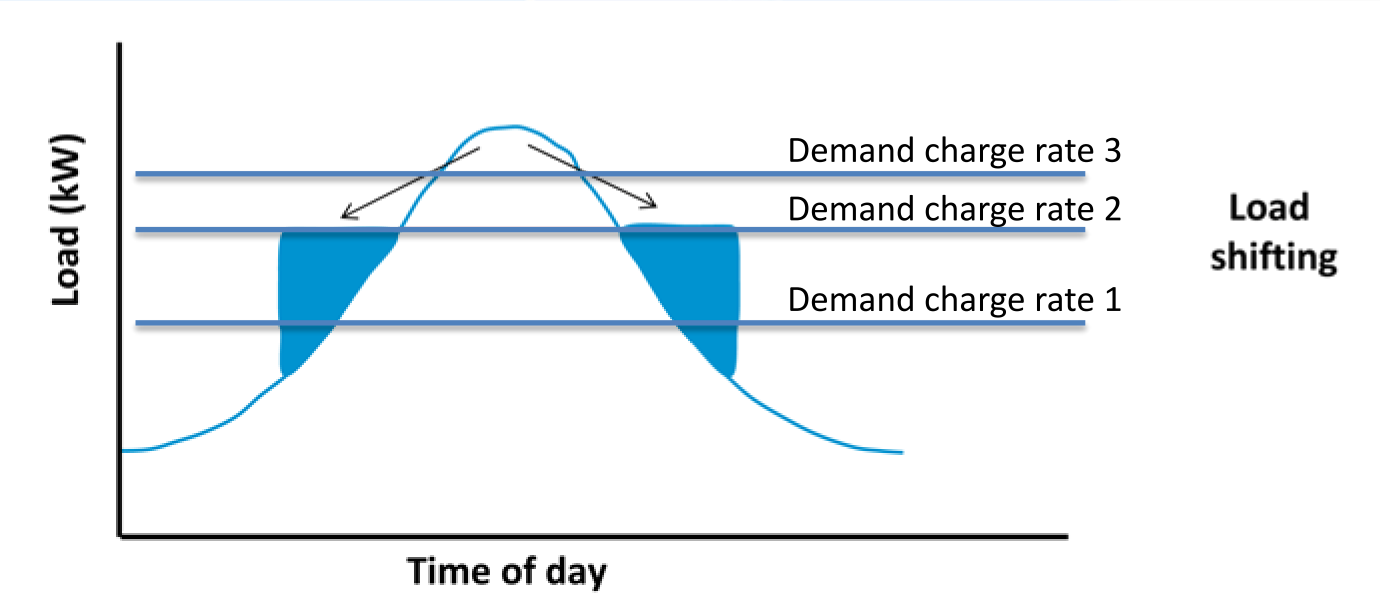
Table of Contents

Step 3: Building Energy Improvement Options
Plug Loads

- Plug Loads Control – Low Cost
  - Check your building's phantom loads
  - Apply power management software: put equipment in sleep mode
  - Use energy misers: vending miser, cooler miser, snack miser, plug miser, etc.
  - Invest in training and education for operators and occupants – change occupant behavior
  - Establish purchasing criteria: Energy Star-labeled appliance/equipment, CFL, LED, etc.

Step 3: Building Energy Improvement Options Load Shifting and Peak Load Reduction

- Load Shifting and Peak Load Reduction
  - Utility energy charge (kWh) & demand charge (kW)



Step 3: Building Energy Improvement Options Load Shifting and Peak Load Reduction

- Options:
  - Change working shift, hours
  - Utilize buildings' thermal mass to pre-cool the building using "free cooling" at night
  - Use ice/thermal storage, stratified chilled water storage
  - Install solar panels/arrays

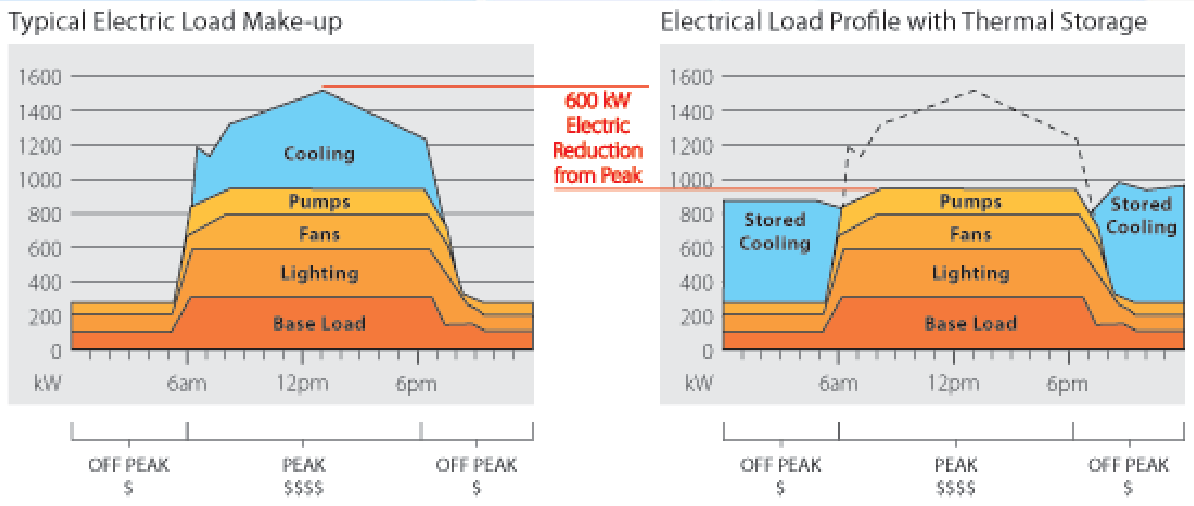


*image from http://www.trane.com

Step 3: Building Energy Improvement Options
Faults and Degradations

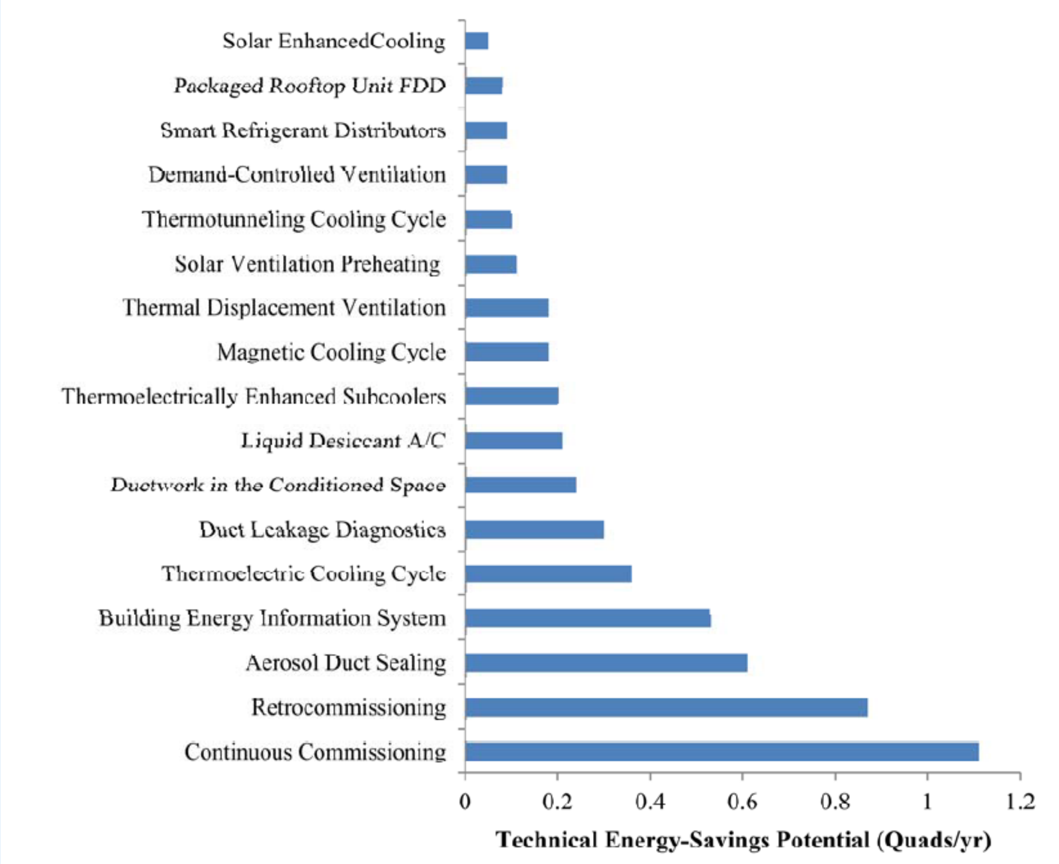
- Why Buildings Are Not Energy Efficient: Faults & Degradation

	National Energy Waste (Quads, primary/year)	Electricity equivalent (BkWh/year)	Cost ($billion/year)
Duct leakage	0.3	28.6	2.9
HVAC left on when space unoccupied	0.2	19.0	1.9
Lights left on when space unoccupied	0.18	17.1	1.7
Airflow not balanced	0.07	6.7	0.7
Improper refrigerant charge	0.07	6.7	0.7
Dampers not working properly	0.055	5.2	0.5
Insufficient evaporator airflow	0.035	3.3	0.3
Improper controls setup / commissioning	0.023	2.2	0.2
Control component failure or degradation	0.023	2.2	0.2
Software programming errors	0.012	1.1	0.1
Improper controls hardware installation	0.01	1.0	0.1
Air-cooled condenser fouling	0.008	0.8	0.1
Valve leakage	0.007	0.7	0.1
Total (central estimate)	1.0	94.6	9.6
Total (range)	0.34-1.8	32.4-171.4	3.3-17.3

Adapted from Roth et al. (2005) assuming 10,500 BTU/kWh, and $0.10/kWh

Step 3: Building Energy Improvement Options
Top 17 HVAC Technologies

- DOE Top 17 HVAC Technologies' Energy Savings Potential



*Goetzler, et al., 2011, Energy Savings Potential and RD&D Opportunities for Commercial Building HVAC Systems

Step 3: Building Energy Improvement Options
Improve Building Operations and Controls

- Improve Building Operations and Controls – No Cost/Low-Cost
  - Reduce HVAC equipment's occupancy hours
  - Reduce lighting hours, use day lighting, or use occupancy sensors
  - Replace/repair/calibrate sensors
  - Use a programmable thermostat
  - Relocate/shield temperature sensors
  - Use economizer
  - Use duct static pressure reset
  - Use supply air temperature reset

Step 3: Building Energy Improvement Options
Improve Building Operations and Controls

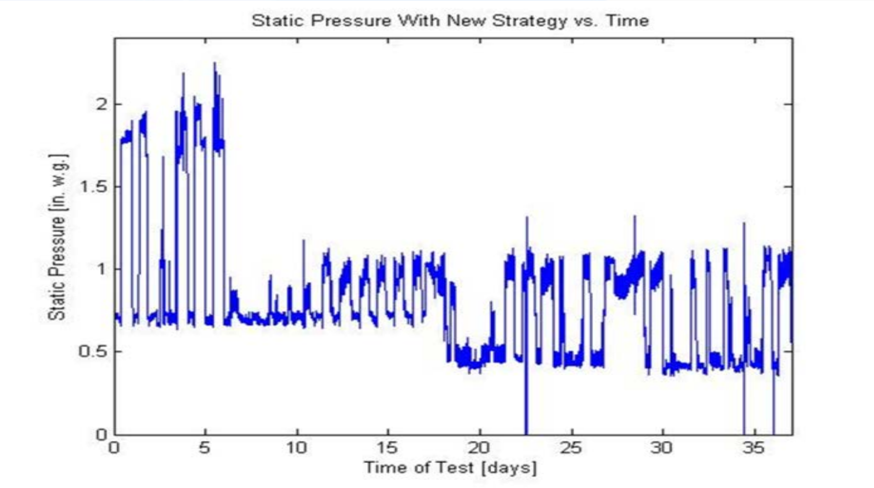
- Use demand-controlled ventilation (DCV)
- Chilled water supply temperature reset
- Optimal start/stop
- Tune HVAC control – check the thermostat schedule!
- Check minimum damper position
- Automated fault detection and diagnostics

Step 3: Building Energy Improvement Options
Improve Building Operations and Controls

AHU Supply Duct Static Pressure Reset Strategy

- Trim & Respond and PI control methods
- Often unstable so operators disable it
- Iowa Energy Center sponsored research developed an “Tiered” Trim & Respond method

TR Strategy Parameter Test Values				
	H	L	Trim	Respond
1	98	87	-0.01	0.01
2	95	84	-0.02	0.02
3	92	81	-0.03	0.03



*Report available at www.iowaenergycenter.org

Step 3: Building Energy Improvement Options
Improve Building Operations and Controls

Iowa State University Hixson-Lied Student Success Center

✓ Using improved <u>duct static pressure reset strategy</u>, saved ~37% of fan energy in 3 month's field testing in this 40,528 sq. ft building; ~$3839 / year .

*Report available at www.iowaenergycenter.org

Step 3: Building Energy Improvement Options
Lighting Retrofit

- Lighting Retrofit
  - Use occupancy sensors
  - Use day lighting, photo cells, and dimming controls
  - Replace with new energy efficient lighting
  - Compact Fluorescent (CFL)
  - Light-emitting Diode (LED)
  - Fluorescent T8 or T5
  - Use external/internal shading devices

While a modern office can be lit using <1W/sq. ft., most still use about 1.5~2W/sq. ft.

Step 3: Building Energy Improvement Options Lighting Retrofit

DOE is focusing on Solid State Lighting (SSL) technology development and demonstration

- CALiPER Program - Commercially Available LED Product Evaluation and Reporting (over 200 products tested): http://www1.eere.energy.gov/buildings/ssl/caliper.html
- L-Prize competition: spur development of ultra-efficient solid-state lighting products to replace common lighting products.
  - 60W Incandescent: LED light bulb has achieved 93.4 lm/W with 25,000 hour life (Winner: Philips)
  - PAR38 Halogen: requires > 123 lm/W

Step 3: Building Energy Improvement Options
Lighting Retrofit

Cedar Rapids Hy-Vee Parking Lot LED Lighting Study

Replacing 1000w Metal Halide with 309w LED

*Report is available at www.iowaenergycenter.org

Step 3: Building Energy Improvement Options
Lighting Retrofit

Cedar Rapids Hy-Vee Parking Lot LED Lighting Study

Replacing 1000w Metal Halide with 309w LED

	Existing Lighting	Designed New Lighting
Model#	QVD499-5 (Ruud Lighting)	VTS-A12-LED-E1-T3-BZ (Cooper Lighting)
Fixture Type	Metal Halide	LED
Distribution	Type 5	Type 3
Nominal Power	1000 Watt	309 Watt
Initial Lumens	11,000 Lumens	20,664 Lumens
Lumens/Watt	11.0 Lumens/Watt	66.9 Lumens/Watt
Lamp Life	12,000 Hours	50,000 Hours
Color Temperature	4000 Kelvin	4000 Kelvin

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Step 3: Building Energy Improvement Options
Lighting Retrofit

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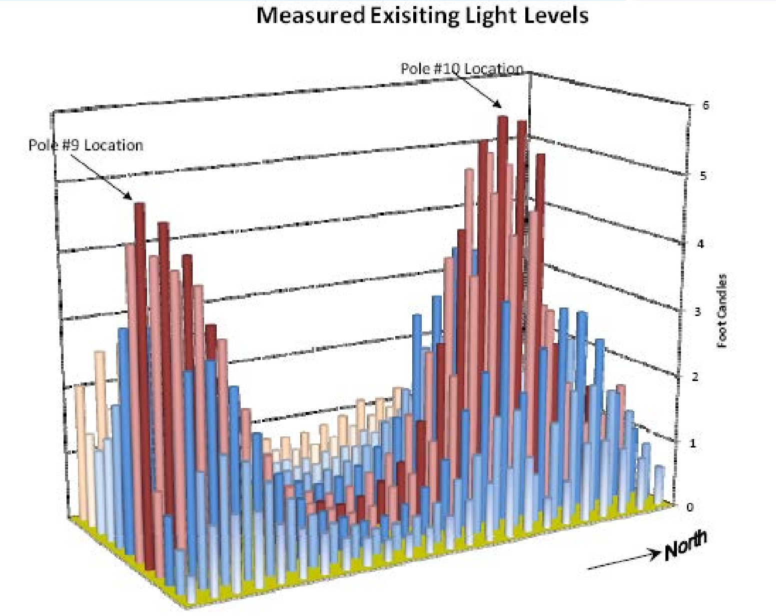

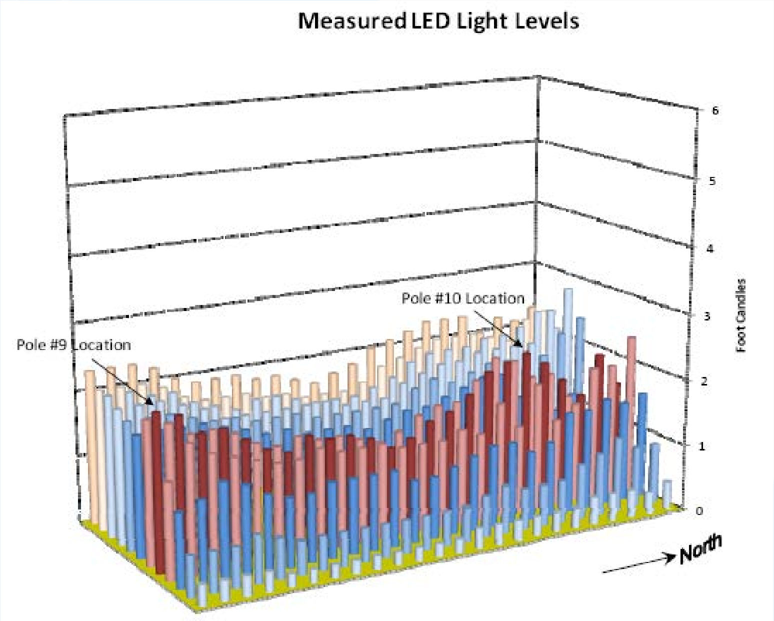

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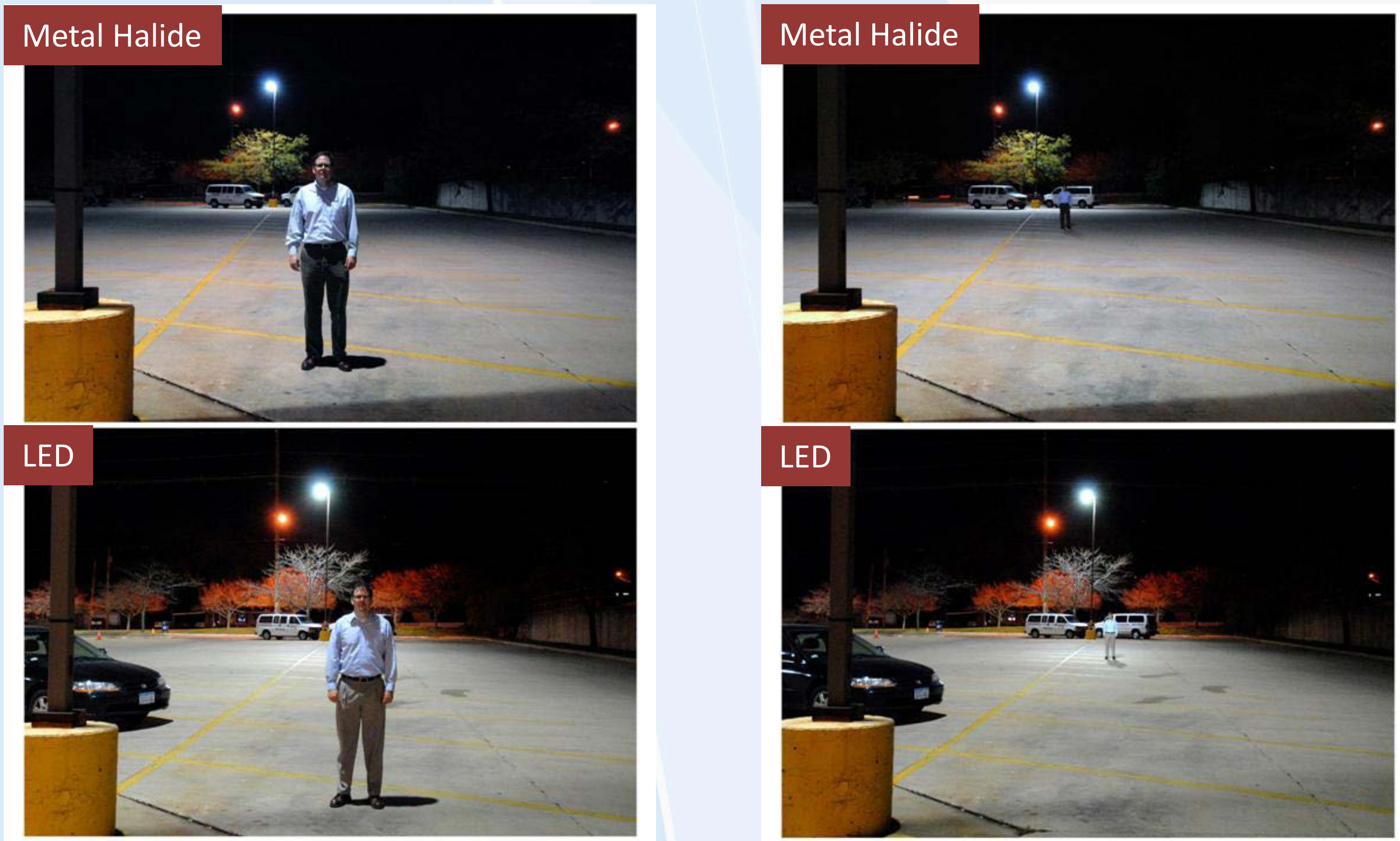
Lighting Retrofit



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Lighting Retrofit

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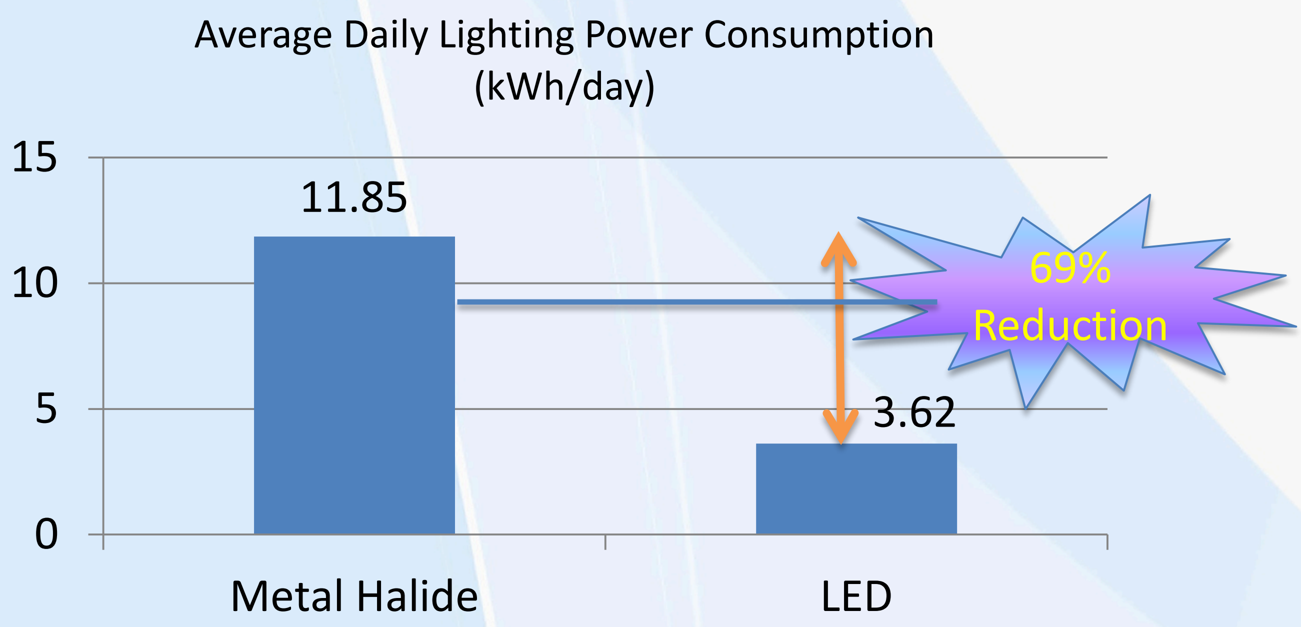

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Step 3: Building Energy Improvement Options
Lighting Retrofit

Lighting Energy Efficiency in Parking (LEEP) Campaign

- www.leepcampaign.org for information and case studies

Step 3: Building Energy Improvement Options
Fix Building Envelop

- Fix Building Envelope Problems
  - Increase insulation and make sure it is installed correctly (roof, wall, etc.)
  - Find and fix air leaks – thermal imaging tools
  - Upgrade windows
    - At a minimum, use double-pane windows
    - High efficiency low-e window
    - Electro-chromic and thermo-chromic windows
  - Window-to-Wall ratio should be < 35%

Step 3: Building Energy Improvement Options
Fix Building Envelop

Insulation Material	Type	R-Value (per inch)
Fiberglass Batt	Blanket	3.2 – 4.3
Cellulose	Blown or Sprayed	3.1 – 3.5
Expanded Polystyrene	Bead Board	3.8 – 4.4
Extruded Polystyrene	Blue/Pink Board	5.0
Polyisocyanurate	Foil Face Board	7.0
Low Density Polyurethane	Spray Foam (Icynene)	3.6
High Density Polyurethane	Spray Foam	6.2 – 7.7

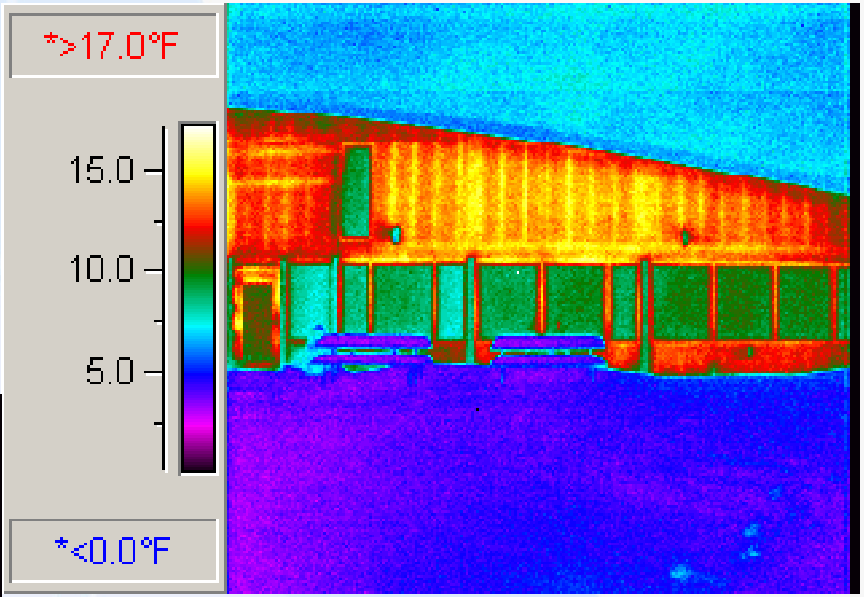
Step 3: Building Energy Improvement Options
Fix Building Envelop

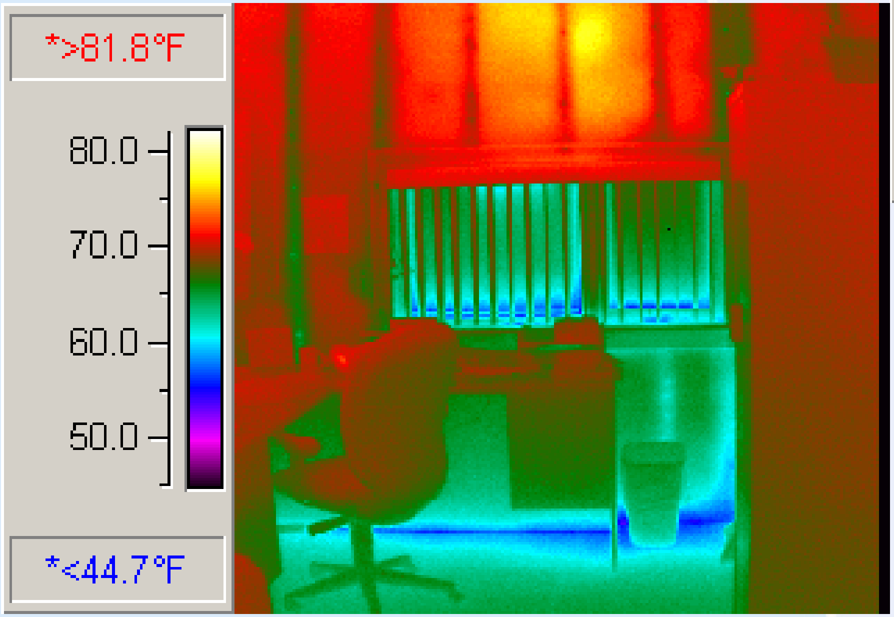
DOE is sponsoring a project to develop Aerogel Impregnated polyurethane pipe and duct insulation (InnoSense, LLC)

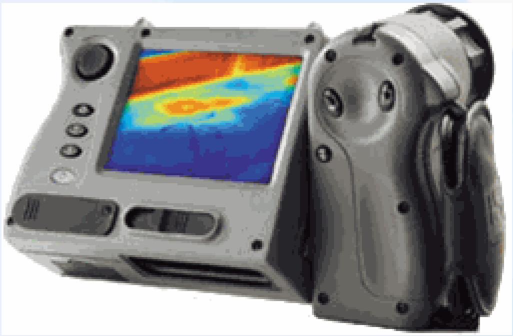
- Aerogel-based insulation (InsuGel)
- Adhere to housing duct work/pipe structures
- Improve R value 30% to about 10/inch

Step 3: Building Energy Improvement Options
Fix Building Envelop

Thermal Bridging







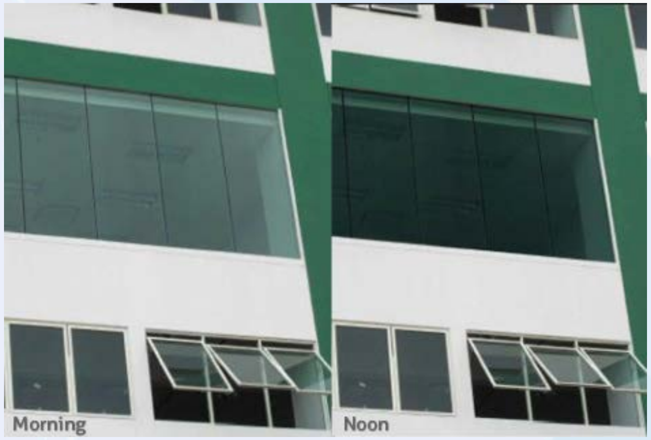
Step 3: Building Energy Improvement Options
Fix Building Envelop

- High Performance Window Rating Factors
  - U – Value (Btu/hr-ft^2-^{o}F)
  - Solar Heat Gain Coefficient (0~1)
  - Visible Transmittance (0~1)
  - Air Leakage (cfm/ft^2)
  - National Fenestration Rating Council (NFRC) Label

Step 3: Building Energy Improvement Options
Fix Building Envelop

Smart Windows: Electrochromic, thermalchromic, and photochromic windows

- Changing window’s thermal property and light transmittance based on small voltage, temperature, or light intensity
- Some products are commercially available, more in research and development stage



Step 3: Building Energy Improvement Options HVAC System and Equipment Upgrade

- Upgrade HVAC System and/or Replace Old HVAC Equipment
  - Any RTUs, electric boilers, or control systems that are older than 10~15 years
  - Chillers, pumps, fans, boilers, motors older than 15~20 years
  - Pneumatic control system of any age
  - Consider adding Energy Recovery Unit (ERU)
  - Inefficient air conditioners, heat pumps, furnaces, boilers
  - Upgrade to high efficiency fans and motors controlled with variable frequency drives (VFD)
  - Convert constant-air-volume (CAV) system to variable-air-volume (VAV) system

Step 3: Building Energy Improvement Options HVAC System and Equipment Upgrade

- Change central domestic hot water systems to point-of-use water heaters; upgrade to high efficiency water heaters
- Many other options depending on the project
- Residential equipment
  - Natural gas furnace, boilers, water heaters
  - Air conditioners
  - Heat pumps
  - Appliances
  - Washers
  - Programmable thermostat

Step 3: Building Energy Improvement Options HVAC System and Equipment Upgrade

DOE's high efficiency equipment challenge

- Sandia National Laboratory: new cooler technology - 30x heat transfer improvement http://www.youtube.com/watch?v=JWQZNXEKkaU
  - A fundamentally new approach to air-cooled heat exchangers
  - Potential to decrease overall electrical power consumption in the U.S. by more than 7 percent, if can scaled up to HVAC applications

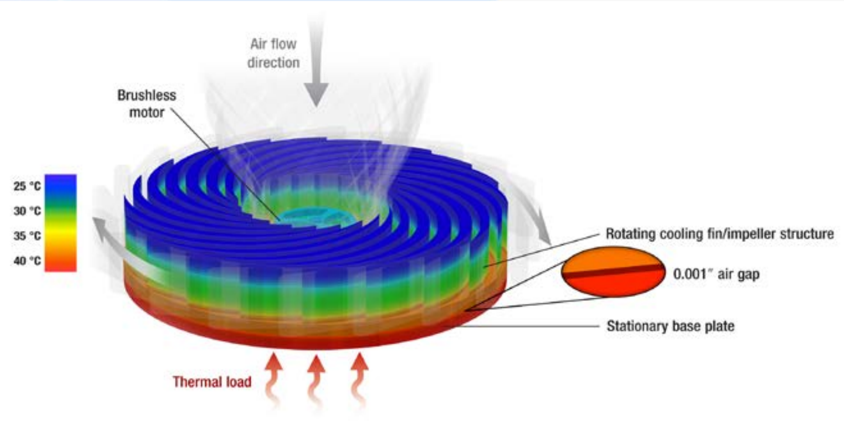
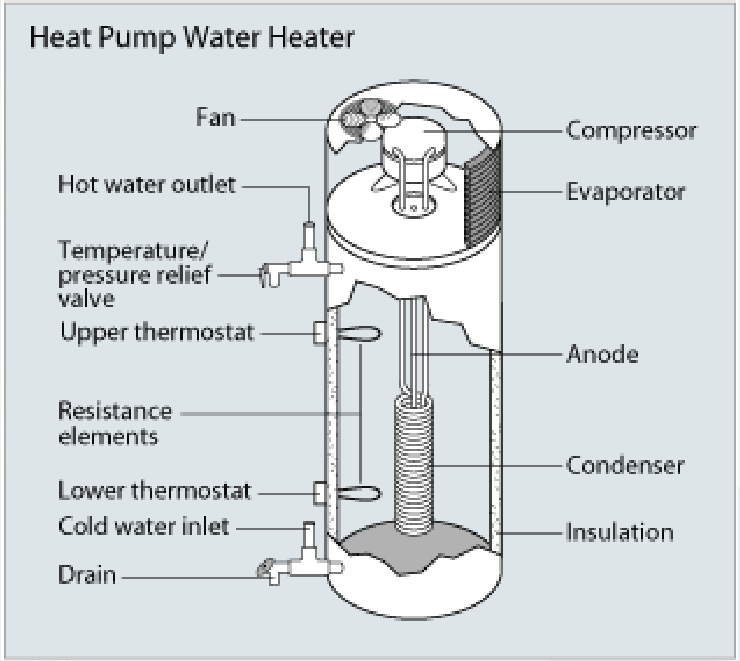


*Image from https://share.sandia.gov/

Step 3: Building Energy Improvement Options
HVAC System and Equipment Upgrade

DOE's high efficiency equipment challenge

- High efficiency heat pump water heater (GE GeoSpring)
  - ~60% more efficient than a standard electric water heater
  - $325 savings per year*



*Based on comparison of a 50-gallon standard electric tank water heater using 4879 kWh per year & 10.65 cents per kWh

Step 3: Building Energy Improvement Options
HVAC System and Equipment Upgrade

DOE's high efficiency equipment challenge

- Variable-speed air-source integrated heat pump (AS-IHP)
  - IHP: all HVAC & water heating service integrated into one system
  - HVAC+WH: 50%~60% more energy efficient than conventional minimum efficiency equipment (SEER 13)
  - Climate Master Trilogy 40 Q-Mode™ 2013 AHR Expo Innovation Award > 40 EER at ground-loop condition

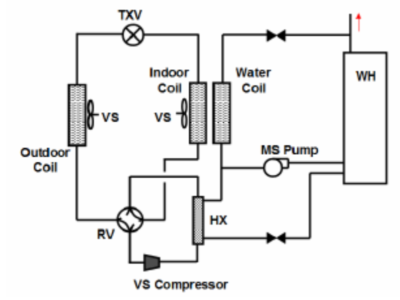


Fig. 1. Air-source IHP concept schematic, space heating mode shown.

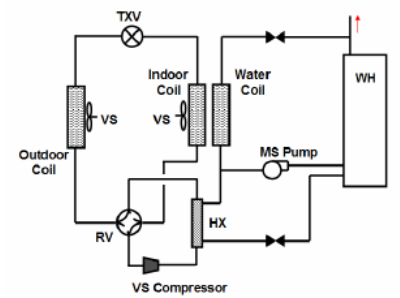


Fig. 2. Air-source IHP concept schematic, space cooling mode shown.

*Murphy et al., 2007, Integrated Heat Pump System Development

Step 3: Building Energy Improvement Options
HVAC System and Equipment Upgrade

DOE’s high efficiency equipment challenge

- High Performance Roof Top Unit (RTU) challenge
  - DOE goal: 20 IEER (Integrated Energy Efficiency Ratio) for a 10~20 ton unit
  - > 50% energy savings vs. minimum efficiency system
  - Daikin McQuay's **Rebel rooftop** is the first to meet the challenge
    - Can be configured as a 100% dedicated outdoor air system, variable air volume (VAV), Single-Zone VAV, or constant air volume (CAV) system
  - Daikin McQuay, Carrier, Lennox, 7AC Technologies, and Rheem participated in this challenge
  - Oakridge National Lab is partnering with Trane to develop the next generation 20 ton RTU

Step 3: Building Energy Improvement Options
Making the Business Case

- Making the Business Case
  - Simple payback = project cost / annual change in cash flow
  - Net present value (NPV) – accounts for the time value of money, compounding
  - Internal rate of return (IRR) – return rate that makes NPV = 0
  - Life-cycle cost analysis (LCCA) – compare alternative EE measures

    LCC = Repl — Res + E + W + OM&R

    - LCC = Total LCC in present-value (PV) dollars of a given alternative
    - Repl = PV capital replacement costs
    - Res = PV residual value (resale value, salvage value) less disposal costs
    - E = PV of energy costs
    - W = PV of water costs
    - OM&R = PV of non-fuel operating, maintenance and repair costs

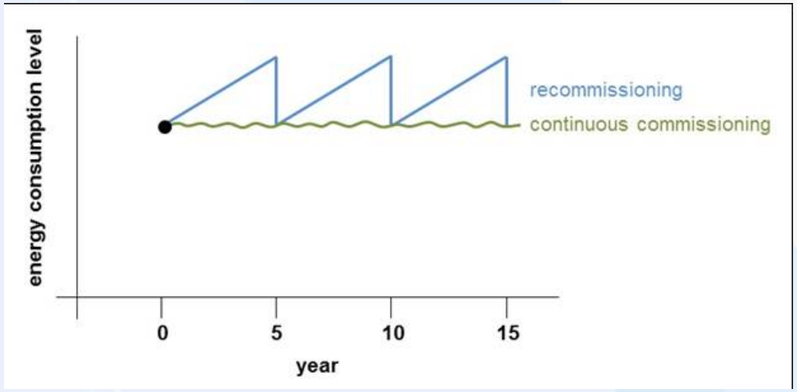
Step 3: Building Energy Improvement Options
Making the Business Case

A chiller replacement project, cost is \$900,000. Annual change in cash flow is \$103,680. Equipment life = 20 years. Discount rate = 7%. Residual cost = \$100,000.

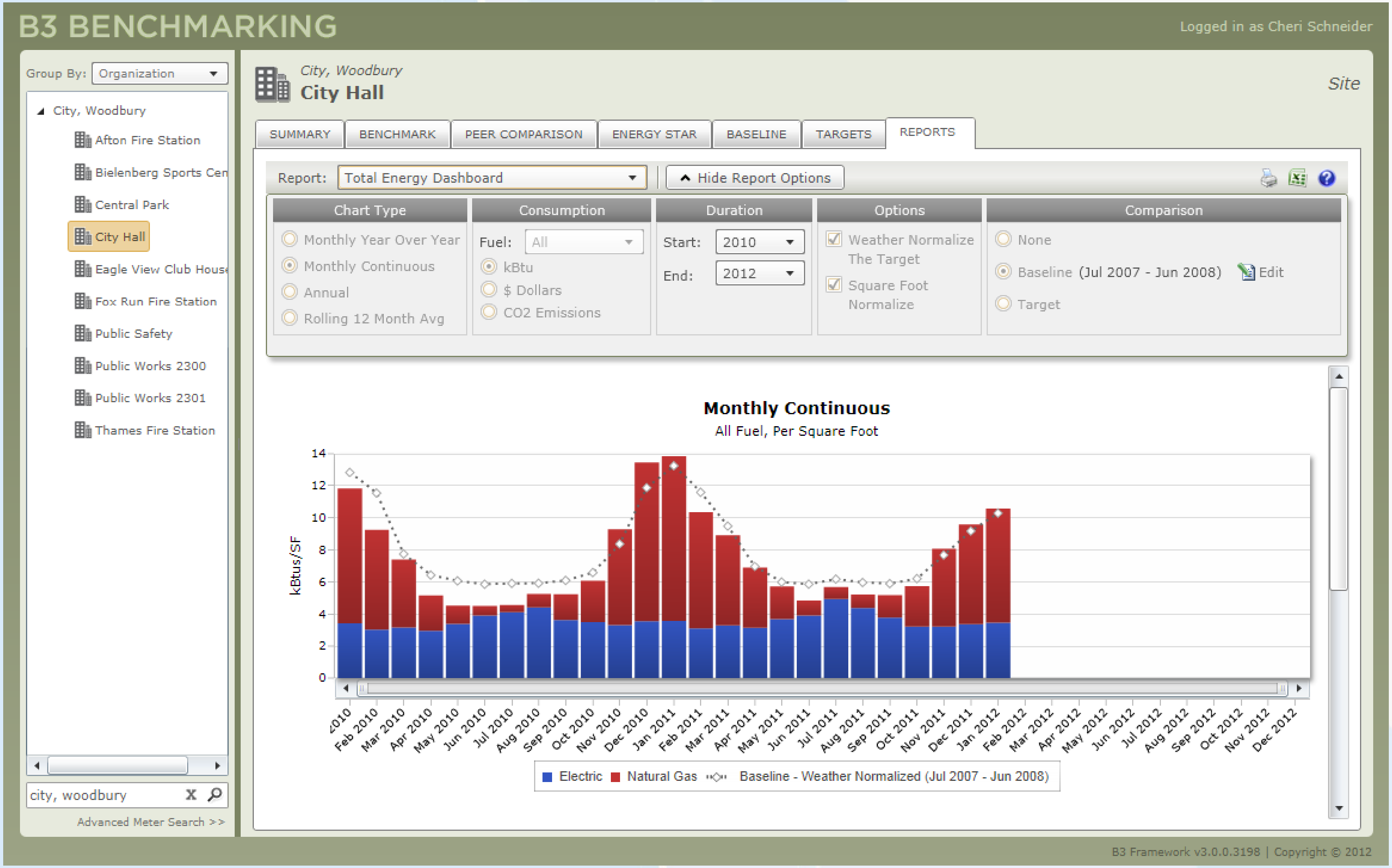
- Simple payback = \$900,000 / \$103,680 = 8.68 (years)
- Net present value (NPV) = $\sum_{n=1}^{20} \frac{\$103{,}680_n}{(1+0.07)^n}$ -\$900,000 = \$198,387
- Internal rate of return (IRR): 9.72%
- Life-cycle cost analysis LCCA 1: \$900,000 - \$25,842 + E + W + OM&R

Step 4: Monitoring Results

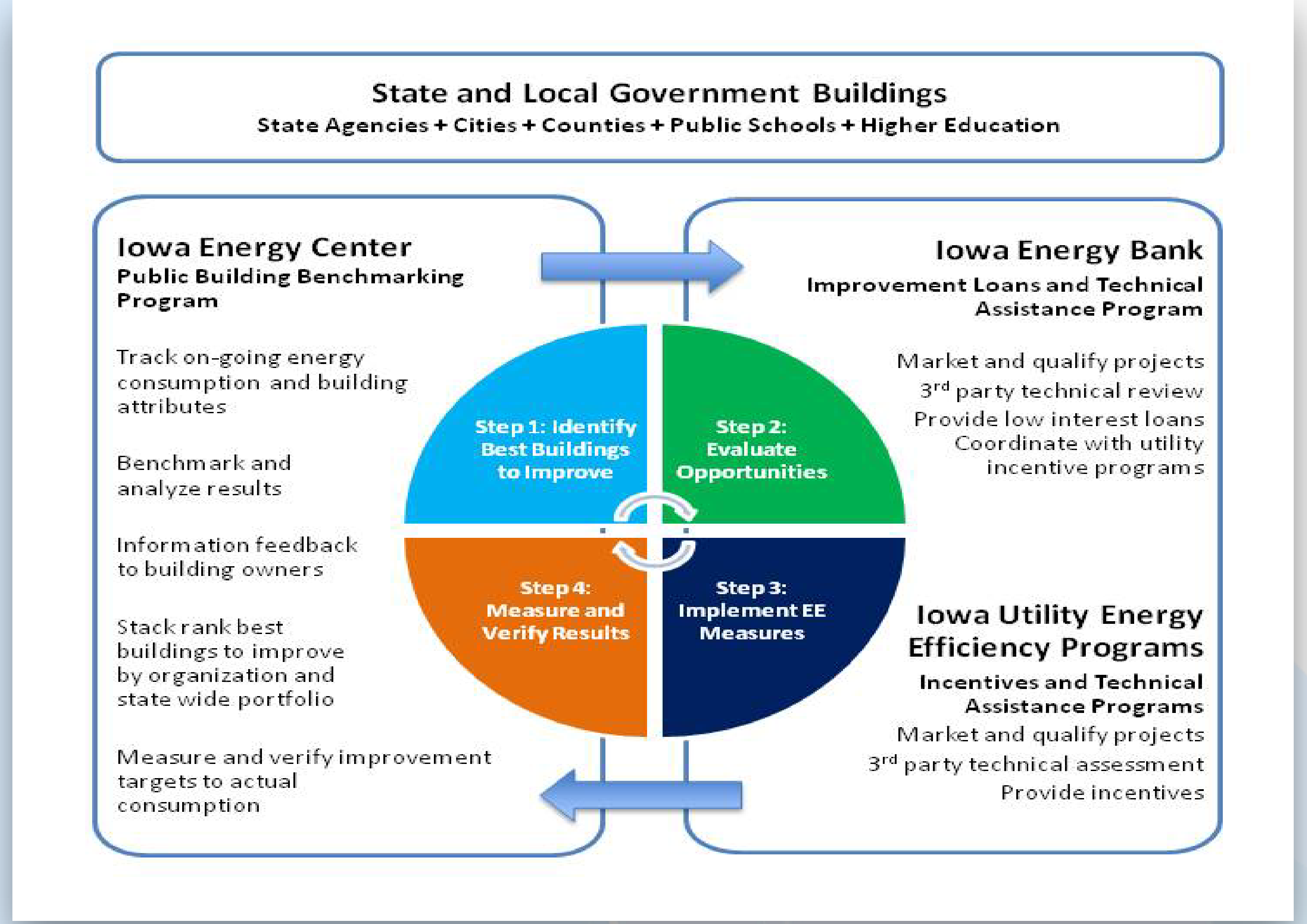
- Continuously Monitor Results
  - Make energy management a priority
  - Require systems manuals (operation and maintenance, etc.)
  - Insist on performance tracking and reporting
  - Develop an effective operation and management plan
  - Be persistent!
  - Continuous-Commissioning



Step 4: Monitoring Results



Step 4: Monitoring Results



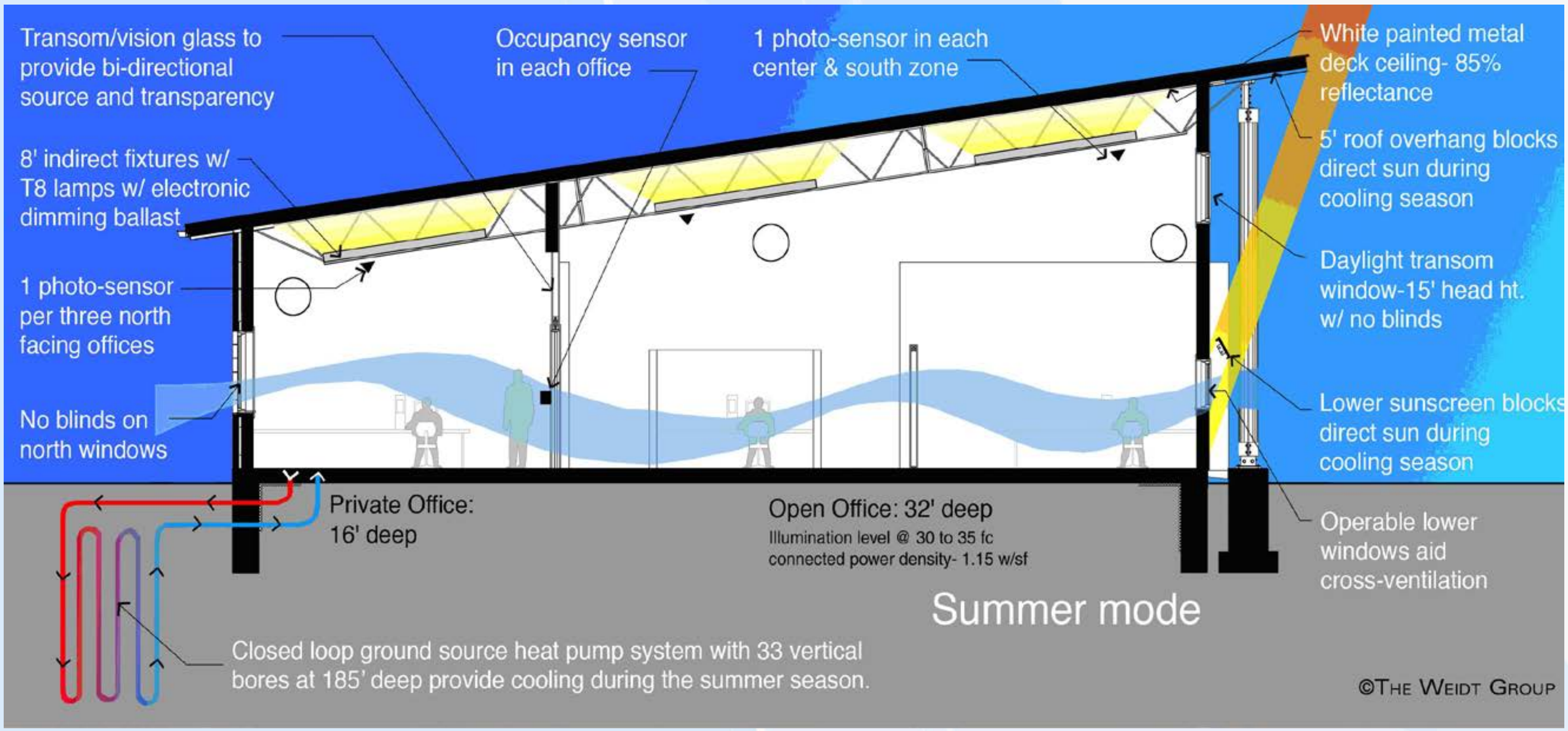
High Performance Buildings

- Whole-building (integrated) building design + all of the above
  - Minimize loads in design stage using building energy simulation tools
  - Use day lighting as the main lighting source
  - Smart building systems integrate sensors, controls, and inputs that optimize comfort and energy efficiency
  - Advanced metering and DDC control
  - Advanced energy storage technologies
  - Geothermal heat pump systems
  - High efficient HVAC equipment and systems

High Performance Buildings
IAMU

- Iowa Association of Municipal Utilities
  - 12,500 sq. ft. office building
  - Whole building modeling w/DOE 2 in 3 phases
    - Benchmark – Base Case Model established
    - Optimization – over 70 independent energy strategies evaluated
    - Compile Options – resulting in 3 alternative energy strategy bundles
  - HVAC System Life Cycle Cost Analysis
    - Consider energy, O&M, repair and replacement costs
    - 8 HVAC System Alternatives evaluated

High Performance Buildings
IAMU

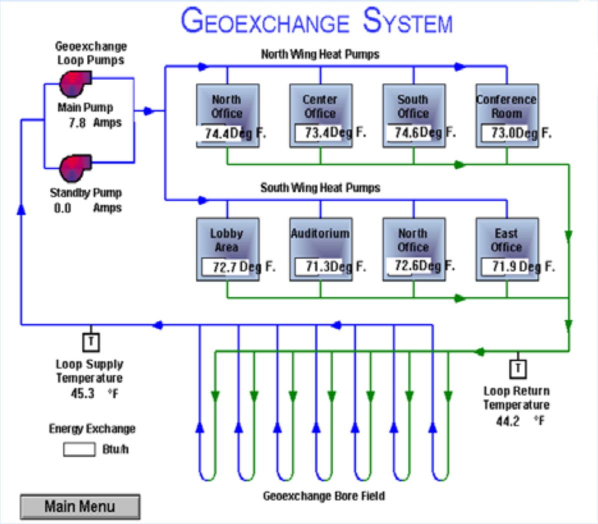


High Performance Buildings
IAMU

- Building envelop: Six Inch Exterior Wall: R = 24.2, Low Density Sprayed Foam Insulation;   Metal Roof / Metal Deck: R = 30+, Insulated ‘Sandwich’ panel
- Windows: Low-E, triple pane, operable windows U = 0.25 – 0.35
- Optimal window/wall ratio: 19%
- Geothermal Heat Pump System: eight thermal comfort zones, 35% less energy costs, lowest life cycle cost
- Energy Recovery Unit
- Daylighting control
- 29 kBTU/sq. ft-yr and Energy Star of 93

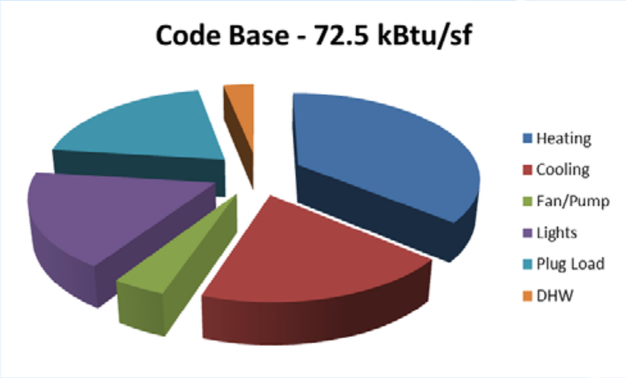
High Performance Buildings
IAMU

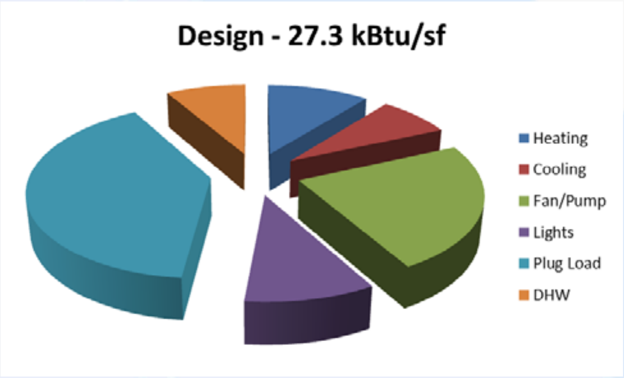
Line Item	Cost $	Cost $/SF	% of Budget
Office Bldg Construction Cost	$ 1,450,000	$116.00	103.6 %
Utility Company Efficiency Incentive	$ 28,000	$ 2.24	2.0 %
Annual Energy Cost	$ 6,540	$ 0.52	72.0 %



High Performance Buildings
IUB/OCA

- Iowa Utility Board / Office of Consumer Advocate
  - 44,500 sq. ft. office building
  - Whole building modeling w/DOE 2





High Performance Buildings
IUB/OCA

- Energy Star rating of 98
- LEED Platinum
- EUI of 22.1 kBtu/sf-year without PV
- EUI of 18.8 kBtu/sf-year with PV

High Performance Buildings
IUB/OCA

- High performance building envelope minimize thermal bridging
- High performance glass at all locations, specifically tuned to each elevation’s exposures
- Proper solar orientation take advantage north and south daylighting
- Roof-mounted 45 kW photovoltaic array covers 20 percent of the building’s energy needs and reduce peak demand
- Geothermal field tied to dual-stage heat pumps (accounting for 39 percent of the total energy savings)
- Total energy recovery unit (both sensible and latent)
- Daylight-harvesting sunscreens to block unwanted summer heat gain and allow passive winter heating
- Circuit-level power meters

High Performance Buildings
Des Moines Franklin Library

- Des Moines Franklin Library
  - Retrofit 15,080 sq. ft. and add another 13,510 sq. ft.
  - LEED Platinum
  - Code: EUI=71.5 kBTU/sq. ft.-yr, design model 25.9 kBTU/sq. ft.-yr
  - Roof insulation with an assembly U of 0.029 (vs. code 0.048)
  - Glazing with assembly U between 0.31 and 0.41 (vs. code 0.55)
  - An air cooled chiller in variable flow primary configuration
  - Condensing boilers and a solar thermal system in a primary – secondary configuration
  - A single dedicated outside air unit with heat recovery supplies the primary air to active chilled beams

High Performance Buildings
Des Moines Franklin Library

- The dedicated outside air unit has both an enthalpy wheel for total heat recovery and a passive desiccant wheel for adsorption drying and heating
- Radiant floor heat at several perimeter rooms
- Interior lighting is 60% T5 fluorescent and 40% LED, exterior lighting all LED
- Occupancy and daylighting control in reading areas
- The onsite PV system modeled as generating 78,624 KWh per year
- The onsite solar thermal system modeled as generating 52,254 KWh per year

Questions?

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