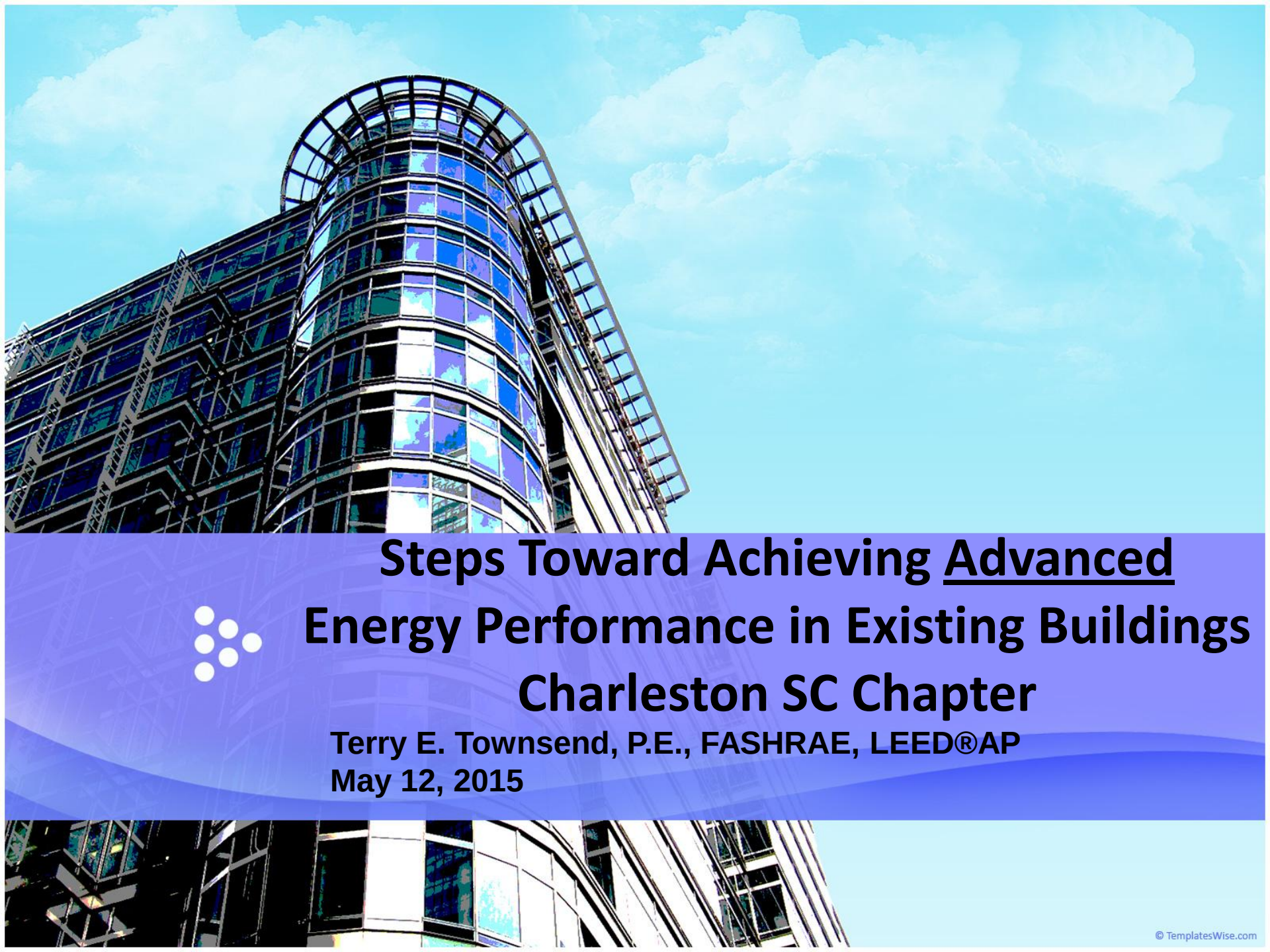


Steps Toward Achieving Advanced Energy Performance in Existing Buildings Charleston SC Chapter

Terry E. Townsend, P.E., FASHRAE, LEED®AP

May 12, 2015

Buildings Represent

- 17% of fresh water consumption
- 25% of wood consumption
- 30% of waste generation
- 39% of CO_2 emissions
- 40% of energy use
- 55% of natural gas use
- 72% of electrical energy use

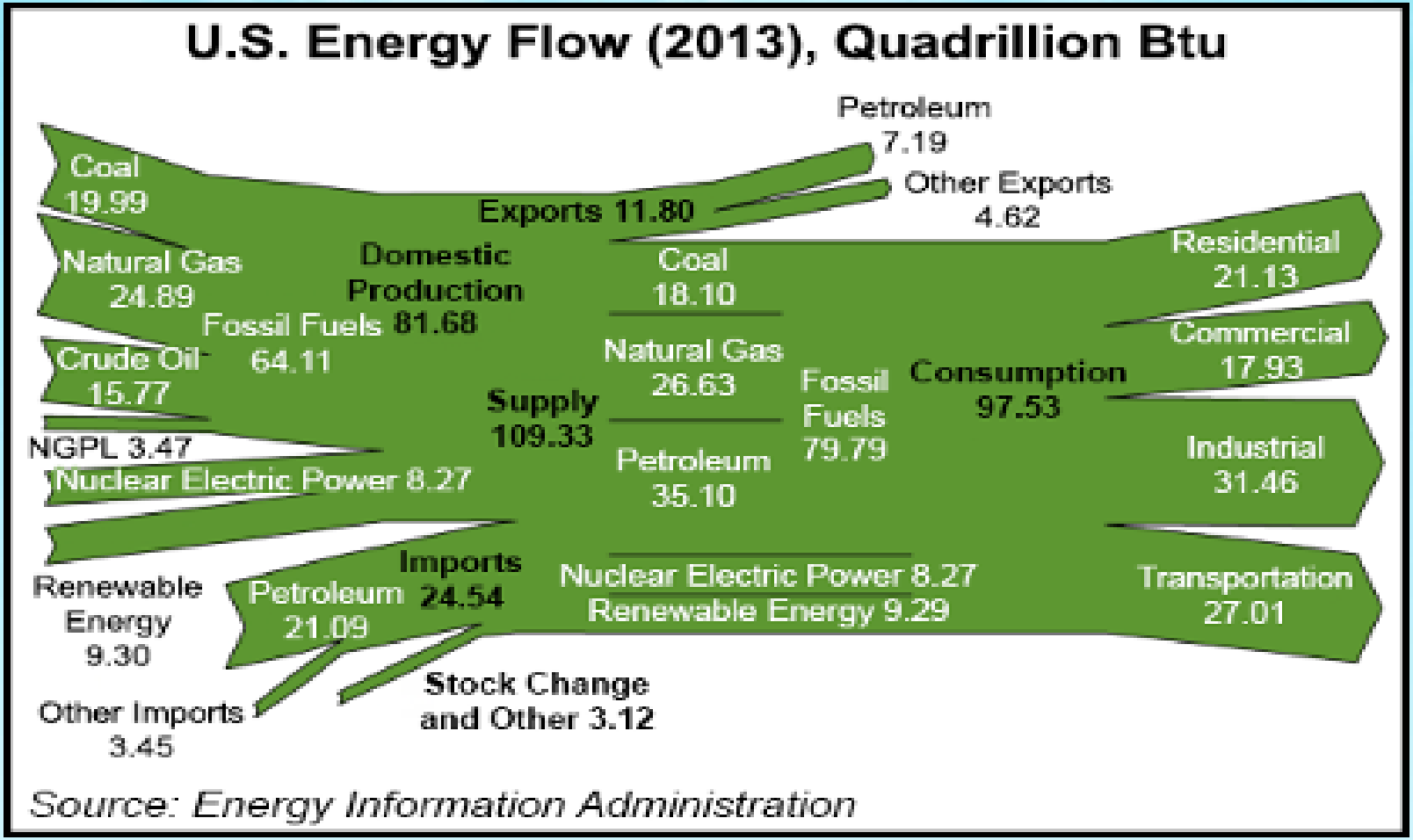
Existing Commercial Buildings

- New Buildings = 2% of Building Programs
- 86% of U.S. Annual Building Construction Expenditures Relate to Building Renovations
- Even with Commissioned Buildings in the U.S., their Performance Deteriorates after 3 years by 30%
- ASHRAE Research has shown that the “potential” for reduction of a building’s energy use is between 10% and 40% simply by changing operational strategies
- 70% - 80% of Buildings in 2030 exist today
- Over next 30 years, 150 billion sq.ft. of existing buildings will be renovated (1/2 U.S. bldg. stock)

Why We Need to Save Energy!

- World energy consumption is projected to grow by 71 percent from 2003 to 2030 (U.S. Energy Information Agency)
- Oil is forecasted to remain dominant energy source with coal forecasted as primary fuel for generating electricity
- The trend is towards more fossil fuel generation and away from Nuclear.

Why is Energy So Important?



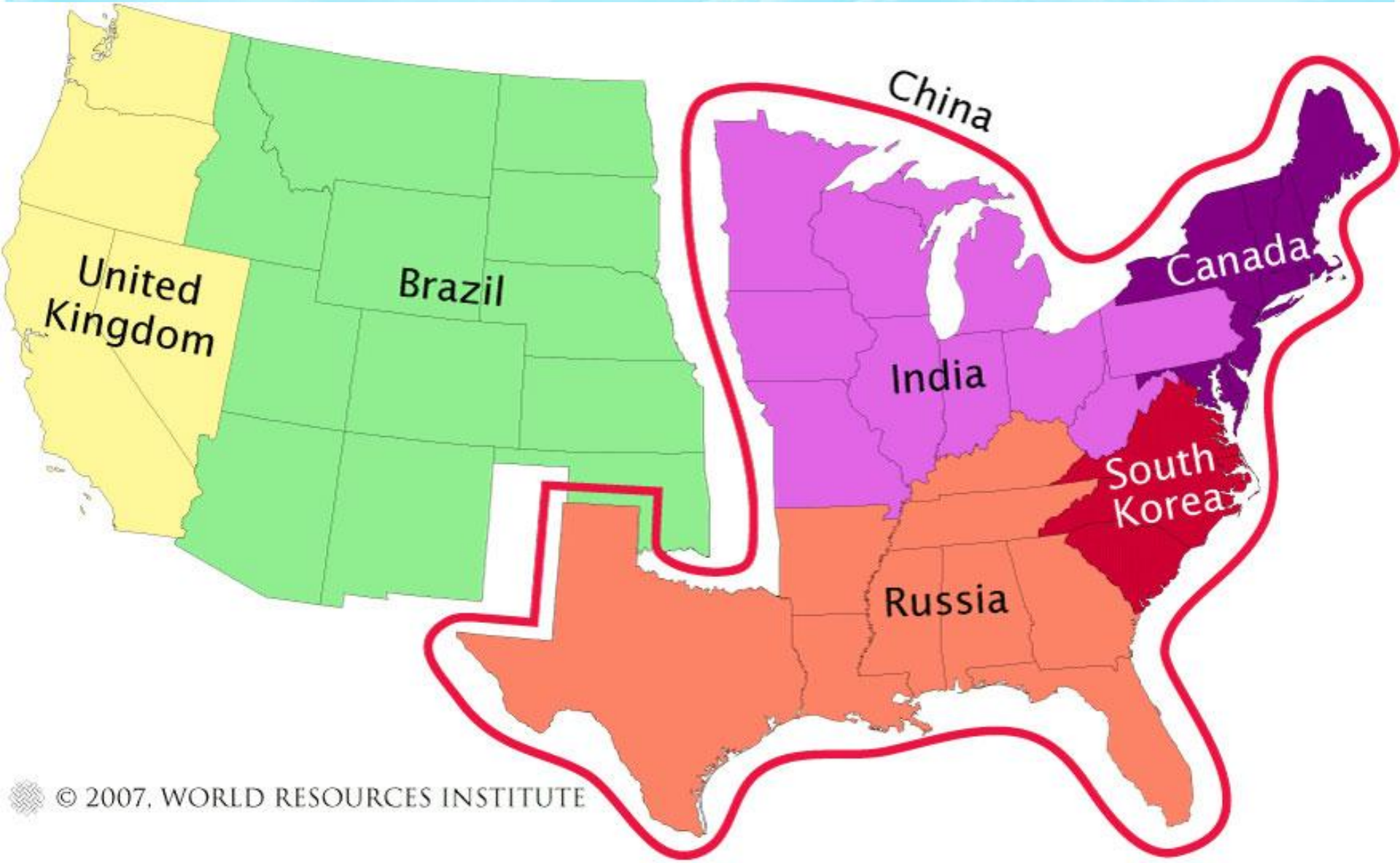
http://www.magnetmail.net/actions/email_web_version.cfm?recipient_id=98404743&message_id=4688440&user_id=IP4192&group_id=1073099&jobid=19187143

Existing Commercial Buildings

Energy Efficiency – A Climate Change Strategy

- U.S. – 5% of world's population & produces 25% of world's greenhouse gas emissions
- DOE – 49% electricity generated from coal; Buildings account for 72% of U.S. electrical load
- U.S. Buildings – 39% of U.S. greenhouse gas emissions (18% commercial & 21% residential) as compared to transportation (29%) and industry (32%)
- IPCC & McKinsey →Greatest opportunity for cost effective CO_2 reductions = making buildings more energy efficient

Comparing International Emissions Data



Steps Toward Achieving Advanced Energy Performance in Existing Buildings

Guaranteeing Improved Building Performance

- **The Technical EBRCx Process Phases:**
    1. Planning Phase
    2. Discovery Phase
    3. Investigation Phase
    4. Analysis Phase
    5. Corrective Action Phase
    6. Performance Verification Phase

Technical Retro-Commissioning Provides -

- **Improved Comfort Levels**
  - Temperature
  - Humidity
  - Sound & Vibration
  - Suitable Lighting Levels
  - Reduction of Daylight Glare
- **Improved Indoor Air Quality**
  - Ventilation Rate
  - CO_2 control
- **Reduced Utility Expense (Efficient Operations)**
  - Improved Electrical Energy Usage
  - Improved Gas Energy Usage
  - Improved Water Usage

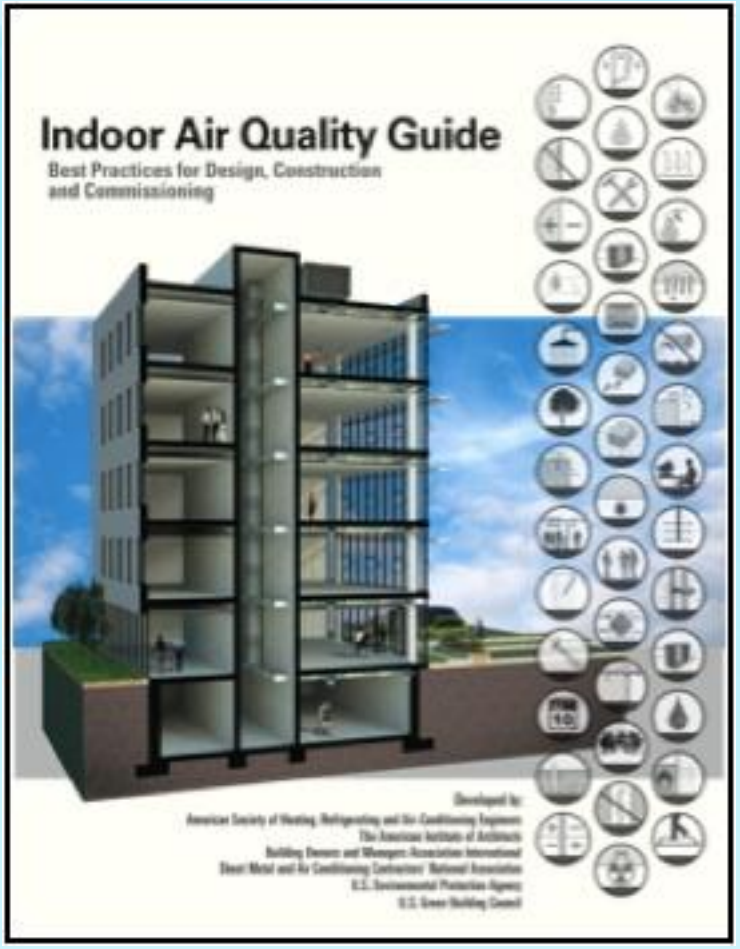
Validation of Commissioning

- First Party (1st) Validation = A firm or individual verifying the project tasks is the same firm or individual performing the tasks.
- Second Party (2nd) Validation = The firm or individual verifying the project tasks is under the control of the firm that performed the tasks.
- Third Party (3rd) Validation = The firm verifying the project tasks is not associated with or under the control of the firm performing or designing the tasks.

Success = Existing Buildings Becoming Energy Efficient, Healthy & Comfortable

- Energy Efficiency = ASHRAE Standards 90.1, 100 & 189.1
- Healthy = ASHRAE Standard 62.1
- Comfortable = ASHRAE Standard 55
- Acceptable IEQ (Lighting/Daylighting, Thermal Comfort, IAQ and Acoustics)

Indoor Air Quality Guide
Best Practices for Design, Construction & Commissioning



Indoor Air Quality Guide
Best Practices for Design, Construction & Commissioning

Document Objective

- **Describes design and construction strategies to improve IAQ relative to current practice and minimum codes & standards.**
- **Beyond Standard 62.1!!!**
- **Transform mid-range of practice** into better practice; not targeting the least or most sophisticated
- **Facilitate O&M** through informed design decisions.
- **Make application easier and more likely**: tabulated recommendations, sample details, great graphics
- Help to define good IAQ practice **for use in green and sustainable building programs**.

Indoor Air Quality Guide
Best Practices for Design, Construction & Commissioning
Top 10 Reasons for IAQ Problems

- 10. Moisture in building assemblies
- 9. Poor outdoor air quality
- 8. Moisture and dirt in air handling systems
- 7. Indoor contaminant sources
- 6. Inadequate ventilation rates
- 5. Ineffective filtration and air cleaning
- 4., 3., 2. and 1. Failure to address IAQ during design, construction and commissioning activities

Indoor Air Quality Guide
Best Practices for Design, Construction & Commissioning

What is Outside Air used for?

1. Dilution for Indoor Air Quality
   - Reduce Concentration of Contaminants by Occupants & their activities
   - Reduce Concentration of Contaminants from Furniture, wall coverings, carpet, and appliances
2. Make-up Air for Hoods, Ranges, Toilet & General Exhaust Fans
3. Combustion Air for Appliances or Heating Equipment

Managing Ventilation Air

- <u>KEY SUGGESTIONS</u>

1. Install a Minimum MERV-8 Filter on O/A Streams
2. Modulate Amounts of O/A with Controls

Measured Ventilation Air Flow - 510 Office Buildings

ASHRAE Standard Requirement (At the time of measurement)

Excess ventilation

	Per Person cfm/person [l/s/person]	Per Unit Floor Area cfm/ft2 [l/s.m2]	Air Changes Per Hour
Mean (Average)	117 [55]	0.4 [2.04]	2.00
Median (Most Common)	63 [30]	0.2 [1.03]	0.98
Standard Deviation	158 [74]	0.5 [2.54]	2.45
Std 62.1-1989	**20 [9]**	**0.07 [0.36]**	**0.34**

STANDARD

ANSI/ASHRAE Standard 55-2013
(Supersedes ANSI/ASHRAE Standard 55-2010)
Includes ANSI/ASHRAE addenda listed in Appendix M

Thermal Environmental Conditions for Human Occupancy

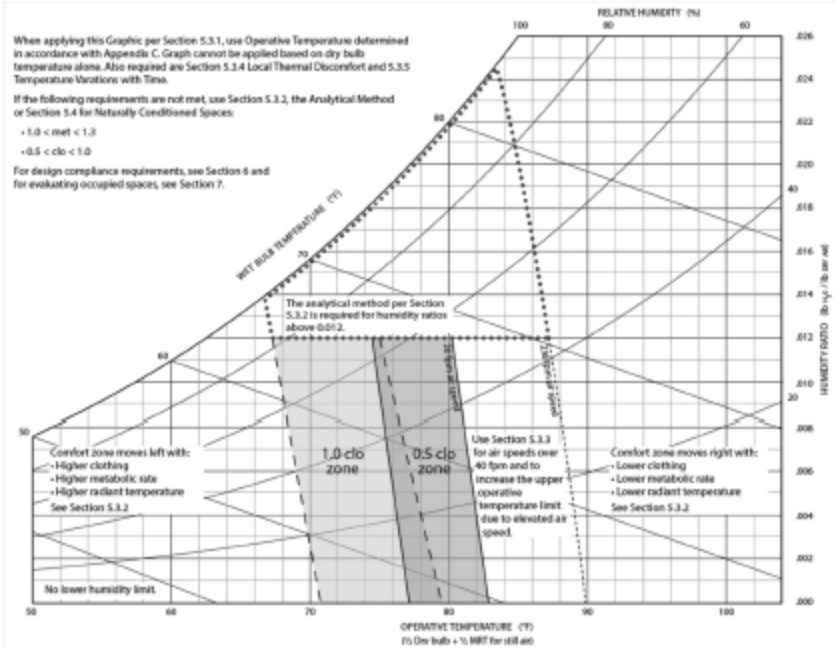
See Appendix M for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE Web site (www.ashrae.org) or in paper form from the Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE Web site (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

 ISSN 1041-2336

Approved American National Standard
ANSI

(a)



(b)

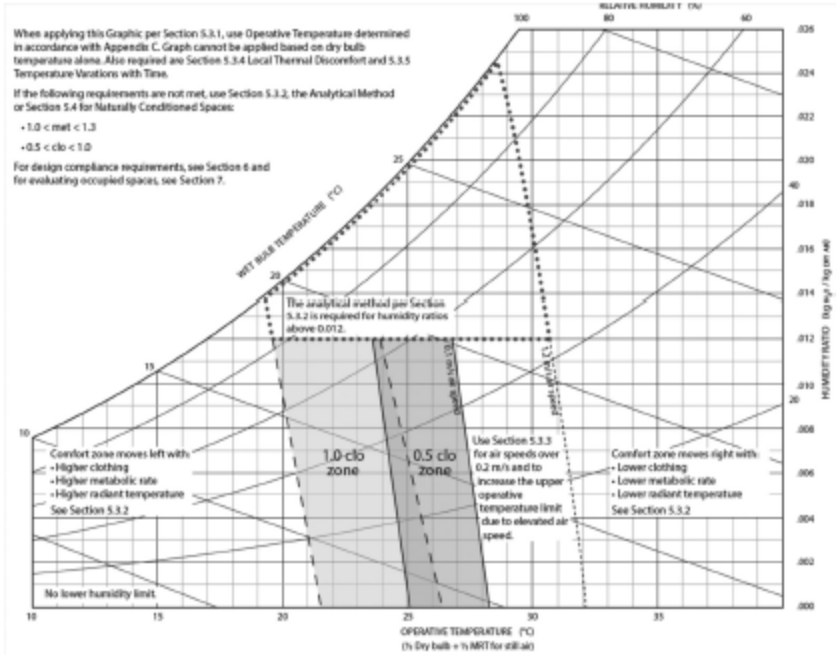


FIGURE 5.3.1 Graphic Comfort Zone Method: Acceptable range of operative temperature (t_o) and humidity for spaces that meet the criteria specified in Section 5.3.1 (1.0 ≤ met < 1.3; 0.5 < clo < 1.0)—(a) I-P and (b) SI.

Energy Efficiency Guide for Existing Commercial Buildings

Measuring a Building's Energy Efficiency & Setting Performance Goals

- Setting a Building's Energy Performance Goals

1. Establish "Benchmark" & ENERGY STAR Rating
2. If ENERGY STAR Rating is below 75%, 1st Target should be to achieve this level of operation
3. 2nd Target →Increase performance 10% - 30% (20%)
4. 3rd Target →Achieve performance of current version of ASHRAE Standard 90.1 (2010)
5. 4th Target →Go 30%, 50% or 70% beyond 90.1/189.1
6. 5th Target →Go to Net-Zero Energy

Existing Commercial Buildings

Measuring a Building's Energy Efficiency & Setting Performance Goals

Determine the Building's Energy Utilization Index (EUI)

- EUI = Ratio of Bldg Energy Use to Gross Floor Area
  * Determine Bldg Annual Energy Use
    - Collect min. 15 months - 2 yrs of energy consumption in order to avoid anomalies
    - Calculate annual BTUs consumed/fuel source & get total annual BTUs
  * 1st full year →"Baseline" or "Benchmark"

Existing Commercial Buildings

Two Types of Energy Indices May Need to be Developed:

* Energy Use Index/Intensity (EUI) – includes no on-site renewable energy generation

$$\textbf{EUI} = \frac{\textbf{Total Annual Energy Use}}{\textbf{Gross Floor Area}} \textbf{ (kBtu/SF-yr)}$$

* Net Energy Use Intensity (NEUI) – includes photovoltaic and other on-site renewable energy production

$$\textbf{NEUI} = \frac{\textbf{Net Annual Energy Use}}{\textbf{Gross Floor Area}} \textbf{ (kBtu/SF-yr)}$$

Energy Usage in Buildings

Meaning of CBECS

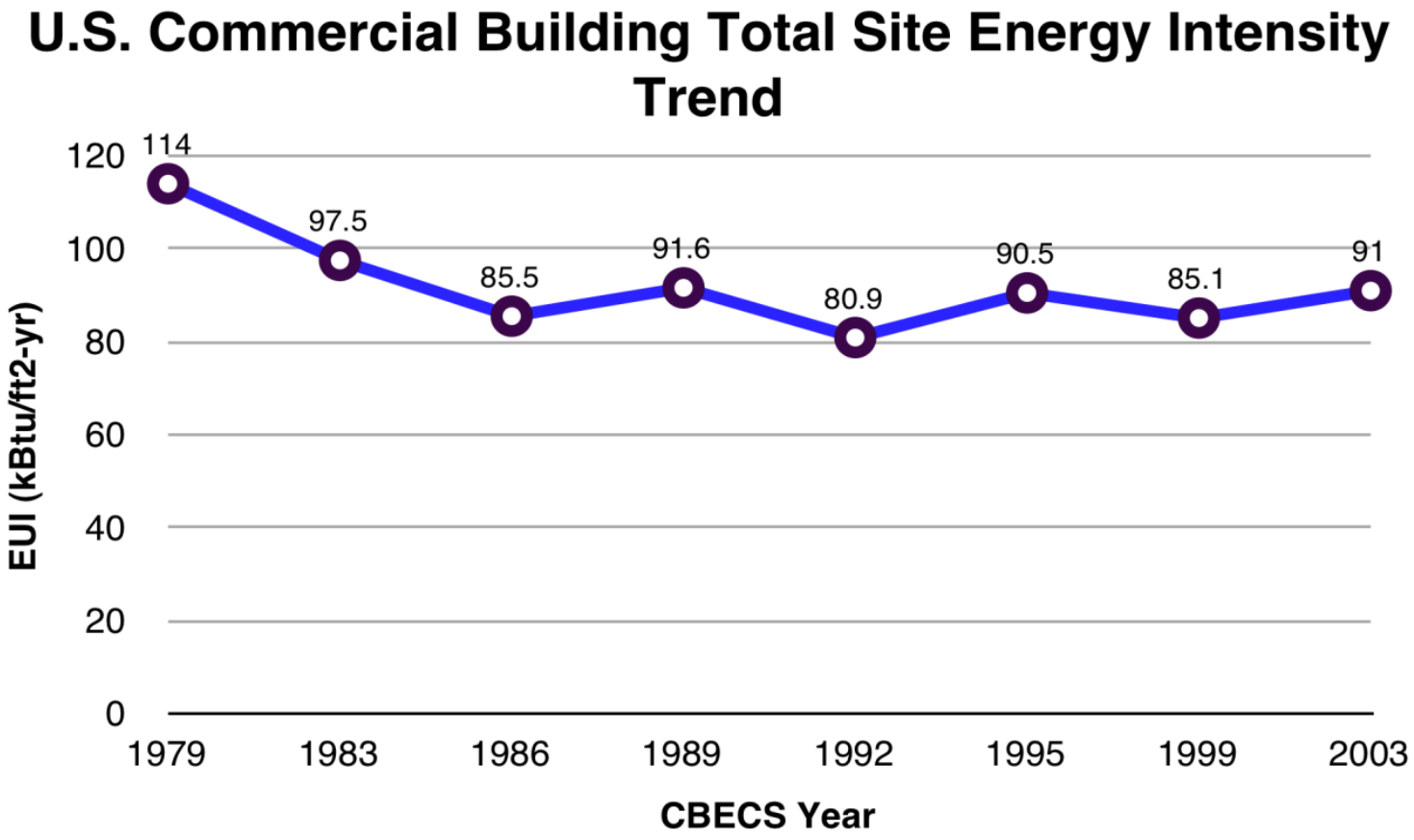
- Primary tool to normalize & compare like buildings is the DOE Commercial Buildings Energy Consumption Survey (CBECS) data.
- CBECS provides EUI comparisons for 18 classifications of building types in all DOE Climate Zones; Total sample = 5,215 buildings
- CBECS is supposed to be updated every 4 years; latest version is based upon 2004 data
- Information presented – Weighted Mean Energy Use Intensities by Subsector & Climate Zone

Table 1-2. 2003 CBECS[1] Weighted Mean Energy Use Intensities[2] by Subsector and Climate Zone[3,4]: IP Units kBtu/ft²·yr

[1] Data source is 2003 CBECS public use microdata

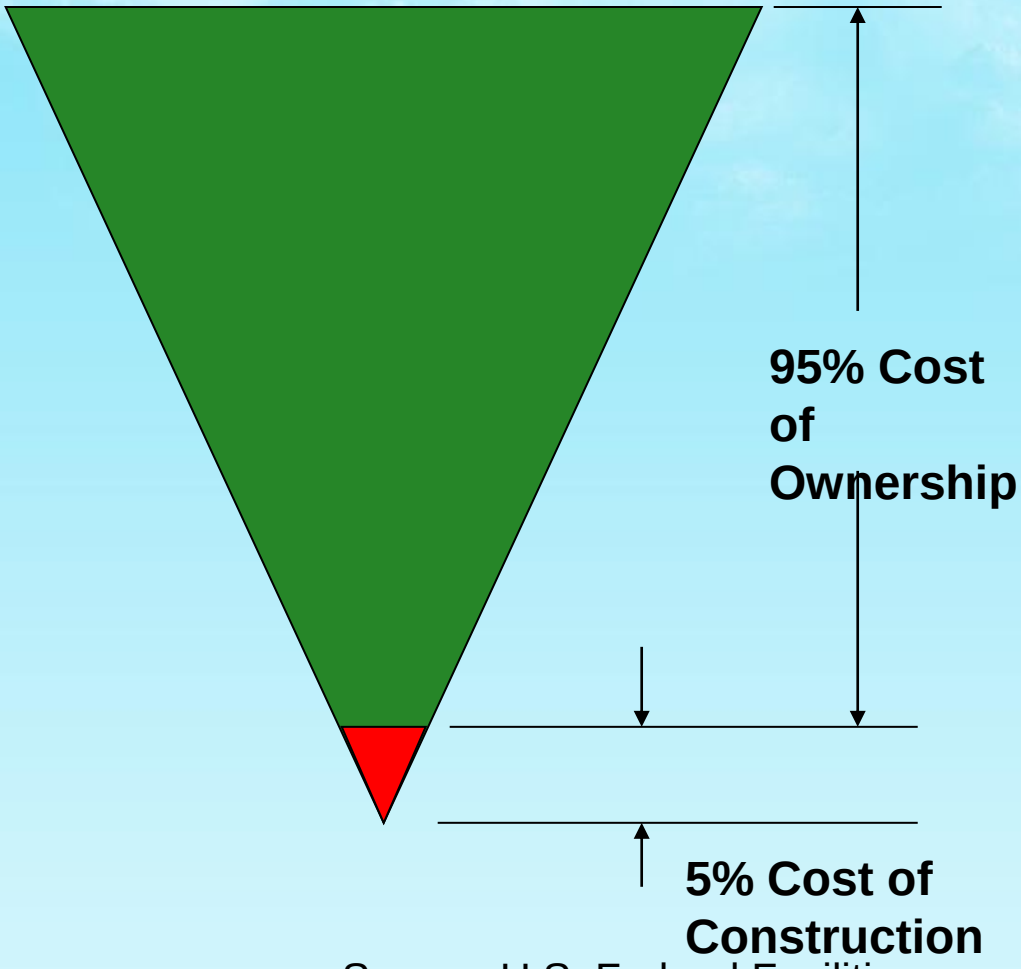
Subsectors	Climate Zones														
	All	1A	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	6A	6B	7
All	90	74	72	114	89	70	62	95	108	99	104	87	89	97	71
Office/professional	93	42	82	72	88	70	58	97	143	95	107	66	110	114	68
Nonrefrigerated warehouse	42	22	16		22	21	20	39	29	37	79	60	37	58	33
Education	83	52	73	160	62	74	105	102	38	58	87	79	90	90	84
Retail (except malls)	74	61	93	129	60	50	31	65	100		88	80	93	97	102
Public assembly	94	75	60		112	48	45	110	44	249	103	97	88	102	97
Service	77	60	53		49	61	27	82	83		80	101	88	99	65
Religious worship	44		31		28	31		47	56		52	39	83	34	
Lodging	94	81	91		98	57		92	264	545	89	65	108	93	68
Food services	258	396	208		423	393	82	234		260	258	228	203	236	192
Inpatient healtchcare	249	200	246	360	205	257	204	248	163		294	245	240	235	256
Public order and safety	116		91		160	79		129			108	94	126	148	
Food sales	200		166		212	183	120	242			203	147	242		199
Outpatient health care	95	19	77		55	106		70	190		111	120	112	91	166
Vacant	21		4	47	4	6	0	40	3	60	21	93	22		55
Other	79		48		100	175		71	26		94	92	69	85	57
Skilled nursing	125		71		84	85		148			148	153	118	134	
Laboratory	305				242	170		600			370		268	115	
Refrigerated Warehouse	99							120			68	51	62		

Energy Usage in Existing Buildings



Energy Information Administration
Commercial Buildings Energy Consumption Survey

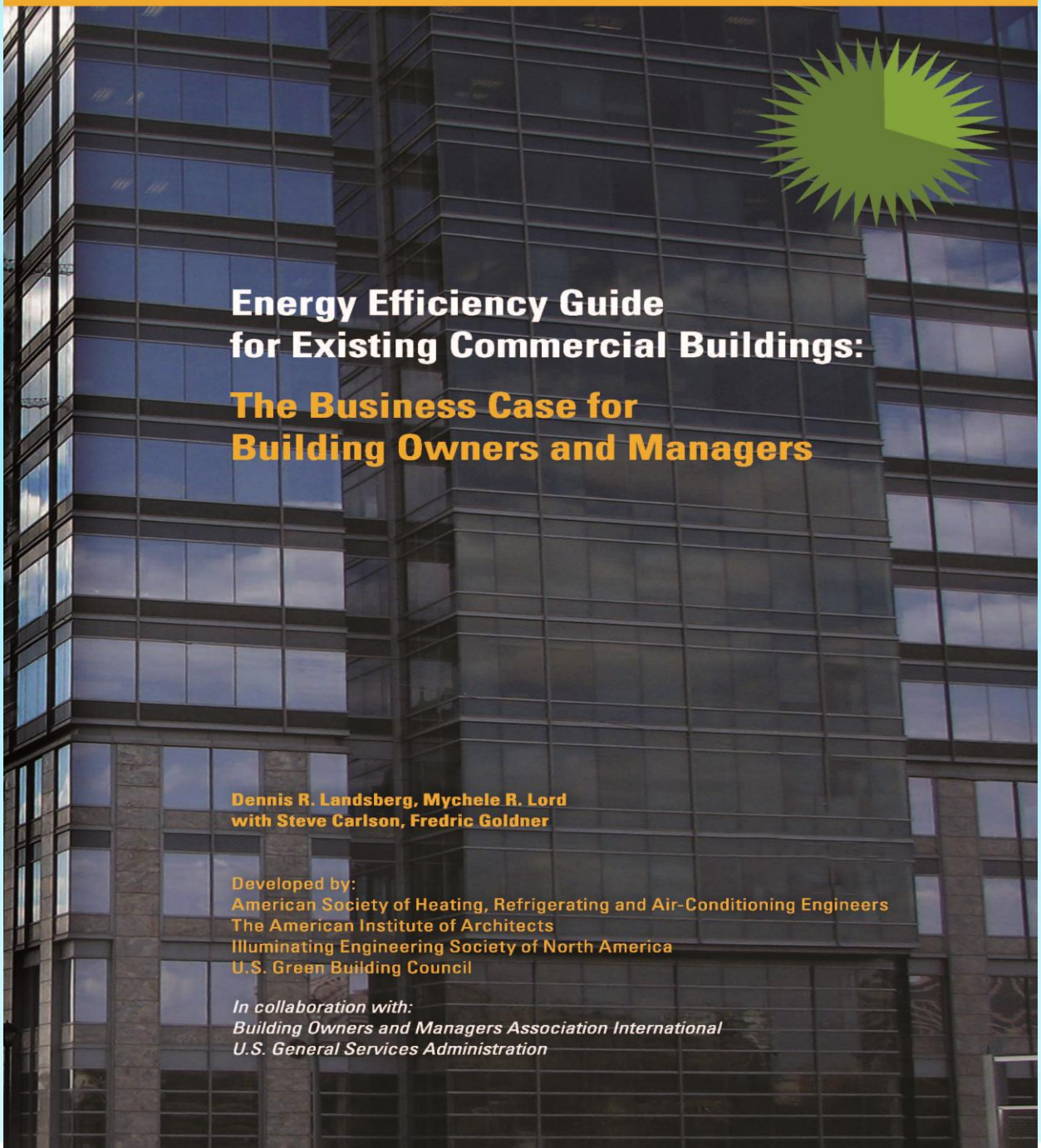
Fundamental Truth – Cost of Ownership



Source: U.S. Federal Facilities Council Technical Report No. 142

Steps Toward Achieving Advanced Energy Performance in Existing Buildings

***"We are confronted with insurmountable opportunities"*……Pogo**



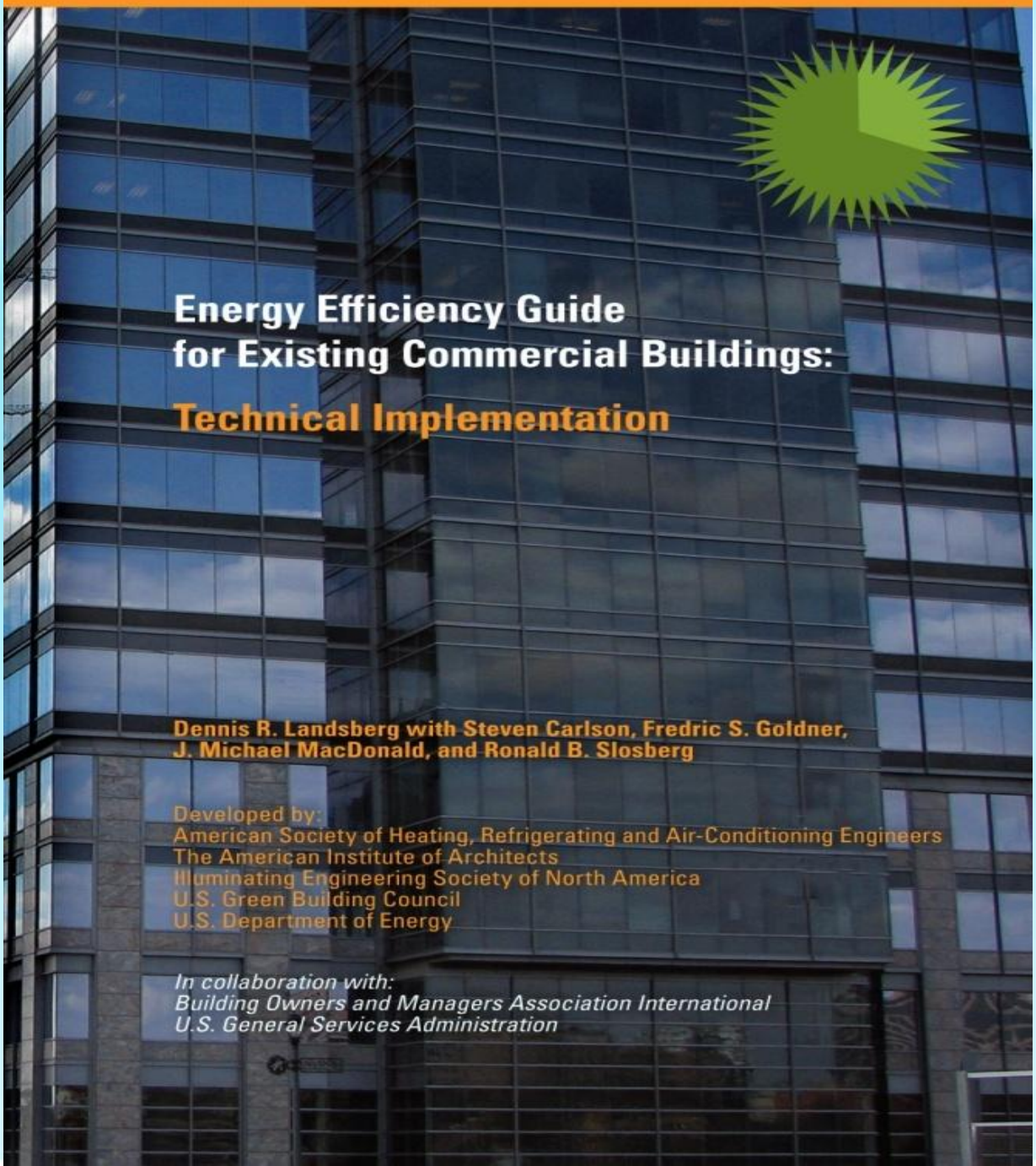
Energy Efficiency Guide for Existing Commercial Buildings:

The Business Case for Building Owners and Managers

Dennis R. Landsberg, Mychele R. Lord
with Steve Carlson, Fredric Goldner

Developed by:
American Society of Heating, Refrigerating and Air-Conditioning Engineers
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council

In collaboration with:
Building Owners and Managers Association International
U.S. General Services Administration


Energy Efficiency Guide
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U.S. Green Building Council
U.S. Department of Energy
In collaboration with:
Building Owners and Managers Association International
U.S. General Services Administration

Table 4-1. Building Category End-Use Percentages

Principal Building Activity	End-Use Ratio Percentages (%)									
	Heating, %	Cooling, %	Ventilation, %	Water Heating, %	Lighting, %	Cooking, %	Refrigeration, %	Office Equipment, %	Computers, %	Other, %
Education	47.4	9.6	10.1	7.0	13.8	1.0	2.0	0.5	3.9	4.8
Food Sales	14.3	4.8	2.8	1.6	18.3	4.4	47.4	0.8	0.8	4.4
Food Service	16.6	6.8	5.6	15.7	9.8	24.6	16.4	0.5	0.5	3.7
Health Care	37.5	7.4	7.1	16.0	17.7	1.9	1.3	0.7	1.7	8.6
Inpatient	36.8	7.4	8.0	19.4	16.0	2.3	0.8	0.4	1.5	7.2
Outpatient	40.3	7.6	3.4	2.5	23.5	*	3.4	1.7	2.5	14.3
Lodging	22.2	4.9	2.7	31.4	24.3	3.1	2.4	*	1.2	7.1
Mercantile	26.3	10.8	6.7	5.6	30.2	2.5	4.8	0.8	1.1	11.3
Retail (other than mall)	33.5	7.8	5.0	1.6	34.8	0.9	6.9	0.9	1.3	7.5
Enclosed and Strip Malls	23.1	12.1	7.3	7.5	28.1	3.4	3.8	0.7	1.1	13.0
Office	35.3	9.6	5.6	2.1	24.8	0.4	3.1	2.8	6.5	9.7

Table 4-1. Building Category End-Use Percentages *(continued)*

Principal Building Activity	End-Use Ratio Percentages (%)									
	Heating, %	Cooling, %	Ventilation, %	Water Heating, %	Lighting, %	Cooking, %	Refrigeration, %	Office Equipment, %	Computers, %	Other, %
Public Assembly	53.0	10.3	17.0	1.1	7.3	0.8	2.4	*	*	7.0
Public Order and Safety	42.9	7.9	7.9	11.9	14.3	0.8	2.4	0.8	1.6	9.5
Religious Worship	60.1	6.7	3.1	1.8	10.4	1.8	3.7	*	0.6	11.7
Service	46.5	5.1	7.7	1.3	20.2	*	2.9	0.3	1.0	14.7
Warehouse and Storage	42.5	3.1	4.4	1.3	28.9	*	7.9	0.4	1.1	10.5
Other	48.3	6.3	3.8	1.4	20.6	*	3.5	*	1.7	11.5

Table 4-2. Electric End-Use Percentages by Building Type

Principal Building Activity	End-Use Ratio Percentages (%)									
	Heating, %	Cooling, %	Ventilation, %	Water Heating, %	Lighting, %	Cooking, %	Refrigeration, %	Office Equipment, %	Computers, %	Other, %
Education	4.0	19.9	22.4	3.0	30.5	0.5	4.3	1.1	8.6	5.7
Food Sales	2.9	5.8	3.4	*	22.1	1.0	57.2	1.0	1.0	4.8
Food Service	4.6	12.9	11.1	4.6	19.4	6.0	32.3	0.9	0.9	6.9
Health Care	2.4	13.7	16.9	0.8	42.3	0.4	3.2	1.6	4.0	14.5
Inpatient	1.7	14.0	21.3	1.1	42.7	0.6	2.2	1.1	3.9	11.8
Outpatient	4.3	13.0	5.8	*	40.6	*	5.8	2.9	4.3	21.7
Lodging	6.0	10.2	6.0	5.1	52.8	0.9	5.1	*	2.6	10.2
Mercantile	7.9	14.9	9.3	5.2	42.0	0.3	6.7	1.1	1.5	11.3
Retail (other than mall)	2.8	11.8	7.6	0.9	52.6	*	10.4	1.4	1.9	10.4
Enclosed and Strip Malls	9.9	16.1	9.8	6.9	37.7	0.4	5.2	1.0	1.5	11.7

Table 4-2. Electric End-Use Percentages by Building Type *(continued)*

Principal Building Activity	End-Use Ratio Percentages (%)									
	Heating, %	Cooling, %	Ventilation, %	Water Heating, %	Lighting, %	Cooking, %	Refrigeration, %	Office Equipment, %	Computers, %	Other, %
Office	4.6	14.0	8.8	1.0	39.1	0.1	4.9	4.5	10.3	12.7
Public Assembly	3.0	21.0	37.7	*	16.2	*	5.4	*	1.8	13.8
Public Order and Safety	3.5	14.0	17.5	5.3	31.6	*	5.3	1.8	3.5	17.5
Religious Worship	4.8	17.7	8.1	*	27.4	*	9.7	*	1.6	29.0
Service	4.0	10.1	16.1	*	42.3	*	6.0	0.7	2.0	18.8
Warehouse and Storage	2.0	5.3	8.2	0.8	54.1	*	14.8	0.8	2.0	12.3
Other	1.5	12.0	8.3	*	44.4	*	7.5	*	3.8	16.5
Vacant	6.7	13.3	6.7	*	26.7	*	*	*	*	46.7

Source: Derived from CBECS 2003 data table E-1a, including malls (EIA 2003).

Existing Commercial Buildings

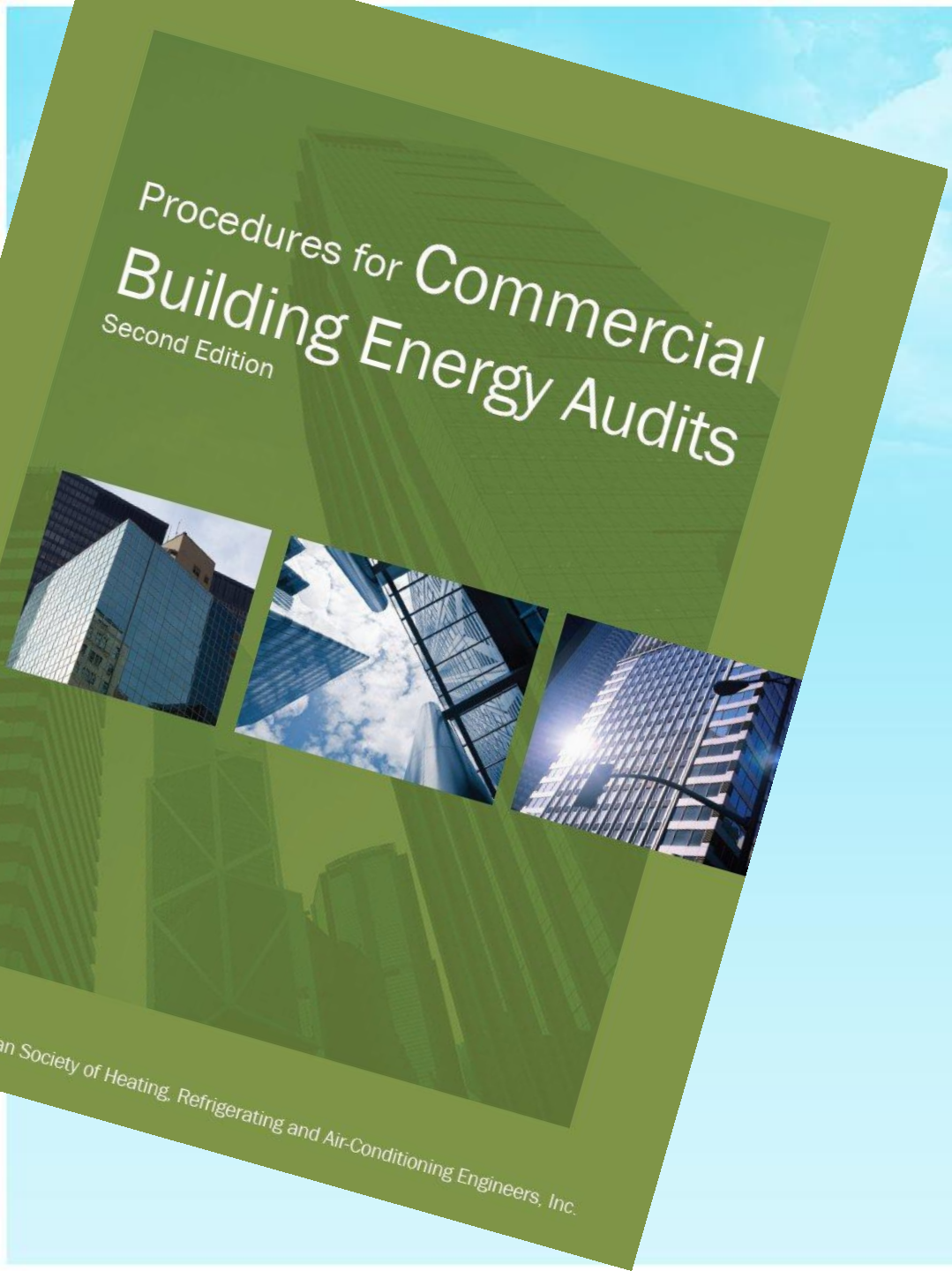
BOMA's Building Energy Efficiency Program (BEEP) reports the following energy savings potentials:

- **7% - 28% achievable thru no-cost/low-cost energy efficiency measures**
- **Add'nl 3.5% - 15.2% savings thru occupant awareness programs, hi-efficiency equip., power management software (EMS) and use of task/ambient lighting**
- **Lighting = 29% of office bldg. consumption →off-the-shelf technologies = < 1 yr simple payback; savings range = 9.4% - 25%**

Existing Commercial Buildings

BOMA's Building Energy Efficiency Program (BEEP) reports the following energy savings potentials:

- **7.3% - 22.9% savings potential thru calibration & monitoring of "control devices"**
- **3.5% - 15.9% whole bldg. energy savings potential thru equipment changes for HVAC systems and controls**
- **Utility expenditures are largest expense after taxes and on the average = 1/5th of total costs and 1/3rd of total variable costs**
- **IFMA →19% Increase in Utility Costs since 2006**



2nd Edition added:

- Established common vocabulary
- Best Practice Methods
  - Site visit methods
  - Measurement methods
  - Economic evaluation
  - How to get a good bid
- Resources
  - Audit forms
  - EEM ideas
  - Simulation checklists

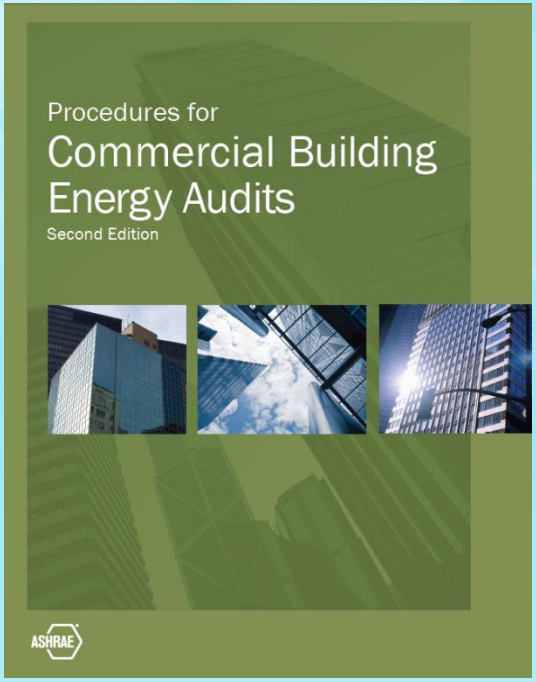
Audit Level Requirements

OVERVIEW of PCBEA

Defining Levels of Effort:

- Preliminary Energy Use Analysis (PEA)
- Level 1 – Walk-Through Survey
- Level 2 – Energy Survey and Analysis
- Level 3 – Detailed Analysis of Capital-Intensive Modifications (Investment Grade Audit – IGA)
- Targeted Audits – per Statement of Work or Owner Requirements

Relationship of ASHRAE Energy Audit Levels I, II, and III



Preliminary Energy Use Analysis

- Gather information
- Calculate kBTU/sf
- Compare to similar

Level I: Walk Through

- No cost/low cost items
- Rough costs and savings for EEM's
- Identify Capital projects

Level II: Energy Survey & Analysis

- End-use Energy breakdowns
- Cost & Savings analysis of major ECM measures
- O&M Changes
- Capital project outlines
- Detailed Analysis

Level III: Detailed Analysis of Capital Projects (includes modeling and simulation)

Refined Analysis, Additional Measurements, Hourly Simulation, Detailed Business and Investment Planning

Broad "Target ECM" Ideas for Consideration

- **Controls** The best opportunities related to controls include making systems automatic and with sequences that save energy
- **Electrical** Replacement of electric motors with high efficient ones and adding VFDs are always good ideas.
- **Internal and Plug Loads** Many opportunities to consider these to be able to turn off when not necessary
- **HVAC** Maintaining and repair/replacement of defective and in-efficient equipment including air handlers, fan coils, kitchen and make up hoods, ventilation devices, etc.
- **Domestic Hot Water** using energy efficient production equipment and deliver devices, and incorporating solar heating where applicable.
- **Lighting.** Lighting usually always pay back fast.
- **Envelope.** Tightening air leakage rates, and replacement of defective fenestrations including windows, doors, etc.
- **Fuel changes**. Consider using more efficient and cost-effective fuel types.
- **Renewables** Such as photovoltaics, solar heating, wind, bio-mass, cisterns, new products coming out every day.

Ideas for Consideration in Control Systems

- Temperature, Humidity, Pressure setpoint reset
- Night setbacks/ Morning warm-up/cool-downs + Optimal start-stop
- Outside air temperature reset
- CO_2 based Demand based ventilation system
- Re-calculation of ventilation requirements based on up to date standards, actual conditions at the site, and technology advances
- Energy recovery and transfer systems / Economizers / Natural ventilation
- Occupancy and non-occupancy/holiday scheduling
- Daylight Harvesting and Dimmers
- Variable Speed Drive tuning

Major Categories of EEM's

- E1. BUILDING ENVELOPE
  - E1.1 Walls
  - E1.2 Roofs
  - E1.3 Floors
  - E1.4 Windows
  - E1.5 Doors
  - E1.7 Moisture Penetration
- E2. HVAC SYSTEMS
  - E2.1 Ventilation
  - E2.2 HVAC Distribution Systems
  - E2.3 Building Automation and Control Systems
- E3. REFRIGERATION
  - E3.1 Reduce Loads
  - E3.2 Improve System Operating Efficiency
- E4. WATER SYSTEMS
  - E4.1 Domestic Hot-Water Systems
  - E4.2 Water Conservation
- E5. ENERGY GENERATION AND DISTRIBUTION
  - E5.1 Boiler System
  - E5.2 Chiller System
  - E5.3 Thermal Storage and Heat Pumps
- E6. NONRESIDENTIAL LIGHTING
  - E6.2 Daylighting
  - E6.3 Luminaire Upgrades
  - E6.4 Signage
  - E6.5 Lighting Controls
  - E6.6 Exterior Lighting
  - E6.7 Luminaire Layout
  - E6.8 Other
- E7. RESIDENTIAL LIGHTING
  - E7.2 Interior
  - E7.3 Exterior
- E8. ELECTRIC SYSTEMS, MOTORS
- E9. APPLIANCES

E1.1,1.2,1.3 Walls, Roofs & Floors

- **E1.1 <u>Walls</u>**
- **E1.1.1** Insulate Walls**.** Retrofit insulation can be external and internal.
- **E1.1.1.1** External post insulation makes large savings possible, as this type of insulation contributes not only to a reduction of the heat loss through large wall surfaces but also eliminates the traditional thermal bridges where floor and internal wall are anchored in the exterior wall.
- **E1.1.1.2** Internal insulation is typically used when external insulation is not allowed (e.g., for historical buildings).
- **E1.1.2** Insulate cavity walls using spray-in insulation.
- **E1.1.3** Consider converting internal courtyard into an atrium to reduce external wall surface.
- **E1.2 <u>Roofs</u>**
- **E1.2.1** Use “cool roof” (high-reflectance roofing material) with reroofing projects.
- **E1.2.2** Determine roof insulation values and recommend roof insulation as appropriate.
- **E1.2.3** Insulate ceilings and roofs using spray-on insulation.
- **E1.2.4** Where appropriate, exhaust hot air from attics.
- **E1.3 <u>Floors</u>**
- **E1.3.1** Insulate floors.
- **E1.3.2** Insulate floors using spray-on insulation.
- **E1.3.3** Insulate basement wall with a slab over unheated basement.

E1.4 Windows

- **E1.4 <u>Windows</u>**
- **E1.4.1** Replace single-pane and leaky windows with thermal/operable windows to minimize cooling and heating loss.
- **E1.4.2** Install exterior shading, such as blinds or awnings, to cut down on heat loss and to reduce heat gain.
- **E1.4.3** Install storm windows and multiple glazed windows.
- **E1.4.4** Use tinted or reflective glazing or energy control/solar window films.
- **E1.4.5** Replace existing fenestration (top lighting and/or side lighting) with dual-glazed low-e glass wherever possible to reduce thermal gain.
- **E1.4.6** Adopt weatherization/fenestration improvements.
- **E1.4.7** Consider replacing exterior windows with insulated glass block when visibility is not required but light is required.
- **E1.4.8** Landscape/plant trees to create shade and reduce air-conditioning loads.

E1.5. 1.7 Doors, Moisture Protection

- **E1.5 <u>Doors</u>**
- **E1.5.1** Prevent heat loss through doors by draft sealing and thermal insulation.
- **E1.5.2** Install automatic doors, air curtains, or strip doors at high-traffic passages between conditioned and unconditioned spaces.
- **E1.5.3** Use self-closing or revolving doors and vestibules if possible.
- **E1.5.4** Install high-speed doors between heated/cooled building space and unconditioned space in the areas with high-traffic passages.
- **E1.5.5** Install separate smaller doors for people near the area of large vehicle doors air leakage
- **E1.5.6** Seal top and bottom of building.
- **E1.5.7** Seal vertical shafts, stairways, outside walls, and openings.
- **E1.5.8** Compartmentalize garage doors and mechanical and vented internal and special-purpose rooms.

- **E1.7 <u>Moisture Protection</u>**
- **E1.7.1** Reduce air leakage.
- **E1.7.2** Install vapor barriers in walls, ceilings, and roofs.

E2.1 HVAC SYSTEMS

- **E2.1 Ventilation**
- **E2.1.1** Reduce HVAC systems outdoor airflow rates when possible. Minimum outdoor airflow rates should comply with ANSI/ASHRAE Standard 62.1 or local code requirements.
- **E2.1.2** Reduce minimum flow settings in single-duct and dual-duct variable-air-volume (VAV) terminals as low as is practical to meet ventilation requirements.
- **E2.1.3** Minimize exhaust and makeup (ventilation) rates when possible by complying with the most stringent federal, state, and/or local code requirements.
- **E2.1.4** When available, use operable windows for ventilation during mild weather (natural ventilation) when outdoor conditions are optimal. Confirm that the facility has been designed for natural ventilation and that control strategies are available to operate the facility in the natural ventilation mode.
- **E2.1.5** Eliminate outside air ventilation during unoccupied building morning warm up.
- **E2.1.6** Convert mixing air supply systems into displacement ventilation systems to create a temperature stratification in spaces with high ceilings and predominant cooling needs.
- **E2.1.7** Consider replacement of all-air HVAC system with a combination of a dedicated outdoor air system coupled with radiant cooling and heating systems.
- **E2.1.8** Convert constant-volume central exhaust systems into demand-based controlled central exhaust systems when possible.
- **E2.1.9** Convert HVAC systems to provide ventilation in accordance with ANSI/ASHRAE Standard 62.1

E2.2 Distribution

- **E2.2 HVAC Distribution Systems**
- **E2.2.1** Convert a constant-air-volume system (CAV) (including dual duct, multizone, and constant-volume reheat systems) into a VAV system with variable speed drives (VFDs) on fan motors. A VAV system is designed to deliver only the volume of air needed for conditioning the actual load.
- **E2.2.2** Control VAV system VFD speed based on the static pressure needs in the system. Reset the static pressure set point dynamically, as low as is practical to meet the zone setpoints.
- **E2.2.3** Reset VAV system supply air temperature setpoint when system is at minimum speed to provide adequate ventilation.
- **E2.2.4** If conversion to VAV from CAV systems is impractical, reset supply air temperatures in response to load.
- Dynamically control heating duct temperatures as low as possible, and cooling duct temperatures as high as possible, while meeting the load.
- **E2.2.5** Use high-efficiency fans and pumps; replace or trim impellers of existing fans if they have excessive capacity relative to peak demand.
- **E2.2.6** Install higher efficiency air filters/cleaners in HVAC system. Size ducts and select filter sizes for low face velocity to reduce pressure drop where available space permits.
- **E2.2.7** Insulate HVAC ducts and pipes, particularly where they are outside the conditioned space. Ensure that duct insulation and vapor barrier is maintained or enhanced to ensure thermal performance and avoid water vapor intrusion.
- **E2.2.8** Check for air leaks in HVAC duct systems, and seal ductwork as indicated.
- **E2.2.9** Rebalance ducting and piping systems.
- **E2.2.10** Provide cooling effect by creating air movement with fans.
- **E2.2.11** Select cooling coils with a face velocity range of 300 to 350 fpm (1.5 to 1.75 m/s) to reduce the air pressure drop across the cooling coil and increase the chilled-water system temperature differential across the system.

E2.2 cont'd

- **E2.2.12** Replace standard fan belts with fan belts designed for minimum energy losses, such as cog belts.
- **E2.2.13** Eliminate or downsize existing HVAC equipment in an existing building or group of buildings when improvements in building envelope, reductions in lighting or plug loads, and other EEMs that reduce cooling or heating loads have been implemented.
- **E2.2.14** Eliminate HVAC usage in vestibules and unoccupied spaces.
- **E2.2.15** Minimize direct cooling/heating of unoccupied areas by system zone controls, occupancy sensors or by turning off fan-coil units and unit heaters.
- **E2.2.16** Replace forced-air heaters with low- or medium temperature radiant heaters.
- **E2.2.17** Replace inefficient window air conditioners with high-efficiency (i.e., high SEER rating) modular units or central systems.

E2.2 cont'd

- **E2.2.18** Employ heat recovery from exhaust air and processes for preheating or precooling incoming outdoor air or supply air.
- **E2.2.19** Install transpired air heating collector (solar wall) for ventilation air preheating.
- **E2.2.20** Modify controls and/or systems to implement night precooling to reduce cooling energy consumption the following day.
- **E2.2.21** Use waste heat (e.g., hot gas, return air heat, return hot water) as an energy source for reheating for humidity control.(Often air is cooled to dew-point to remove moisture and then must be reheated to desired temperature and humidity.)
- **E2.2.22** Avoid temperature stratification with heating, either by proper air supply system design or by using temperature de-stratifiers (e.g., ceiling fans).
- **E2.2.23** In humid climates, supply air with a temperature above the dew point to prevent condensation on cold surfaces.
- **E2.2.24** Insulate fan-coil units and avoid their installation in unconditioned spaces.
- **E2.2.25** Clean heat exchangers (to maintain heat exchange efficiency) in the evaporators and condensers of refrigeration equipment on a seasonal basis.
- **E2.2.26** Use high-efficiency dehumidification systems based on either dedicated outdoor air systems (DOAS) or VAV systems.
- **E2.2.27** Identify if there are any rogue zones (i.e., zones that determine the cooling or heating demand on the entire system) in a multiple-zone air-handling system, and modify them to eliminate their negative impact.
- **E2.2.28** Modify supply duct systems to eliminate duct configurations that impose high friction losses on the system.
- **E2.2.29** Convert three-pipe heating/cooling distribution systems to four-pipe or two-pipe systems. Eliminate simultaneous heating and cooling through mixed returns.

E2.2 cont'd

- **E2.2.30** Convert steam or compressed air humidifiers to ultrasonic or high-pressure humidifiers.
- **E2.2.31** Replace mechanical dehumidification with desiccant systems using heat-recovery regeneration.
- **E2.2.32** Consider small unitary systems for small zones with long or continuous occupancy. Avoid running large distribution systems to meet needs of small, continuously occupied spaces.
- **E2.2.33** Install thermostatic control valves on uncontrolled or manually controlled radiators.
- **E2.2.34** Replace unitary systems with newer units with high-efficiency and high SEER ratings.
- **E2.2.35** Install evaporative precooling for direct-expansion (DX) systems.
- **E2.2.36** Install air-side heat recovery for systems using 100% makeup air (e.g., run-around piping or energy exchange wheels).
- **E2.2.37** In reheat systems, making adjustments as necessary to minimize reheat energy consumption while maintaining indoor environmental quality.
- **E2.2.38** In multiple-zone systems, identify any rogue zones that consistently cause the reset of system level setpoints in order to satisfy that one zone's heating or cooling demands.

E2.3 Building Automation and Control Systems

- **E2.3.1** Create building/air-conditioned space zones with separate controls to suit solar exposure and occupancy.
- **E2.3.2** Use night setback, or turn off HVAC equipment when building is unoccupied.
- **E2.3.3** Install occupancy sensors with VAV systems; set back temperatures and shut off boxes.
- **E2.3.4** Install system controls to reduce cooling/heating of unoccupied space.
- **E2.3.5** Lower heating and raise cooling temperature setpoints to match the comfort range prescribed in ANSI/ ASHRAE Standard 55.8
- **E2.3.6** Install an air-side and/or water-side economizer cycle with enthalpy switchover when compatible with the existing equipment, space occupancy, and distribution system
- **E2.3.7** Schedule off-hour meetings in a location that does not require HVAC in the entire facility.
- **E2.3.8** Retrofit multiple-zone VAV systems with direct digital controls (DDC) controllers at the zone level, and implement supply air duct pressure reset to reduce supply air duct pressure until at least one zone damper is nearly wide open.
- **E2.3.9** Eliminate duplicative zone controls (e.g., multiple thermostats serving a single zone with independent controls).
- **E2.3.10** Adjust hot-water and chilled-water temperature to develop peak-shaving strategies based on an outside air temperature reset schedule.
- **E2.3.11** Adjust housekeeping schedule to minimize HVAC use.
- **E2.3.12** Install programmable zone thermostats with appropriate dead bands.
- **E2.3.13** Use variable-speed drives (VSDs) and DDC on water circulation pump and fan motors and controls.
- **E2.3.14** Reduce operating hours of complementing heating and cooling systems. Ensure proper location of thermostat to provide balanced space conditioning.
- **E2.3.15** Implement an energy management system (EMS) designed to optimize and adjust HVAC operations based on environmental conditions, changing uses, and timing.

E3.1 REFRIGERATION

- **E3.1 Reduce Loads**
- **E3.1.1** Install strip curtains or automatic fast open and close doors on refrigerated space doorways.
- **E3.1.2** Replace open refrigerated cases with reach-in refrigerated cases.
- **E3.1.3** Replace old refrigerated cases with new high-efficiency models (improved glazing, insulation, motor efficiency, and reduced anti-sweat requirements).
- **E3.1.4** Replace worn door gaskets.
- **E3.1.5** Replace broken or missing automatic door closers.
- **E3.1.6** Check defrost schedules and avoid excessive defrost.
- **E3.1.7** Repair/install refrigeration piping insulation on suction lines.
- **E3.1.8** Install humidity-responsive antisweat heating (ASH) controls on refrigerated case doors.
- **E3.1.9** Install refrigerated case, walk-in, or storage space lighting controls (scheduled and/or occupancy sensors).
- **E3.1.10** Install night covers to reduce infiltration in open cases.
- **E3.1.11** Install low/no ASH refrigerated case doors.
- **E3.1.12** Replace lights with LED strip lights with motion sensors in refrigerated cases and spaces.
- **E3.1.13** Increase insulation on walk-in boxes and storage spaces that have visible moisture or ice on walls, corners, etc. Ensure that insulation and vapor barrier are maintained or enhanced to ensure thermal performance and avoid water vapor intrusion.

E3.2 Refrigeration System Operating Efficiency

- **E3.2 Improve System Operating Efficiency**
- **E3.2.1** Clean condenser coils.
- **E3.2.2** Check the refrigerant charge and add when needed.
- **E3.2.3** Reclaim heat from hot gas line for domestic water heating or space heating.
- **E3.2.4** Install floating-head pressure controls, adjustable head pressure control valve, and balanced port expansion valves for DX systems.
- **E3.2.5** Install floating suction pressure controls on DX systems.
- **E3.2.6** Install evaporator fan motor VSDs and controllers in walk-ins and refrigerated storage spaces.
- **E3.2.7** Replace single-phase, less than 1-hp evaporator fan motors with electrically commutated motors.
- **E3.2.8** Replace three-phase evaporator and condenser motors with premium efficiency motors.
- **E3.2.9** Replace single compressor systems with multiplex systems and control system.
- **E3.2.10** Install mechanical sub cooling.
- **E3.2.11** Install mechanical unloaders on appropriate multiplex reciprocating semi hermetic compressors.
- **E3.2.12** Install VFD on ammonia screw compressors.
- **E3.2.13** Install high specific-efficiency (Btu/W) condensers.
- **E3.2.14** Install hybrid air-cooled/evaporative-cooled condensers.

E4.1 DOMESTIC HOT WATER SYSTEMS

- **E4.1 Domestic Hot-Water Systems**
- **E4.1.1** Lower domestic water setpoint temperatures to 120°F (49°C)
- **E4.1.2** Install point-of-use gas or electric water heaters.
- **E4.1.3** Install water-heater blankets on water heaters.
- **E4.1.4** Where permitted by the manufacturer, and in conjunction with the manufacturer's control system, install automatic flue dampers on fuel-fired water heaters.
- **E4.1.5** Insulate hot-water pipes.
- **E4.1.6** Reclaim heat from waste water, refrigeration systems, cogeneration, or chillers.
- **E4.1.7** Install solar heating where applicable.
- **E4.1.8** Replace dishwashers by installing low-temperature systems that sanitize primarily through chemical agents rather than high water temperatures.
- **E4.1.9** Retrofit dishwashers by installing electric-eye or sensor systems in conveyor-type machines so that the presence of dishes moving along the conveyor activates the water flow.
- **E4.1.10** Reduce operating hours for water-heating systems.
- **E4.1.11** Install gray water heat recovery from showers, dishwashers, and washing machines.
- **E4.1.12** Install low-flow dishwashing prewash spray nozzles.
- **E4.1.13** Replace outdated laundry equipment with newer models.

E4.2 Water Conservation

- **E4.2 <u>Water Conservation</u>**
- **E4.2.1** Replace faucets with units that have infrared sensors or automatic shutoff.
- **E4.2.2** Install water flow restrictors on shower heads and faucets.
- **E4.2.3** Install covers on swimming pools and tanks.
- **E4.2.4** Install devices to save hot water by pumping water in the distribution lines back to the water heater so that hot water is not wasted. Install industrial waste/sewage metering.
- **E4.2.5** Install water metering.
- **E4.2.6** Install landscape irrigation timers to schedule sprinkler use to off-peak, night, or early morning hours when water rates are cheaper and water used is less likely to evaporate.
- **E4.2.7** Use low-flow sprinkler heads for landscape irrigation instead of turf sprinklers in areas with plants, trees, and shrubs.
- **E4.2.8** Use sprinkler controls for landscape irrigation that employ soil tensiometers or electric moisture sensors to help determine when soil is dry and to gauge the amount of water needed.
- **E4.2.9** Use trickle or subsurface drip systems for landscape irrigation that provide water directly to turf roots, preventing water loss by evaporation and runoff.
- **E4.2.10** Install low-flow toilets and waterless urinals
- **E4.2.11** Use water reclamation techniques.

E5.1 ENERGY GENERATION AND DISTRIBUTION

- **E5.1 Boiler System**
- **E5.1.1** Install air-atomizing and low NOx burners for oil-fired boiler
- **E5.1.2** Investigate economics of adding insulation on presently insulated or uninsulated lines. If pipe or duct insulation is missing, replace it with new material. Ensure that the pipe insulation and vapor barrier is maintained or enhanced to ensure thermal performance and avoid water vapor intrusion.
- **E5.1.3** Review mechanical standby turbines presently left in the idling mode.
- **E5.1.4** Review operation of steam systems used only for occasional services, such as winter-only tracing lines.
- **E5.1.5** Review pressure-level requirements of steam-driven mechanical equipment to consider using lower exhaust pressure levels.
- **E5.1.6** Survey condensate presently being discharged to waste drains for feasibility of reclaim or heat recovery.
- **E5.1.7** Reduce boiler operating pressure to minimize heat losses through leakage.

E5.2 Chillers

- **E5.2 <u>Chiller System</u>**
- **E5.2.1** Chiller retrofits with equipment that has high efficiency at full and part load.
- **E5.2.2** Cooling tower retrofits including high-efficiency fill, VSD fans, fiberglass fans, hyperbolic stack extensions, fan controls, VSD pump drives, and improved distribution nozzles.
- **E5.2.3** Install economizer cooling systems (HX between cooling tower loop and chilled-water loop before the chiller).
- **E5.2.4** Install evaporative cooled, evaporative precooled, or water-cooled condensers in place of air-cooled condensers.
- **E5.2.5** Isolate offline chillers and cooling towers.
- **E5.2.6** Reduce over pumping on chilled-water systems.
- **E5.2.7** Replace single compressor with multiple different size staged compressors.
- **E5.2.8** Compressor motors.
- **E5.2.9** Use of absorption chiller when there is cogeneration system, waste heat, or solar thermal available.
- **E5.2.10** Install double-bundle chillers for heat recovery.
- **E5.2.11** Free cooling cycle by piping chilled water to condenser during cold weather.

E5.2 cont'd

- **E5.2.12** Prevent chilled water or condenser water flowing through the offline chiller. Chillers can be isolated by turning off pumps and closing valves.
- **E5.2.13** For equipment cooling, control makeup water and reduce blowdown by adding temperature control valves to cooling water discharge lines in equipment such as air compressors and refrigeration systems.
- **E5.2.14** For evaporative cooling systems, install drift eliminators or repair existing equipment.
- **E5.2.15** For evaporative cooling systems, install softeners for makeup water, side-stream filtration (including nanofiltration, a form of low-pressure reverse osmosis), and side stream injection of ozone.
- **E5.2.16** For evaporative cooling systems, install sub meters for makeup water and bleed-off water for equipment such as cooling towers that use large volumes of water.
- **E5.2.17** Evaporative cooling systems control cooling tower bleed off based on conductivity by allowing bleed off within a high and narrow conductivity range. This will achieve high cycles of concentration in the cooling system and reduce water use in cooling towers.
- **E5.2.18** Clean evaporator and condenser surfaces of fouling.
- **E5.2.19** Optimize plant controls to raise evaporator temperature as high as possible while meeting system loads. Also optimize condenser water temperature control to achieve best combination of chiller and tower efficiency.
- **E5.2.20** Optimize multiple chiller sequencing.
- **E5.2.21** Control crankcase heaters off when they're not needed.
- **E5.2.22** Raise evaporator or lower condenser water temperature.
- **E5.2.23** Optimize multiple chiller sequencing.
- **E5.2.24** Use two-speed or variable-speed fans instead of water bypass to modulate the cooling tower capacity.
- **E5.2.25** Balance water flow in the chilled-water system.
- **E5.2.26** Use VFDs for the primary chilled-water pumps above 5 hp (3.7 kW). Consult chiller and tower manufacturers' specifications to set appropriate minimum flow limits.
- **E5.2.27** Apply cooling load-based optimization strategies.
- **E5.2.28** Install water-source heat pumps (WSHPs) to augment the capacity of the hot-water boiler and to reduce the cooling load on the existing chiller systems when heat is required.
- **E5.2.29** Trim impellers on all condenser water and chilled water pumps that are oversized.
- **E5.2.30** Replace all pump and fan motors with premium efficiency motors.

E5.3 Thermal Storage and Heat Pumps

- **E5.3 <u>Thermal Storage and Heat Pumps</u>**
- **E5.3.1** Install cool storage to reduce peak demand and lower electric bills.
- **E5.3.2** Install hot-water storage to shave peaks of hot-water usage or to store reclaimed energy from combined heat and power systems or waste heat from chillers for later use.
- **E5.3.3** Install add-on heat pumps.
- **E5.3.4** Install secondary pumping systems.
- **E5.3.5** Install VFDs on secondary pumps and replace most three-way valves with two-way valves.
- **E5.3.6** With cool storage and VFDs on fans and pumps, consider use of low-temperature chilled water to reduce fan and pump energy.
- **E5.3.7** Replace electrically powered air conditioning and heating units with heat pumps. Consider geothermal or ground-source heat pumps.
- **E5.3.8** Replace electric water heaters with electric heat pump water heaters.
- **E5.3.9** The application of cogeneration should be considered where use of both electrical and thermal energy can be achieved on a cost-effective basis.

E6.1, 6.2, 6.3 Lighting

- **E6.1 NONRESIDENTIAL LIGHTING** In implementing any of these EEMs, care should be taken to not compromise the photometric distribution or any required light levels.
- **E6.1 General.** Check the current IES recommended light levels for the tasks in the facility. They may be lower than when the original lighting system was designed. Use these current recommended light levels to help shape all future lighting decisions, including those enumerated here.
- **E6.2 Daylighting**
- **E6.2.1** In any spaces with fenestration, evaluate opportunities for daylight harvesting by determining the spatial daylight autonomy(sDA) in accordance with IES LM-83. In spaces where sDA300,50% is greater than 55%, consider installing daylight switching or daylight dimming controls (and appropriate ballasts if the lighting system is fluorescent or HID) to reduce use of electric lighting.
- **E6.2.2** In any spaces with fenestration, evaluate the need for shading by determining the annual sunlight exposure (ASE) in accordance with IES LM-83. In spaces where ASE1000,250 is greater than 10%, interior and/or exterior shading should be installed to reduce solar heat gain and cut down on heat loss and control the amount of light entering the space from the exterior.
- **E6.2.3** Install a skylight, tubular daylighting device, or sunlight delivery system to reduce the use of electric lighting and provide natural daylight to the internal spaces of the building.
- **E6.3 Luminaire Upgrades**
- **E6.3.1** Upgrade incandescent lamps in existing luminaires with more effective sources, such as halogen, integrally ballasted compact fluorescent, solid state (LED), or metal halide retrofit lamps. Alternatively, replace incandescent luminaires with luminaires using these sources.
- **E6.3.2** Upgrade T12 fluorescent luminaires with more effective sources, such as high-performance T8 or T5 systems, by replacing lamps and ballasts, utilizing luminaire upgrade kits, or installing new luminaires.
- **E6.3.3** If the lighting system is already a high-performance fluorescent system, consider replacing the lamps with reduced wattage lamps (where appropriate).
- **E6.3.4** For fluorescent lighting, install high-performance electronic ballasts that are multilevel or continuously dimmable with the appropriate controls.
- **E6.3.5** Replace mercury vapor or probe-start metal halide HID luminaires with pulse-start metal halide or high-performance T8 or T5 fluorescent luminaires.
- **E6.3.6** Upgrade task and display lighting, including lighting in refrigeration and freezer cases, to more effective sources such as LED.

E6.4 Signage

- **E6.4 Signage**
- **E6.4.1** Evaluate upgrading standard fluorescent or neon
- signage with more effective sources, such as high-performance
- T8 or T5 fluorescent systems or solid-state (LED) systems.
- **E6.4.2** Upgrade all exit signs to solid state (LED). Supplemental
- lighting may need to be added if the existing exit sign
- also provided general lighting.

E6.5 Lighting Controls

- **E6.5 <u>Lighting Controls</u>**
  - **E6.5.1** Reduce lighting use through management and controlled systems. In general, consider bringing the lighting control protocols for the building up to ASHRAE/IES Standard 90.1-2010 (Section 9.4.1) standards; this includes the following.
  - **E6.5.2** Reduce operating hours for lighting systems through the use of controls and building management systems. This includes the use of shut-off controls, such as time switches.
  - **E6.5.3** Use reduced lighting levels, including off, when spaces are unoccupied, during nighttime hours, for restocking, cleaning and security. Whenever possible move restocking and cleaning operations to normal operating hours.
  - **E6.5.4** Use occupancy, vacancy, or motion sensors. Wherever applicable, these sensors should either be manual-on or turn lighting on to no more than 50% of lighting power.
  - **E6.5.5** Use controls to provide multiple light levels or dimming where appropriate.
  - **E6.5.6** Recircuit or rezone lighting to allow personnel to only turn on zones based on use rather than operating the entire lighting system.
  - **E6.5.7** Install personal lighting controls so individual occupants can vary the light levels within their spaces.
  - **E6.5.8** Consider installation of lighting systems that facilitate load shed requests from the electric utility or energy aggregator.
  - **E6.5.9** Evaluate turning emergency lighting off or to a lower level when a building or portion of a building is completely unoccupied, without sacrificing safety requirements.

E6.6 Exterior Lighting

- **E6.6 <u>Exterior Lighting</u>**
- **E6.6.1** Use automatic controls that can reduce outdoor lighting levels or turn lights off when either sufficient daylight is available or when lighting is not needed. All façade and landscape lighting should be off from an hour after closing until an hour before opening. All other lighting should be reduced by at least 30% during that same time frame or when a motion sensor detects no activity for 15 minutes. These controls are not applicable to lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security, or eye adaptation.
- **E6.6.2** Reduce power levels or turn exterior signage off when appropriate.
- **E6.6.2.1** Signs that are meant to be on for some part of daylight hours should be reduced in power by at least 65% during nighttime hours. All other sign lighting should automatically turn off during daylight hours and reduced in power by at least 30% from an hour after closing until an hour before opening. These controls are not applicable to sign lighting using metal halide, high-pressure sodium, induction, cold cathode, or neon lamps that are automatically reduced by at least 30% during nighttime hours.
- **E6.6.3** When selecting new outdoor luminaires, consider the amount of backlight, uplight, and glare delivered by each luminaire type to improve functionality and minimize environmental impacts. See Section 5.3.3 of ANSI/ASHRAE/USGBC/IES Standard 189.1-2011, *Standard for the Design of High-Performance Green Buildings*.

E6.7, 6.8 Luminaire Layout & Other

- **E6.7 <u>Luminaire Layout</u>**
- **E6.7.1** Consider using lower levels of general illumination overall and then supplement with task lighting where needed.
- **E6.7.2** Consider new layouts that may maximize efficiency and reduce the total connected lighting load. Consider plug and-play systems to provide flexibility as space use changes.
- **E6.8 <u>Other</u>**
- **E6.8.1** Implement a plan to recycle lamps, ballasts, and luminaires removed from the building.
- **E6.8.2** Consider updating lighting systems to provide for demand response capability so that lighting loads are reduced during periods of peak electricity demand. These types of systems can provide day-to-day energy savings in addition to demand response capability.

E8 Electric Systems, Motors
E9 Appliances

- **E8.1** Install energy-efficient transformers. Use infrared cameras to identify high-heat-loss transformers.
- **E8.2** Install electrical meters for sub metering lighting, elevators, plug loads, and HVAC equipment.
- **E8.3** Reduce demand charges through load shedding, operational changes, and procedural changes.
- **E8.4** Replace oversized electric motors with right-sized or slightly oversized motors.
- **E8.5** Replace existing three-phase, 1 hp (746 W) and greater electric motors with premium-efficiency motors (often a better choice than rewinding motors).
- **E8.6** Replace existing one-phase, 1 hp (746 W) and less motors with electrically commutated motors.
- **E9. APPLIANCES**
- **E9.1** Install appliances (clothes washers, dehumidifiers, dishwashers, freezers, refrigerators, room air cleaners and purifiers, office equipment, and televisions) that are certified as ENERGY STAR® compliant.
- **E9.2** Reduce plug loads, using devices to shut off equipment not being used (use occupancy sensors or timers).
- **E9.3** Install vending-machine controllers.

Case Study #1 – Existing Office Building

- 6 – Story, 140,000 SF occupied in 2000
- Existing operational cost = $1.40/SF as compared to original projection of $0.90/SF
- Investigation Phase results –
  - VFDs ran at 100% output
  - 2-way valves of re-heat boxes leaked
  - Duct static pressure set very high
  - Fresh air dampers "opened" when AHUs went into night set-back mode
  - Bldg ran "occupied mode" for 16 hours while occupancy was only 10 hours

Case Study #1 – Existing Office Building

- Investigation Phase results –
  - High air flows when offices/rooms were empty
  - AHU discharge air controllers gave constant temp of 55°F
  - Building exhaust system ran 24/7
  - Space temps varied > 7°F; T'stats required 5°F differential before full output occurred
  - Occupants able to adjust T'stats between 55°F and 85°F
  - Unoccupied VAV boxes setpoints = occupied setpoints

Case Study #1 – Existing Office Building

- Investigation Phase results –
  - Electric baseboard radiation energized when outdoor temperature < 50°F
  - Boiler reset temp = 120°F during summer & caused reheat in spaces
  - Most VAV boxes required constant reheat year around
  - Excessive outside air was introduced per CO_2 measurements
  - AHUs had full economizers + chiller energized at 50°F outdoor air temperature

Case Study #1 – Existing Office Building

- Improvement Phase –
  - VAV minimums were lowered from 8 ACH to 4 ACH
  - CO_2 levels controlled at 800 ppm
  - Lowering of duct static pressure & one duct replacement allowed better overall operation
  - Fresh air dampers kept closed on night setback
  - Occupancy times correspond to actual occupant requirements
  - Interior zone VAV boxes set to low-flow/no flow on night setback

Case Study #1 – Existing Office Building

- Improvement Phase –
  - Occupancy sensors and lighting interlocks put on all conference and meeting room VAV boxes
  - Unoccupied VAV minimum setpoint were set below occupied setpoints
  - Building exhaust system shut off in unoccupied mode
  - Mixed air and discharge air temps reset per cooling and humidity control requirements based on outside air temperatures
  - Chiller activated at 58°F outdoor temperature

Case Study #1 – Existing Office Building

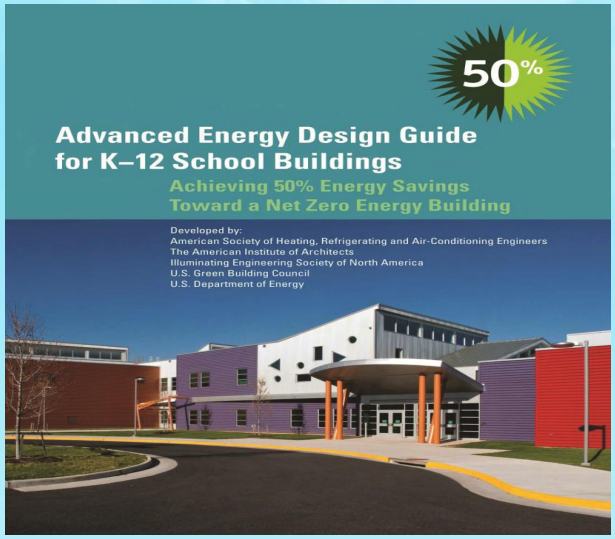
- Improvement Phase –
  - Boiler operating temperatures reset for heating and re-heating requirements
  - Baseboard electric radiation deactivated until outside air temperature was 30°F; Heaters cycled every 5 minutes to reduce electric demand
  - DDC modified to control all thermostats; occupants could still adjust full range but DDC only allowed ± 2°F change from predetermined setpoints
  - Control parameters adjusted to maintain control within ± 0.5°F

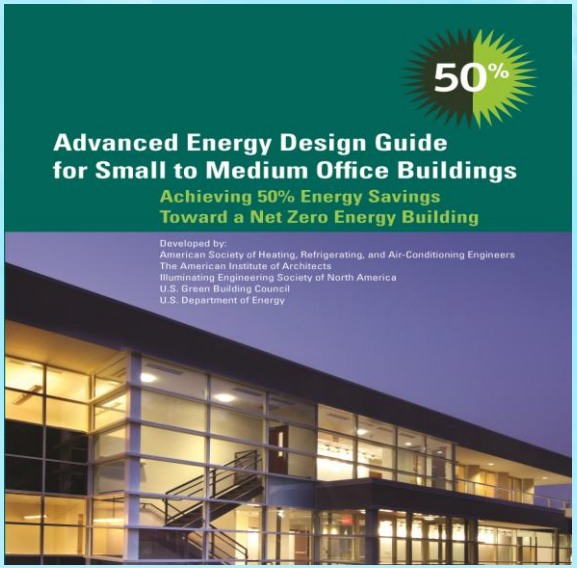
Case Study #1 – Existing Office Building

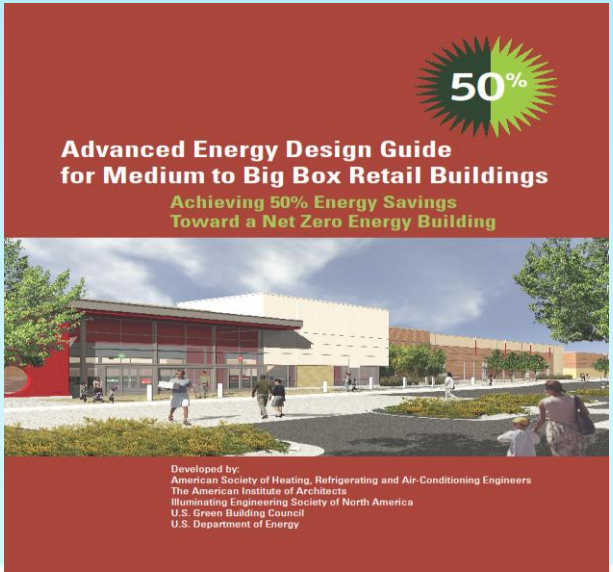
EEM	Cost	Savings	SPP
• Reduce airflows	$25,000	$7,540	3.31
• Reset DA Temps	$800	$4,708	0.17
• Red. Occ. Run Times	$700	$7,976	0.1
• Red. O/A	$7,500	$27,432	0.27
• Red. AHU S.P.	$2,000	$2,068	0.96
• Red. Pump Press.	$500	$2,072	0.24
• Elim. RH Leaks	$2,500	$8,368	0.30
• Improve Control Seq.	$5,000	$5,000	1.00
• Investigative Costs	$56,000	$2,836	19.70
Totals (2002 $)	$100,000	$68,000	SPP = 1.5

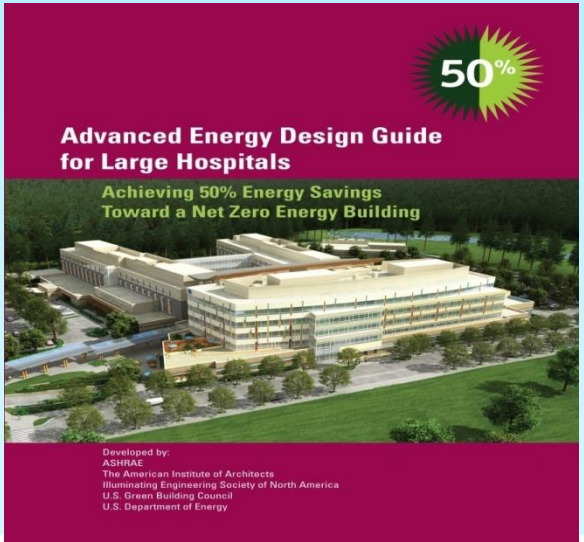
Advanced Energy Design Guidance

Advanced Energy Design Guidance

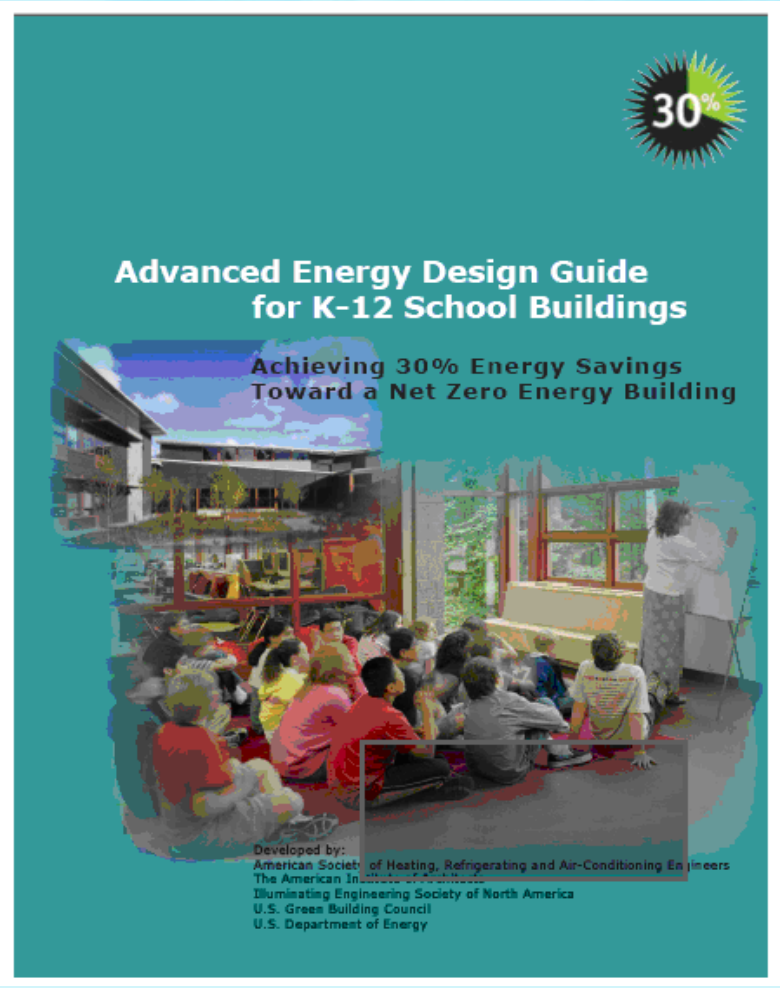




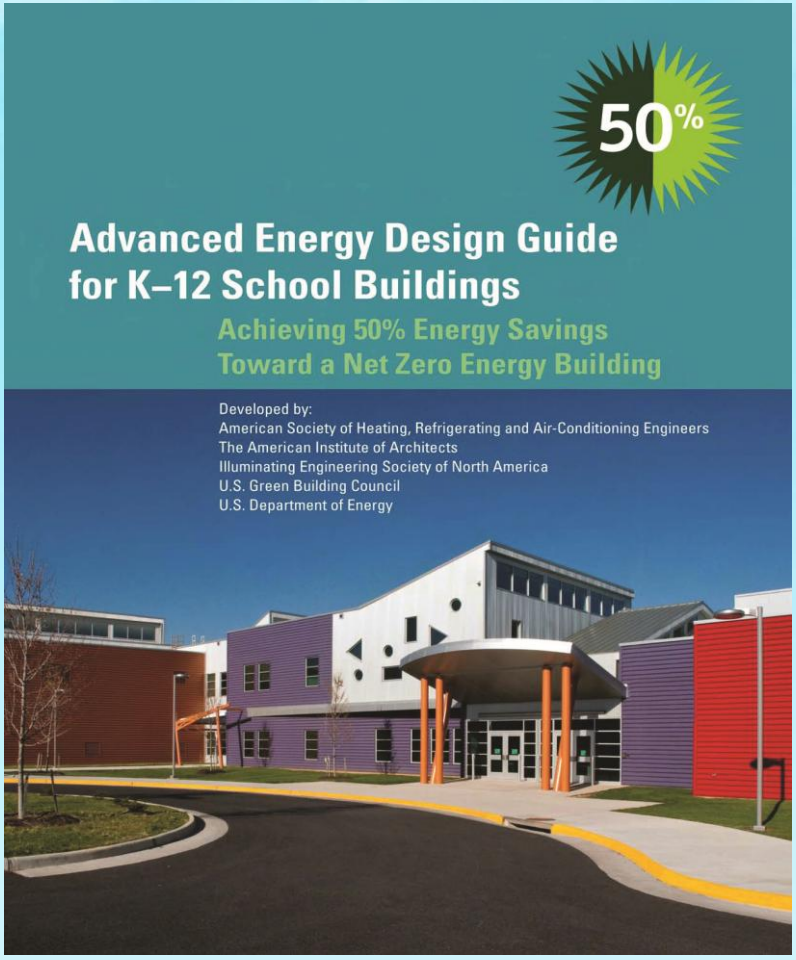




Advanced Energy Guidance (30%)



Advanced Energy Guidance (50%)



Analytical Approach

- Prototypes for representative:
  - K-12 schools: elementary, middle, high school
  - Space types: Classroom, Hallway, Gym, Administration, Cafeteria, Media room, Auditorium, Specialty use
  - Six HVAC systems in K-12 schools (30%) & Three HVAC systems in K-12 schools (50%)
- Recommendations by 8 DOE climate zones
- Hour-by-hour simulation using EnergyPlus & eQuest,
- Assure that 30% or 50% savings achieved in all 15 climates analyzed within these zones

Prescriptive Recommendations

- Envelope (30% & 50%)
  - Roof
  - Walls
  - Floors
  - Slabs
  - Doors
  - Vestibules(50%)
  - Vertical Fenestration
  - Interior Finishes
- Interior Lighting – Two options-30%
  - Multiple options-50%
- HVAC
  - DX -30%
  - WSHP-30%
  - GSHP-50%
  - Unit Ventilator and Chiller-30%
  - Fancoil & Chiller-30% & 50%
  - Package Rooftop VAV-30%
  - VAV and Chiller-30% & 50%
  - Ventilation Systems-30% & 50%

Prescriptive Recommendations

- HVAC
  - Ducts & Dampers-30% & 50%
  - M&V/Benchmarking-50%
- Exterior Lighting-50%
- Equipment Choices-50%

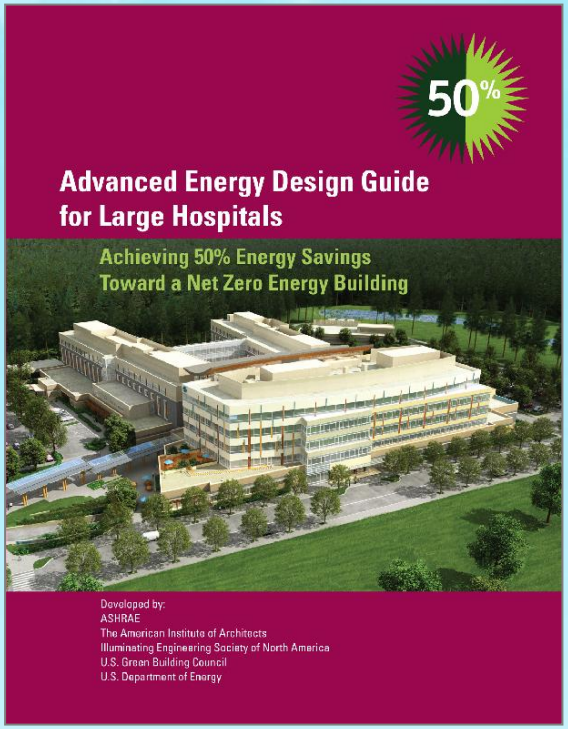
  - Computers

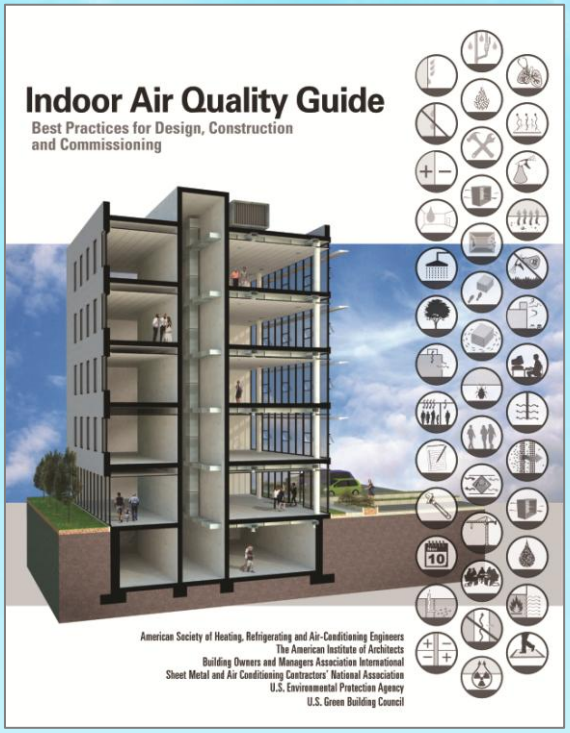
  - Vending Machines
- Controls/Programs-50%

  - Power/outlet controls
- Service Water Heating
  - 30% & 50%
- Kitchen Equipment-50%

"FREE" Related ASHRAE bEQ Publications

- **AEDG;** Advanced Energy Design Guides
- **IAQG;** Indoor Air Quality Guide--

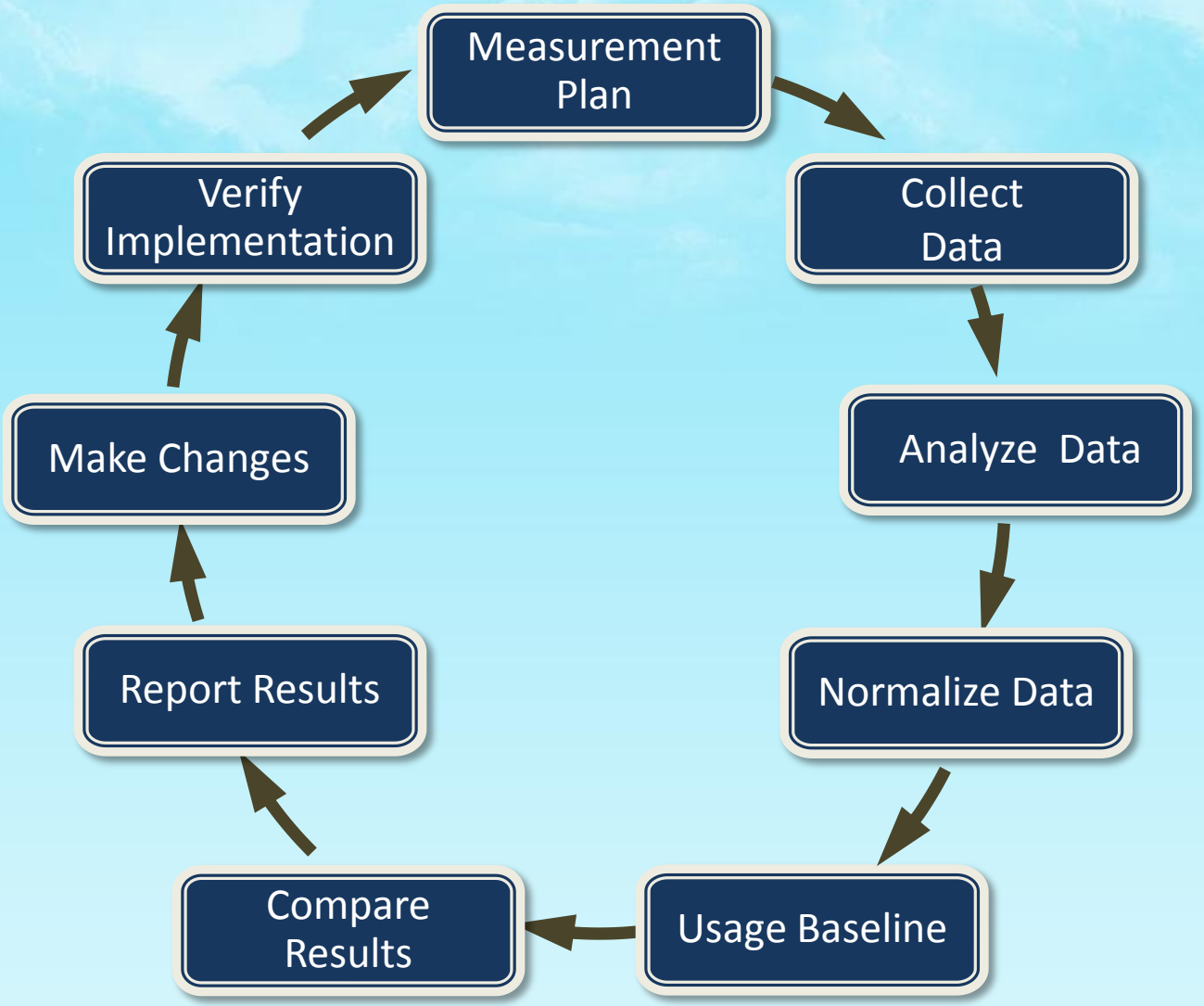




www.techstreet.com/ashrae

On Going Commissioning

On Going Commissioning

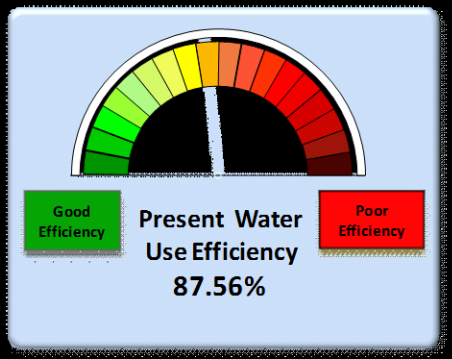


On Going Commissioning

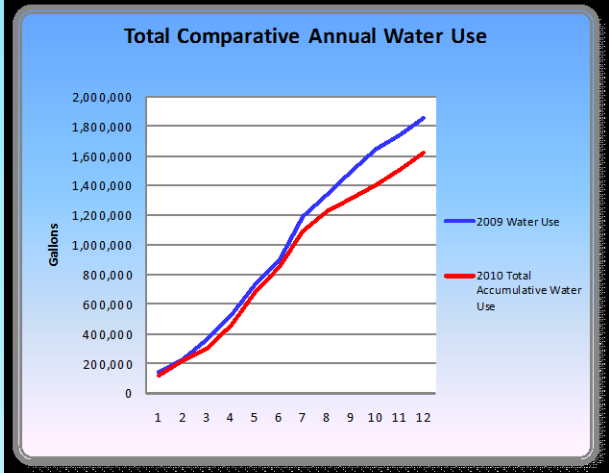
- What is Measured?
  - Energy Usage both in KWH and $
  - Gas Usage both in Therms and $
  - Water Usage both in Gallons and $
  - Purchased Energy both in BTUH and $
  - Occupant Comfort or Building Performance
    - Annual Occupant Survey
    - Monitor Maintenance Management System

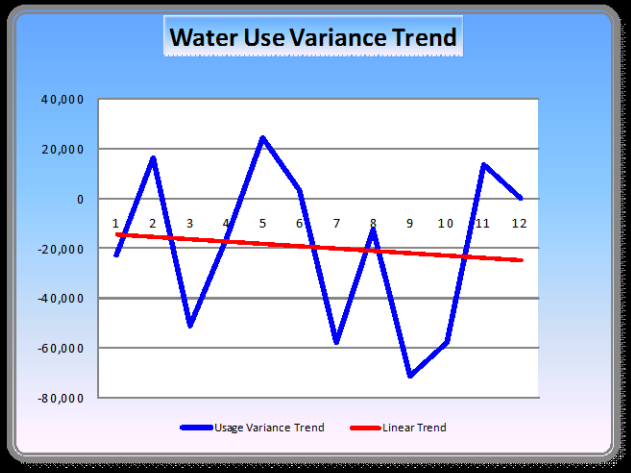
Water Use Charts for: Tester Products

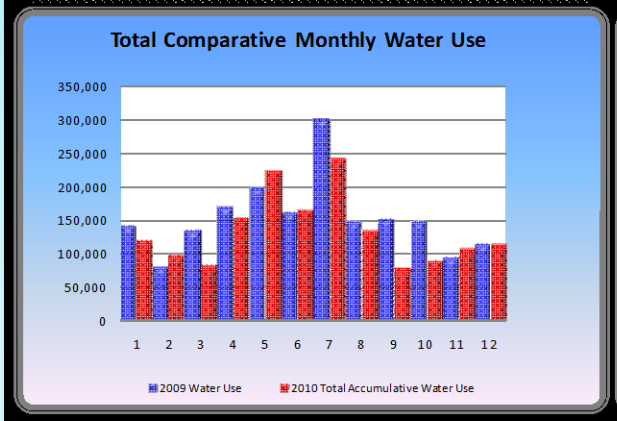
Date: 12/31/2010

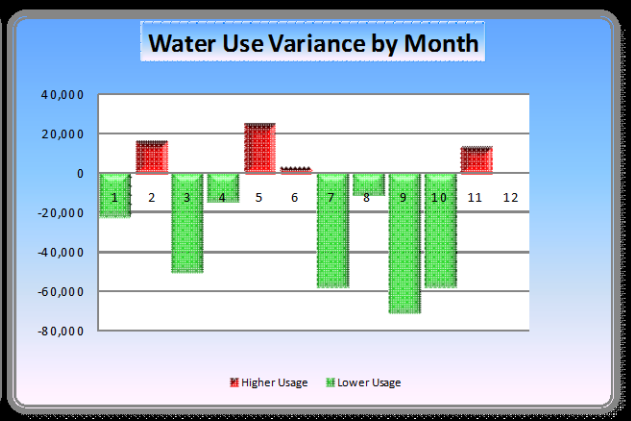


	Current Year	Prior Year	Variance
Square Feet	100,000	100,000	0
WUI Gal / Square Foot	16.25	18.56	-2.31
$ / Square Foot	$0.071	$0.067	$0.003







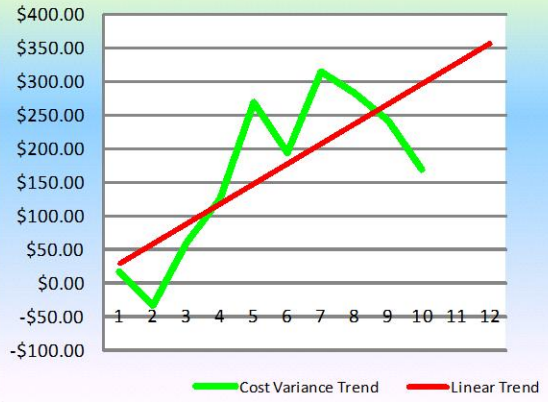


Water Cost Charts for: Tester Products

Date: 12/31/2010

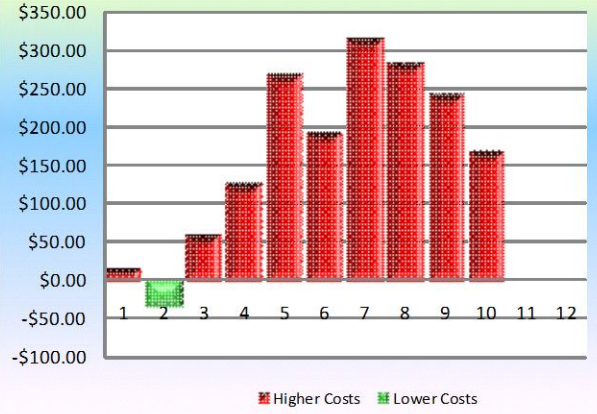
Total Annual Water Costs

Water Cost Variance Trend



Total Monthly Water Costs

Water Cost Variance by Month



Potential Renewable Energy Conservation Measures

1. Install solar water heating panels on the roof or other suitable area and pipe into the domestic or pool heating system.
2. Install a Photovoltaic (PV) solar electric panels to produce electricity without generating any greenhouse emissions.
3. Install geothermal water source heat pump units – either closed ground loop or open loop wells.
4. Install a wind turbine to generate electricity.
5. Install a fuel cell to generate electricity and heat with the only reaction being production of water.

NZEB and NREL

"Assessment of the Technical Potential for Achieving Net-Zero-Energy Buildings In The Commercial Sector"

December 2007

"With current technologies and design practices → 62% of the U.S. commercial buildings could become Net-Zero-Energy-Buildings."

EUI Ad Hoc Strategy 3 – Re-evaluate and update the information in "*Assessment of Technical Potential…*"

Net Zero Energy Buildings

The Audubon Center at Debs Park
LOS ANGELES, CALIFORNIA

The David & Lucile Packard Foundation

Gebhard-Mueller-School, Biberach
GERMANY

CSIRO • Energy Center
NEWCASTLE, NSW, AUSTRALIA

Your Role, Your Duty and Your Responsibility

"What will you do today, tomorrow or next week that will make a difference?" (Floyd Lee & the Pegasus Chow Hall, Baghdad)

"Don't be put off by people who know what is not possible. Do what needs to be done, and then check to see if it was impossible only after you are done."

Paul Hawken

University of Portland Graduation Address

May 2009