Steps Toward Achieving Advanced Energy Performance in Existing Buildings
USGBC-Missouri Gateway/ASHRAE-St. Louis Chapter
Terry E. Townsend, P.E., FASHRAE, LEED®AP
August 9, 2016
Making Existing Commercial Buildings More Efficient, Healthy & Comfortable©

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ASHRAE Presidential Member 2006-2007
NEBB BSC-CP; RCx-CP
Making Existing Commercial Buildings More Efficient, Healthy & Comfortable

Day 1

1. BEAP Certification Program Overview
2. Technical Retro-Commissioning of Existing Buildings (EBRCx) Program
   - Planning Phase
   - Discovery Phase
   - Investigation Phase – PEA; Levels 1, 2, 3 & Targeted Audits
   - Analysis Phase
   - Corrective Action Phase & Technical Commissioning of Construction Activities
   - Performance Verification Phase & Ongoing Commissioning
3. Preparation for Site Visit – __________
Making Existing Commercial Buildings More Efficient, Healthy & Comfortable

Day 2

1. Site Visit – 8:00 AM – 11:30 AM
2. Lunch
3. Completion of bEQ “In Operation” Forms
4. Presentation of Results to Owner’s Representative…. “And the Winning Team is…..”
5. Seminar Survey & Recommendations
6. Plan of Action for Submittal of bEQ Workbook to ASHRAE and Preparation of Article for ASHRAE Journal
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 is Energy So Important?

U.S. Energy Flow (2013), Quadrillion Btu

Source: Energy Information Administration

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; Bldgs 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 CO₂ reductions = making buildings more energy efficient
Comparing International Emissions Data
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”
Two Types of Energy Indices May Need to be Developed:

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

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

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

\[
 NEUI = \frac{\text{Net Annual Energy Use (kBtu/SF-yr)}}{\text{Gross Floor Area}}
\]
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>
<thead>
<tr>
<th>Subsectors</th>
<th>Climate Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
</tr>
<tr>
<td>All</td>
<td>90</td>
</tr>
<tr>
<td>Office/professional</td>
<td>93</td>
</tr>
<tr>
<td>Nonrefrigerated warehouse</td>
<td>42</td>
</tr>
<tr>
<td>Education</td>
<td>83</td>
</tr>
<tr>
<td>Retail (except malls)</td>
<td>74</td>
</tr>
<tr>
<td>Public assembly</td>
<td>94</td>
</tr>
<tr>
<td>Service</td>
<td>77</td>
</tr>
<tr>
<td>Religious worship</td>
<td>44</td>
</tr>
<tr>
<td>Lodging</td>
<td>94</td>
</tr>
<tr>
<td>Food services</td>
<td>258</td>
</tr>
<tr>
<td>Inpatient healthcare</td>
<td>249</td>
</tr>
<tr>
<td>Public order and safety</td>
<td>116</td>
</tr>
<tr>
<td>Food sales</td>
<td>200</td>
</tr>
<tr>
<td>Outpatient health care</td>
<td>95</td>
</tr>
<tr>
<td>Vacant</td>
<td>21</td>
</tr>
<tr>
<td>Other</td>
<td>79</td>
</tr>
<tr>
<td>Skilled nursing</td>
<td>125</td>
</tr>
<tr>
<td>Laboratory</td>
<td>305</td>
</tr>
<tr>
<td>Refrigerated Warehouse</td>
<td>99</td>
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</table>

Table 1-2. 2003 CBECS\(^1\) Weighted Mean Energy Use Intensities\(^2\) by Subsector and Climate Zone\(^3,4\); IP Units \(\text{kBtu/ft}^2\text{-yr}\)

\(^1\) Data source is 2003 CBECS public use microdata.
Energy Usage in Existing Buildings

U.S. Commercial Building Total Site Energy Intensity Trend

Energy Information Administration
Commercial Buildings Energy Consumption Survey
Fundamental Truth – Cost of Ownership

95% Cost of Ownership

5% Cost of Construction

Steps Toward Achieving Advanced Energy Performance in Existing Buildings

“We are confronted with insurmountable opportunities” ......Pogo
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
Validation of Commissioning

• First Party (1\textsuperscript{st}) Validation = A firm or individual verifying the project tasks is the same firm or individual performing the tasks.

• Second Party (2\textsuperscript{nd}) Validation = The firm or individual verifying the project tasks is under the control of the firm that performed the tasks.

• Third Party (3\textsuperscript{rd}) Validation = The firm verifying the project tasks is not associated with or under the control of the firm performing or designing the tasks.
Technical Retro-Commissioning Provides -

• **Improved Comfort Levels**
  - Temperature
  - Humidity
  - Sound & Vibration
  - Suitable Lighting Levels
  - Reduction of Daylight Glare

• **Improved Indoor Air Quality**
  - Ventilation Rate
  - CO₂ control

• **Reduced Utility Expense (Efficient Operations)**
  - Improved Electrical Energy Usage
  - Improved Gas Energy Usage
  - Improved Water Usage
ASHRAE Standard 55-2013
Thermal Environmental Conditions for Human Occupancy

Conditions That Provide Thermal Comfort:

a. Metabolic Rate – Table 5.2.1.2
b. Clothing Insulation – Table 5.2.2.2A & B
c. Air Temperature – Figure 5.3.1
d. Radiant Temperature – Chapter 9 in ASHRAE Fundamentals Handbook
e. Air Speed – Figure 5.3.3A
f. Humidity - Figure 5.3.3A
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.
ANSI/ASHRAE Standard 62.1-2010
(Supersedes ANSI/ASHRAE Standard 62.1-2007)
Includes ANSI/ASHRAE Addenda Listed in Appendix J

Ventilation for Acceptable Indoor Air Quality

See Appendix J 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: 404-321-5478. 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.

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ISSN 1041-2336
ASHRAE Standard 62.1-2010
Ventilation for Acceptable Indoor Air Quality

• Procedures
1. Ventilation Rate Procedure – a prescriptive design procedure (Section 6.2)
2. IAQ Procedure – performance-based design procedure (Section 6.3)
3. Natural Ventilation – a prescriptive design procedure (Section 6.4)
ASHRAE Standard 62.1-2010
Ventilation for Acceptable Indoor Air Quality

Ventilation Rate Procedure – Overview
Basis = ASHRAE Standard 62.1-2010, Table 6-1
\[ V_{bz} = R_p \times P_z + R_a \times A_z \]

Where:
\( R_p \) = Outdoor Rate/Person
\( P_z \) = Largest Number of People to Occupy the Zone
\( R_a \) = Outdoor Rate/Unit Area
\( A_z \) = Zone Floor Area
<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>People Outdoor Air Rate $\dot{V}_p$</th>
<th>Area Outdoor Air Rate $\dot{V}_a$</th>
<th>Default Values</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>cfm/person L/s/person</td>
<td>cfm/ft$^2$ L/m$^2$</td>
<td>Notes</td>
</tr>
<tr>
<td><strong>Correctional Facilities</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Cell</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
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<tr>
<td>Dayroom</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Guard stations</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Booking/waiting</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Educational Facilities</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Daycare (through age 4)</td>
<td>10</td>
<td>5</td>
<td>0.13</td>
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<tr>
<td>Daycare sickroom</td>
<td>10</td>
<td>5</td>
<td>0.13</td>
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<tr>
<td>Classrooms (ages 5–8)</td>
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<td>5</td>
<td>0.12</td>
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<tr>
<td>Classrooms (age 9 plus)</td>
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<td>5</td>
<td>0.12</td>
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<tr>
<td>Lecture classroom</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
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<tr>
<td>Lecture hall (fixed seats)</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
</tr>
<tr>
<td>Art classroom</td>
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<tr>
<td>Science laboratories</td>
<td>10</td>
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<td>0.13</td>
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<tr>
<td>University/college</td>
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<td>0.13</td>
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<tr>
<td>laboratories</td>
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<td></td>
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<tr>
<td>Wood/metal shop</td>
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<td>5</td>
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<tr>
<td>Computer lab</td>
<td>10</td>
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<td>0.12</td>
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<tr>
<td>Media center</td>
<td>10</td>
<td>5</td>
<td>0.12</td>
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<tr>
<td>Music/theater/dance</td>
<td>10</td>
<td>5</td>
<td>0.06</td>
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<tr>
<td>Multi-use assembly</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
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<td><strong>Food and Beverage Service</strong></td>
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<td>Restaurant dining rooms</td>
<td>7.5</td>
<td>3.8</td>
<td>0.13</td>
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<tr>
<td>Cafeteria/fast-food dining</td>
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<td></td>
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</tr>
<tr>
<td>Bars, cocktail lounges</td>
<td>7.5</td>
<td>3.8</td>
<td>0.13</td>
</tr>
<tr>
<td>Kitchen (cooking)</td>
<td>7.5</td>
<td>3.8</td>
<td>0.12</td>
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<tr>
<td><strong>General</strong></td>
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<td>Coffee stations</td>
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<td>0.06</td>
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<tr>
<td>Conference/meeting</td>
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<td>2.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Corridors</td>
<td>–</td>
<td>–</td>
<td>0.06</td>
</tr>
<tr>
<td>Occupiable storage rooms</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>for liquids or gels</strong></td>
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<tr>
<td><strong>Hotels, Motels, Resorts, Dormitories</strong></td>
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<tr>
<td>Bedroom/living room</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Barracks sleeping areas</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
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<tr>
<td>Laundry rooms, central</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
</tr>
<tr>
<td>Laundry rooms within</td>
<td>5</td>
<td>2.5</td>
<td>0.12</td>
</tr>
<tr>
<td>dwelling units</td>
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<td></td>
</tr>
<tr>
<td>Lobbies/prefunction</td>
<td>7.5</td>
<td>3.8</td>
<td>0.06</td>
</tr>
<tr>
<td>Multisource assembly</td>
<td>5</td>
<td>2.5</td>
<td>0.06</td>
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</tbody>
</table>
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**.
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

• **KEY SUGGESTIONS**
  1. Install a Minimum MERV-8 Filter on O/A Streams
  2. Modulate Amounts of O/A with Controls
Managing Ventilation Air

Ventilation is Mostly Dehumidification

[Chart showing ventilation and dehumidification loads]
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%)


5. 4th Target → Go 30%, 50% or 70% beyond 90.1/189.1

6. 5th Target → Go to Net-Zero Energy

Dennis R. Landsberg, Mychelle 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
for Existing Commercial Buildings:

Technical Implementation

Dennis R. Landsberg with Steven Carlson, Fredric S. Goldner,
J. Michael MacDonald, and Ronald B. Slosberg

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U.S. Department of Energy

In collaboration with:
Building Owners and Managers Association International
U.S. General Services Administration
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**
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%
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 = \( \frac{1}{5} \)th of total costs and \( \frac{1}{3} \)rd of total variable costs
- IFMA \( \rightarrow \) 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 PCB EA

Part 1 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
- No cost/low cost items
- Rough costs and savings for EEM’s
- Identify Capital projects

**Level I:**
*Walk Through*

**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)*
Revised Analysis, Additional Measurements,
Hourly Simulation, Detailed Business and Investment Planning
ASHRAE STANDARD

Energy Conservation in Existing Buildings

Approved by the ASHRAE Standards Committee on June 24, 2006; by the ASHRAE Board of Directors on June 29, 2006; by the Illuminating Engineering Society of North America on July 17, 2006; and by the American National Standards Institute on June 30, 2006.

ASHRAE Standards are scheduled to be updated on a five-year cycle; the date following the standard number is the year of ASHRAE Board of Directors approval. The latest copies may be purchased from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2505. E-mail: orders@ashrae.org. Fax: 404-321-5478. Telephone: 404-636-8400 (worldwide) or toll free 1-800-527-4723 (for orders in US and Canada).

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ISSN 1041-2336

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org
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.
Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

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

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ASHRAE Standard 90.1-2010
Energy Standard for Buildings Except Low-Rise Residential Buildings

Sections of Interest

- Building Envelope – Table 5.5-1
- Heating, Ventilating, and Air Conditioning – Tables 6.8.1A thru 1K
- Service Water Heating – Table 7.8
- Lighting – Tables 9.4.3B, 9.5.1(Building Area Method), and 9.6.1 (Space-by-Space Method)
- Performance Rating Method – Normative Appendix G
ASHRAE Standard 189.1-2011
Standard for the Design of High-Performance Green Buildings

Sections of Interest

• Site Sustainability – addresses requirements that pertain to site selection, site development, mitigation of heat island effect, and light pollution reduction.

• Water Use Efficiency – requirements for potable and non-potable water use efficiency, both for the site and for the building, and water monitoring.
ASHRAE Standard 189.1-2011
Standard for the Design of High-Performance
Green Buildings

Sections of Interest

• Energy Efficiency – requirements for energy efficiency for buildings and appliances, for on-site renewable energy systems and for energy measuring.

• Indoor Environmental Quality (IEQ) – requirements for indoor air quality, environmental tobacco smoke control, outdoor air delivery monitoring, thermal comfort, acoustical control, daylighting, and low emitting materials.
ASHRAE Standard 189.1-2011
Standard for the Design of High-Performance Green Buildings

Sections of Interest

• Normative Appendix E: IAQ Limit Requirements for Office Furniture Systems and Seating – IAQ limit requirements and VOC concentration limits

• Informative Appendix H: Integrated Design – integrated/iterative project design process and integrated project delivery process enables the design, construction, and operation of high performance green buildings.
Advanced Energy Design Guidance
Advanced Energy Design Guidance

Advanced Energy Design Guide for K–12 School Buildings
Achieving 50% Energy Savings Toward a Net Zero Energy Building

Advanced Energy Design Guide for Small to Medium Office Buildings
Achieving 50% Energy Savings Toward a Net Zero Energy Building

Advanced Energy Design Guide for Medium to Big Box Retail Buildings
Achieving 50% Energy Savings Toward a Net Zero Energy Building

Advanced Energy Design Guide for Large Hospitals
Achieving 50% Energy Savings Toward a Net Zero Energy Building
Advanced Energy Design Guide for Grocery Stores

Achieving 50% Energy Savings Toward a Net Zero Energy Building

Developed by:
ASHRAE
The American Institute of Architects
Illuminating Engineering Society of North America
U.S. Green Building Council
U.S. Department of Energy
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

Measurement Plan

- Collect Data
- Analyze Data
- Normalize Data
- Usage Baseline

- Compare Results
- Report Results
- Make Changes
- Verify Implementation
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
Present Water Use Efficiency 87.56%

<table>
<thead>
<tr>
<th></th>
<th>Current Year</th>
<th>Prior Year</th>
<th>Variance</th>
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</thead>
<tbody>
<tr>
<td>Square Feet</td>
<td>100,000</td>
<td>100,000</td>
<td>0</td>
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<tr>
<td>WUI Gal / Square Foot</td>
<td>16.25</td>
<td>18.56</td>
<td>-2.31</td>
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<tr>
<td>$ / Square Foot</td>
<td>$0.071</td>
<td>$0.067</td>
<td>$0.003</td>
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</table>

Total Comparative Annual Water Use

Water Use Variance Trend

Water Use Variance by Month
Water Cost Charts for: Tester Products

**Total Annual Water Costs**

- 2009 Total Costs
- 2010 Total Accumulated Costs

**Water Cost Variance Trend**

- Cost Variance Trend
- Linear Trend

**Total Monthly Water Costs**

- 2009 Total Costs

**Water Cost Variance by Month**

- Higher Costs
- Lower Costs

Date: 12/31/2010
<table>
<thead>
<tr>
<th>Form 4 - Suggestions for Additional Energy Savings for In Operation Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source EUI:</strong> 146.8</td>
</tr>
<tr>
<td><strong>bEQ Rating:</strong> B</td>
</tr>
</tbody>
</table>

**Suggested Energy Savings Measures by Category:**

**Envelope Suggestions**

1. Install or replace existing door weatherstrips.  
   - Cost Range: $200-$500  
   - Payback: >10yrs

2. Install closed cell foam pre-cut gaskets under exterior wall light switches and two-gang outlets.  
   - Cost Range: $2/switch or  
   - Payback: <1yr

3. Increase roof insulation.  
   - Cost Range: $75,000-  
   - Payback: >10yrs

**Lighting/Daylighting Suggestions**

1. Replace 668 - 32 Watt F32T8 - 3500 Kelvin lamps with 688 - 28 Watt - 4100 Kelvin lamps. No ballast change required.  
   - Cost Range: $2,000-$2,500  
   - Payback: 1-4yrs

2. Provide occupancy sensor controls for lighting.  
   - Cost Range: $2,000-$5,000  
   - Payback: 5-10yrs
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td><strong>HVAC Suggestions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1. Utilize optimum start for AHU in lieu of starting at 6:30AM.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$200-1,000</td>
<td>&lt;1yr</td>
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<tr>
<td>41</td>
<td>2. Reset hot water supply temperature setpoint based on demand in lieu of outside air temperature.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$200-1,000</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>42</td>
<td>3. Reset hot and cold deck based on zone demand instead of resetting off outside air temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$500-2,000</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>43</td>
<td>4. Modify zone temperature setpoints to match temperature standards.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Negligible</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>44</td>
<td>5. Fix economizer/OA controls so that system economizes properly and provides proper minimum ventilation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Varies</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>45</td>
<td>6. Perform a level 2 audit or at a minimum functionally test HVAC equipment and review setpoints.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Varies</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>46</td>
<td>7. Utilize occupancy sensor control to reduce minimum zone flows.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$3,500-7,000</td>
<td>5-10yrs</td>
</tr>
<tr>
<td>47</td>
<td>8. Provide reversible ceiling fan to improve destratification in winter.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$2,000-5,000</td>
<td>&gt;10yrs</td>
</tr>
<tr>
<td>48</td>
<td>9. Remove preheat coil to reduce pressure drop (pump is currently manually set off).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500-$3,000</td>
<td>&gt;10yrs</td>
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<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td><strong>Utility/Operational Suggestions</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>52</td>
<td>1. Remove birds nest on exterior lighting photocell.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Negligible</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>53</td>
<td>2. Review filter replacement duration and utilize existing dirty filter alarm.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Negligible</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>54</td>
<td>3. Provide strainer basket for condenser water cleaning.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$4,000-6,000</td>
<td>&gt;10yrs</td>
</tr>
<tr>
<td>55</td>
<td>4. Participate with We Energies Account Monitor to obtain quick feedback on energy operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Free</td>
<td></td>
</tr>
</tbody>
</table>
Culinary Arts Building

SLCC LHM Campus, Energy Assessment
Building Statistics

- Located in Sandy, Utah
- 26,000 sq.ft., single story
- Occupancy scheduled from 5am to 11pm 7 days per week
- VAV fan powered boxes, Hot water reheat (180F-160F)
- (2) DX Rooftop Units
- 7 Make up air Units, with Evaporative cooling
- 7 hood exhaust fans
- 2 gas fired domestic hot water heater
Controls Assessment

- VAV operation: Continuous Reheat (E.S. $1,000 - $2,000)
- VAV min/max: Settings are Missing from Graphics (E.S. $0-$2,500)
- VAV Control: Does Not Utilize Occupancy Sensors (E.S. $ 1,500 - $2,500)
- Building Controls: Maintenance Cannot see Control Set Points
  - Allows maintenance staff to optimize building use. (Priceless)
  - Graphics missing tons of useful data.
Controls Assessment Cont.

• Roof Top Unit:
  – Needs Static Pressure Reset (E.S. $ 1,500 - $2,500)
  – Mix air temp sensors
  – Damper position
  – Building Static Pressure Control

• Make-up Air and Exhaust Hood systems to be connected to the DDC

• Temperature sensors are in the wrong locations
HVAC Assessment Cont.

• Provide circuit setters in HW piping to VAV units
• Electrical Room Exhaust fan should be controlled by thermostat
• Both Hot Water Pumps are running at the same time. Look to cycle the pumps based on demand.
• No exhaust of coolers, servers, locker rooms, ice makers.
• Dining room doesn't need to be multi-zoned.
• No back draft dampers on any exhaust fans or MAU's.
• Chilled Water turned off to 4 of 7 MAU's. Probably why summer chef cooling complaints.
• DX is cycling on the RTU's pretty often.
• West RTU leaking a lot of air.
• West RTU economizers broken.
HVAC Assessment Cont.

- VAV's cool and heat simultaneously.
- No pressure control of kitchens.
- Heating water could benefit from all 2-way valves and monitoring position (95%) to reset pump VFD's (add VFD's) and a bypass valve for boiler firing.
- Whole building could benefit from evaporative cooling (perhaps IDEC too).
- Should put DHWRC Pump on aquastat.
- VAV's should control to 88 deg F in the heating mode.
- Boilers could be enabled at 150 deg F HWS and then shut off at 190 deg F.
- DHW and heating water systems could be interconnected via BPHX. Boiler System connected
Plumbing

- Change to 90% Efficient Water Heaters
- Hot Water Recirculation Pump should be controlled by an aquastat
- Auto-supply and flush fixtures in restrooms
September 18, 2014
Team 1

SLC FIRE HALL #2
BEQ RECOMMENDATIONS
Current bEQ Rating: C

<table>
<thead>
<tr>
<th>Name:</th>
<th>Salt Lake City Fire Station No. 2</th>
<th>Assessment Date:</th>
<th>2014-09-18</th>
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<tr>
<td>270 W 300 N</td>
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</tr>
<tr>
<td>Salt Lake City</td>
<td>State/Prov: UT</td>
<td>Zip/Post:</td>
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<tr>
<td>Owner:</td>
<td>Salt Lake City Corporation</td>
<td>Building Type:</td>
<td>Fire station/police station</td>
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<td>Contact/Title:</td>
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<td>Phone:</td>
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<td></td>
<td></td>
<td>E-mail:</td>
<td></td>
</tr>
<tr>
<td>/Company:</td>
<td>Jane Guyer, ETC Group</td>
<td>Phone:</td>
<td>801-278-1927x105</td>
</tr>
<tr>
<td></td>
<td>1997 S 1100 East</td>
<td>E-mail:</td>
<td><a href="mailto:jguyer@etcgrp.com">jguyer@etcgrp.com</a></td>
</tr>
<tr>
<td></td>
<td>Salt lake City</td>
<td>Zip/Post:</td>
<td>84106</td>
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<td>Climate Data</td>
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<td>Date Zone:</td>
<td>5B</td>
<td>HDD65:</td>
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<td></td>
<td></td>
<td>CDD50:</td>
<td>4607</td>
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<td>Period of Data:</td>
<td>8/2013 - 8/2016</td>
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<tr>
<td>Building Characteristics</td>
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<tr>
<td>Total Floor Area (ft²):</td>
<td>12,460</td>
<td>Total Conditioned Area (ft²):</td>
<td>12,460</td>
</tr>
<tr>
<td>Heated Area, heated only (ft²):</td>
<td>12,460</td>
<td>Conditioned Area, cooled only (ft²):</td>
<td>12,460</td>
</tr>
<tr>
<td>of Conditioned Floors:</td>
<td>3</td>
<td>Floors Above Grade:</td>
<td>3</td>
</tr>
<tr>
<td>Year of Construction:</td>
<td>1966</td>
<td>Hours of Operation:</td>
<td>Continuous</td>
</tr>
</tbody>
</table>
Domestic Hot water Pipe
Uninsulated

Unconditioned space

Penthouse Storage?
Refrigerant Piping Gaps, UV Exposure
Is the Refrigerant Piping Insulated below Grade?
Refrigerant Leak at Branch Controller!

POE OIL

Port Number 4 Leak
### Suggested Energy Savings Measures by Category:

<table>
<thead>
<tr>
<th>Envelope Suggestions</th>
<th>Cost Range</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Seal wall between laundry room and main building and fix door and add door closer</td>
<td>$600</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>2 Adjust seal around fireman pole to be more airtight</td>
<td>$1,500</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>3 Install (3) air curtains in the front of the fireman pole shaft</td>
<td>$10,000</td>
<td>5-10yrs</td>
</tr>
<tr>
<td>4 Re-seal around gas line to make-up air unit</td>
<td>$100</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>Lighting/Daylighting Suggestions</td>
<td>Cost Range</td>
<td>Payback</td>
</tr>
<tr>
<td>---------------------------------------------------------------------</td>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>1 Retrofit lighting from T8 to LED</td>
<td>$1,500</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>2 Install occupancy sensors everywhere</td>
<td>$1,200</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>3 Ensure current occupancy sensors are working properly - tape over some</td>
<td>$100</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>4 Daylight exercise room</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC Suggestions</td>
<td>Cost Range</td>
<td>Payback</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>1 Mandate setpoint to 72 degrees plus/minus 2 degrees during summer months</td>
<td>$0</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>2 Mandate setpoint to 69 degrees plus/minus 2 degrees during winter months</td>
<td>$0</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>3 Insulate ductwork in ceiling spaces</td>
<td>$5,000</td>
<td>5-10yrs</td>
</tr>
<tr>
<td>4 Change makeup air filters on a more regular basis and seal around filters to</td>
<td>$300</td>
<td>&lt;1yr</td>
</tr>
<tr>
<td>prevent bypass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Partition off raquetball court and relocate thermostat for court</td>
<td>$3,000</td>
<td></td>
</tr>
<tr>
<td>6 Fill in refrigerant piping insulation gaps</td>
<td>$3,000</td>
<td>5-10yrs</td>
</tr>
<tr>
<td>7 Verify underground refrigeration pipe is insulated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Reinsulate and cover (for UV protection) outdoor refrigeration piping</td>
<td>$500</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>9 Repair refrigerant piping leaks - 2nd floor branch controller across from</td>
<td>$1,000</td>
<td>1-4yrs</td>
</tr>
<tr>
<td>kitchen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Investigate water stained ceiling tiles to locate uninsulated duct and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>piping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Recommission makeup air unit to maintain consistent discharge temperatures</td>
<td>$1,000</td>
<td>5-10yrs</td>
</tr>
</tbody>
</table>
Stuart Hall
- BuildingEQ Rating – C
- EUI – 95 kBtu/sf/yr
- ECI - $1.60/sf

Energy Savings Goal
Reduce energy by 23% in order to obtain a BuildingEQ Rating of B
EEMs (Payback of Less Than 2 Years)

- LED Bi-level stairwell lighting with occupancy sensors
- Lighting controls
  - Occupancy and daylighting, in classrooms and offices
  - Replace existing occupancy sensors (non-functioning)
  - Exterior lighting controlled through campus BMS
- Repacking steam valves
- T-12 fluorescent to T-8 retrofits (mechanical rooms)
- Insulate re-heat coils
- Re-caulking windows
- Adjust entrance doors
- Re-gasket exterior doors
- Toilet exhaust fans should be scheduled
- Low-flow fixtures on lavatories
- Plug load occupancy strips
EEMs (Payback of Less Than 5 Years)

- 3rd Floor Reading Room Lighting Redesign
- Remove integrated thermostats from hot-water cabinet heaters and relocate with remote thermostat.
- VFD on supply and return fans static control.
- Exhaust mechanical rooms with integrated thermostat communicated through BAS
- DCV control for all AHUs
EEMs (Payback Greater Than 5 Years)

- Sealing Ductwork
- Replace Computer AC unit with more efficient unit
Observations

• Air leakage into closets in classrooms (Room 101)
• Chilled Water pump VFDs in bypass
• Office space redundant lighting
• Integrate Computer AC into BAS, (Room 217)
• Fans on roof, either put on isolation pads or remove if not in use.
Overview

- Global House is a 6 storey office building in the City of Hamilton.
- The gross internal floor area is 52,960 ft\(^2\).
- Global House was constructed in 1982.
- Major internal renovation on level 2 in 1999.
- Throughout the years, there have been assorted refits to reconfigure office spaces as alternative use spaces.
• Excessive Lighting
• 169 foot candles at desktop level
• Mixture of florescent, CFL, Incandescent and LED.
Air Quality

- Complaints from clients
- Air purifiers required
- Lack of appropriate ventilation
Outside Air Intake to Main Air Handler
Recommendations

• Quick Fixes
  – Realign the chiller water pump 1
  – Eliminate bearing wear on chiller water pump 1
  – Synchronize the supply and return on the air handler.
  – Install alarm on the sewage injection pump
  – Install timer on the hot water heater
  – Circulation pump to be plugged in
  – Patch Inlet ducting in the basement
Recommendations

• Medium Term Fixes
  – Modify the supply and return air ducting to suit the new office layouts
  – Realign the lighting to suit new office layouts
  – Fresh air intake louvers to be replaced
  – Energy Recover Ventilators needs to be reconfigured.
  – Rooftop package units need to be replaced.
  – Install lighting controls to align with Occupancy and times
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


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...”
NZEB and NREL

(Reference Points TODAY & TOMORROW - 2025)

• Energy Efficiency + IBD $\rightarrow$ EUI = 40 kBTU/SF/yr

• PV Threshold to NZEB $\rightarrow$ EUI = 19 kBTU/SF/yr

• Projected Max Tech + BIPV $\rightarrow$ EUI = 12.2 kBTU/SF/yr
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)

Do we have “any other option” but to work toward achieving an independent and sustainable future for those who are depending upon us?