Building Operator Certification – Level I

A Partnership of the CUNY Institute for Urban Systems Building Performance Lab, the CUNY School of Professional Studies, and the New York State Energy Research & Development Authority
Energy Audits & Reading

Energy Audits

Lesson 19
Introduction to Energy Audits

Topic 1: How Audits are conducted
- Process and Objectives
- The role of you as facility operator in the process

Topic 2: Reading and using the Energy Audit Report
- Standard sections of the report
- What to look for
- The facility operator’s role in Quality Control
Energy Audits: Definition and Elements

An energy audit is a systematic investigation of existing energy use patterns in a facility and an engineering analysis of energy savings opportunities.

The audit process and its conclusions are summarized in a report that includes a range of recommended energy conservation measures (ECMs) to help you:

- Understand how and how much energy is used in your facility
- Identify are where energy can be saved
- Identify specific projects for facility energy savings
Objectives of an Energy Audit

Audit objectives are how you measure, meet and reach your goal of saving energy in your facility

• Capital Projects- new and/or replacements- emphasis of most Audit Reports
• Operations & Maintenance, low- cost, repairs, Retro-commissioning (RCx)
• Set performance targets (M&V Plan)

Quantifying your facility energy use
  – Costs and End-uses.
  – Checking Baselines and Benchmarks

• Recommended audit measures typically focus on Capital Improvement Measures, new and replacement projects.

• Operations and maintenance measures (which include health and safety conditions) are traditionally listed and further detailed in the retro-commissioning process.
Broader Energy Audit Benefits

Benefits in using and adopting audit results include:
- Improvement in facility operating efficiencies
- Reduced operating costs
- Maintaining or increasing facility IEQ

Beyond this, broader Citywide environmental benefits can encompass:
• Building-specific and departmental (budget) effects of audit-led efficiencies and savings.
• Given larger budget issues (budget vs. staff costs, etc.), this reinforces the point that ‘there’s only one pot’ (for each organization’s budget) and only one reservoir (for the overall environment).
Energy Audit

• An Energy Audit is a **Process**
  – Why and How?
  – Conducted by whom
  – How You Learn, Plan and Act throughout the auditing process

• Who’s involved in the audit process?
  -Utility companies and power authorities (NYPA), government agencies,
  -Outside engineers, consultants, In-house staff, Equipment Vendors

• *The Energy audit as a collaborative process*
Auditor’s Role in the Process

Step 1: Data prep and review/analyze
- Formulate questions for investigation based on data

Step 2: Site visit(s)
- Interview
- Survey, Data Collection, Tests, Observation

Step 3: Analyze Building Performance and Identify Energy Conservation Measures (ECMs)
- Identifies energy-saving improvements

Step 4: Quantifies the ECMs
- Quantifies projected energy savings in each piece of energy-consuming equipment.
- Adds up the total energy savings of all ECMs facility-wide

Step 5: Reporting and Reviewing with client
- Summarizes all ECMs and quantified savings in report.
- Reviews report with facility staff.
Operator’s Role in the Process

Step 1: Data prep and review/analyze
- Verifies data and operational plans.
- Responds to Auditor’s questions about building.

Step 2: Site visit(s)
- Provides Auditor access during site visit.
- Confirms site details are correct.
- Informs auditor of building dynamics or issues operator has identified.

Step 3: Analyze Building Performance and Identify Energy Conservation Measures (ECMs)
- Voices opinion on priorities for building’s energy improvement.

Step 4: Quantifies the ECMs
- Responds to Auditor’s final questions about energy costs and use.

Step 5: Reporting and Reviewing with client
- Reviews Audit Report.
- Corrects any errors in equipment, boundary and/or systems.
- Examines energy savings predictions.
Energy Audit as Product

- What type and **how much energy** is used in your facility.

- Identify **areas** where energy can be saved.

- For those areas, identify **Energy Conservation Measures (ECMs).**
How is the Audit Report Typically Organized?

Very large document – can run 75- 145 pages (this one is 158 pages) depending on the facility -and often very repetitive

When you get a copy, be prepared to thumb back and forth between sections, including Appendices

<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>14.0 APPENDIX H – ENERGY BENCHMARKING REPORT ............................ 150</td>
</tr>
</tbody>
</table>
Audit Report- Executive Summary

• Executive Summary
  – Tabulated results
  – Summary of recommended ECMs
  – Total Project Summary

• Maintenance and Safety
  – Purpose of recommended measures, their effect on the respective equipment- why we’re doing thi

Notes:
• The Executive Summary highlights the leading recommended energy conservation Measures (ECMs), including the type of upgrade or replacement and the nature of the improvement by type for each measure. This summary is often the only part of the audit report that your manager may read or review.
The Audit Report - the Facility

• Facility Description
  – Building function, schedules, size, footprint
  – Envelope characteristics

• Building and systems
  – Descriptions and inventories of systems
    • Lighting
    • HVAC
    • Other
The Audit Report - Energy Use

• Utility Description
• Provider (tariff) rates by energy type
  – Summary of charges (annual)
  – EUI Index for facility

• Disaggregated energy bill (a la Herzog)
  - Utility History - current, seasonal average
  - Annual charges (by month/commodity)

• Utility data is included in both the Executive Summary (as Utility description) and in a leading Appendix (as Utility Information or History).
Monthly Utility Demand

Utility Rate Summary - Year 2008

<table>
<thead>
<tr>
<th>Utility Rate</th>
<th>Rate ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Rate (kWh)</td>
<td>0.06358</td>
</tr>
<tr>
<td>Demand Rate (kW) Inc. delivery</td>
<td>30.64</td>
</tr>
<tr>
<td>Fuel Oil Rate (gal)</td>
<td>1.85</td>
</tr>
<tr>
<td>Natural Gas Rate (Therm)</td>
<td>1.43</td>
</tr>
</tbody>
</table>

The annual utility summary table for the year 2008 is shown below:

<table>
<thead>
<tr>
<th>Month</th>
<th>Monthly Electrical Consumption (kWh)</th>
<th>KBTU from Electricity</th>
<th>KBTU from Oil</th>
<th>KBTU from Natural Gas</th>
<th>Total KBTU from all energy sources</th>
<th>Total Monthly Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1,039,200</td>
<td>3,546,790</td>
<td>129,882</td>
<td>6,401,000</td>
<td>10,077,672</td>
<td>$180,847</td>
</tr>
<tr>
<td>February</td>
<td>1,041,300</td>
<td>3,553,957</td>
<td>94,972</td>
<td>5,665,100</td>
<td>9,314,028</td>
<td>$179,893</td>
</tr>
<tr>
<td>March</td>
<td>980,400</td>
<td>3,346,105</td>
<td>79,145</td>
<td>4,009,800</td>
<td>7,435,051</td>
<td>$159,497</td>
</tr>
<tr>
<td>April</td>
<td>953,100</td>
<td>3,252,930</td>
<td>39,929</td>
<td>2,296,400</td>
<td>5,589,259</td>
<td>$134,918</td>
</tr>
<tr>
<td>May</td>
<td>1,060,500</td>
<td>3,619,487</td>
<td>21,293</td>
<td>448,100</td>
<td>4,088,879</td>
<td>$125,855</td>
</tr>
<tr>
<td>June</td>
<td>1,400,400</td>
<td>4,779,565</td>
<td></td>
<td>1,527,500</td>
<td>6,307,065</td>
<td>$228,989</td>
</tr>
<tr>
<td>July</td>
<td>1,418,200</td>
<td>4,840,317</td>
<td></td>
<td>1,502,000</td>
<td>6,342,317</td>
<td>$235,796</td>
</tr>
<tr>
<td>August</td>
<td>1,438,200</td>
<td>4,908,577</td>
<td></td>
<td>1,692,400</td>
<td>6,600,977</td>
<td>$246,427</td>
</tr>
<tr>
<td>September</td>
<td>1,368,200</td>
<td>4,669,667</td>
<td></td>
<td>1,250,500</td>
<td>5,920,167</td>
<td>$226,541</td>
</tr>
<tr>
<td>October</td>
<td>1,332,600</td>
<td>4,548,164</td>
<td>31,318</td>
<td>876,700</td>
<td>5,456,181</td>
<td>$146,834</td>
</tr>
<tr>
<td>November</td>
<td>1,022,200</td>
<td>3,488,769</td>
<td>63,319</td>
<td>3,513,700</td>
<td>7,065,788</td>
<td>$143,818</td>
</tr>
<tr>
<td>December</td>
<td>1,047,000</td>
<td>3,573,411</td>
<td>93,342</td>
<td>6,495,200</td>
<td>10,161,953</td>
<td>$186,729</td>
</tr>
<tr>
<td>Totals</td>
<td>14,101,300</td>
<td>48,127,737</td>
<td>553,200</td>
<td>35,678,400</td>
<td>84,359,337</td>
<td>$2,196,144</td>
</tr>
</tbody>
</table>
The Energy Usage Index (EUI) was calculated from the utility data and is given below:

<table>
<thead>
<tr>
<th>Building Snapshot</th>
<th>Annual Usage</th>
<th>Annual Expenditures</th>
<th>kBtu/sq.ft.</th>
<th>kWh/sq.ft.</th>
<th>$/sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric (kWh)</td>
<td>14,101,300</td>
<td>$1,684,567.41</td>
<td>52.90</td>
<td>15.50</td>
<td>$1.85</td>
</tr>
<tr>
<td>Fuel Oil (gal)</td>
<td>3,980</td>
<td>$9,949.00</td>
<td>0.61</td>
<td>-</td>
<td>$0.01</td>
</tr>
<tr>
<td>Natural Gas (therms)</td>
<td>356,784</td>
<td>$501,627.47</td>
<td>39.22</td>
<td>-</td>
<td>$0.55</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>$2,196,143.88</strong></td>
<td><strong>92.73</strong></td>
<td><strong>15.50</strong></td>
<td><strong>$2.41</strong></td>
<td></td>
</tr>
</tbody>
</table>
ASHRAE “Levels of Effort”

Procedures for Commercial Building Energy Audits

• Level 1 – “Walk-through Analysis”
• Level II – “Energy Survey and Analysis”
• Level III – “Detailed Analysis of Capital Intensive Modifications”

• Increasing levels of detail and confidence in projection of savings and costs
• Role of computerized building modeling

• Level 1 demands the most experienced eye

Notes:
• This outline examines the various levels of audit - which level audit is being conducted on your facility? Why? (Discuss)
• Can you think of advantages/disadvantages for each level of audit presented here?
Topic 2: Reading an Energy Report

Reading and using the Energy Audit Report
- Standard sections of the report
- What to look for
- The facility operator’s role in Quality Control

Objectives for Topic 2
- Understand the critical role you play in an Energy Audit.
- Read and interpret Energy Audit Report findings
- Main Audit Report sections
- Confirm and question report’s project savings.
- Better understand your role as Operator in an Energy Audit.
The Audit Report - What to Look For

• Upper-level Execs/management may only read the Executive Summary and Table of Recommended Measures. Building Managers should also be concerned with

  Is description of site and operation accurate?
  • Age and condition of major equipment
  • Facility schedule
  • Are potential or implemented operational measures correctly captured?

• Are the recommended measures based on the descriptions?
• Do projected savings make sense in terms of energy use?

  Projected savings > 40% should elicit a “show-me” reaction
Energy Audit Report by Sections

What’s contained in each section?

• Executive Summary
• Introduction
• Facility Description
• Historical Energy Consumption Analysis
• Summary of Potential Energy Savings by System
• Energy Conservation Measures
• Retro-Commissioning Measures
Facility & Systems Description

- Read the Facility and Existing Systems Description beginning on page 7.
- What information does it contain?
  - Envelope and Mechanical Systems
  - Equipment Type(s)
### Example of Lighting Schedule

<table>
<thead>
<tr>
<th>Line Item</th>
<th>Floor</th>
<th>Location</th>
<th>Pre Qty</th>
<th>Fixture Code</th>
<th>Existing Description</th>
<th>Post Qty</th>
<th>Post Description</th>
<th>Annual Hours</th>
<th>Post Hours w/ sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>G</td>
<td>METER ROOM</td>
<td>2</td>
<td>I1X100/P-h42</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 100w Incandescent A Lamp</td>
<td>2</td>
<td>New 4’ Industrial Fixture w/ (2) F32T8 Lamps &amp; (1) 2/32 Elec. Normal-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>G</td>
<td>SALT STORAGE</td>
<td>1</td>
<td>I1X135/P-h42</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 135w Incandescent Lamp</td>
<td>1</td>
<td>New 4’ Industrial Fixture w/ (2) F32T8 Lamps &amp; (1) 2/32 Elec. Normal-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>G</td>
<td>STORAGE (EST)</td>
<td>4</td>
<td>I1X75/P-w221</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 75w Incandescent Lamp</td>
<td>4</td>
<td>New 2’ Wrap Fluorescent w/ (2) F17T8 &amp; (1) 2/17 Elec. Low-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>G</td>
<td>C17 STORAGE (EST)</td>
<td>4</td>
<td>I1X100/P-w221</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 100w Incandescent Lamp</td>
<td>4</td>
<td>New 2’ Wrap Fluorescent w/ (2) F17T8 &amp; (1) 2/17 Elec. Low-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>G</td>
<td>C15 STORAGE (EST)</td>
<td>6</td>
<td>I1X135/P-w221</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 135w Incandescent Lamp</td>
<td>6</td>
<td>New 2’ Wrap Fluorescent w/ (2) F17T8 &amp; (1) 2/17 Elec. Low-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>G</td>
<td>C13 KITCHEN STORAGE</td>
<td>5</td>
<td>I1X75/P-h42</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 75w Incandescent Lamp</td>
<td>5</td>
<td>New 4’ Industrial Fixture w/ (2) F32T8 Lamps &amp; (1) 2/32 Elec. Normal-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>C11 STORAGE</td>
<td>3</td>
<td>I1X135/P-h42</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 135w Incandescent Lamp</td>
<td>3</td>
<td>New 4’ Industrial Fixture w/ (2) F32T8 Lamps &amp; (1) 2/32 Elec. Normal-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>G</td>
<td>C11 STORAGE</td>
<td>1</td>
<td>add-cfl-ws</td>
<td>Add Controls To Existing Lighting</td>
<td>1</td>
<td>New wall sensor</td>
<td>3000</td>
<td>2400</td>
</tr>
<tr>
<td>9</td>
<td>G</td>
<td>STORAGE (EST)</td>
<td>2</td>
<td>I1X135/B-h42</td>
<td>Incandescent Bare-Lamp Fixture w/ (1) 135w Incandescent Lamp</td>
<td>2</td>
<td>New 4’ Industrial Fixture w/ (2) F32T8 Lamps &amp; (1) 2/32 Elec. Normal-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>G</td>
<td>STORAGE (EST)</td>
<td>1</td>
<td>I1X135/P-h42</td>
<td>Incandescent “Poker Hat” Fixture w/ (1) 135w Incandescent Lamp</td>
<td>1</td>
<td>New 4’ Industrial Fixture w/ (2) F32T8 Lamps &amp; (1) 2/32 Elec. Normal-Power Ballast</td>
<td>3000</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>G</td>
<td>STORAGE (EST)</td>
<td>1</td>
<td>add-cfl-ws</td>
<td>Add Controls To Existing Lighting</td>
<td>1</td>
<td>New wall sensor</td>
<td>3000</td>
<td>2400</td>
</tr>
<tr>
<td>12</td>
<td>G</td>
<td>C7 SHOP</td>
<td>4</td>
<td>W42/EE-w64L</td>
<td>4’ Wrap Fluorescent w/ (2) F40T12/34w Lamps (1) Energy Saving Magnetic Ballast</td>
<td>2</td>
<td>New 8’ Wide-Wrap Fixture w/ (4) F32T8 Lamps &amp; (1) 4/32 Elec. Low-Power Ballast</td>
<td>2500</td>
<td></td>
</tr>
</tbody>
</table>
Example: O&M Measures tied to Retro- Commissioning (RCx)

- You are operating a facility with (rooftop) AHU with motorized dampers and belt-drive fan for heating and cooling. What do you think/do in each of the following cases:

1. One AHU’s outlet (supply air) damper is manually set at 50%.
2. Outdoor air damper stays at minimum position when air-conditioning is required on a mild (65dF), dry day.
3. Outdoor air damper is 40% open (at more than minimum position) when heating is required.
4. During the building warm-up in the early morning (during pre-occupancy) what position should the OA dampers be in?
Energy Audits - Reviewing ECM

- What does ECM mean?
- In the case of a burner replacement ECM, what role must the operator play if the measure is going to save energy as projected?
- How are ECM’s usually prioritized in the Summary of Recommendations?
- What is “Simple Payback”? How is it calculated?

ECM = Energy Conservation Measure

- What role must the operator play if the measure is going to save energy as projected? Answer: The projected energy savings was 17% of fuel usage. This energy savings will occur only if the burners operate in a normal way, as designed. They have to run correctly and not short cycle. They boiler controls must be set up correctly for proper burner operation.

- How are ECM’s usually prioritized in the Summary of Recommendations?
  They are usually listed in order of the Simple Payback, with the best one listed first. The shortest payback is listed first.

- ECM – Burner Replacement – 4 Year Simple Payback
- ECM – Motors Upgrade – 7 Year Simple Payback
- ECM – Steam Traps Replace – 10 Year Simple Payback

- What is “Simple Payback”? How is it calculated?

  Simple Payback = \frac{\text{Cost of Project}}{\text{Savings per Year}} = \frac{40,000}{10,000} = 4 \text{ year}
The Audit Report - Summing Up

• Energy Conservation Measures (ECMs)
  – Cost effectiveness analysis usually simple pay back (measure cost / savings value)
  – Accounting for interactive effects
  – Report of all identified ECMs, from those selected to not recommended
  – M&V plan

• Appendices
  – Detailed engineering calculations that allow the reader to recreate audit conclusions
Here’s a blank Summary Table for measures (ECMS) that would be included in the recommended measures in an Executive Summary.

A Summary Table provides measure costs, construction costs and savings per measure with simple payback, both measure-by-measure and for the facility-wide scope of work (the total job). Simple payback is just that- total project cost divided by annual savings, expressed in years.
<table>
<thead>
<tr>
<th>Category</th>
<th>Recommended Measure</th>
<th>Annual Energy Savings (kWh)</th>
<th>Annual Fuel Oil Savings (gal)</th>
<th>Natural Gas Savings (therms)</th>
<th>Electric Cost Savings</th>
<th>Fuel Oil Cost Savings</th>
<th>Natural Gas Cost Savings</th>
<th>Estimated Project Cost 1</th>
<th>Simple Payback 1</th>
<th>Environmental Savings (metric Tons of CO2e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>ECM-1 Lighting Upgrades</td>
<td>853,014</td>
<td>273.4</td>
<td>$102,408</td>
<td>$1,117,932</td>
<td>10.9</td>
<td>299.76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-2 Occupancy Sensors</td>
<td>107,338</td>
<td></td>
<td>$6,825</td>
<td>$103,491</td>
<td>15.2</td>
<td>37.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-3a Replace existing Chiles in [Redacted]</td>
<td>202,800</td>
<td>153.4</td>
<td>$45,795</td>
<td>$842,500</td>
<td>18.4</td>
<td>71.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-3b Replace existing Chiles in [Redacted] Bldg</td>
<td>263,424</td>
<td>131.7</td>
<td>$44,998</td>
<td>$810,000</td>
<td>18.0</td>
<td>92.57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-4 Replace Motors</td>
<td>59,902</td>
<td></td>
<td>$3,812</td>
<td>$105,381</td>
<td>27.6</td>
<td>21.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-5 Replace and or Install VFD's</td>
<td>334,983</td>
<td></td>
<td>$21,298</td>
<td>$248,349</td>
<td>11.7</td>
<td>117.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HVAC</td>
<td>ECM-6a Install Controls System - DDC -</td>
<td>482,534</td>
<td>20,522</td>
<td>$30,680</td>
<td>$400,000</td>
<td>6.7</td>
<td>278.73</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-6b Install Controls System - DDC -</td>
<td>430,019</td>
<td>10,045</td>
<td>$27,341</td>
<td>$400,000</td>
<td>9.6</td>
<td>204.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-7 Install 3 Feedwater economizers on boilers</td>
<td>-</td>
<td>22,072</td>
<td>$31,563</td>
<td>$300,000</td>
<td>9.5</td>
<td>117.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-8 Install 3 O2 Trim Control systems on boilers</td>
<td>-</td>
<td>20,527</td>
<td>$29,354</td>
<td>$99,000</td>
<td>3.4</td>
<td>109.20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-9 Replace two DHWater heaters in [Redacted] Basement</td>
<td>-</td>
<td>7,143</td>
<td>$10,215</td>
<td>$125,000</td>
<td>12.2</td>
<td>38.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Project</td>
<td>2,734,014</td>
<td>559</td>
<td>80,309</td>
<td>$283,156</td>
<td>0</td>
<td>$114,842</td>
<td>$4,551,652</td>
<td>11.4</td>
<td>1388</td>
</tr>
</tbody>
</table>

Notes: 1. The ECM Costs and Simple Paybacks shown in this table are based on direct construction costs (Material and Labor) only. For overall project cost and payback refer to the Executive Summary Table.
5.0 RECOMMENDED ENERGY CONSERVATION MEASURES

The building has a variety of lighting fixture types. The majority of lighting consists of linear fluorescent T-12 lamps. Less than ten percent of the fixtures have been upgraded to T-8 lamps. The second most common type of lamp in the building is incandescent lamps of varying wattage.

Exterior lighting counts and wattages were obtained from the lighting maintenance department. This step was taken to observe the security restrictions implicit in surveying a public building. The exterior lighting consists of a variety of lamp and fixture types. Metal halide (175W, 150W), high pressure sodium (250W), compact fluorescent (23W, 26W), and incandescent (135W) lamps are all used to provide light for external spaces around the building. The maintenance staff also indicated that there were non-operational street lamps that would place a demand on the building if they were repaired. As these fixtures are completely external and serve to illuminate parking spaces and public areas, we have treated these fixtures as outside of our scope.

Exit signs are also varied in lamp type and fixture type ranging from incandescent bulbs to LED lighting. Some of the exit signs appear to be the original fixtures installed in the building. Of the more modern exit signs, the single faced fixture with incandescent lamps was the most common type.

Approximately one hundred out of twelve hundred areas were locked and inaccessible even after multiple visits.

1. ECM-1: Lighting Upgrades

T-12 lamps contribute to over fifty percent of the demand. The opportunity to upgrade these lamps and fixtures to drop overall demand should be strongly considered. In addition, the incandescent lamps in this facility contribute to demand disproportionately as they are the least efficient lighting solution, having a lower lumens-to-watt ratio than any other kind of lamp at the site. Both the T-12 linear fluorescents and incandescent lamps would be candidates for retrofit.

While our survey reflects an accurate count of exits signs in the building, exit sign refixturing may not be required as the facility group has made arrangements with an outside contractor to retrofit all existing exit signs to LEDs. This should be taken into account if the project enters the design phase.
Existing exterior lighting may be upgraded by both refixturing and upgrading lamps and ballasts. Metal halide fixtures can be upgraded by a lamp and ballast retrofit to a lower wattage bulb, while high pressure sodium fixtures would be a better candidate for refixturing altogether. One discordant element of an exterior lighting upgrade is wall mounted sconces with 23W CFL lamps along the ramp to the loading dock and at other exterior locations. Our recommended retrofit of Eagle II 100W Metal Halides encompasses the possibility of delamping some of these exterior fixtures in order to offset the increased load and lumen count associated with a footprint for footprint replacement.

a) Scope of Work

Depending on usage, T-12 lamps and fixtures will either be refixedtured completely or retrofitted with lamp and ballast only. Linear fluorescent lighting is a strong candidate for lamp and ballast replacement as decorative lenses are being employed to hide fixtures and lamps from staff and visitors. These are large areas of ceiling fitted with four foot strip lighting in rows and columns. Modern T-8 lamps and electronic ballasts will replace the current outdated T-12 lamps and magnetic ballasts. No delamping will be considered for these areas, again, due to the decorative nature of this structure. For the remainder of the building, only cove lighting, decorative, and industrial fixtures were considered fit for lamp and ballast change out.

All remaining linear fluorescent lighting will be refixedtured and delamped where adequate lighting levels will permit the opportunity to do so.

Recessed incandescent lighting will be refixedtured with Delray horizontal cans and appropriate 4-pin or 2-pin CFL lamps. Ceiling mounted incandescent fixtures will be replaced with 78 series two foot linear fluorescent fixtures. Wall mounted incandescent fixtures will be replaced with 44 series two foot linear fluorescent fixtures. Both fixtures will be fitted with new T-8 lamps and electronic ballasts.

As discussed above, exterior wall mounted CFLs may be delamped and replaced with Eagle II 100W luminaires, existing metal halide lamps may be retrofit with lower wattage and more efficient lamps and ballasts; and finally high pressure sodium lamps may be refixedtured, also with Eagle II 100W luminaires.

b) Opinion of Probable Cost and Annual Energy Savings

The cost to implement this ECM is estimated at $1,117,932. The annual savings that can be realized is $102,408. This results in a simple payback period of 10.9 years.

c) Basis of Savings

The basis of savings for this measure is the decrease in energy usage that will be realized by utilizing lower wattage fluorescent bulbs in the existing light fixtures.
2. ECM-2: Install Occupancy Sensors

The lighting in the **area** is controlled by wall mounted switches. Significant savings in energy can be achieved with the installation of occupancy sensors.

**a) Scope of Work**

The wall mounted light switches in the offices, closets and bathrooms will be replaced with dual technology occupancy sensors for lighting control. The occupancy sensors will be wall or ceiling mounted depending on the specific application.

Due to security concerns, occupancy sensors will not be installed in **area** or any public areas in the facility. In keeping with best engineering practice, we do not recommend the installation of sensors in the hallways as they are a point of egress, nor in utility areas or mechanical rooms.

**b) Opinion of Probable Cost and Annual Energy Savings**

The estimated cost to install the occupancy sensors is $103,491. The proposed annual savings is $6,825. This gives a simple payback period of 15.2 years.

**c) Basis of Savings**

The basis of savings for this measure is the reduction in energy usage that will be realized by automatically turning off the lights when a room is unoccupied.
Life Cycle Cost Analysis

Life-cycle cost analysis (LCCA) is a means of assessing total cost of facility ownership. It accounts for all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when project alternatives that meet the same performance requirements, but have different initial costs and operating costs, have to be compared to select the one that maximizes net savings. (Source: http://www.wbdg.org)

The ASHRAE II Life Cycle Cost Analysis is a financial analysis and comparison of the total cost of operating a facility under different conditions. The report helps to determine the most cost effective way to invest in, operate, and maintain a facility. LCCA helps decision-makers understand the economic impact of a capital investment in equipment, such as energy efficient equipment. The final dollar figures are expressed in present value terms, which means that all dollar figures are expressed as “today’s dollars”. This allows a like-to-like comparison of costs and savings over the 20 year time period being analyzed.

The LCCA will be completed using the DOE free software, BLCC to produce a comparison summary that details the economic impact of the energy conservation measures proposed, changes in energy consumption and subsequent greenhouse gas emissions reduction. The LCCA model compares two scenarios. The first (Base Case) is called “Do Nothing” and represents current operating conditions. The second (Alternative) is called “Implement ECMs” and is the scenario with all recommended energy conservation measures implemented.
LIGHTING RETROFIT ECM-1 SUMMARY TABLE

TOTAL LOAD REDUCED: 273.40 KW

CALCULATION
AVERAGE RUN TIME: 12 HRS/DAY
5 DAY/WEEK

$\times$ 52 WKS/YR
3120 HRS/YR

3120 HRS/YR
$\times$ 273.40 KW

CONSUMPTION SAVINGS: 853,014 KWHR/YR

DEMAND SAVINGS: 273.402 KW/MONTH

FINANCIAL SAVINGS
CONSUMPTION SAVINGS: 0.06358 $/KWH

$\times$ 853,014 KWHR/YR

$54,235

DEMAND (WINTER) COSTS: 10.97 $/KW
WINTER MONTHS 8 MONTH/YR
DEMAND SAVINGS $\times$ 273.40 KW/MONTH

$23,994

DEMAND (SUMMER) COSTS: 22.11 $/KW
SUMMER MONTHS 4 MONTH/YR
DEMAND SAVINGS $\times$ 273.40 KW/MONTH

$24,180

TOTAL SAVINGS: $102,408 /YEAR
Life Cycle Costing Analysis
Assumptions

Utility Rates:
- Electricity Cost = $0.1194/kWh
- Natural Gas Cost = $1.43/Therm
- Residual Fuel Oil #2= $1.95/gal

Escalation:
- No Escalation is assumed for this analysis.

Lighting:
- Lamps and ballast last 20,000 hours on average

HVAC:
- Chillers:
  - ASHRAE life for chillers is 20 years. ASHRAE assumes that maintenance is done annually.

- Boilers:
  - ASHRAE life for boilers is 30 years. ASHRAE assumes that maintenance is done annually.

- Burners:
  - Burner life is assumed to be 20 years with proper maintenance.

- Air Handlers:
  - Life of an air handler is 20 years assuming proper maintenance.
<table>
<thead>
<tr>
<th>Category</th>
<th>Recommended Measure</th>
<th>Current Annual Maintenance Costs</th>
<th>Annual Maintenance costs after ECM Implementation</th>
<th>Comments for Maintenance Costs</th>
<th>Average Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lighting</strong></td>
<td>ECM-1 Lighting Upgrades</td>
<td>$8,000</td>
<td>$8,000</td>
<td>starts after 5 years</td>
<td>$6,000</td>
</tr>
<tr>
<td></td>
<td>ECM-2 Occupancy Sensors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECM-3a Replace Existing Chillers in Bldg</td>
<td>$8,000</td>
<td>$4,000</td>
<td>after 5 years</td>
<td>$3,000</td>
</tr>
<tr>
<td></td>
<td>ECM-3b Replace Existing Chillers in Bldg</td>
<td>$8,000</td>
<td>$4,000</td>
<td>after 5 years</td>
<td>$3,000</td>
</tr>
<tr>
<td></td>
<td>ECM-4 Replace Motors</td>
<td>$4,000</td>
<td>$2,000</td>
<td>after 5 years</td>
<td>$1,500</td>
</tr>
<tr>
<td><strong>HVAC</strong></td>
<td>ECM-5 Replace and or Install VFD’s</td>
<td>$0</td>
<td>$2,000</td>
<td>in 5th, 8th, 11th, 14th, 17th &amp; 20th years</td>
<td>$600</td>
</tr>
<tr>
<td></td>
<td>ECM-6a Install Controls System - DDC - Bldg</td>
<td>$3,000</td>
<td>$3,000</td>
<td>$7000 after 4th year</td>
<td>$5,400</td>
</tr>
<tr>
<td></td>
<td>ECM-6a Install Controls System - DDC - Bldg</td>
<td>$3,000</td>
<td>$3,000</td>
<td>$7000 after 4th year</td>
<td>$5,400</td>
</tr>
<tr>
<td></td>
<td>ECM-7 Install Feedwater economizers on boilers</td>
<td>$0</td>
<td>$5,000</td>
<td>$7000 after 4th year</td>
<td>$5,400</td>
</tr>
<tr>
<td></td>
<td>ECM-8 Install 302 Trim Control systems on boilers</td>
<td>$0</td>
<td>$3,000</td>
<td>after 3 years</td>
<td>$2,550</td>
</tr>
<tr>
<td></td>
<td>ECM-9 Replace Tow DHWater Heaters in Bldg Basement</td>
<td>$1,000</td>
<td>$2,000</td>
<td>after 3 years</td>
<td>$1,700</td>
</tr>
<tr>
<td><strong>Total Project</strong></td>
<td></td>
<td>$35,000</td>
<td>$40,000</td>
<td></td>
<td>$28,350</td>
</tr>
</tbody>
</table>
### NIST BLCC 5.3-10: Summary LCC

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

**General Information**

File Name: C:\ProgramFiles\BLCC5\projects\QCC.xml
Date of Study: Tue May 03 16:03:05 EDT 2011
Analysis Type: FEMP Analysis, Energy Project
Project Name: [REDACTED]
Project Location: New York
Analyst: AP
Base Date: May 1, 2010
Service Date: May 1, 2010
Study Period: 20 years 0 months (May 1, 2010 through April 30, 2030)
Discount Rate: 3%
Discounting Convention: End-of-Year

Discount and Escalation Rates are REAL (exclusive of general inflation)

### Alternative: Do Nothing

**LCC Summary**

<table>
<thead>
<tr>
<th></th>
<th>Present Value</th>
<th>Annual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Energy Consumption Costs</td>
<td>$33,315,614</td>
<td>$2,239,554</td>
</tr>
<tr>
<td>Energy Demand Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Energy Utility Rebates</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Water Usage Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Water Disposal Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Annually Recurring OM&amp;R Costs</td>
<td>$520,750</td>
<td>$35,006</td>
</tr>
<tr>
<td>Non-Annually Recurring OM&amp;R Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Replacement Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Less Remaining Value</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total Life-Cycle Cost</strong></td>
<td><strong>$33,836,364</strong></td>
<td><strong>$2,274,560</strong></td>
</tr>
</tbody>
</table>

### Alternative: Implement ECMs

**LCC Summary**

<table>
<thead>
<tr>
<th></th>
<th>Present Value</th>
<th>Annual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost</td>
<td>$4,551,652</td>
<td>$305,973</td>
</tr>
<tr>
<td>Energy Consumption Costs</td>
<td>$27,211,343</td>
<td>$1,829,211</td>
</tr>
<tr>
<td>Energy Demand Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Energy Utility Rebates</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Water Usage Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Water Disposal Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Annually Recurring OM&amp;R Costs</td>
<td>$424,783</td>
<td>$28,555</td>
</tr>
<tr>
<td>Non-Annually Recurring OM&amp;R Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Replacement Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Less Remaining Value</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total Life-Cycle Cost</strong></td>
<td><strong>$32,187,778</strong></td>
<td><strong>$2,163,738</strong></td>
</tr>
</tbody>
</table>
Do savings from the ECMs seem reasonable?

• Examine the total costs for an ECM (earlier slide)
• Compare interaction between savings for ECMs #5 and #6 (earlier slides)
  What interactive effects have not been calculated in the mix?

• Compare savings shown to appropriate energy use
• Where are these figures located in the audit report? Where do you find the savings from replacement of controls?
• What are the potential/added savings that may accrue from updating the controls.
How are Energy Savings Tied to Energy Use Data?

• Should look at TWO different parts of the report:
  – Existing conditions vs. measures recommended.
• Some rules of thumb:
  – 10 – 15% savings from O&M, RCx.
  – 25 – 30% savings usually cost-effective
  – > 40% savings requires careful vetting.
  – > 60% savings means you should closely review all of your calculations!
  – > 100% savings are rare but do happen.
• Where are “short paybacks” likely to be found in the NYC area?
Common Sources of Savings Overestimation

• Operating hours excessive.
• Calculations based on equipment ratings, not actual loads.
• Use of degree days unadjusted for operating schedules.
• Failure to account for measure interaction (cascading effect).
A Look at Quantifying Cascading” Savings

More accurately estimates new “usage” of one ECM based on savings from another ECM.

Example: Your facility uses 74,000 therms of gas in its two boilers:

• ECM1: Improve average combustion efficiency (saving 10%).
• ECM 2: Improve fuel by replacing steam trap elements (saving 9%).

ECM 1: Burner adjustment to improve efficiency:

\[ 10\% \times 74,000 = 7400 \text{ therms / year} \]

ECM 2: Replace Steam Traps:

\[ .09 \times (74,000 - 7400) = 9\% \times 66,600 = 5,994 \text{ therms / year} \]

Total Savings = 13,395 therms / year .......vs 14,060 (19% x 74,000)
Individual Measure Analysis

**Current:** 50 HP motor (1 hp = .746 kW), 90% efficient, runs full-time (8,760 hours/yr).

**Projected:** 93% high-efficiency motor.

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (Baseline)</td>
<td>50*.746 / .90 = 41.4 kW</td>
<td>50*.746*8760 / .90 = 363,053 kWh</td>
</tr>
<tr>
<td>Projected</td>
<td>50*.746 / .93 = 40.1 kW</td>
<td>50*.746*8760 / .93 = 351,342 kWh</td>
</tr>
<tr>
<td>Savings</td>
<td>41.4 – 40.1 = 1.3 kW (assuming on-peak)</td>
<td>363,053 – 351,342 = 11,711 kWh</td>
</tr>
</tbody>
</table>

Alternative calculation using percentages:
(93-90) / 90 = 3.3% improvement
363,053 * .033 = 11,980 kWh
Source of Overestimation

Load Factor: Reduces motor energy consumption and savings by 20 - 50% in many cases.

- **Current use:** \(50 \times 0.746 \times 8760 \times 0.6 / 0.9 = 217,832\) kWh
- **Projected use:** \(50 \times 0.746 \times 8760 \times 0.6 / 0.93 = 210,805\) kWh
- **Savings:** \(217,832 - 210,805 = 7,027\) kWh/yr

Savings now 7,027 vs. 11,711
Source of Overestimation

**Operating hours:** what happens if the motor we thought was operating continuously actually had shut down for 8 hours/day at night and all day on Saturday and Sunday?

- **Hours shut down:** \((5 \times 8 \times 52) + (2 \times 24 \times 52) = 4,576\)
- **Corrected operating hours:** \(8,760 - 4,576 = 4,184\)
- **Current use:** \(50 \times 0.746 \times 4,184 \times 0.6 / 0.9 = 104,042 \text{ kWh}\)
- **Projected use:** \(50 \times 0.746 \times 4,184 \times 0.6 / 0.93 = 100,685 \text{ kWh}\)
- **Savings:** \(104,042 - 100,685 = 3,357 \text{ kWh/yr}\)

Savings now 3,357 vs. 11,711
Quantifying ‘Cascading’ Savings

Caution in estimating savings when two measures are taken in sequence? Example: Your facility uses 74,000 therms of gas in its two boilers.

ECM1: Improve average combustion efficiency (saving 10%)

ECM 2: Improve fuel by replacing steam trap elements (saving 9%).

ECM 1: Burner adjustment to improve efficiency:

\[
10\% \times 74,000 = 7400 \text{ therms / year}
\]

ECM 2: Replace Steam Traps:

\[
.09 \times (74,000 - 7400) = .09 \times 66,600 = 5,994 \text{ therms / year}
\]

Total Savings = 13,395 therms / year ...and not \((.10+.09)\times 74,000\)
Measure Calculation
Individual Measure Analysis

Example

• 50 HP motor, 90% efficient, runs full-time (8,760 hours/yr). Change to 93% high-efficiency motor. Remember, 1 hp = .746 kw
  – Capacity requirement (baseline) = $50 \times .746 / .9 = 41.4$ kw
  – Present use (baseline) = $50 \times .746 \times 8760 / .9 = 363,053$ kwh
  
  – New capacity = $50 \times .746 / .93 = 40.1$ kw
  – Projected use = $50 \times .746 \times 8760 / .93 = 351,342$ kwh
  
  – KW savings = $41.4 - 40.1 = 1.3$ kw (assuming on-peak)
  – KWH savings = $363,053 - 351,342 = 11,711$ kwh/yr

• Note that Efficiency is always in the denominator

• alternative, using percentage improvement,
  – $(93 - 90) / 90 = 3.3\%$ improvement
  – $363,053 \times .033 = 11,980$ kwh/yr

• Refer to Capehart Ch. 12, Turner ch.
Measure Calculation
Individual Measure Analysis

• Pitfall of Individual Measure Analysis: *Susceptible to over-estimation*

• For previous motor example, add consideration of motor **Load Factor**. Reduces motor energy consumption and savings opportunity by 20 - 50% in many cases.
  
  – Present use (baseline) = \(50 \times 0.746 \times 8760 \times 0.6 / 0.9 = 218,118 \text{kWh}\)
  
  – *Projected use = 50 \times 0.746 \times 8760 \times 0.6 / 0.93 = 210,805 \text{kWh}*
  
  – KWH savings = 218,118 – 210,805 = 7,313 \text{kWh/yr} \)

• **Method has no check against actual energy use**
Measure Calculation
Individual Measure Analysis

- Pitfall of Individual Measure Analysis: *Susceptible to over-estimation - Operating hours*

- For previous motor example, what happens if the motor we thought was operating continuously actually shut-down for 8 hours/day at night and all day Saturday and Sunday?
  - \((5*8*52) + (2*24*52) = 4,584\) hours of shut-down
  - Corrected operating hours = \(8,760 - 4,584 = 4,176\)
  - Present use (baseline) = \(50*.746*4,176*.6 / .9 = 103,980\) kwh
  - *Projected use = 50*.746*4,176*.6 / .93 = 100,493kwh*
  - KWH savings = \(103,980 - 100,493 = 3,487\) kwh/yr
Source of Overestimation

Operating hours: what happens if the motor we thought was operating continuously actually had shut down for 8 hours/day at night and all day on Saturday and Sunday?

- **Hours shut down**: \((5\times8\times52) + (2\times24\times52) = 4,576\)
- **Corrected operating hours**: \(8,760 - 4,576 = 4,184\)
- **Current use**: \(50\times.746\times4,184\times.6 / .9 = 104,042 \text{ kWh}\)
- **Projected use**: \(50\times.746\times4,184\times.6 / .93 = 100,685 \text{ kWh}\)
- **Savings**: \(104,042 - 100,685 = 3,357 \text{ kWh/yr}\)

Savings now 3,357 vs. 11,711
Class Review and Reading Assignment

Topic 1: How Audits are conducted
- Process and Objectives
- The role of you as facility operator in the process

Topic 2: Reading and using the Energy Audit Report
- Standard sections of the report
- What to look for
- The facility operator’s role in Quality Control

Reading Assignment for Class 20: Finish reading the audit handout, complete project #4 and study for Exam 4.