This course has been registered with GBCI for CE hours.

HVAC Systems: Effective Design vs. Operations

BY U.S. Green Building Council

NUMBER OF CE HOURS: 1.0
LEARNING OBJECTIVES

1. Identify tools to assist in tracking facility improvements.
2. Develop strategies to improve existing facility operation.
3. Identify low cost & capital improvement projects.
• Associate Principal
• Healthcare Client Executive
• 13+ Years @ IMEG
• Registered Engineer (PE)

Affiliations
• IAEE
• ASHRAE
• AHA
• ASHE

Presentations
• 2018 ISHE Fall Conference
• 2019 USP <797> & <800>
• 2020 PDC Summit

Publications & Awards
• 2019 ASHRAE Technology Award
• White Paper: Off-Site CSS Facility
IMEG Firm Overview

AT-A-GLANCE

100 YEAR HISTORY
1,300 EMPLOYEES
U.S. BASED & EMPLOYEE-OWNED
40 LOCATIONS
400 LICENSED ENGINEERS
$177M IN ANNUAL REVENUE
#104 / TOP 500 DESIGN FIRM

TOP 10 ENGINEERING FIRM IN U.S.
(Building Design + Construction)

SPECIALTY SERVICES
- Acoustics
- Architectural Lighting
- Building Performance Analysis
- Building Certification
- Commissioning
- Medical Equipment Planning
- Security
- Utility Infrastructure

KEY DIFFERENTIATORS
- MARKET-SECTOR FOCUSED
- INNOVATIVE THOUGHT LEADERSHIP
- GROWTH ORIENTED
- SUSTAINABLE DESIGN SOLUTIONS
- PROACTIVE DESIGN PARTNERS
PRESENTATION AGENDA

• ESTABLISHING A BASELINE
• BENCHMARKING YOUR FACILITY
• CAMPUS STANDARDIZATION
• IMPLEMENTATION CONCEPTS
• CASE STUDY
ESTABLISHING A BASELINE
Understanding Your Facility

Documenting Your Facility

▷ AHU Zone Maps

▷ Multiple Plants & How They Operate
  • Boiler Plants
  • Chiller Plants
  • Domestic Water Systems

▷ Operation Setpoints, Sequences & Reasons
  • “We open this valve when these people complain, and close it when those people complain”
Benchmarking Your Facility

Create Your Facility’s Baseline

Create a Facility Assessment
- Internal / External

Create a System
- Assign Asset Tags
- Facility Nomenclature
  - Retroactive & New Project

Maintain Documentation
- Test & Balance Reports
- Joint Commission Documentation
- Code Deficiencies
- Operating Costs

Priority Classification

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>PRIORITY</th>
<th>COST</th>
<th>ASSUMPTIONS</th>
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<tr>
<td>87</td>
<td>Chiller Plant</td>
<td>P2</td>
<td>TBD</td>
<td></td>
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<tr>
<td>88</td>
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<td></td>
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<tr>
<td>93</td>
<td>Heating Water System</td>
<td>P3</td>
<td>TBD</td>
<td>Exact routing and flow calculations need to be investigated in order to avoid budgetary numbers</td>
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<tr>
<td>94</td>
<td>Heating Water System</td>
<td>P2</td>
<td>TBD</td>
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<td>95</td>
<td>Air Handling Unit Replacement</td>
<td>P1</td>
<td>TBD</td>
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Note: PRIORITY 1 (P1): Item does not meet code, presents a safety hazard or has direct impact on patient care
PRIORITY 2 (P2): Affects the building performance
PRIORITY 3 (P3): General recommendations, Modernization Upgrades, Good Practice
Benchmarking Your Facility

Tools for Tracking Performance

➤ Systems Metering
  • Natural Gas
  • Electricity
  • Steam
  • Heating Water
  • Chilled Water
  • Domestic Water

➤ Types of Meters
  • Electromagnetic In-line
  • Electromagnetic Insertion
  • Clamp-on Ultrasonic

➤ FMCS Trending
BENCHMARKING YOUR FACILITY
Energy Star Portfolio Manager

- [www.energystar.gov](http://www.energystar.gov)

Based on National Median, Not Average

Measured in Energy Use Intensity (EUI)

Provides a Baseline for Similar Facilities

<table>
<thead>
<tr>
<th>Broad Category</th>
<th>Primary Function</th>
<th>Further Breakdown (where needed)</th>
<th>Source EUI (kBTU/m²)</th>
<th>Site EUI (kBTU/m²)</th>
<th>Reference Data Source - Peer Group Comparison</th>
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<td>Healthcare</td>
<td>Ambulatory Surgical/Center</td>
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<td>62.0</td>
<td>CBEC - Outpatient Healthcare</td>
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<td>224.3</td>
<td>Industry Survey</td>
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<td>Other/Specialty Hospital</td>
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<td>Medical Office*</td>
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<td>Industry Survey</td>
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<td>145.8</td>
<td>64.5</td>
<td>CBEC - Clinics/Outpatient</td>
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</tbody>
</table>
Energy Consumption

- Energy use intensity (kBtu/ft²/yr)
- Building size
- IMEG projects
- Inpatient facilities (Chicago)
- Senior care facilities

- Lighting
- Heating
- Cooling
- Fans
- Pumps
- DHW

Energystar – Inp.
Energystar – Sr. Care
Prioritize Action

**Tier 1**
- Low-cost/no-cost operational improvement

**Tier 2**
- Operational and capital projects

**Tier 3**
- Likely need capital projects to reduce further
CAMPUS STANDARDIZATION
Does This Describe Your Facility?
Ask Yourself…

- If every building had the same type of air handling unit, would it be easier or harder to train staff?
- Could you better negotiate service contracts?
- Would it be easier to store replacement parts?
- Could you more easily compare performance from one building to the next?
- Would it be easier or harder to troubleshoot issues?
- Could staff from one building more easily help staff from another?
- What would this approach do for your lighting?
Establish Campus Standards

**Tier 1 Goals**
**Minimum Maintenance**
- LED lighting
- Occupancy sensors
- Daylight sensors
- Condensing boilers
- High-efficiency chillers/DX
- Lower hot water temperature
- Higher chilled water temperature
- Variable frequency drives
- Automatic scheduling of OFF
- Unoccupied mode patient room and OR
- Efficient ductwork sizing
- Dedicate AHU to usage type (e.g., OR AHU vs. patient AHU)
- Low-flow water fixtures
- Collecting metered data

**Tier 2 Goals**
**Involved Maintenance**
- Automatic air/water reset
- Dynamic VAV resets
- Tracking/benchmarking energy use
- Retro-commissioning
- Hybrid systems
- Scattered terminal units
- Heat recovery chiller
- Economizer
- Control sequences

**Not Allowed**
- Window A/C units
- Rooftop units
- Window-to-wall ratios above 40%
- External architecture doesn’t move
- Control sequences X, Y, Z
Title, Purpose, and Scope

1. PURPOSE:
The purpose of this guideline is to provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics.

2. SCOPE:
2.1 This guideline provides detailed sequences of operation for HVAC systems.
2.2 This guideline describes functional tests that when performed will confirm implementation of the sequences of operation.
IMPLEMENTATION CONCEPTS

• You Don’t Need the Most Efficient Equipment
• Small Steps Can Result in Big Impacts
Low-Cost First Steps

- **Commissioning (Cx)**
  - Retro-Cx & New Construction
  - Is Your Building Operating as Designed?

- **Low Cost Capital Improvements**
  - Replace and Install VFD’s
  - Explore Converting Constant Volume to Variable Volume
    - Air & Water Systems
  - Remove 3-way Valves in the System
    - Thumb rule: 1GPM/HP
  - Economizer Controls
    - Add / Verify
  - Take Advantage of Condensing Boilers & HEX’s
    - Heating Water Reset Schedule
Combine Chiller Plants

- Evolution of a Facility
- Expensive, but Significant Benefits
  - Redundancy
  - Air-cooled / Water-cooled Hybrid System
  - Efficiently Load (1) Chiller vs. Inefficiently Loading Multiple
  - Filling / Starting Cooling Towers
- Try to Piggy-back onto other Projects
- BUYER BEWARE: System Design can be Challenging
  - IMEG’s Experience
Chiller Plant Optimization

- Install VFD’s on all Chiller System Components
  - System Pumps (Primary, Secondary, etc.)
  - Condenser Loop Pumps
  - Cooling Tower Fan
- VFD’s Provide Means of Monitoring kW
  - Modify Controls to Calculate Plant & Total System kW
- Controls System to Calculate kW/Ton
- Facility Staff Trial & Error
  - Change Primary Pump Speed
  - Change Chiller Setpoint
  - Change Cooling Tower Speed
  - Change Condenser Pump Speed
- Trend kW/Ton and Optimize Your System
Capital Improvement Projects (cont.)

Install RO System for Boiler Feed & Humidification

- Ideal in Poor Water Quality Areas
- Decrease Frequency of Blowdown
  - Case Study: 5 Cycles vs. 50 Cycles of Concentrate
  - Water Savings
  - Energy (heating) Savings
- Decrease Operating & Maintenance Costs
  - Less Frequent PM of Humidification System
Measures: See Handout After Session

Phase I - No or low cost measures to reach 10-20% savings (years 1-3)

**Encourage good habits**
- More effective than single time interventions.
  - Clearly baseline the existing energy baseline (energy use, not cost) to make case for rolling all savings into capital improvement projects.
  - Make agreement up front before savings occur.
  - Consider tracking in EnergyStar Portfolio Manager.
- Initial focus on the 20% of facilities that use 80% of the system-wide energy use.
- Clearly post energy use of all facilities with all personnel — recognition leaders.
  - Share all energy expense data with the facilities staff.
  - Engage facility staff of poor performing buildings with those from other buildings.
  - Conduct minimum number of these measures each year, allow each building to select the best options for them.
  - Consider Building Operator Certification for facilities personnel — send 2-3 per year.
- Begin/move campus energy standards for New Construction and Renovation.
- Bolded items below have the largest operational cost savings potential.

**Immediately fix measures that impact multiple end uses**
- Semi-annual survey of OA dampers — for operation to design minimum OA and full closure.
  - Check OA settings at the largest units first and work down the list.
  - Hire a balancer to do a survey.
  - Trend mixed air temperature settings — set alarms.
- Monthly survey of nighttime shutdown for all non-essential AHUs.
- Semi-annual survey all independent exhaust fans for unoccupied shutdown.
- Reduce static pressure supply on all VFDs by 10% or higher until worst case loss value is 100% open.
- Survey VAV box minimums every 3-4 months; consider reset if minimum is >30%.
  - Adjust heating/cooling water supply temperature throughout.
  - Raise/CWS and reduce HWS by 2-4 degrees or higher until demand is not met.
  - (Note — maintain AHU humidity control)
  - Consider supply reset temperature based on return water temperature or outside air temperature.

**Lighting**
- Begin installing lighting occupancy sensors in areas with greatest occupant variability and highest connected load (do 30 or 20/year, for example).
- Replace existing cans fixtures with retrofit LED cans (50 year, for example).
- Install photocell to control exterior lighting — especially parking lot.
- De-lamp fixtures in non-critical spaces (reduce e-De-lamp fixtures to 2).

**Air handling units**
- Reset supply air temperature based on mixed air or outside air humidity.
- Assess and implement economizer cycle on all RTUs (even partial economizer if it is the only option).
- Install time clocks or demand sensors on kitchen hoods to turn off when not in use.
  - Hire a balancer to re-adjust high exhaust spaces every 2-3 years.
  - Re-wire restroom fans to operate with lights (or add timer).

**Cooling**
- Reset cooling tower condenser water temperature based on wet bulb — automated or seasonally.
- Perform weekly water testing of cooling tower — reduce blowdown in increments until maximum concentration is reached.
- Clean DK and evaporator coils monthly during cooling season.

**Heating**
- Reset steam pressure seasonally — higher in winter, lower in summer.
- Reset hot water supply temperature seasonally.
- Weekly testing of boiler chemical treatment.
- Annual testing of boiler combustion efficiency.
- Buy thermal imaging cameras and share among facilities; perform walk-through with spray foam insulation each December.

**Water and domestic hot water**
- Low flow aerators (0.5 gpm) and low flow showerheads (1.6 gpm) (do 10 or 20 per year, for example).
- Install low-flow dishwashing prewash spray nozzles.
- Install landscaping irrigation timers.

Phase II - Engage in Capital Projects to Reduce Energy Use (year 2-5)

**Use energy audits or retro-commission studies as starting point for analysis (seek utility programs for low or no cost assessments)**

**Lighting**
- Begin lighting upgrades in buildings with highest demand — target a specific square footage per year (20,000 sf per year for example).
- Daylight dimming for lobbies, atrium, common space with many windows.

**Air handling units**
- Add VFDs to constant volume systems.
- Add VFDs to kitchen exhaust and makeup.
  - Incorporate smoke or occupancy sensors.
- Transfer makeup air from adjacent dining space.
- Implement unoccupied mode for Operating Room ventilation.
  - Single large button to reset exhaust rates, temperature, and lighting when room is unoccupied.
- Add energy recovery to any replacement air handling units — use flat plate or heat plate if cross-contamination is a concern.
  - When replacing fan coil or fan powered boxes, select units with variable speed (ECM) motors.
- Add carbon dioxide sensors to high occupancy, variable use spaces — control AHUs, VAV box, and outside air damper based on CO2 levels.
- Add VFD to cooling tower fans — per individual towers to individual pumps. Turn off during part load conditions.
- Install banner management system utilizing stack temperature analysis and control of fuel/air mixture.
- Convert from constant volume chilled water distribution to variable volume.
  - Convert all AHU 3-way valves to two-way control.
  - Add VFD to pump(s).
- Add VFD to cooling tower fans — per individual towers to individual pumps. Turn off during part load conditions.

**Heating**
- Add VFD to chillers with 10+ years of remaining life.
- Convert from constant volume chilled water distribution to variable volume.
  - Convert all AHU 3-way valves to two-way control.
  - Add VFD to pump(s).

**Water and domestic hot water**
- Replace flush valves with dual flush or low flow (1/8 gallon for urinals) 10-20 per year, for example.
- Install heat exchanger that uses cooling tower condenser water to pre-heat domestic hot water.
CASE STUDY
Project Overview

- Existing Campus: 277,000 SF

- Project Size
  - 87,000 SF Addition (31.5% / 24%)
  - 18,000 SF Renovation (6.5%)

- Project Scope
  - Emergency Department
  - Surgical Suite
  - PACU
  - Heart Center
  - Central Sterilization Services (CSS)
  - Mechanical Penthouse

- Project Completion: 2017
HVAC Systems & Strategies

› Traditional HVAC Systems

› Chiller Plant
  • Combined Campus Plant
  • (2) Water-cooled
  • (3) Air-cooled
  • Spring/Fall Operation

› Boiler Plant
  • (3) Steam Boilers

› AHU Replacement
  • Constant Volume vs. Variable Volume

› AHU Coil Design
  • CW: 45°F EWT, ↑ ΔT
  • HW: Pumped Coil, 110°F EWT, 3FPS

› Ductwork Sizing

› LED Lighting
  • 0.785 W/SF \(\rightarrow\) Exceeds Code by ~30%

› Equipment Standardization

“The team was conscious of equipment ratings and high efficiency options, but did not allow expensive specialty systems to be the driver for project design.”
*Per Hospital’s annual energy performance review, natural gas consumption increased in 2018 due to an increased heating demand – increased heating degreedays.*