We will start in just a few minutes. Tell us…

What questions do you have about pandemic preparedness?

Please go to slido.com and use event code #DOE to submit your responses.
Monitoring Healthy Buildings: Using EMIS to Identify Issues with Ventilation, Air Quality, and Thermal Health

Monday, June 21, 2021
1:00 – 2:00 pm ET
# Agenda & Housekeeping

<table>
<thead>
<tr>
<th>1</th>
<th>Introduction &amp; Polls</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Presentation from NREL</td>
</tr>
<tr>
<td>3</td>
<td>Q&amp;A</td>
</tr>
</tbody>
</table>

You have joined on a muted line.

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Please go to www.slido.com using your mobile device, or by opening a new window

Enter Event Code

#DOE
Better Buildings HVAC Technology Research Team at NREL

Marcus Bianchi
Senior Research Engineer

Greg Shoukas
Research Engineer

Michael Deru
Senior Research Engineer
HVAC Resource Map

What is this resource?

The Central Plant Resource Map is an intuitive graphical interface that provides quick access to a broad array of quality information on operations and maintenance best practices and energy and water efficiency measures. The resources cover the central plant, distribution systems, and zone systems. The primary audiences for this resource are facility managers, operations staff, and design engineers who are looking to improve central plant and distribution efficiency but don’t have time to search for these resources.

This Resource Map is not a repetition of guidance provided in codes and standards. It should not be used in lieu of professional engineering services.

Explore HVAC Resources

Use the horizontal navigation above or the interactive diagram to dive into resources on different HVAC components.

The resources listed on this site have been carefully selected to help narrow your search for helpful information.

https://hvacresourcemap.net
Outline for Today’s Presentation

- Healthy Buildings Definition, Certification, and Standards

- Approaches to monitoring healthy buildings:
  - Level 1: Energy information system (EIS)
    - Supports healthy buildings through high level data reports at the building level, providing indirect help to improve HVAC schedule and operations
  - Level 2: EIS with additional monitoring points/IoT
    - Supports healthy buildings through specific data points like CO₂ to indicate zone and AHU-level health in buildings
  - Level 3: Fault detection and diagnostics (FDD)
    - Supports healthy buildings with robust HVAC system and equipment data to provide specific FDD related to ventilation, IEQ, and other healthy building metrics
## How is a Healthy Building Defined?

**Harvard School of Public Health: 9 Foundations of a Healthy Building**

<table>
<thead>
<tr>
<th>Ventilation-air ventilation guidelines</th>
<th>Air Quality-chemical emissions, RH levels</th>
<th>Thermal Health-comfort (temperature and RH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture-potential condensation which leads to mold</td>
<td>Dusts and Pests (and viruses)-surface cleaning and filtration</td>
<td>Safety and Security-fire safety and CO monitoring</td>
</tr>
<tr>
<td>Water Quality-drinking water purification systems</td>
<td>Noise-outdoor noise, mechanical and machinery equipment</td>
<td>Lighting and Views-provide as much daylighting and get screen breaks</td>
</tr>
</tbody>
</table>
Healthy Building Certification Programs

- WELL Building Standard (https://www.wellcertified.com/)
- Fitwel (https://www.fitwel.org/)
- Reset (https://www.reset.build/)
- UL Verified Health Building Program (https://www.ul.com/services/verified-healthy-buildings)
- Indoor environmental quality in LEED v4.1
  https://www.usgbc.org/leed/v41
  https://www.usgbc.org/articles/healthy-air-all-people-through-leed-v41
Healthy Building Focused Standards

Ventilation:

ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality

Source: www.ashrae.org
Healthy Building Focused Standards

Air Quality and Thermal Comfort (IEQ):

ANSI/ASHRAE Standard 55

Source: www.ashrae.org
8 Objectives:

1. Manage the design and construction process to achieve good IAQ
2. Control mixture in building assemblies
3. Limit entry of outdoor contaminants
4. Control moisture and contaminants related to mechanical systems
5. Limit contaminants from indoor sources
6. Capture and exhaust contaminants from building equipment and activities
7. Reduce contaminant concentration through ventilation, filtration and air cleaning
8. Apply more advanced ventilation approaches

Source: ASHRAE Indoor Air Quality Guide (ashrae.org)
Healthy Building Monitoring Approaches

- **Level 1: Energy information system (EIS)**
  - Supports healthy buildings through high level data reports at the building level, providing indirect help to improve HVAC schedule and operations

- **Level 2: EIS with additional monitoring points/IoT**
  - Supports healthy buildings through specific data points like CO$_2$ to indicate zone and AHU-level health in buildings

- **Level 3: Fault detection and diagnostics (FDD)**
  - Supports healthy buildings with robust HVAC system and equipment data to provide specific FDD related to ventilation, IEQ, and other healthy building metrics
Healthy Building Monitoring Level 1: Energy Information System (EIS)

Points

Electricity points
- Consumption (kWh)
- Demand (kW)

Natural gas
- Consumption (therms)

Chilled water
- Consumption (tons-hrs or BTUs)

Steam
- Pressure (psi)

KPIs/analytics
- Energy use intensity (kBtu/sq ft)
- Heat maps
- Load profile, filtered by day type
- Predictive models of energy use

Issues identified
- Comparisons of utilities to occupancy schedule
- See when purge cycles occur in utility data
- Share energy information with occupants to encourage changes
Healthy Building Monitoring Level 1: Energy Information System (EIS)

Images, left to right: Carleton College, Macalester College, Tishman Speyer
Healthy Building Monitoring Level 2: EIS with additional monitoring points/IoT

- Level 1: Energy information system (EIS)
  - Supports healthy buildings through high level data reports at the building level, providing indirect help to improve HVAC schedule and operations

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- Level 3: Fault detection and diagnostics (FDD)
  - Supports healthy buildings with robust HVAC system and equipment data to provide specific FDD related to ventilation, IEQ, and other healthy building metrics
Healthy Building Monitoring Level 2: EIS with additional monitoring points/IoT

Points/sensors
- Zone-level CO₂
- Occupancy
- Temperature
- Relative humidity

KPIs/analytics
- Live dashboard, heat maps and KPIs for decision making
- Indoor/Outdoor air quality monitoring
- Summary of zone-level temperature/CO₂ sensors
Healthy Building Monitoring Level 2: Targets

- Carbon Dioxide 200–500 ppm differential above outside air
- Relative Humidity 40–60%
- Total Volatile Organic Compounds < 500 µg/m³
- Micro Respiratory Particles (0.3 – 0.5 µm)
- PM 2.5 (0.5 – 2.5 µm) < 15 µg/m³
- Carbon Monoxide < 9 ppm
- Hot water > 140F

Sources: Aircuity Healthy Building Brochure for Commercial Office; ASHRAE Epidemic Task Force (Hot water)
Healthy Building Level 2: KPIs-Compliance and Reporting

Source: Building Analytics for COVID-19 Operations, CopperTree Analytics
Healthy Building Monitoring Level 2: KPIs and dashboards

Source: IoTConnect

Source: Aircuity
Healthy Building Monitoring Approaches: Level 3 FDD

- **Level 1: Energy information system (EIS)**
  - Supports healthy buildings through high level data reports at the building level, providing indirect help to improve HVAC schedule and operations.

- **Level 2: EIS with additional monitoring points/IoT**
  - Supports healthy buildings through specific data points like CO₂ to indicate zone and AHU-level health in buildings.

- **Level 3: Fault detection and diagnostics (FDD)**
  - Supports healthy buildings with robust HVAC system and equipment data to provide specific FDD related to ventilation, IEQ, and other healthy building metrics.
Healthy Building Monitoring Level 3: Fault Detection and Diagnostics (FDD)

How EMIS work:

Data Warehouse: Integrates and organizes building data

Data Analytics: Transmits actionable information to building engineer

Monitoring: Tracks improvements and measures savings

EMIS TOOLS: Energy information systems (EIS) help find energy waste using smart meter data. Fault detection and diagnostic tools (FDD) detect and prioritize HVAC system faults. Automated system optimization (ASO) includes control algorithms to minimize energy use across systems.

Implementation: Building engineer reviews analytics and makes repairs or improvements

Source: Smart Energy Analytics Campaign final report
Fault Rules from EIS data:
- Start/stop schedules
- Weekend/holiday energy use
- High baseload
- Demand spikes
- High energy use relative to portfolio or prior usage (modeled prediction)

Fault Rules from FDD:
- Setpoints
- Simultaneous H&C (IEQ)
- Economizer (Ventilation)
- Reset schedules
- Equipment staging/Control loop tuning

Source: Smart Energy Analytics Campaign final report
Healthy Building Level 3: FDD Helps Prioritize

### Top 5 Issues

<table>
<thead>
<tr>
<th>Building</th>
<th>Equipment</th>
<th>Notes</th>
<th>Cost/Qtr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anon Hospital</td>
<td>AHU_6_CAVs</td>
<td>Low Damper Position – opportunity for static pressure reset.</td>
<td>$11,120</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>AHU_11</td>
<td>No supply temp reset. Cooling valve issues.</td>
<td>$7,778</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>AHU_6</td>
<td>No supply temp reset. Cooling valve issues.</td>
<td>$6,163</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>AHU_5</td>
<td>Supply temp lower than setpoint. No supply temp reset. Cooling valve issues.</td>
<td>$5,029</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>AHU_4</td>
<td>Supply temp lower than setpoint. No supply temp reset. Cooling valve issues.</td>
<td>$4,318</td>
</tr>
</tbody>
</table>

### Maintenance

<table>
<thead>
<tr>
<th>Building</th>
<th>Equipment</th>
<th>Notes</th>
<th>Severity Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anon Hospital</td>
<td>AHU_11</td>
<td>Static pressure lower than setpoint. Supply fan speed constant. Return fan speed constant.</td>
<td>6</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>AHU_10</td>
<td>Static pressure lower than setpoint. Supply fan speed constant.</td>
<td>6</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>CAV8_2</td>
<td>Room temp lower than setpoint. Stuck reheat valve.</td>
<td>4</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>CAV5_82</td>
<td>Supply flow lower than setpoint. Stuck reheat valve. – May be sensor error.</td>
<td>4</td>
</tr>
<tr>
<td>Anon Hospital</td>
<td>CAV3_11</td>
<td>Sensor error. Stuck reheat valve.</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Schneider Electric Building Analytics
Healthy Building Level 3: FDD Helps Prioritize

### Diagnostics

The Diagnostics module provides a prioritized, searchable list of identified faults and energy saving opportunities across your portfolio.

#### Generate Data

16,525 data records found for 9/8/2019 to 9/8/2019 in daily intervals.

<table>
<thead>
<tr>
<th>Building</th>
<th>Equipment</th>
<th>Analysis</th>
<th>Start Date</th>
<th>Tasks</th>
<th>Cost</th>
<th>E</th>
<th>C</th>
<th>M</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monarch Central Plant</td>
<td>CCHWS (Cooling System)</td>
<td>CCHW Loop</td>
<td>9/8/2019</td>
<td>2</td>
<td>$590</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseville Hospital</td>
<td>AHU-4 (Air Handler)</td>
<td>AHU Fan</td>
<td>9/8/2019</td>
<td>122</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseville MOB1 - Building D</td>
<td>AHU-1 (Air Handler)</td>
<td>AHU Fan</td>
<td>9/8/2019</td>
<td>74</td>
<td>10</td>
<td></td>
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</tr>
<tr>
<td>Redwood City CUP</td>
<td>CUP/CW (Cooling System)</td>
<td>CW Loop</td>
<td>9/8/2019</td>
<td>3</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseville CUP</td>
<td>PCHWS (Cooling System)</td>
<td>CCHW Loop</td>
<td>9/8/2019</td>
<td>57</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseville Hospital</td>
<td>AHU-2 (Air Handler)</td>
<td>AHU Fan</td>
<td>9/8/2019</td>
<td>85</td>
<td>10</td>
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<td></td>
<td></td>
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<tr>
<td>Roseville Folsom MOB</td>
<td>Hot Water System (Heating System)</td>
<td>HW Loop</td>
<td>9/8/2019</td>
<td>40</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roseville MOB1 - Building D</td>
<td>AHU-2 (Air Handler)</td>
<td>AHU Fan</td>
<td>9/8/2019</td>
<td>46</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Bay South Hospital Co...</td>
<td>PCHW (Cooling System)</td>
<td>CCHW Loop</td>
<td>9/8/2019</td>
<td>39</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zion Medical Center</td>
<td>AHU-14 (Air Handler)</td>
<td>AHU Heat Recovery</td>
<td>9/8/2019</td>
<td>37</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarch Hospital Building</td>
<td>A2-2-3-10-03 (Zone Equipment)</td>
<td>Zone Unit</td>
<td>9/8/2019</td>
<td>34</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Kaiser Permanente (Clockworks)
Healthy Building Level 3: BAS Points and FDD

Monitoring Points

Global points
- Outside air temperature
- Outside air enthalpy

System points
- Building or AHU Schedules
- CHW and Boiler schedules
- CHW and HW temperatures

Equipment points
- Status points
- AHU temperatures
- Damper/Coil signals
- Zone temperatures and setpoints
- Zone RH
- CO₂

FDD
- MAT calculation versus outside air damper signal
- Enthalpy comparison and economizer status
- Fouled or blocked coil and dirty filters/pressure drop range in AHU
- Differential RACO₂ vs OACO₂ comparison
- Zone temperature/RH/CO₂ don’t meet setpoint or expected value
Healthy Building Level 3: KPIs and Reporting

- Daily/Weekly Outdoor Air Fraction for all AHUs
- Daily and Weekly Occupied Hours
- Maintenance Digest for Filters
- Daily/Weekly Hours Hot Water Valve at 100%
- Daily/Weekly Hours Chilled Water Valve at 100%
- Daily/Weekly Hours Zone Reheat Valve at 100%
- Daily/Weekly Damper at 100%
- Daily/Weekly Hours Pumps at High Speed
- Daily/Weekly Equipment Run Time Report
- Daily/Weekly Hours in Purge Mode
- Zone Temperature Analysis
- Zone Air Flow Analysis
- Critical Zone Air Changes Per Hour
- Compliance Reporting

Source: CopperTree Analytics Building Health Compliance Package
Healthy Building Level 3: KPIs-Compliance and Reporting

Source: EMA Webinar: Building Analytics for COVID-19 and Post-COVID-19 Building Operations, CopperTree Analytics
Healthy Building Level 3: Sensors and Analysis, Pitfalls & Success

- Which BAS points do you use for analysis?
- How many BAS points do you need to adequately cover zones, floors, buildings?
- Where do you place them?
- Sensor calibration?
- What if I want to add sensors?
- What substitute points or sequences can I use for analysis if I don’t want to add additional sensors?
Figure 24: High limit control performance: Climate Zones 6 to 8.
Healthy Building Level 3: Sensors and Analysis, Pitfalls & Success

- Which BAS points do you use for analysis?
- How many BAS points do you need to adequately cover zones, floors, buildings?
- Where do you place them?
- Sensor calibration?
- What if I want to add sensors?
- What substitute points or sequences can I use for analysis if I don’t want to add additional sensors?

Source: ASHRAE Using Occupant Centric Control for Commercial HVAC Systems
Healthy Building Level 3: Sensors and Analysis, Pitfalls & Success

Source: ResearchGate AHU-VAV Schematic
Healthy Building Level 3: Occupancy Sensing

Occupancy sensing
- 1 and 2 binary yes or no presence of occupancy in the building or zones
- 3 and 4 number of people in building or zone
- 5 and 6 comfort (setpoint adjustments)

Implicit sensing
- CO₂
- Humidity
- Lighting or plug loads

Source: ASHRAE Using Occupant Centric Control for Commercial HVAC Systems
Healthy Building Level 3: Customer Success with FDD and IAQ

- Number of issues: 3,876
- Number of IAQ issues filtered in fault summary: 367
Healthy Building Summary

- Certification program:
  - WELL Building Standard (https://www.wellcertified.com/)
  - Fitwel (https://www.fitwel.org/)
  - Reset (https://www.reset.build/)
  - UL Verified Health Building Program (https://www.ul.com/services/verified-healthy-buildings)

- Levels of analysis:
  - Level 1: Energy information system (EIS)
  - Level 2: EIS with additional monitoring points/IoT
  - Level 3: Fault detection and diagnostics (FDD)
Proving the Business Case for Building Analytics

Results from scaled implementation of Energy Management and Information Systems, as documented by the Smart Energy Analytics Campaign

BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Lawrence Berkeley National Laboratory

PREPARED BY:
Hannah Kramer, Guang Lin, Diane Curran, Diet Crowe, and Jessica Granderson

PREPARED FOR:
Amy Bow and Oliver Bacon, U.S. Department of Energy

October 2020

EMIS Applications Showcase
Highlighting Applications of Energy Management and Information Systems (EMIS)

BUILDING TECHNOLOGY & URBAN SYSTEMS DIVISION
Lawrence Berkeley National Laboratory
By Ehst Crow, Hannah Kramer, Jessica Granderson
October 2020

Proving the Business Case for BUILDING ANALYTICS

Lawrence Berkeley National Laboratory has partnered with commercial building owners across the country to gather data on the costs and benefits of Energy Management and Information Systems (EMIS). EMIS are the technologies behind automated data-driven energy management that help identify, diagnose, and implement building systems improvements. Through this partnership, Berkeley Lab has assembled the largest dataset to date on building analytics costs and benefits, proving the business case for their use at scale.

How EMIS work:

- Data Warehouse: Integrates data from building systems
- Data Analytics: Provides insights from building data
- Implementation: Building owner invests in analytics and data systems

Largest Dataset Documents the Costs and Benefits of EMIS

- 104 BUILDINGS
- 6,500 MBIUS
- $567 MILLION EIGHT YEARS

EMIS Software Replicates 40 DIFFERENT EMIS SYSTEMS HAVE BEEN INSTALLED

- ENERGY SAVINGS: 3%
- OPEX REDUCTION: 0.9%
- INVESTMENT PAYBACK: 2 YEARS
- COST OF SAVING 1 MBTU: $95 million
- INVESTMENT: $3 million

The NREL-DOE Smart Buildings Partnership uses energy data under partnership program protocols. The concerted efforts of the DOE and NREL and the energy data and analytics services provided under this project were used to develop this dataset. Additional datasets and services may be found on the Smart Buildings website.
Thank you

Questions?

- David Landman (dslandman@lbl.gov)
- Hannah Kramer (hkramer@lbl.gov)

Get involved:

- Building owners, operators, and managers: join the Better Buildings Alliance or contact bba@ee.doe.gov with questions
- Join the EMIS Tech Team list: send request to emis@lbl.gov
Thank you!

David Landman (dslandman@lbl.gov)
Hannah Kramer (hkramer@lbl.gov)
Q & A

Submit Questions

www.slido.com event code #DOE
Additional Resources

- COVID-19 Resource Center
  - [https://betterbuildingssolutioncenter.energy.gov/covid19](https://betterbuildingssolutioncenter.energy.gov/covid19)

- HVAC Resource Map
  - [https://hvacresourcemap.net](https://hvacresourcemap.net)

- ASHRAE COVID-19 Resources
  - [ashrae.org/covid19](https://ashrae.org/covid19)
Upcoming Webinar in the COVID-19 Webinar Series

Office Buildings and Ventilation:
How COVID-19 and other pathogens spread between zones

Monday, July 19, 2021 | 1:00 – 2:00 PM ET

How does COVID-19 and other pathogens spread between different zones of the office? Dr. Jason DeGraw of the Oak Ridge National Laboratory (ORNL) will discuss the effect of ventilation rates on the concentration and spread of COVID-19 and other pathogens within office buildings as well as the energy implications of the ventilation strategies addressed. Analysis of air movement using CONTAM, a multizone indoor air quality and ventilation model developed by the National Institute of Standards and Technology (NIST), provides a detailed understanding of how ventilation rates and office building design can affect the exposure of office workers and can help building operators balance these considerations with the associated energy impacts.
Better Buildings: Summer Webinar Series

ELECTRIFYING OUR BUILDINGS: CHALLENGES AND SOLUTIONS  
June 8  WATCH RECORDING

FINANCING IN HIGHER EDUCATION  
June 22  WATCH RECORDING

ESPC IN THE EXPRESS LANE: NEW PROJECT TRACKING TOOLS  
July 13  REGISTER TODAY

WASTE REDUCTION: LESSONS LEARNED AND WHAT COMES NEXT  
August 3  REGISTER TODAY

BECOMING ESPC-READY  
June 15  WATCH RECORDING

WHAT’S HOT WITH HEAT PUMPS  
June 29  REGISTER TODAY

WORKPLACE EVOLUTION: SUPPORTING OCCUPANT HEALTH WHILE ACHIEVING ENERGY EFFICIENCY  
July 20  REGISTER TODAY

VISUALIZE YOUR ENERGY FUTURE WITH ‘SLOPE’: THE STATE AND LOCAL PLANNING FOR ENERGY PLATFORM  
August 10  REGISTER TODAY

BOOSTING INDUSTRIAL AND MANUFACTURING EFFICIENCY AND RESILIENCY WITH CHP  
June 17  WATCH RECORDING

HOW TO IDENTIFY CHP PROJECTS THAT FIT YOUR GOALS  
July 1  REGISTER TODAY

ENERGY-SAVING ENVELOPE SUCCESS STORIES  
July 27  REGISTER TODAY

https://betterbuildingssolutioncenter.energy.gov/events-webinars
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- **Learn from the experts** with resources from ASHRAE, EPA, DOE, and more…
- **View resources** grouped by technology type
- **Watch webinars** & register for upcoming virtual learning opportunities

Learn more at: https://betterbuildingssolutioncenter.energy.gov/covid19