Using Benchmarking to Identify Energy Efficiency Opportunity in Cleanrooms: The Labs 21 Approach

William Tschudi
October 22, 2003
WFTschudi@lbl.gov
Preview

- Premise
- Metrics
- Use of Benchmarks to Identify Where to Look
- Use of Benchmarks to Identify Opportunity
- Use of Benchmarks to Set Operational Targets
- Conclusion
Benefits of Benchmarking

- Establish Baseline to Track Performance Over Time
- Prioritize Where to Apply Energy Efficiency Improvement Resources
- Identify Best Practices
- Identify Maintenance and Operational Problems
- Operational Cost Savings
Energy Benchmarking

The Premise:
In Cleanrooms, Benchmarks of Energy End-Use and Efficiency of Key Systems Can Identify Areas for Potential Efficiency Improvement and Can Be Used to Set Operational Targets
System Efficiency vs. Production Metrics

- Compare System Efficiency Regardless of Process
- Production Metrics can mask inefficient systems
Cleanroom HVAC metrics

- Air systems – cfm/kW
  - Recirculation
  - Make-up
  - Exhaust

- Cleanroom air changes – ACH/hr
  - Recirculated, filtered air
  - Outside air (Make-up and Exhaust)

- HEPA Air Velocity - ft/sec
Central Plant metrics

Chilled Water Efficiency – kW/ton

- Cooling tower/fans
- Condenser pump(s)
- Chilled water distribution pump(s)
- chiller
Energy End Use

Facility 1
- Hot Water & Steam: 23%
- Chilled Water: 19%
- Cleanroom Fans: 16%
- Process: 13%
- Other Misc.: 8%
- Compressed Air & Process Vacuum: 6%
- Cleanroom Lights: 1%
- Office (Lights, Plugs): 9%

Facility 2
- Hot Water, Steam and Cafeteria: 17%
- Total Chilled Water: 20%
- Cleanroom Fans: 27%
- Other Misc.: 10%
- Process: 9%
- Compressed Air: 7%
- Cleanroom Lights: 1%
- Office (Lights, Plugs): 9%

Facility 3
- Hot Water & Steam: 7%
- Total Chilled Water: 18%
- Cleanroom Fans: 11%
- Process Utilities: 17%
- Cleanroom Lights: 1%
- Process: 35%
- Other Misc.: 6%
- Office (Lights, Plugs): 9%
Energy Intensive systems

Recirculation of air in cleanrooms

- Process Tools: 34%
- Recirculation and Make-up Fans: 19%
- Chillers and Pumps: 21%
- DI Water: 5%
- Support: 3%
- Process Water Pumping: 4%
- Exhaust Fans: 7%
- Nitrogen Plant: 7%
Recirculation Air Comparison

Averages (cfm / kW)
- FFU: 1664
- Ducted: 1733
- Pressurized Plenum: 5152

Overall Average 3440
Recirculation System Efficiency - Industry Association Study

Recirculation Efficiencies

Average 1953 cfm/kW
Using Benchmarks To Set Goals

Building Owners and Designers can use benchmark data to set energy efficiency goals.
Looking Within the System...

HVAC Efficiency Choices are Many

- Equipment – Fans, Motors, Chillers, Controls, Filters, floor systems
- System Pressure Drop – face velocity, duct velocity, chases, plenums, adjacency, layout
- Air change rates
- Ceiling coverage
Here’s one Choice: Ducted HEPA Filters
Make-up Air Comparison

Average 972
Make-up Air Efficiency – Industry Association Study

Make-up Air Energy Efficiency

Average 946

Facility

cfm/kW

0 500 1000 1500 2000 2500

1 2 3 4 5 6 7 8 9 10 11 12 13 14
Make-up System Efficiency Choices

- Adjacency of air handler(s) to cleanroom
- Resistance of make-up air path
- Pressurization/losses
- Air handler face velocity
- Coil Pressure Drop
- Fan and motor efficiency
- Variable Speed
Air-Change Rate Comparison

IEST Recommended Ranges

Class 100: 94 - 276
Class 10: 385 - 591
A Closer Look at Air Change Rates

Cleanroom Benchmarking Data
ISO Class 5 (Class 100) Cleanrooms

Measured Air Change Rate (AC/hour)

Facility A  Facility B  Facility C  Facility D  Facility E  Facility F  Facility G  Facility H

TYPICAL RECOMMENDED DESIGN RANGE
Air Change and Velocity Choices

- IEST Recommended Recirculation Air Change Rates
- Variable Speed Fans (start low with ability to increase)
- Ceiling Coverage
- Pressurization/Losses
Chilled Water Systems Comparison

- Water Cooled 42F
- Air Cooled 42F
- Air Cooled 40F
- Air Cooled 48F
- Air Cooled 50F
- Water Cooled 40F
- Water Cooled 38F
- Water Cooled 36F
- Water Cooled 44F
- Water Cooled 43F

KW / ton (lower is better)
Chiller Comparison

Air Cooled Average: 0.8 kW/ton

Water Cooled Average: 0.62 kW/ton

- Water Cooled 42°F
- Air Cooled 42°F
- Air Cooled 40°F
- Air Cooled 48°F
- Air Cooled 50°F
- Water Cooled 40°F
- Water Cooled 38°F
- Water Cooled 36°F
- Water Cooled 44°F
- Water Cooled 43°F
- Fac. A
- Fac. B.1
- Fac. B.2
- Fac. B.2
- Fac. B.2
- Fac. C
- Fac. D
- Fac. E.1
- Fac. E.2
- Fac. F
Chilled Water System Choices

- Free Cooling
- Chiller Efficiency
- Variable Speed Chiller
- System Pressure drop
- Primary only or primary/secondary
- System controls
- Efficient Pumping
- Water vs. Air Cooled
Labs 21 Also Recognizes the Non-energy Benefits of Benchmarking

- Reliability Improvement
  - Controls
  - Setpoints
- Maintenance
  - Leaks
  - Motors, pumps, Fans
  - Filters
  - Chillers, boilers, etc.
- Safety
  - Hazardous air flow
Chilled Water Pump Power

Time: Hour, Day; October 2000

Chilled Water Pump Power

Time: Hour, Day; October 2000
Goal Setting Based Upon Benchmarks

- Facility and End Use “Energy Budgets”

- Efficiency Targets and/or Design Requirements for Key Systems and Components
  - Cfm/ KW
  - KW/ ton
  - System resistance - i.e. Pressure drop
  - Face velocities
  - Etc.
Cleanroom Benchmarking highlights some important issues

- Contamination Control Can Often Be Obtained With Reduced Air Change Rates
- Cleanliness Rating is Often Higher Than Needed
- Existing Guidance for Chilled Water Systems is Under-utilized
- Criteria Based Upon Rules Of Thumb Should Be Examined (90ft/min, air change rates etc.)
Conclusion

- Benchmarking Can Be Used To Find Efficiency Opportunity
- Building Owners, Operators, and Designers Can Use Benchmarks to Set Criteria
- More Robust Data is Needed To Identify All Current Best Practices
- If You Have Benchmark Data – Share It!