ADVANCED BUILDING ANALYST TRAINING PROGRAM

Mechanical Systems Efficiency and Management for Light Commercial Buildings

Unit I

Instructor's Guide

Acknowledgements

Development of the Mechanical Systems Efficiency and Management for Light Commercial Buildings program involved many professionals. Unless otherwise noted, the individuals listed below are affiliated with the University of Florida.

Craig Miller – Associate In, Program for Resource Efficient Communities. Mr. Miller served as overall coordinator for development of the Mechanical Systems Efficiency and Management for Light Commercial Buildings program. In addition to structuring the course and training materials for program presenters, he assisted in the developed of the individual modules.

Lynn Jarrett, M.S. – Water Resources Engineer, Program for Resource Efficient Communities. Ms. Jarrett was responsible for developing the modules on Codes and Standards and Financial Analysis as well as a contributor on all of the modules

Ward Simonton. PhD – Consultant and co-founder of Simonton and McKinney, LLC, an energy efficiency consulting firm. Dr. Simonton researched Nebraska-specific guidelines and supported the development of the course structure and the individual modules.

Nelson Stephens – Energy Services Specialist, Lincoln Electric System. Mr. Stephens provided input on light commercial HVAC applications in Nebraska and provided monthly utility data on various LES customers.

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Kenny Reed – Associate, ME Group. Mr. Reed provided input on light commercial HVAC applications in Nebraska.

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Christine Swanson – Program Assistant, Program for Resource Efficient Communities. Mrs. Swanson assisted in early development of the materials.

Barbara Haldeman – Editorial Assistant, Program for Resource Efficient Communities. Mrs. Haldeman handled the design and layout of the program materials.

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Table of Contents

Preface

Mechanical systems and equipment account for about 64% of the electricity consumed in the U.S. industrial/commercial sector. In these sectors alone, improvements to mechanical systems could yield dramatic energy and cost savings. The key to these savings is applying energy-efficiency equipment or implementing sound energy management practices. The Program for Resource Efficient Communities (PREC) at the University of Florida developed a *Mechanical Systems Efficiency and Management for Light Commercial Buildings* course that will provide the mechanical worker/building managers the knowledge and tools necessary to improve equipment and system performance. Specific focus areas will include light commercial building HVAC and Refrigeration Systems.

The training materials include an instructor's manual of presentation materials (e.g. PowerPoint slides) and a comprehensive student workbook/resource guide for each module. Modules include a list of objectives, skills, and requirements. Most modules consist of demonstrations, exercises, discussions (individual / group), and/or activities.

The training is proposed to be delivered in a 2-day format and consist of approximately 14-16 contact hours, which may in whole or in part, be credited toward continuing education units (CEUs) required for licensure. The materials have been assembled into the following units:

Unit I: (~ 7 hours):

Module 1: Introduction

Module 2: Fundamentals of Commercial Energy Use

Module 3: Mechanical Systems Codes and Standards

Module 4: Improvements in Heating, Ventilation and Air-Conditioning (HVAC)

Unit II: (~7 hours):

Module 5: Improvements in Refrigeration

Module 6: Health and Safety

Module 7: Financial Analysis

Module 8: Putting It All Together

Units I and II require a written pre- and post-class assessment, which you are expected to develop from the questions/answers provided on the included CD. Each unit also includes a participant evaluation/feedback form.

Notes to the Instructor

Sample agenda

The following sample agenda is a guide to allow enough time for you to adequately address each module topic. The sample is by no means definite and you are encouraged to deliver the training materials at a pace that is best for your particular audience. You are encouraged, as part of the initial class introductions, to solicit feedback from participants on their experiences and backgrounds. This agenda is based on seven continuing education hours (CEU's) or approximately 350 minutes.

Sample Agenda: Unit I

Class introductions, course overview and agenda for the day	5–10	minutes
Pre-class assessment	15–20	minutes
Module 1: Introduction	30	minutes
Module 2: Fundamentals of Commercial Energy Use	60	minutes
Module 3: Mechanical Systems Codes and Standards	80	minutes
Module 4: Improvements in Heating, Ventilation and Air-Conditioning (HVAC)	120	minutes
Post-class assessment	15–20	minutes
Participant evaluations/Summary	5–10	minutes

Pre/post-class assessments

You are responsible for selecting at least 20 questions from the Unit I Question Bank (found on the supplied CD) for written assessments, which are assigned before and after each day's instruction. The questions and answers specific to each module are also found in the Lesson Plan for that module. The Participant's Guide contains the questions for each module for you to use as a review.

Participant Evaluations

Please be sure that each individual completes the course evaluation at the end of the unit.

1: Introduction

Learning Objectives

By attending this session, participants will:

- ✓ Understand the objectives of the course (Advanced Building Analyst III: Mechanical Systems)
- ✓ Become familiar with the process of conducting a complete commercial audit
- ✓ Become familiar with certain steps in the processes of conducting a complete commercial audit.

Key Terminology

Action plan

Benchmarking

Client goals

Energy audit

Incentive

Initial analysis

Retro-commissioning

Supplemental Materials

*Energy Savings Potential and RD&D Opportunities for Commercial Building HVAC Systems***.** U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program. Sep 2011. http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/savings_potential_comm_hvac.pdf

"HVAC &R Market Trends & the Influence of ASHRAE Members". *ASHRAE Journal*. 2012. www.ashrae.org/File%20Library/docLib/Media%20Kit/2012MediaKit/ASHRAEJournal_2012_HVAC-R-Market.pdf

Institute for Building Efficiency, Benefits Beyond Energy
http://www.institutebe.com/Existing-Building-Retrofits/Productivity-Gains-from-Energy-Efficiency.aspx

Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat. Pacific Northwest National Laboratory for the U.S. Department of Energy. Dec 2011.

ASHRAE HVAC Applications Handbook, Section 35

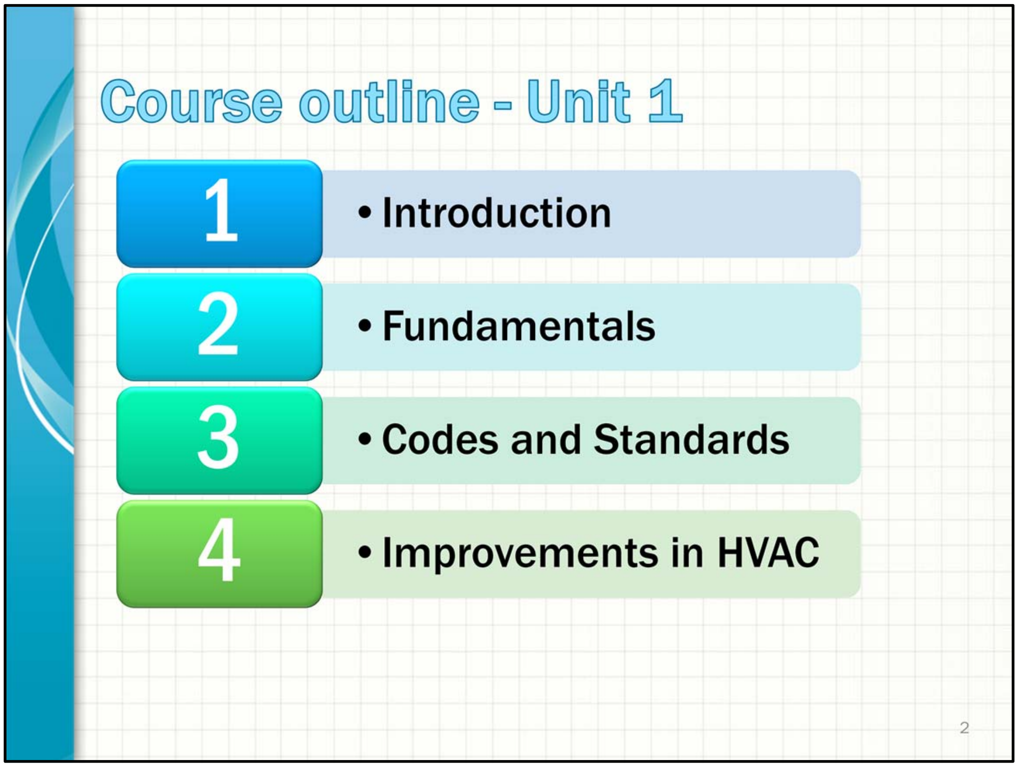
Classroom Props and Preparations

- Printed samples of commercial energy audits
- Example analysis reports

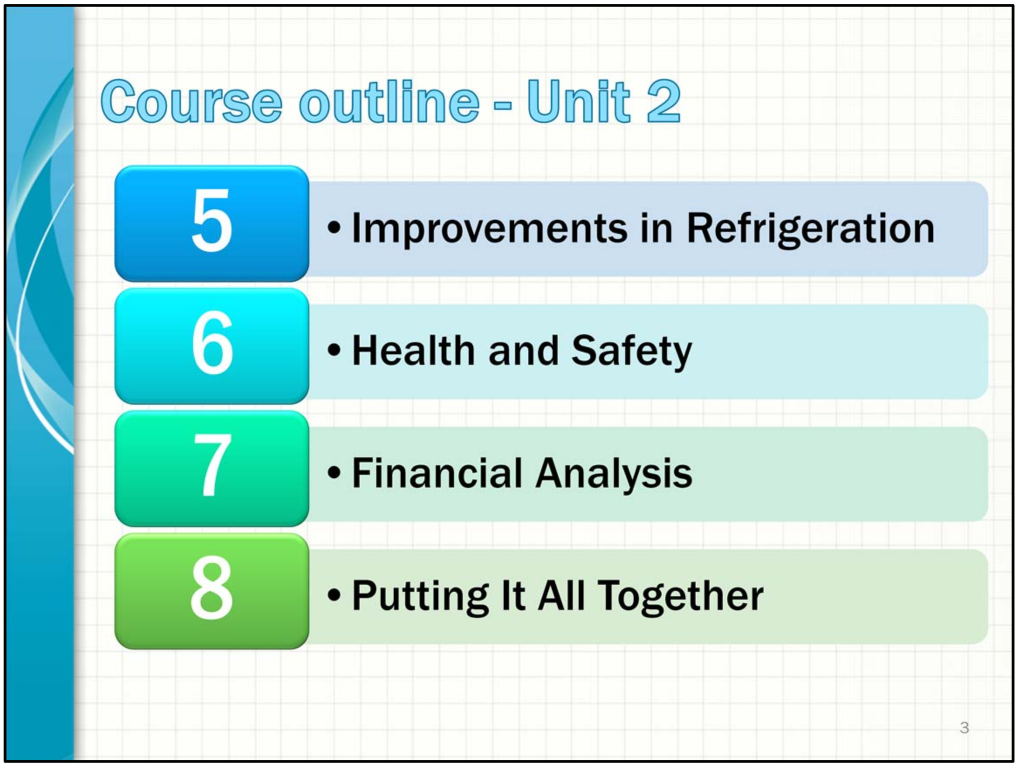
Possible Activities

1. **Group discussion (facility managers, business owners)**: Discuss what barriers exist that prevents many businesses to consider investing in whole-building energy audits and/or retro-commissioning.
2. **Group discussion (contractors and other service providers)**: Discuss strategies for promoting and providing commercial building energy audit and/or retro-commissioning for mechanical systems and refrigeration equipment.

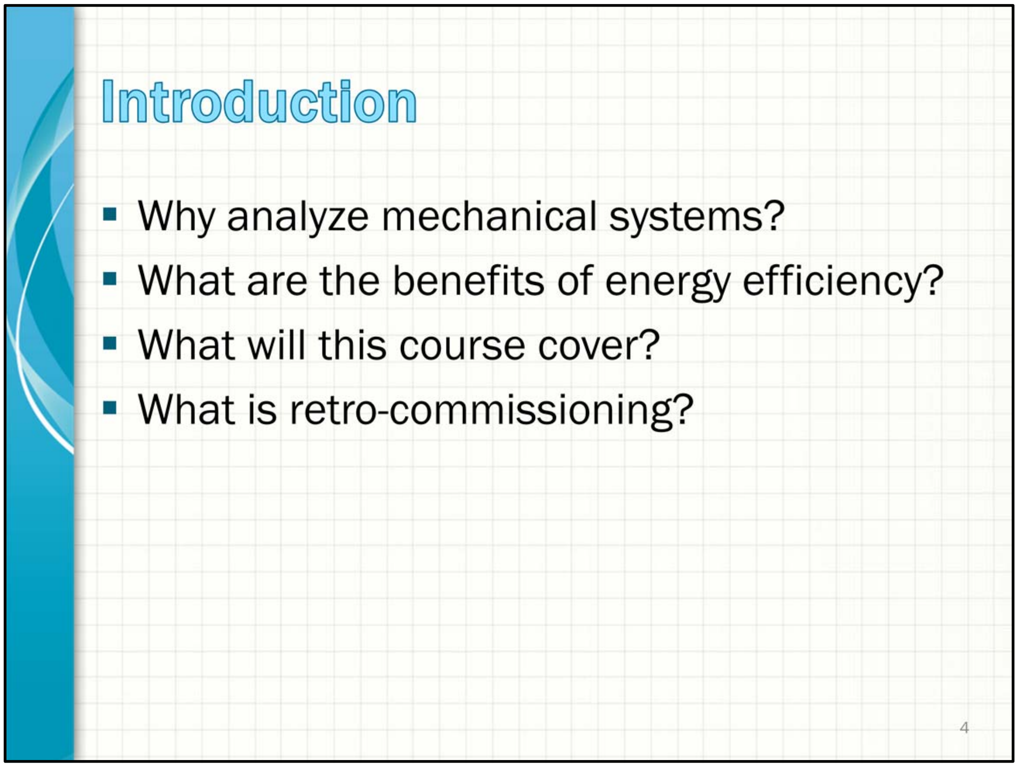

Advanced Building Analyst III
Mechanical Systems
Introduction
Module 1
1

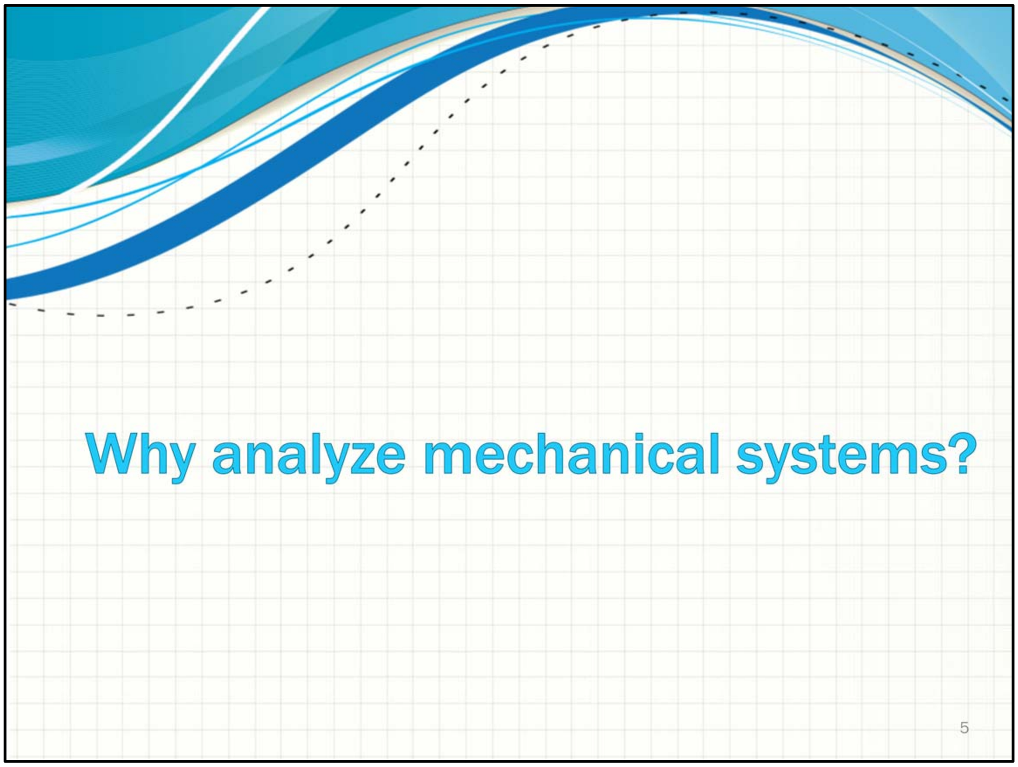


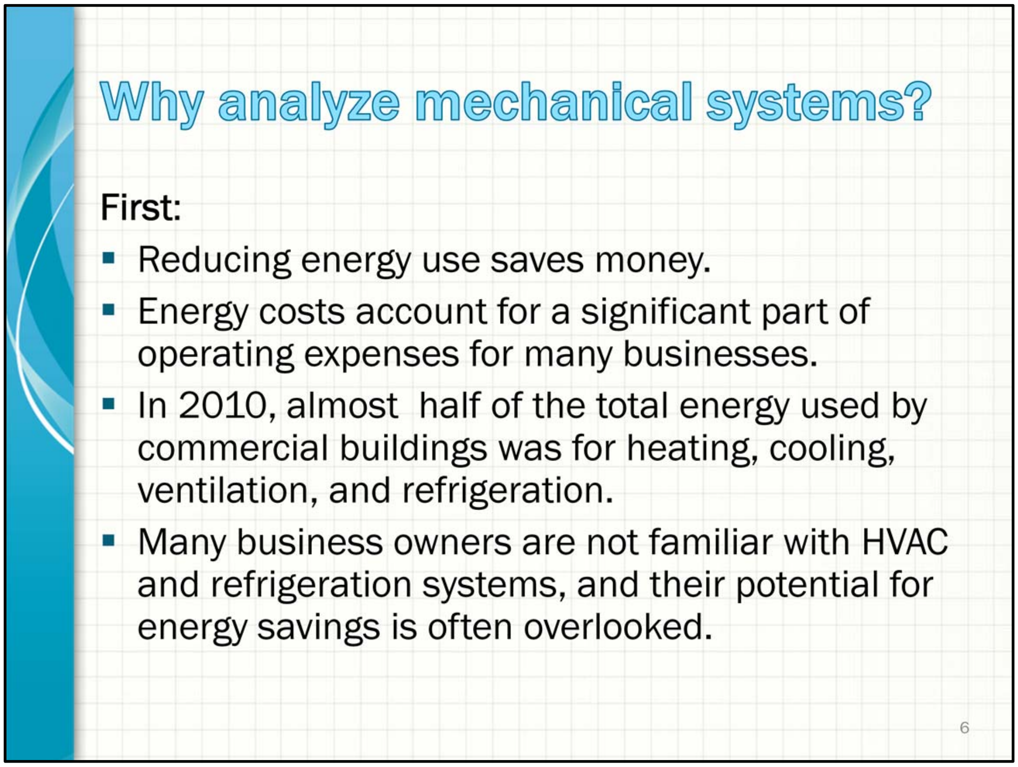
1. Introduction
2. Fundamentals of Commercial Energy Use
3. Mechanical Systems Codes and Standards
4. Improvements in Heating, Ventilation and Air Conditioning



5. Improvements in Refrigeration
6. Health and Safety
7. Financial Analysis and Incentives
8. Putting It All Together

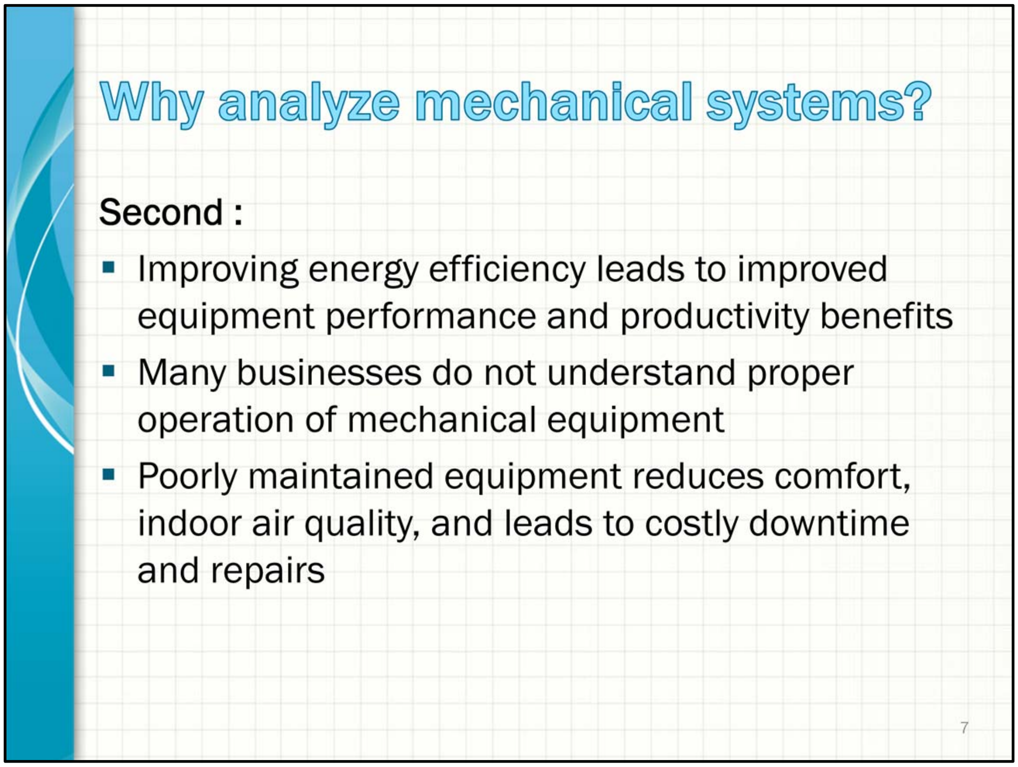

Introduction
Why analyze mechanical systems?
What are the benefits of energy efficiency?
What will this course cover?
What is retro-commissioning?
4

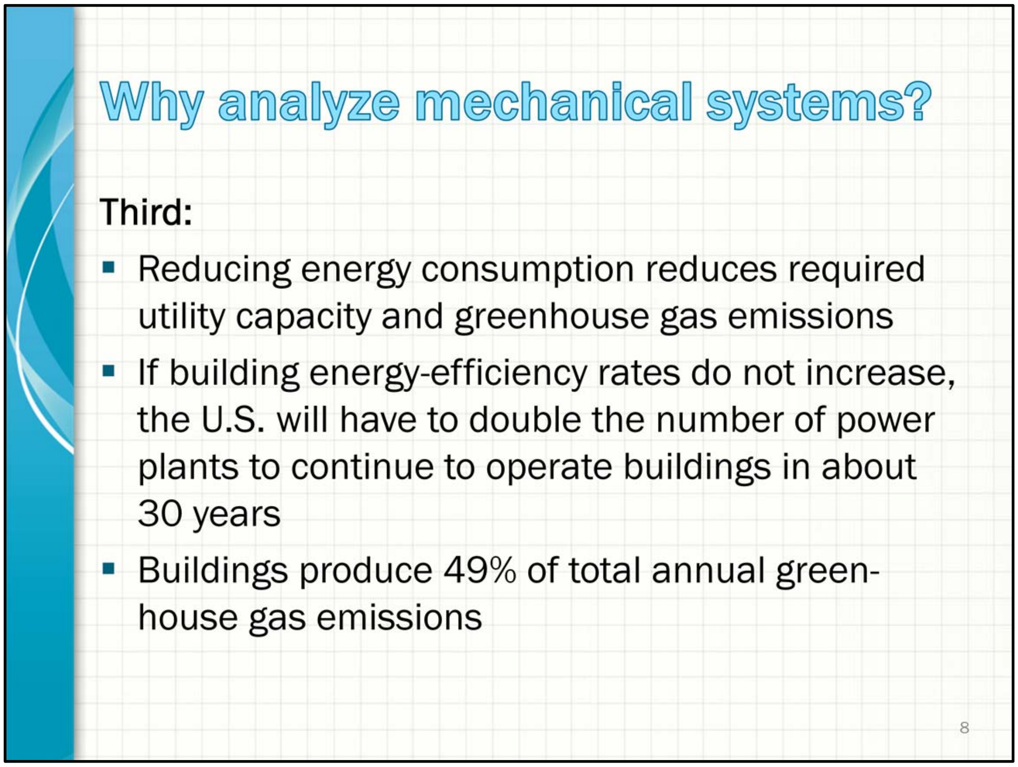

Why analyze mechanical systems?
5



Energy Savings Potential and RD&D Opportunities for Commercial Building HVAC Systems, U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program, Sept. 2011

http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/savings_potential_comm_hvac.pdf


Why analyze mechanical systems?
Second :
Improving energy efficiency leads to improved equipment performance and productivity benefits
Many businesses do not understand proper operation of mechanical equipment
Poorly maintained equipment reduces comfort, indoor air quality, and leads to costly downtime and repairs
7



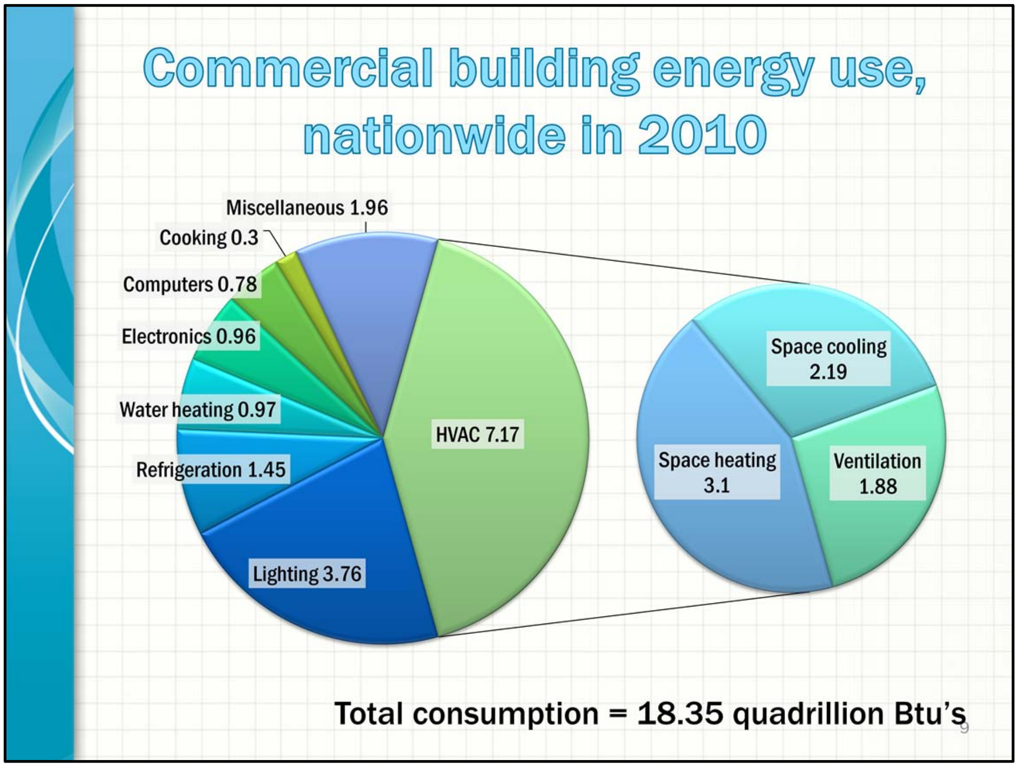
"Increasing efficiency still is an underutilized and untapped energy resource in the world. [page 2] … An estimated 85% of buildings that will exist in urban areas in 2030 have already been built. During an ASHRAE Net Zero Energy Building conference, the audience was told that if every new building from this day forward was designed as net-zero, only 15% of the marketplace would be impacted by the year 2030.

Renovation of today's building stock offers the opportunity of significantly impacting overall energy demand, reducing building carbon footprints and building a sustainable future. The green building movement is growing with more requirements mandated by federal, state and local governments.

While we can build efficient buildings, that means nothing if we cannot keep them operating efficiently. Building performances typically deteriorate as much as 30% in the first three to four years of operation. Commissioning is a quality focused process that if implemented early in the design, can save time, money and improve the quality of a healthy and productive building.

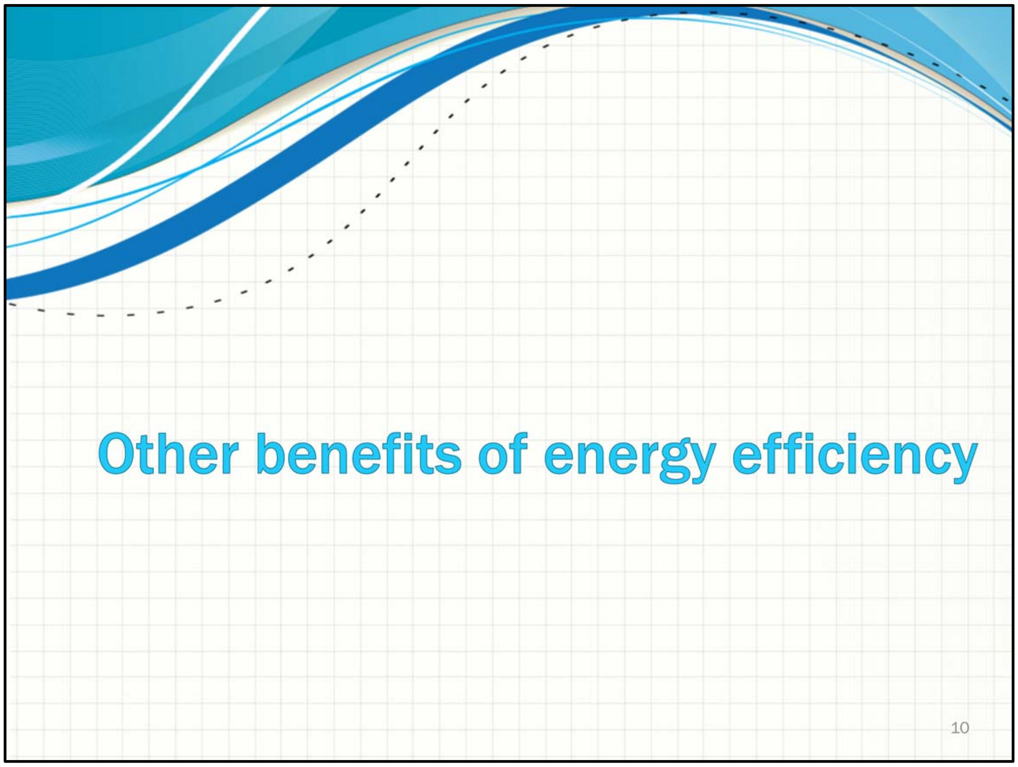
Studies show that retro-commissioning of existing buildings can save 10% to 40% simply by improving operational strategies. The 20- to 50-cents-persquare-foot cost can returned in less than one year through energy savings of at least 15%, according to the Building Commissioning Association." [page 7]

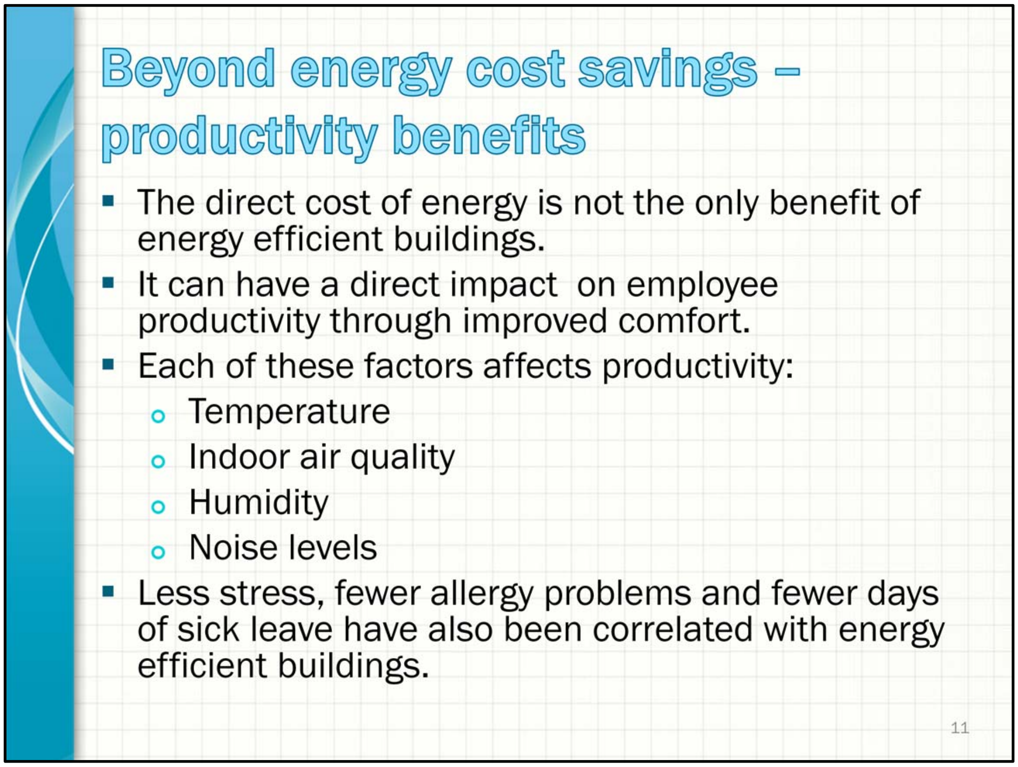
www.ashrae.org/File%20Library/docLib/Media%20Kit/2012MediaKit/ASHRAEJournal_2012_HVAC-R-Market.pdf



Energy Savings Potential and RD&D Opportunities for Commercial Building HVAC Systems, US Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program, Sept. 2011

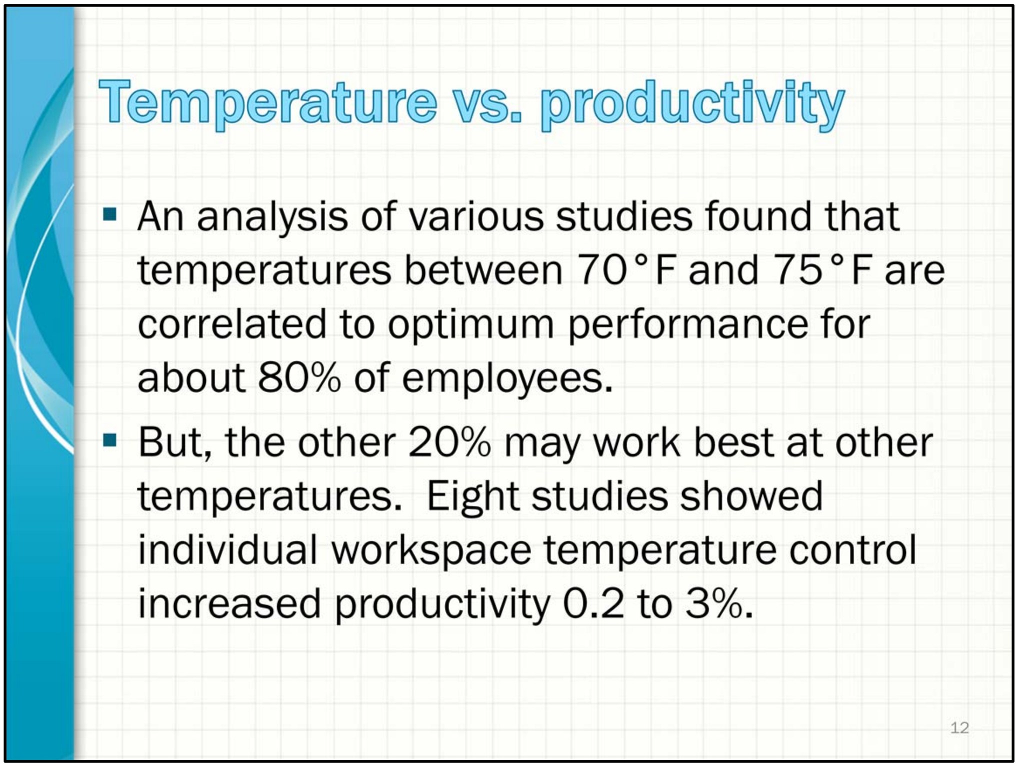
http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/savings_potential_comm_hvac.pdf


Other benefits of energy efficiency
10



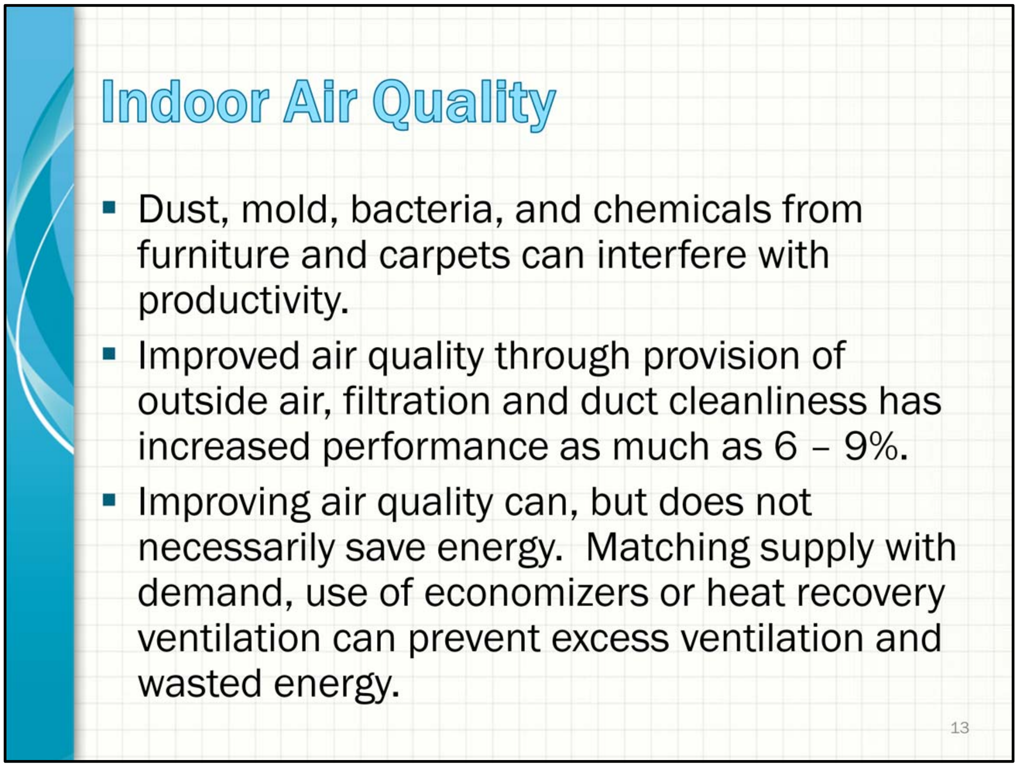
While it is difficult to quantify productivity in many workplaces, studies have been performed based on questionnaires, interviews, and direct observations, as well as on objective data such as absenteeism and incidence of complaints. These studies consistently show that productivity increases when energy efficiency is improved.

http://www.institutebe.com/Existing-Building-Retrofits/Productivity-Gains-from-Energy-Efficiency.aspx



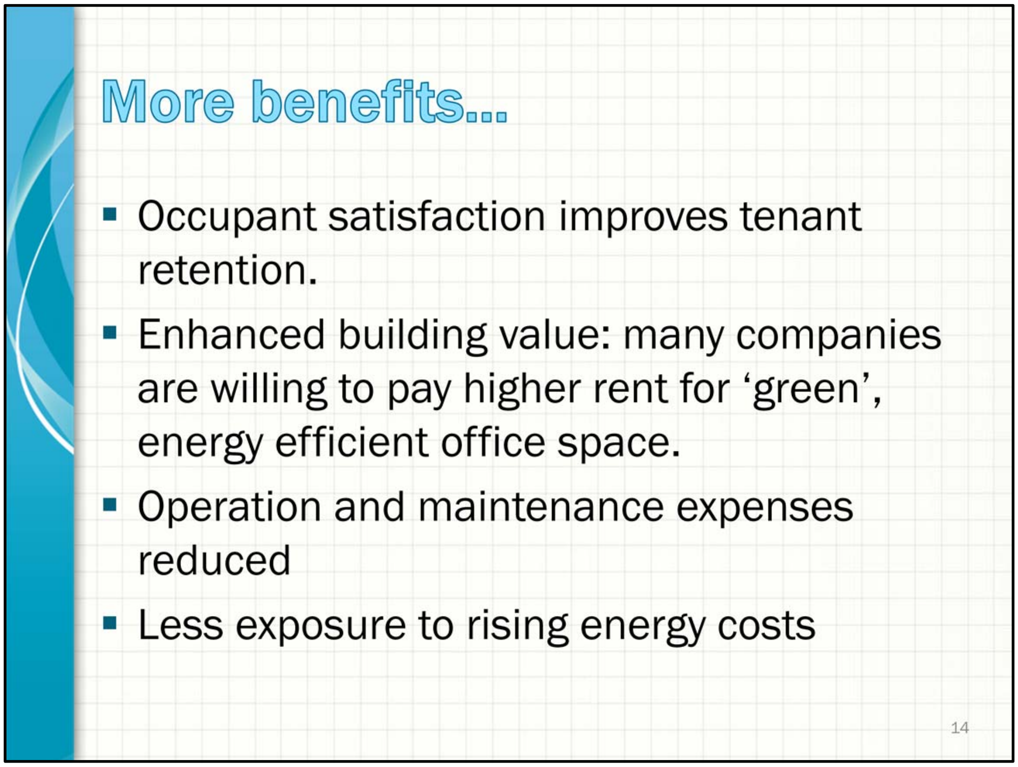
Institute for Building Efficiency, Benefits Beyond Energy

http://www.institutebe.com/Existing-Building-Retrofits/Productivity-Gains-from-Energy-Efficiency.aspx



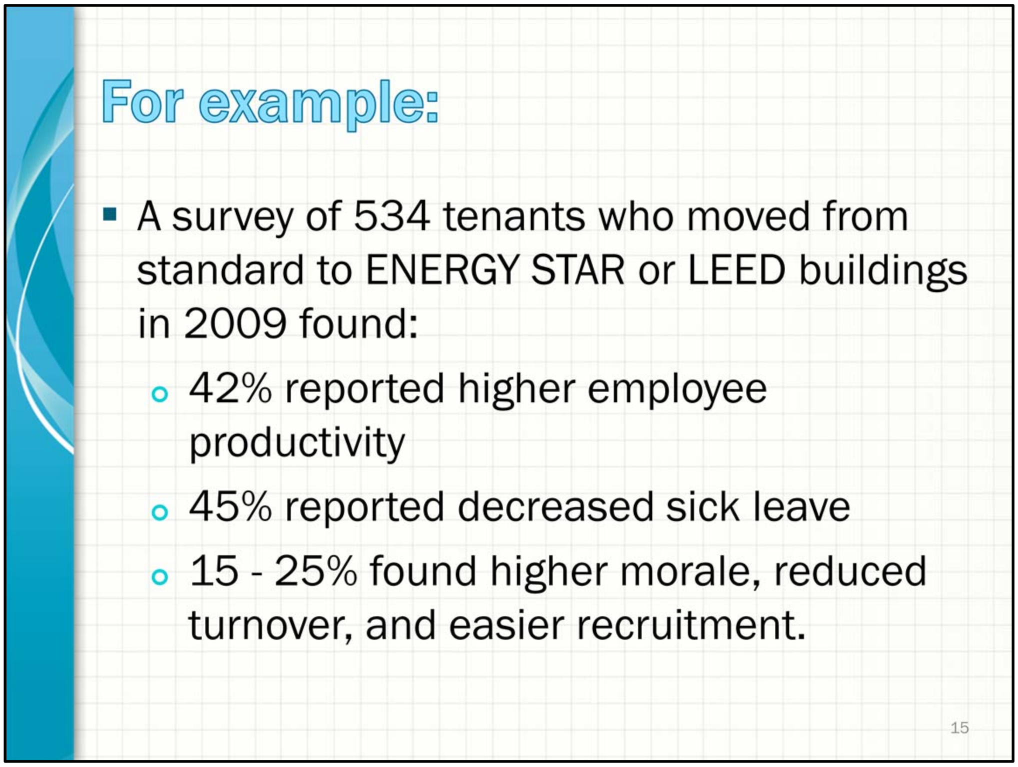
Institute for Building Efficiency, Benefits Beyond Energy

http://www.institutebe.com/Existing-Building-Retrofits/Productivity-Gains-from-Energy-Efficiency.aspx



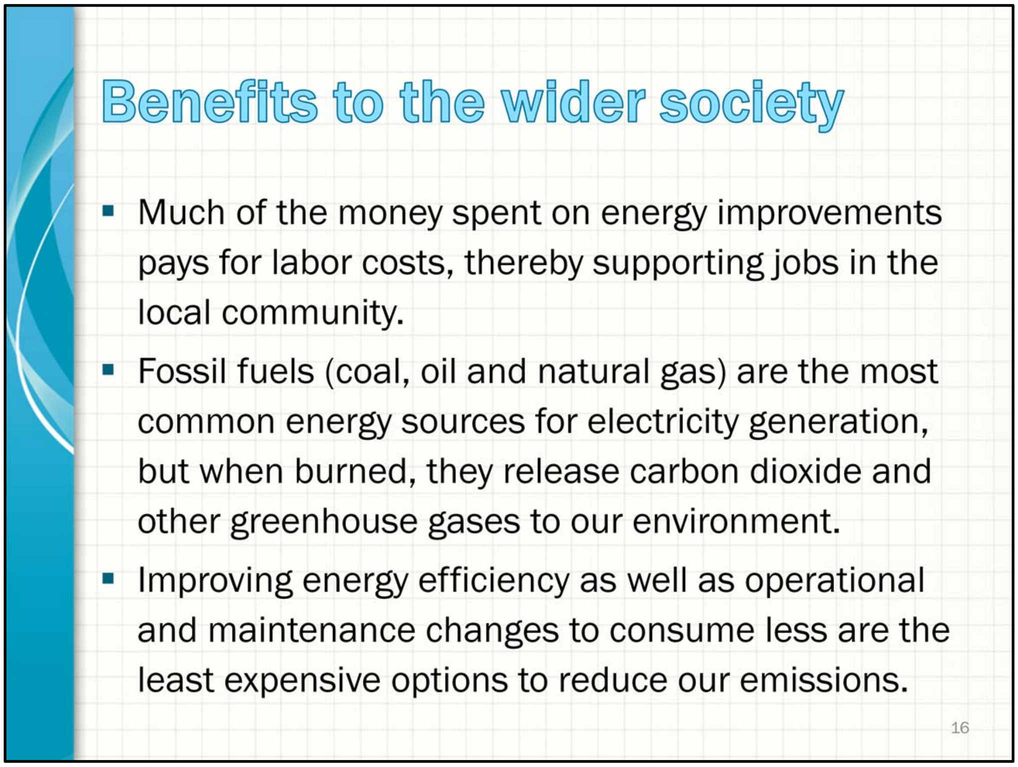
Institute for Building Efficiency, Benefits Beyond Energy

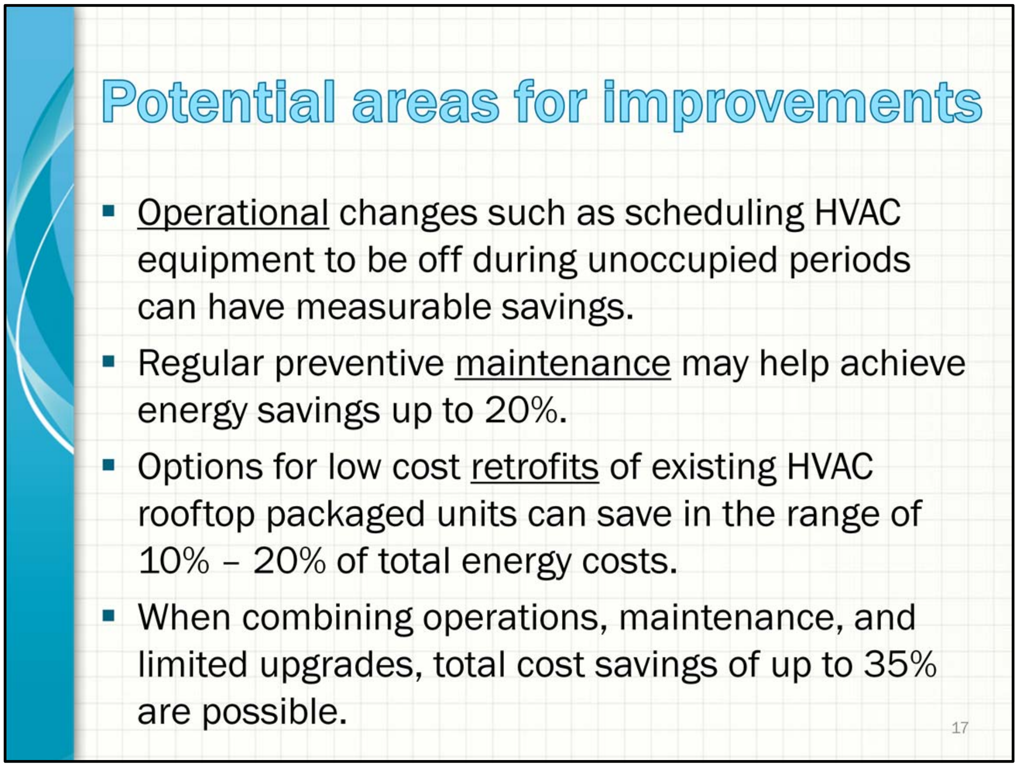
http://www.institutebe.com/Existing-Building-Retrofits/Productivity-Gains-from-Energy-Efficiency.aspx



Study by CBRE (a commercial real estate services firm) and the University of San Diego in May 2009 Institute for Building Efficiency, Benefits Beyond Energy

http://www.institutebe.com/Existing-Building-Retrofits/Productivity-Gains-from-Energy-Efficiency.aspx

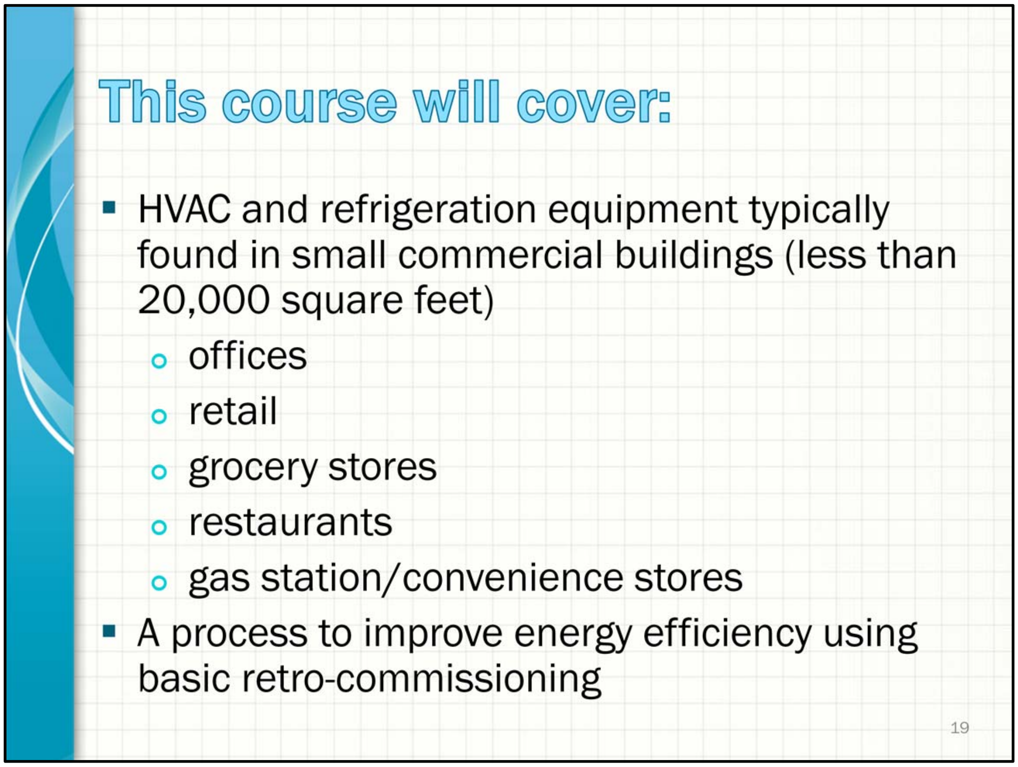

Benefits to the wider society
Much of the money spent on energy improvements pays for labor costs, thereby supporting jobs in the local community.
Fossil fuels (coal, oil and natural gas) are the most common energy sources for electricity generation, but when burned, they release carbon dioxide and other greenhouse gases to our environment.
Improving energy efficiency as well as operational and maintenance changes to consume less are the least expensive options to reduce our emissions.
16



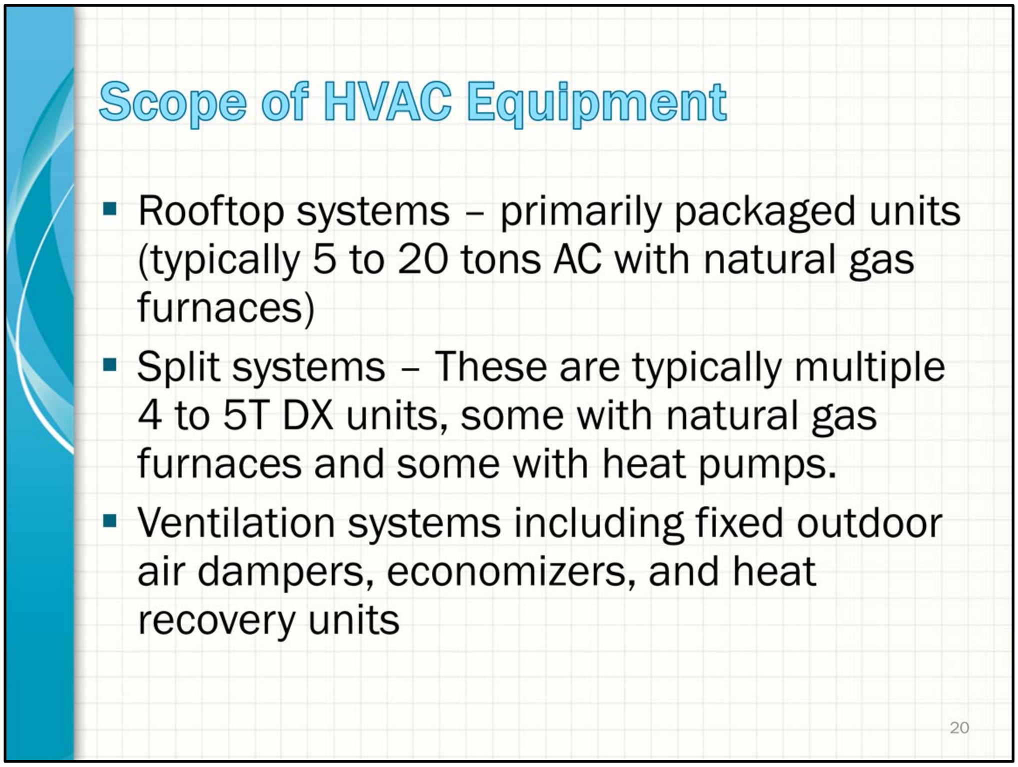
Specifics of various energy savings measures will be discussed in the following modules.

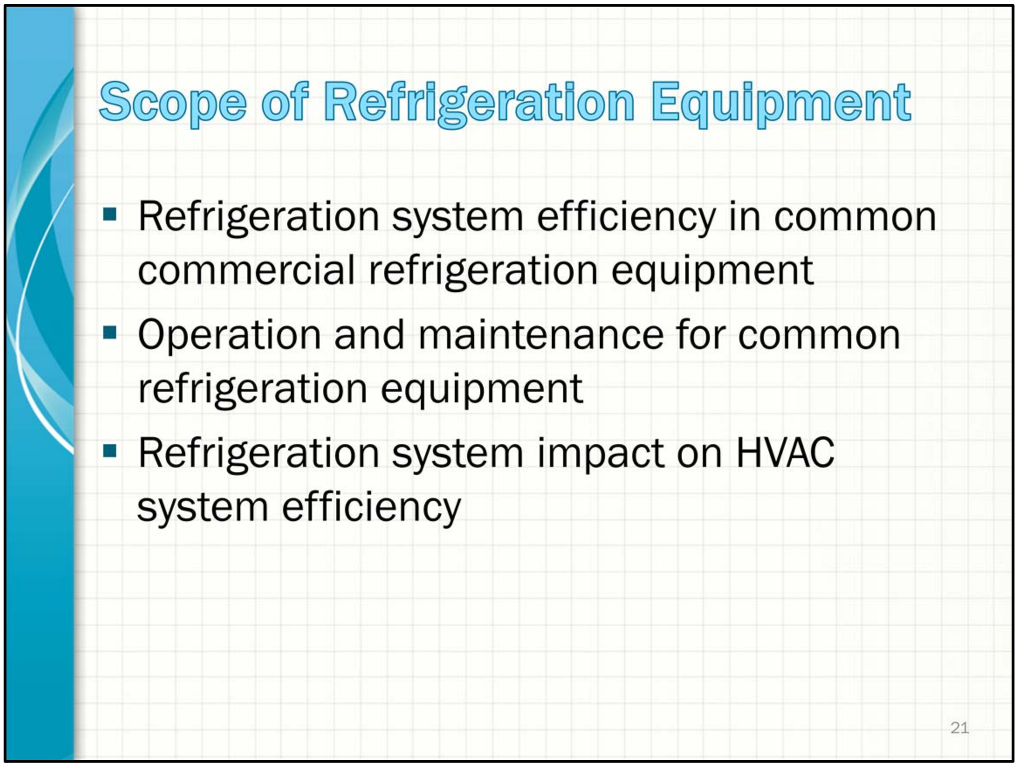
Data for roof-top units (RTUs) from a study by Pacific Northwest National Laboratory for the U.S. Department of Energy, *Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat*, Dec 2011.

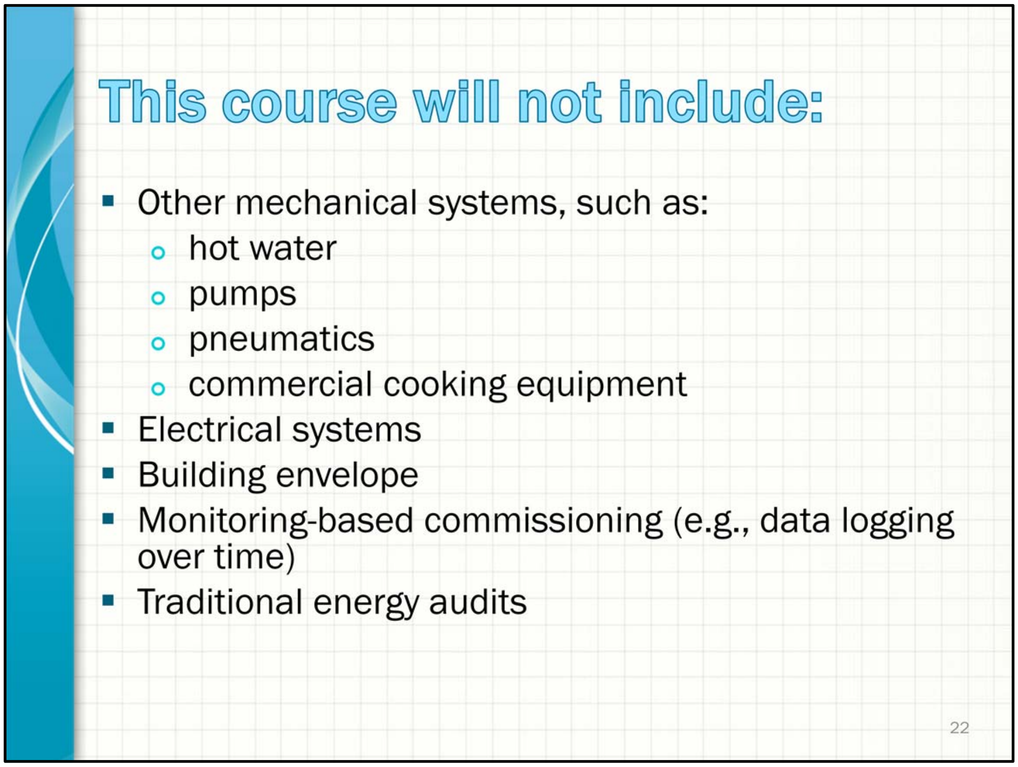

What will this course cover?
18

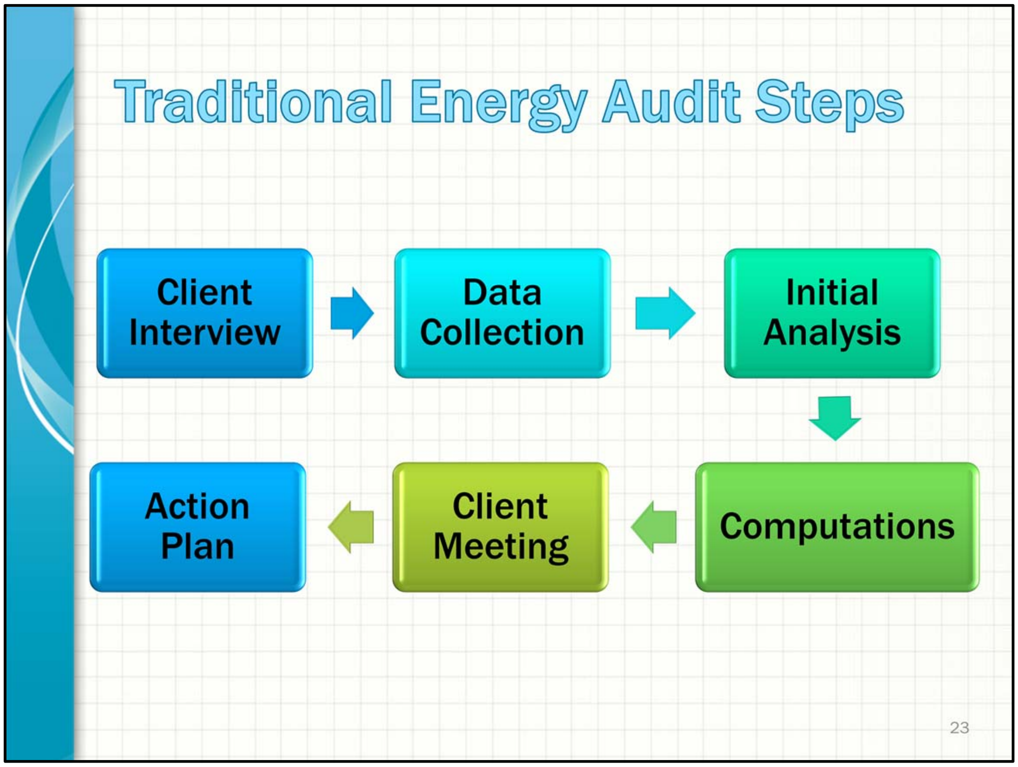


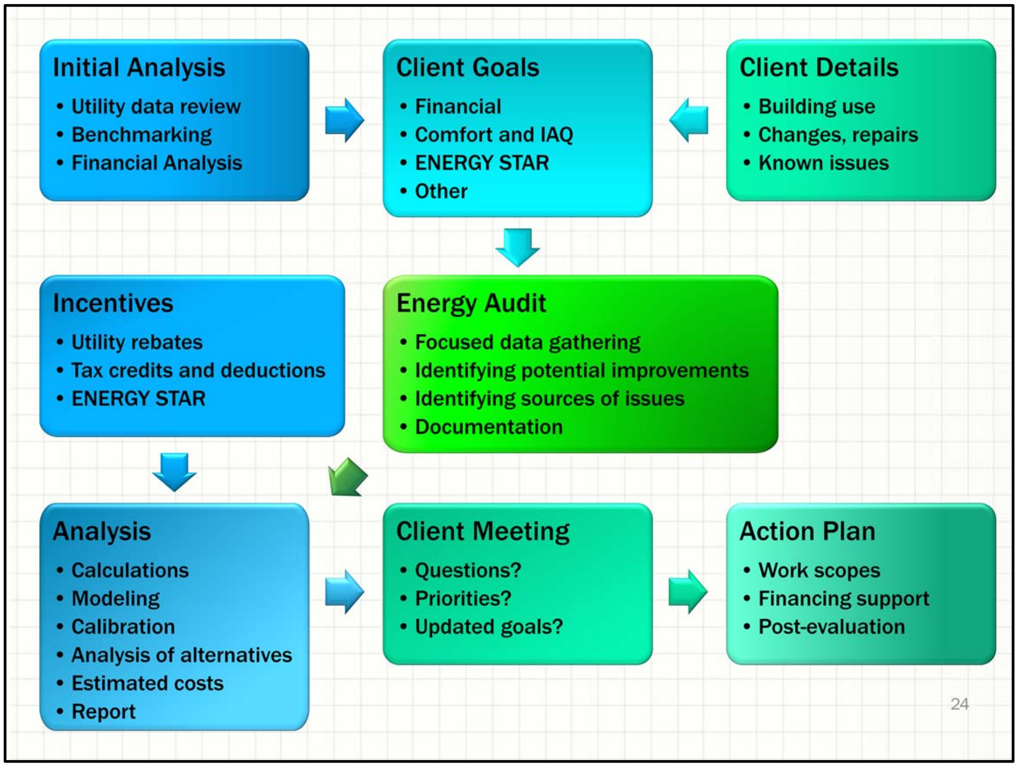
Heating, ventilation, air conditioning, and refrigeration account for a majority of the energy consumption by mechanical systems in commercial buildings under 20,000 sq ft. Retro-commissioning is based on operational improvements, regular maintenance, and cost-effective equipment upgrades to improve energy efficiency and equipment performance before more intensive capital projects are deployed.


Scope of HVAC Equipment
Rooftop systems – primarily packaged units (typically 5 to 20 tons AC with natural gas furnaces)
Split systems – These are typically multiple 4 to 5T DX units, some with natural gas furnaces and some with heat pumps.
Ventilation systems including fixed outdoor air dampers, economizers, and heat recovery units
20

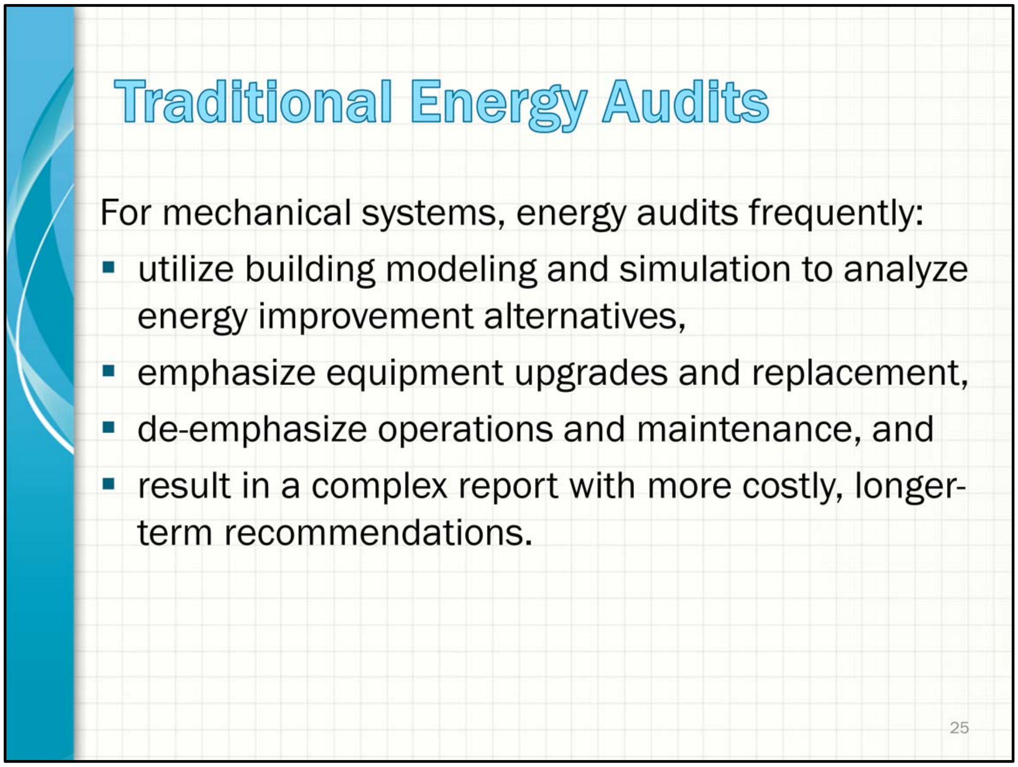

Scope of Refrigeration Equipment
Refrigeration system efficiency in common commercial refrigeration equipment
Operation and maintenance for common refrigeration equipment
Refrigeration system impact on HVAC system efficiency
21


This course will not include:
Other mechanical systems, such as:
hot water
pumps
pneumatics
commercial cooking equipment
Electrical systems
Building envelope
Monitoring-based commissioning (e.g., data logging over time)
Traditional energy audits
22

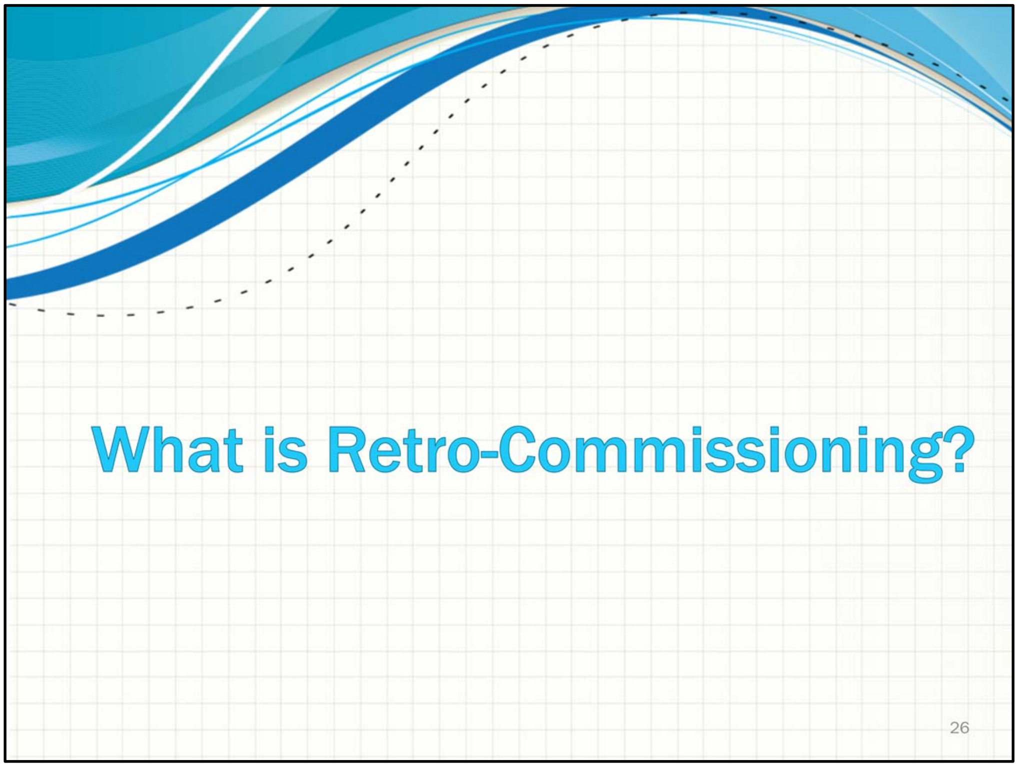

Traditional Energy Audit Steps
Client Interview
Data Collection
Initial Analysis
Computations
Client Meeting
Action Plan
23

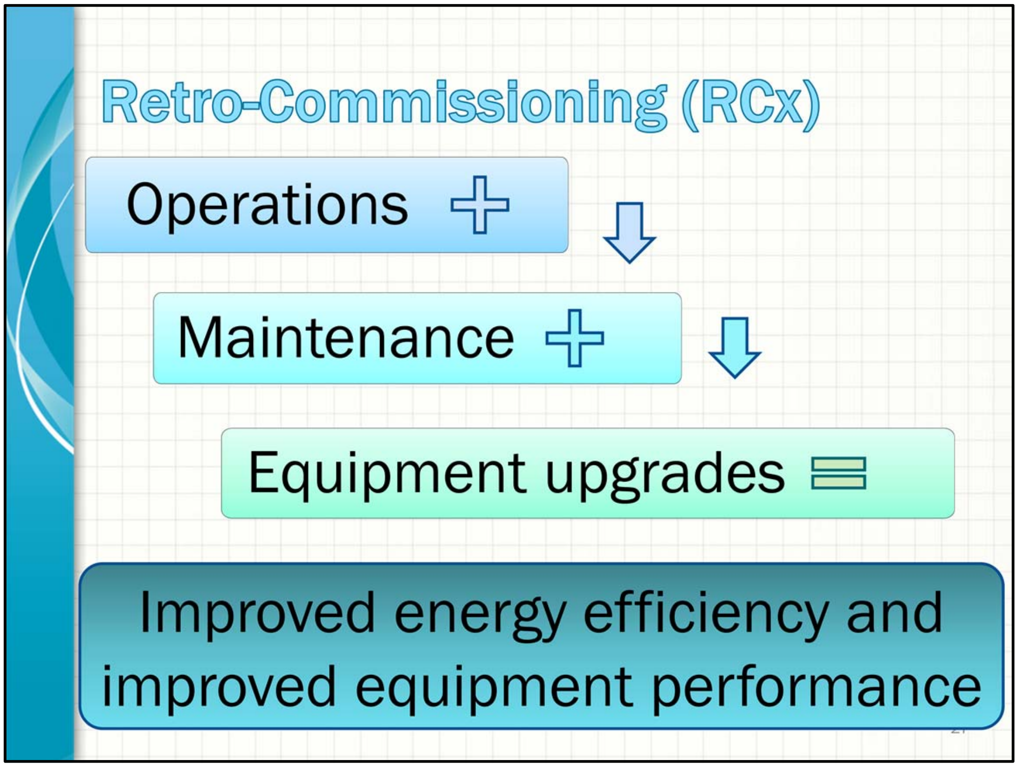


Traditional commercial energy audits involve many detailed steps. The ASHRAE *HVAC Applications Handbook*, Section 35, identifies and distinguishes the tasks of three different levels of energy audits: Level I, Walk-Through Assessment; Level II, Energy Survey and Analysis; and Level III, Detailed Analysis of Capital Intensive Modifications. These levels are helpful in identifying the tasks involved in building analysis; however, the approaches recommended are tailored more to larger facilities and not light commercial applications.



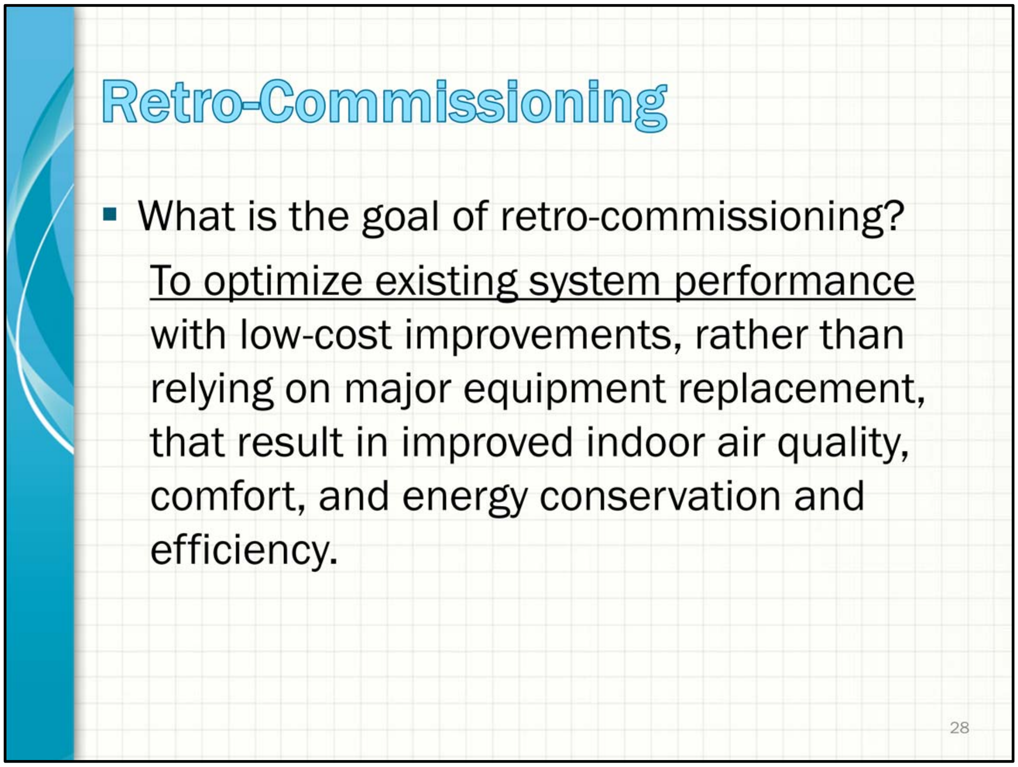
Traditional energy audits may not be the best approach for many light commercial applications. The cost of the audit, the focus on capital equipment replacement that is not affordable by many businesses; the need for modeling to confirm energy savings; and the history of audit reports not being acted upon, all combine to limit the effectiveness of audits for many commercial buildings.


What is Retro-Commissioning?
26

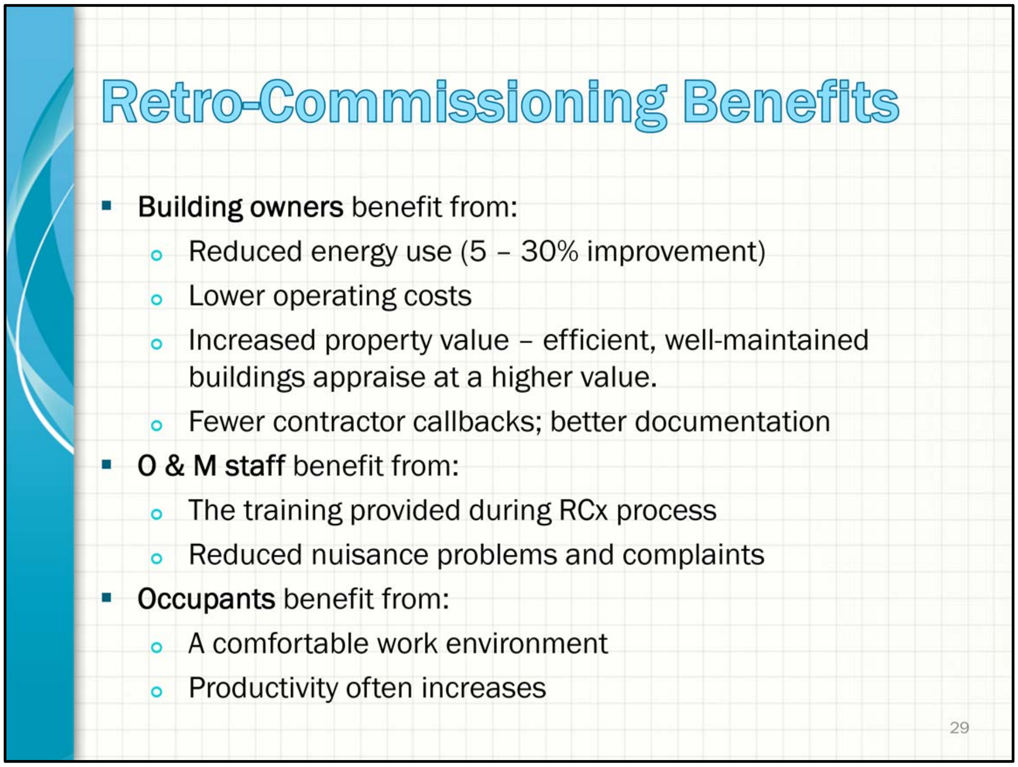


RCx is a more focused process than traditional energy audits. The emphasis is on low cost improvements beginning with operations and maintenance. RCx includes an assessment of the building incorporating a study of past utility bills and interviews with facility personnel. Diagnostic monitoring and functional tests of building systems may be required.

Component upgrades can also be a part of the solution (such as with HVAC equipment: thermostat upgrade, zone control, variable speed fan motors and control (VFD), demand-controlled ventilation (DCV), economizer). RCx should be applied periodically, every three to seven years based on a building's use, changes, and equipment.

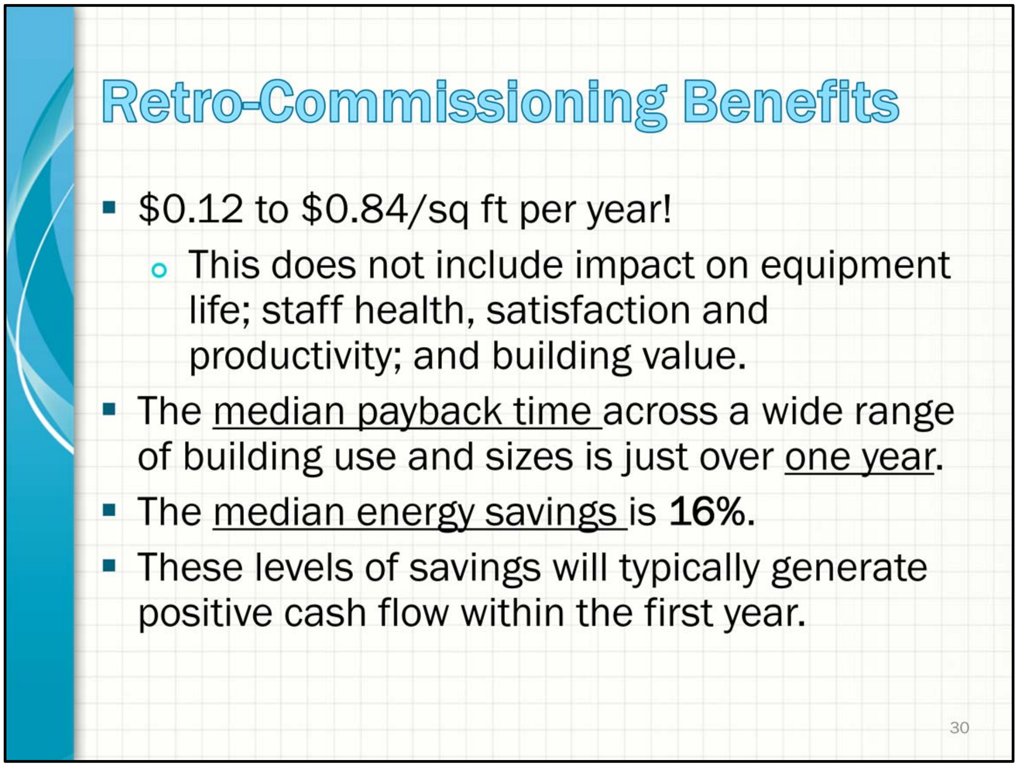


Because of its applicability to a wide range of light commercial applications, retro-commissioning will be the focus of this course.



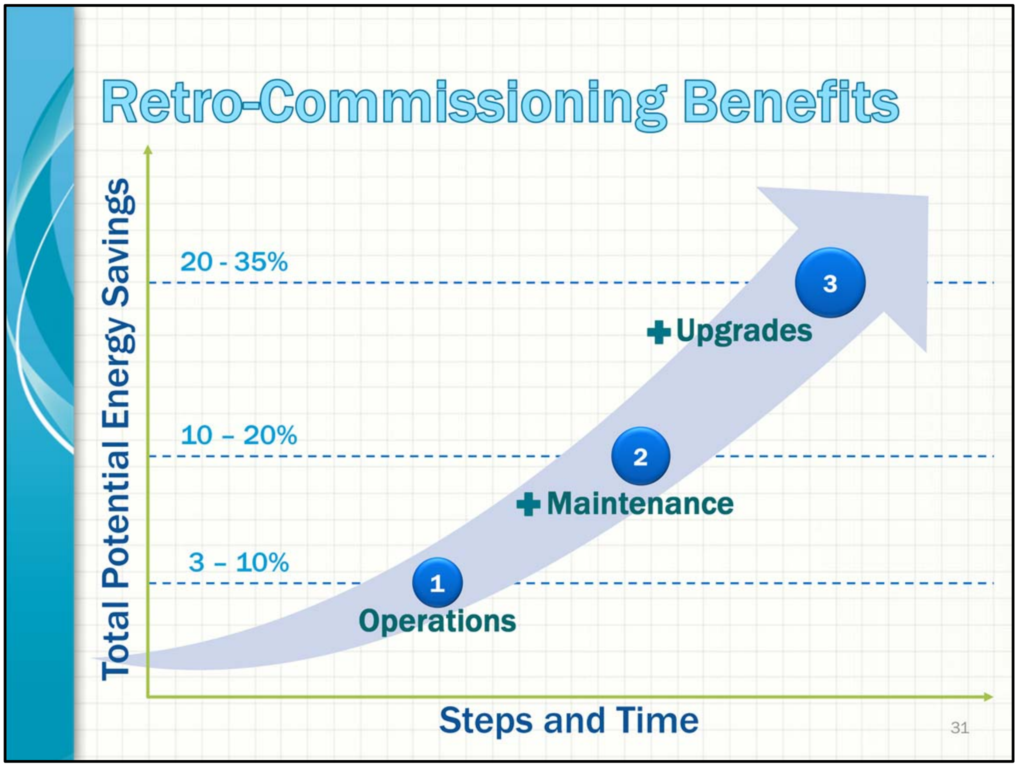
Cost savings from reduced energy use - electricity costs increased by an average of 43% nationwide between 1999 and 2008 and are expected to continue to rise.

http://www.cacx.org/PIER/documents/bpt-handbook.pdf



Sources:

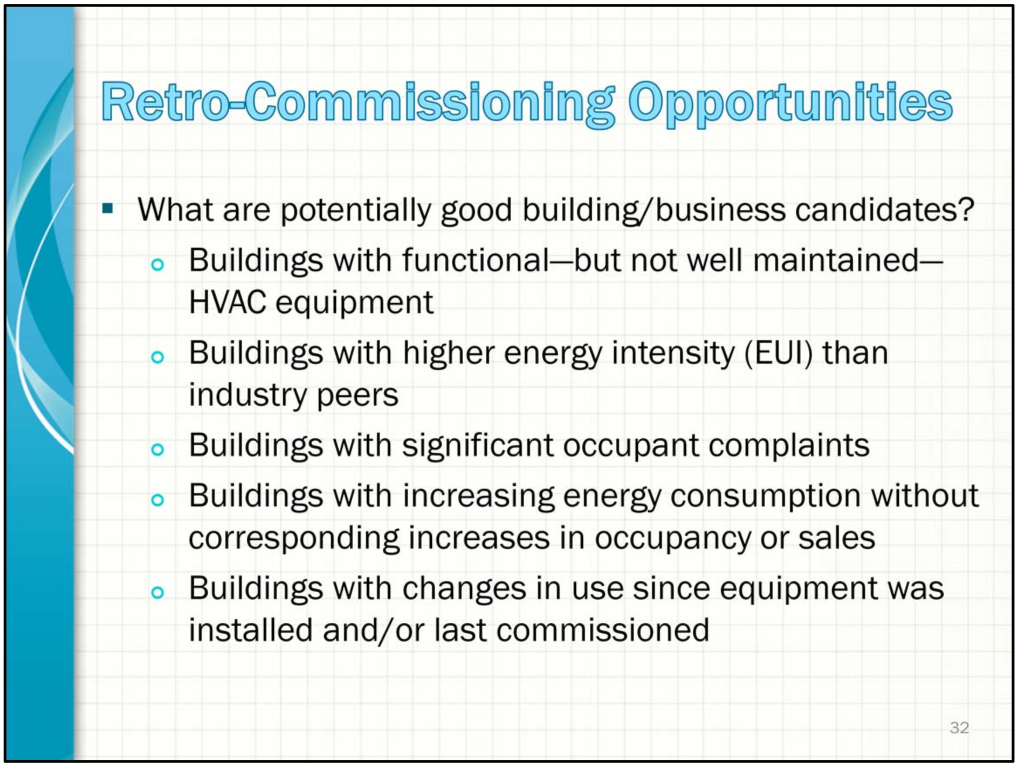
- Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M.A. Piette. 2004, "The Cost-Effectiveness of Commercial-Buildings Commissioning," Lawrence Berkeley National Laboratory. $0.11 to $0.72/sq ft in 2004
- *Energy Efficiency Guide for Existing Commercial Buildings*, F.S. Goldner, NYC ASHRAE May 25, 2010
- Lawrence Berkeley National Laboratory – http://cx.lbl.gov/documents/2009-assessment/LBNL-Cx-Cost-Benefit.pdf



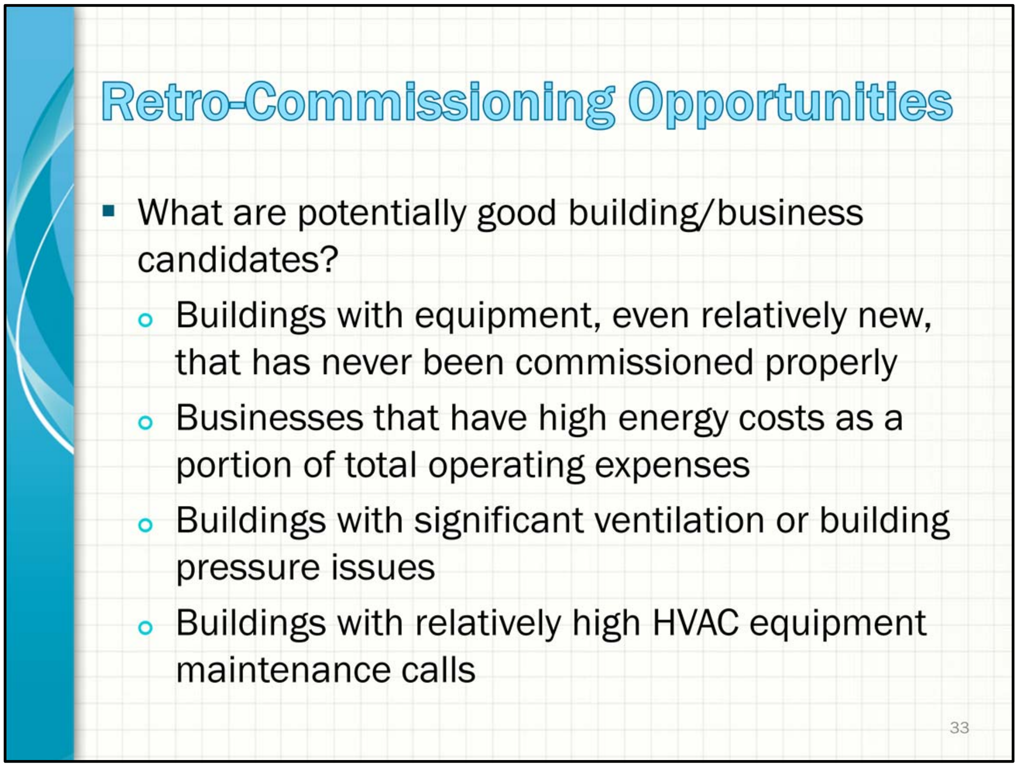
Many studies over the years have shown the impact that operational improvements, maintenance, and relatively lower cost upgrades can have on both energy consumption and system performance.

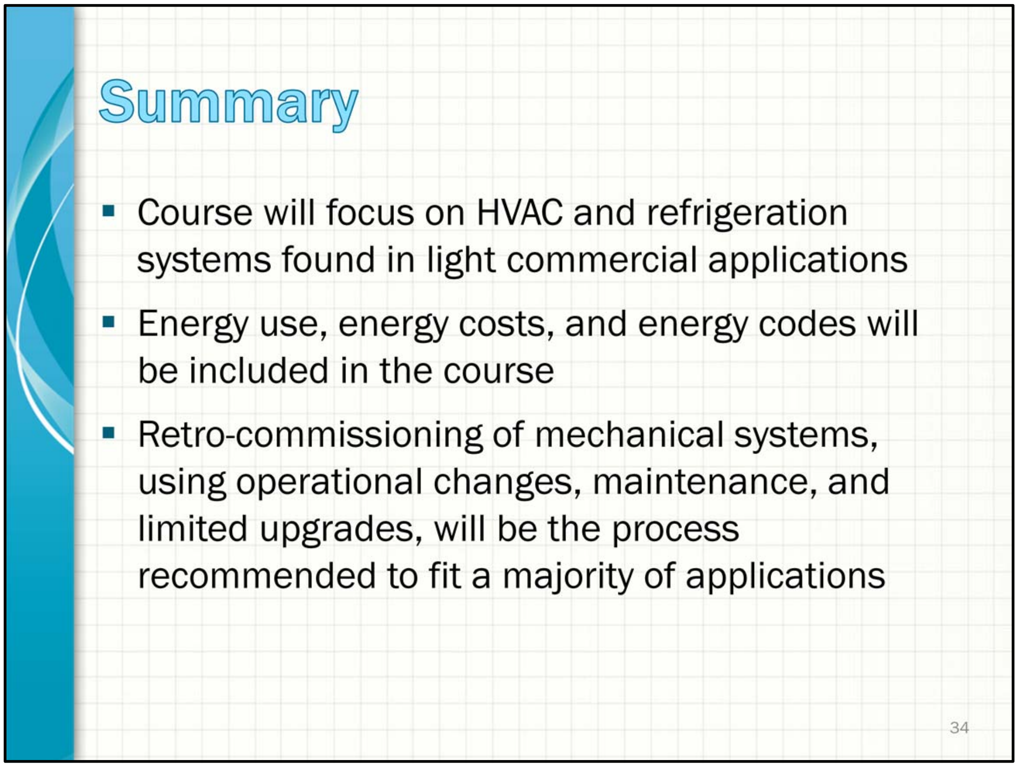
References:

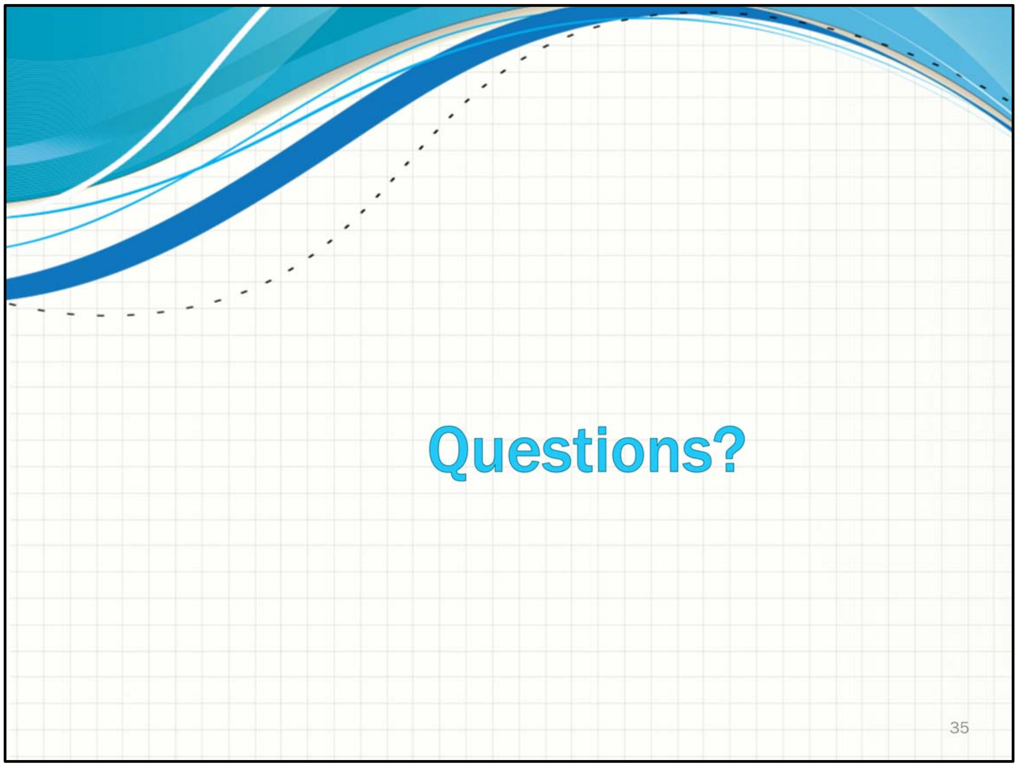
- *Retro-Commissioning*. M.E. Group Presentation. Maniktala, N, and K. Reed. 2010.
- *Improving Building Performance*. The Carbon War Room – Green Capital Operation. June, 2012.
- *Energy Saving Strategies and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat.* PNNL Report 20955. Wang, W., Y. Huang, S. Katipamula, & M. Brambley. Dec 2011.
- *Small Commercial HVAC – Surveying the frontier of energy efficiency.* Energy Center of Wisconsin Presentation. 2010. L. DeBaillie, PE.



Buildings that are not good candidates may include those with older equipment that should be replaced, buildings that have been commissioned in past 3 – 5 years, and buildings with low EUI relative to peers.


Retro-Commissioning Opportunities
What are potentially good building/business candidates?
Buildings with equipment, even relatively new, that has never been commissioned properly
Businesses that have high energy costs as a portion of total operating expenses
Buildings with significant ventilation or building pressure issues
Buildings with relatively high HVAC equipment maintenance calls
33


Summary
Course will focus on HVAC and refrigeration systems found in light commercial applications
Energy use, energy costs, and energy codes will be included in the course
Retro-commissioning of mechanical systems, using operational changes, maintenance, and limited upgrades, will be the process recommended to fit a majority of applications
34


Questions?
35

Assessment

Questions

1. Name two potential incentives for completing a commercial energy audit.

    a. ______________________________

    b. ______________________________

2. By conducting an initial analysis (data review, benchmarking, and financial analysis) and determining client details (building type, use, changes, etc.) what can be identified?

    ____

    ____

True or false

3. This course includes information on the complete commercial energy audit process including benchmarking.

Answers

1. Name two potential incentives for completing a commercial energy audit.

   Any two of the following:

   - **Utility rebates**
   - **Tax credits and deductions**
   - **Participation in green building certification programs such as ENERGY STAR, LEED, etc.**

2. By conducting an initial analysis (data review, benchmarking, and financial analysis) and determining client details (building type, use, changes, etc.) what can be identified?

   Potential improvements

True or false

3. This course includes information on the complete commercial energy audit process including benchmarking.

   False

2: Fundamentals of Commercial Energy Use

Learning Objectives

By attending this session, participants will:

- ✓ Be able to rank energy consumption by use for various types of commercial buildings
- ✓ Understand the various energy consumption and energy cost components of a commercial utility bill
- ✓ Be able to utilize utility bill data to prioritize mechanical system opportunities for energy conservation and efficiency
- ✓ Understand benchmarking and how it is used to identify the potential impact of energy conservation and efficiency measures

Key Terminology

Baseload

Benchmarking

Energy Utilization Intensity (EUI)

Portfolio Manager

References & Supplemental Materials

Commercial Buildings Energy Consumption Survey, U.S. Department of Energy
http://buildingsdatabook.eren.doe.gov/CBECS.aspx

Commercial Energy Benchmarks http://members.questline.com

ENERGY STAR Building Upgrade Manual, Chapter 2 – Benchmarking, EPA Office of Air & Radiation, 2008
www.energystar.gov/index.cfm?c=business.bus_upgrade_manual

ENERGY STAR Portfolio Manager Overview
www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

Classroom Props and Preparations

- Be familiar with the Excel-based tool provided for utility bill analysis (UBA)
- Be familiar with the CBECS web site: http://www.eia.gov/consumption/commercial/
- Be familiar with Portfolio Manager: www.energystar.gov/istar/pmpam/
- Make the case study utility bill datasets accessible
- Pre-load the UBA spreadsheet tool with some of the case study data

Possible Activities

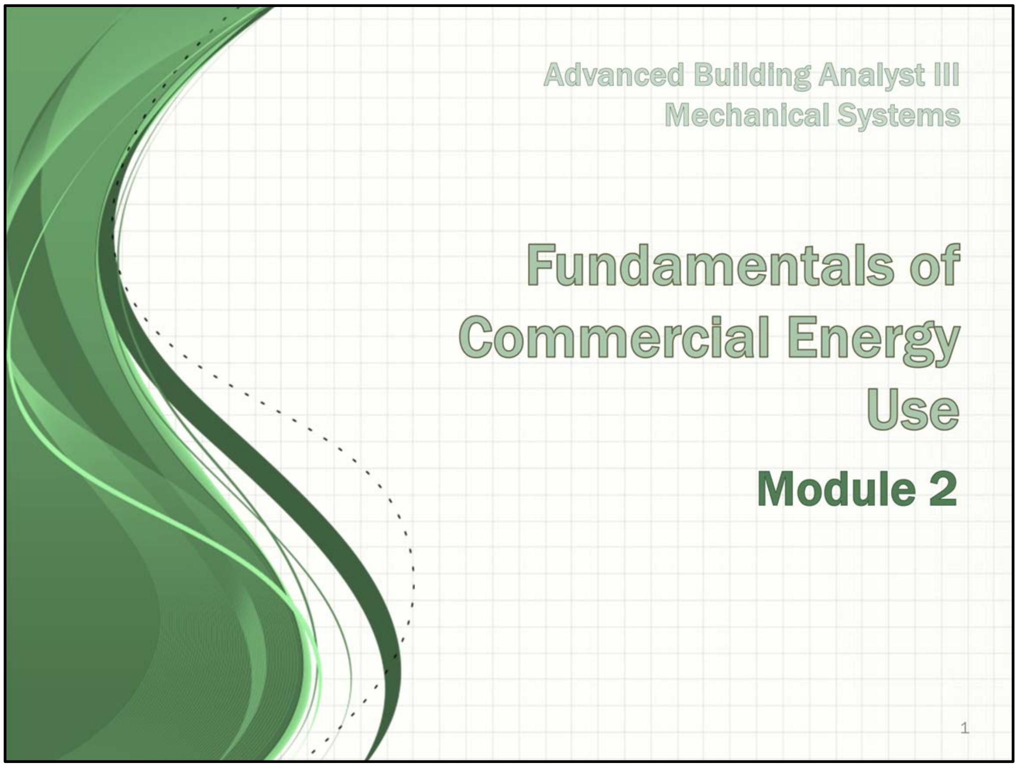
1. **Utility Bill Analysis:** With one of the two case study utility bill datasets –
   a) Enter the missing data into the UBA Excel tool
   b) On the Electricity and Gas Consumption charts –
      - How much of the energy use is baseload and how much is seasonal? What might this say about the opportunities for improving mechanical system energy efficiency?
      - Does the building have electricity demand charges? If so, do they vary significantly over the year? Do they spike during certain times of the year? How do demand charges compare to consumption charges? What might this say about mechanical system performance?
      - Do electrical costs dominate or are gas costs significant as well? What does this indicate about priorities for improvement?
      - Are there other observations that might impact the potentially reducing energy consumption?

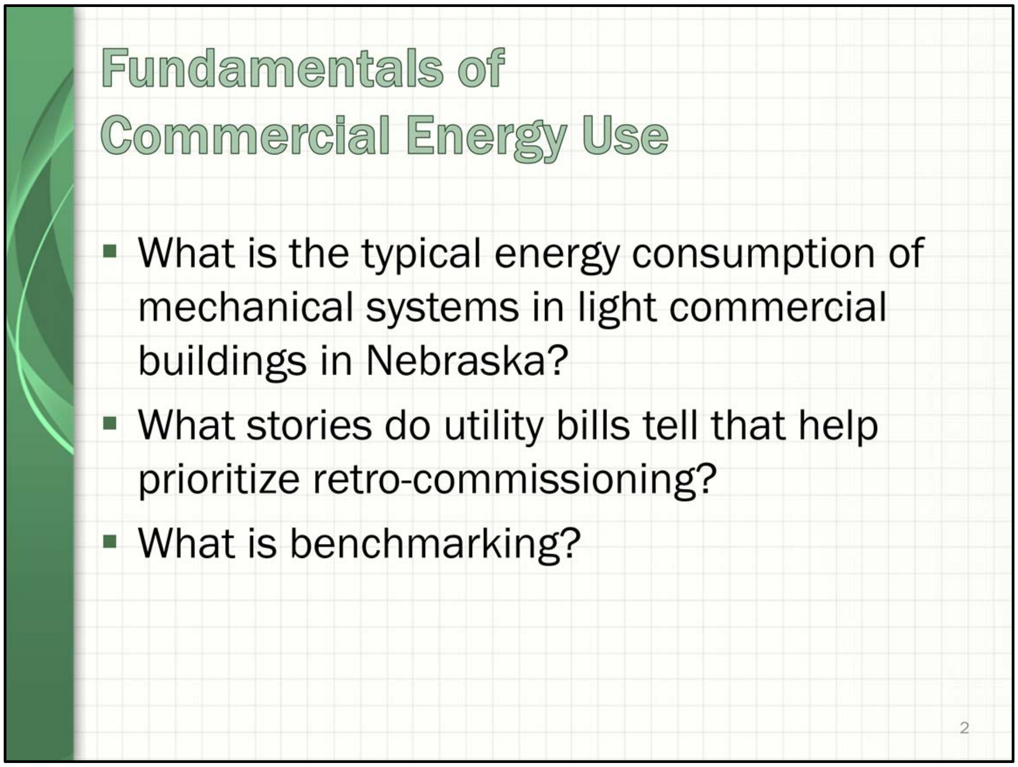
2. **Benchmarking:** Using the case study dataset from Activity 1 –

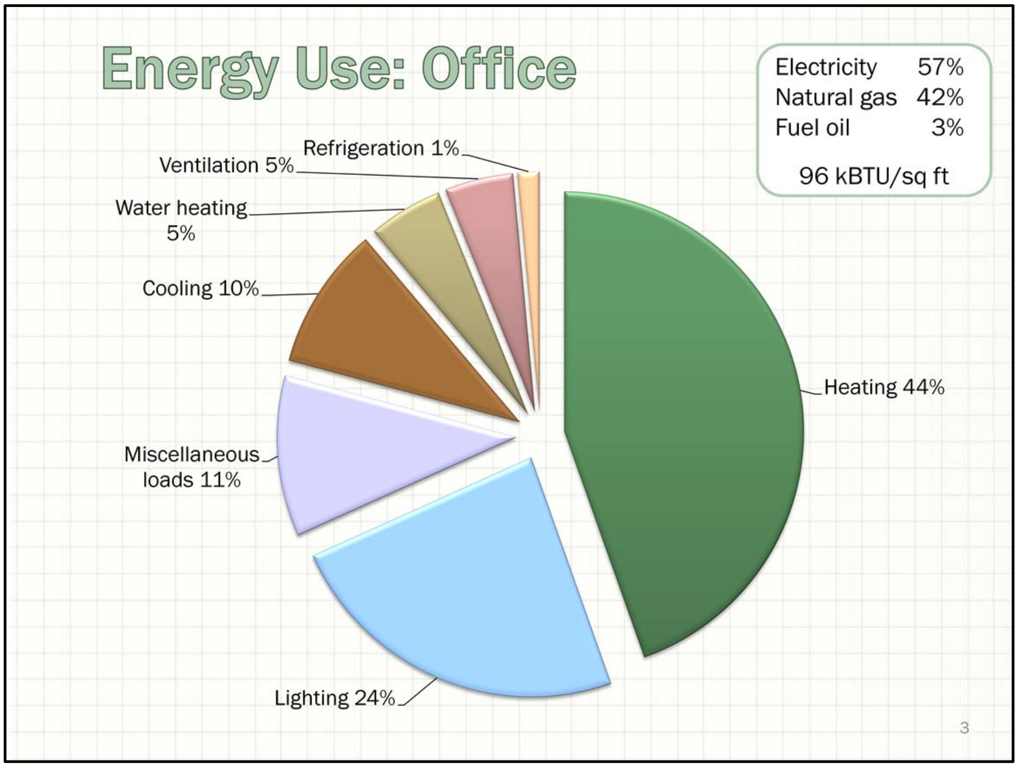
   a. Compare the EUI of the case study with the appropriate chart in this module for average businesses (office, retail, … etc). Is the EUI higher or lower than the average? Given that the average for each classification may use 25% or more energy than an efficient operation, what does this indicate about the potential for improvement in this building?

   b. Using a pre-loaded Portfolio Manager building dataset, run the benchmarking report to determine the statistical-based ranking relative to the median and to an ENERGY STAR level of energy consumption.

   c. Modify the Portfolio Manager example (e.g. by changing the building size or staffing level) and re-run the benchmarking report to see the impact on the ranking.

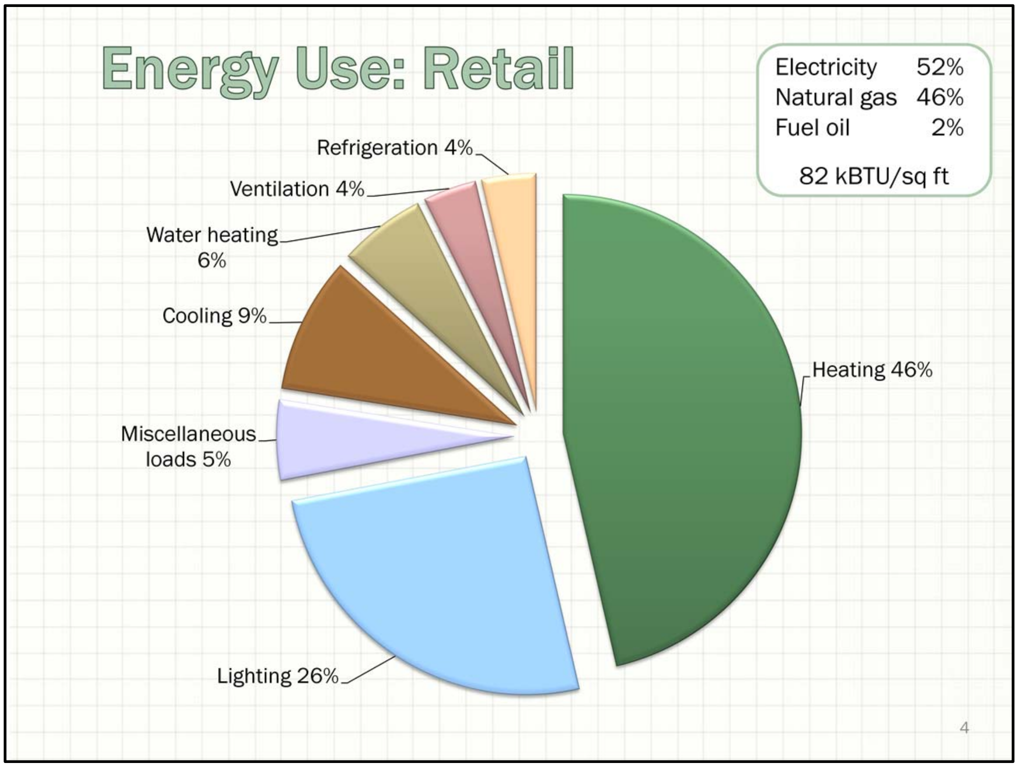

Advanced Building Analyst III
Mechanical Systems
Fundamentals of Commercial Energy Use
Module 2
1


Fundamentals of
Commercial Energy Use
What is the typical energy consumption of mechanical systems in light commercial buildings in Nebraska?
What stories do utility bills tell that help prioritize retro-commissioning?
What is benchmarking?
2



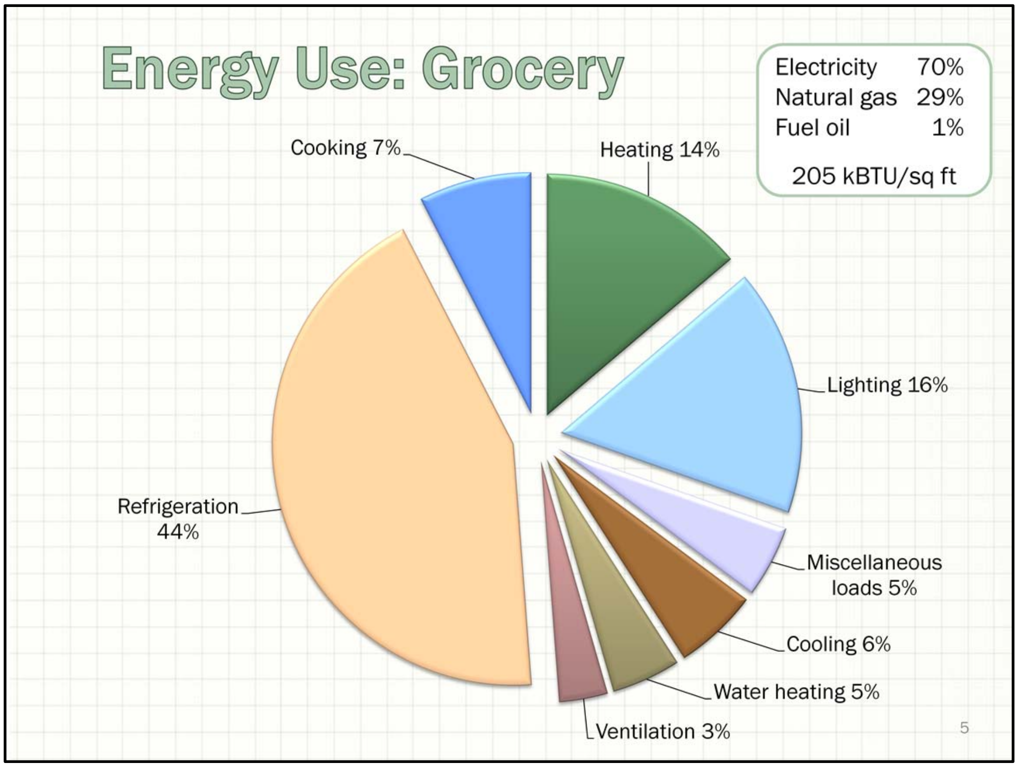
Sources for Nebraska light commercial buildings –

1. Commercial Energy Benchmarks (members.questline.com)
2. DOE CBECS Building Energy Handbook (buildingdatabook.eren.doe.gov)



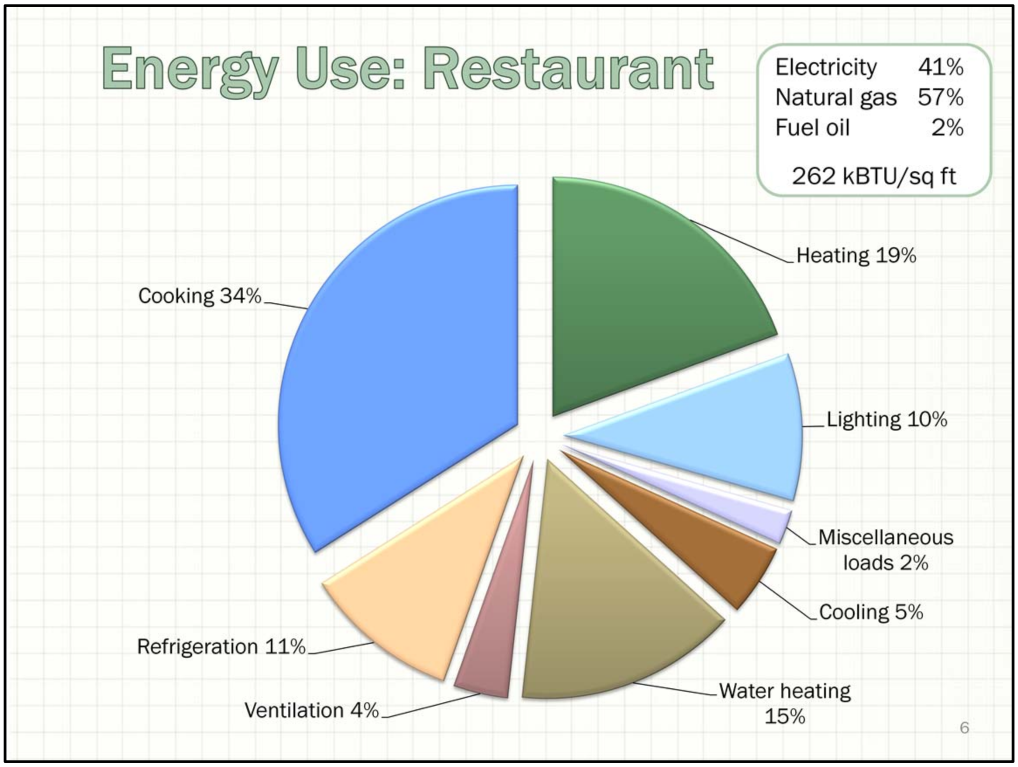
Sources for Nebraska light commercial buildings –

1. Commercial Energy Benchmarks (members.questline.com)
2. DOE CBECS Building Energy Handbook (buildingdatabook.eren.doe.gov)



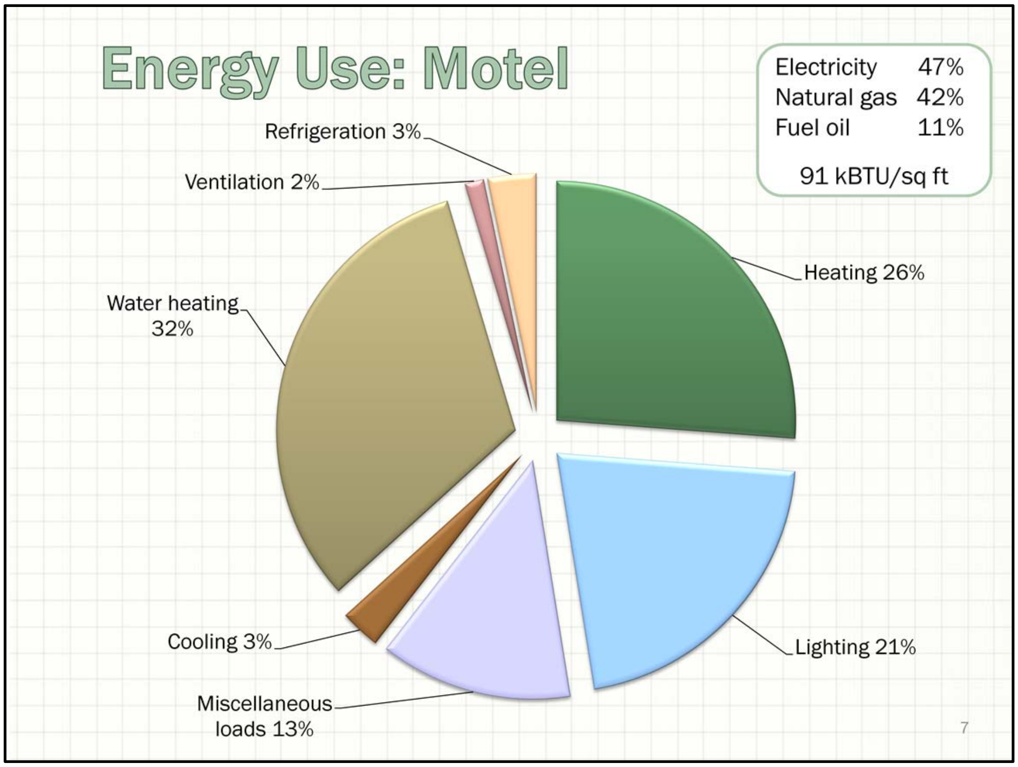
Sources for Nebraska light commercial buildings –

1. Commercial Energy Benchmarks (members.questline.com)
2. DOE CBECS Building Energy Handbook (buildingdatabook.eren.doe.gov)



Sources for Nebraska light commercial buildings –

1. Commercial Energy Benchmarks (members.questline.com)
2. DOE CBECS Building Energy Handbook (buildingdatabook.eren.doe.gov)



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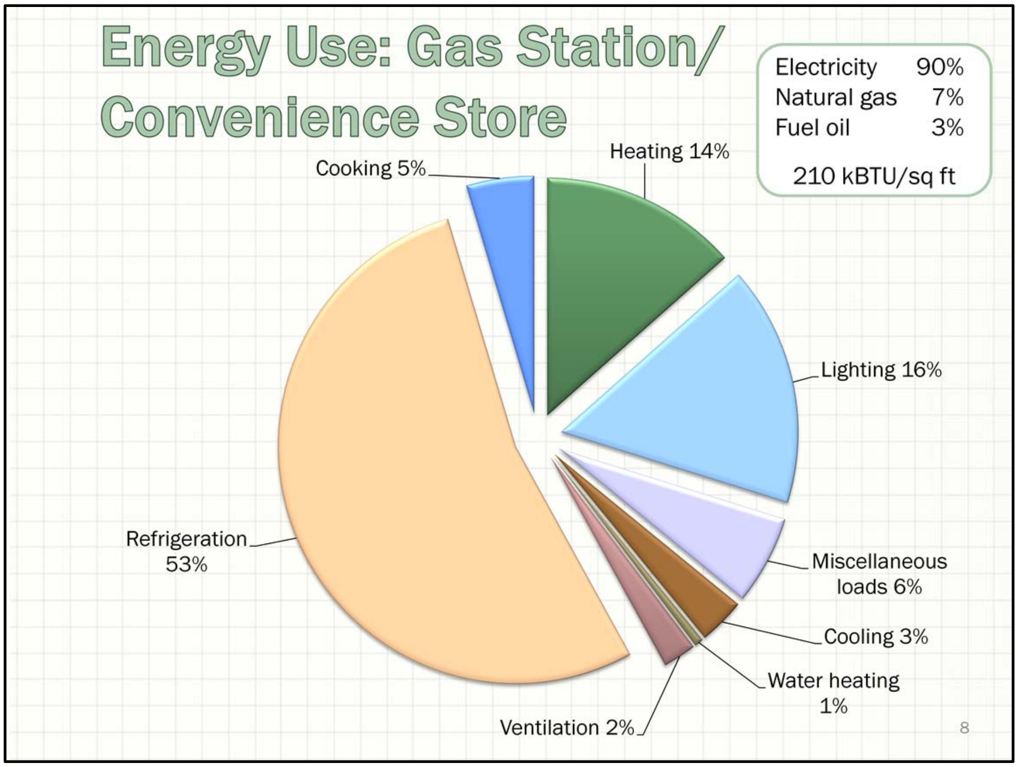
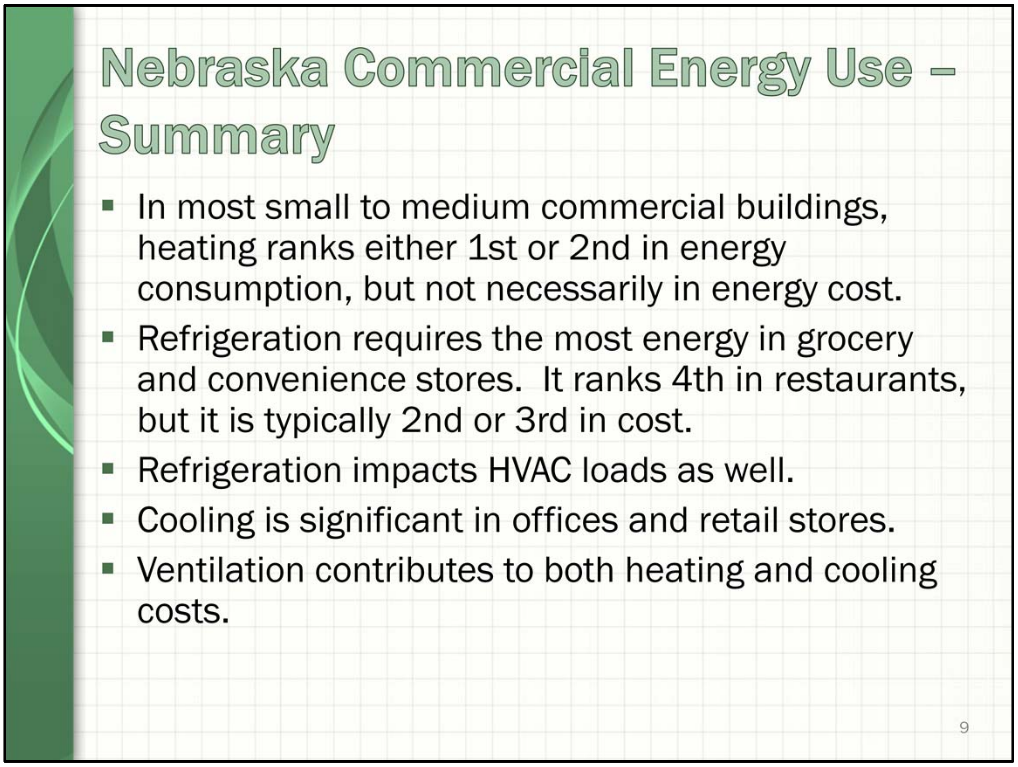
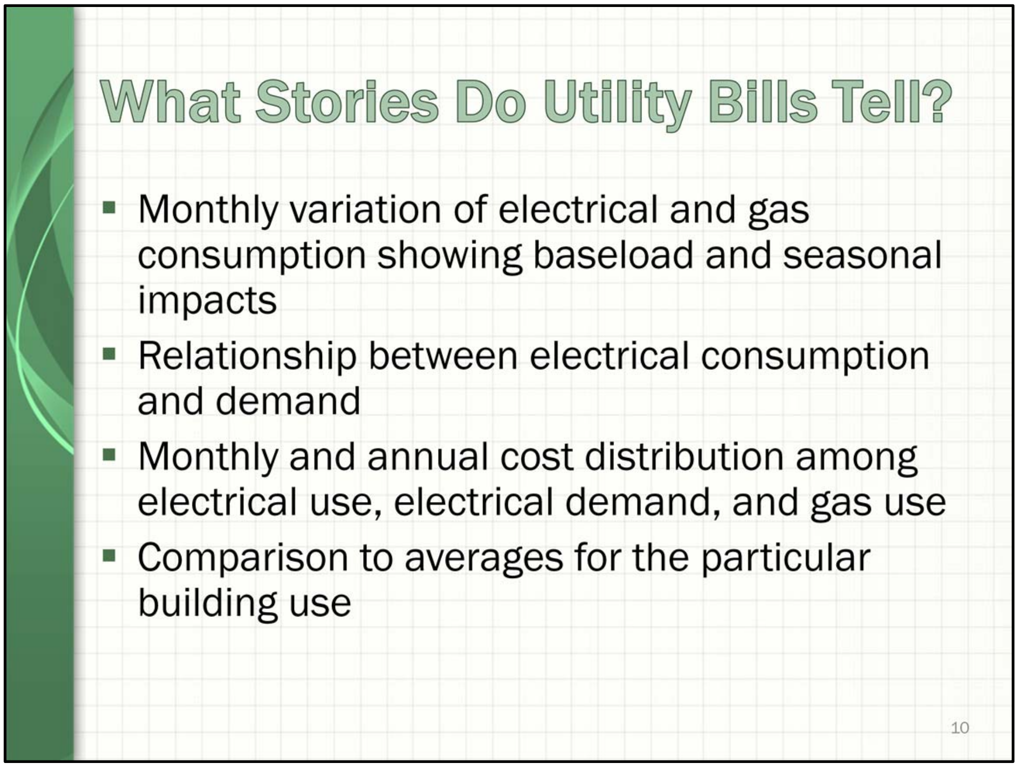
1. Commercial Energy Benchmarks (members.questline.com)
2. DOE CBECS Building Energy Handbook (buildingdatabook.eren.doe.gov)



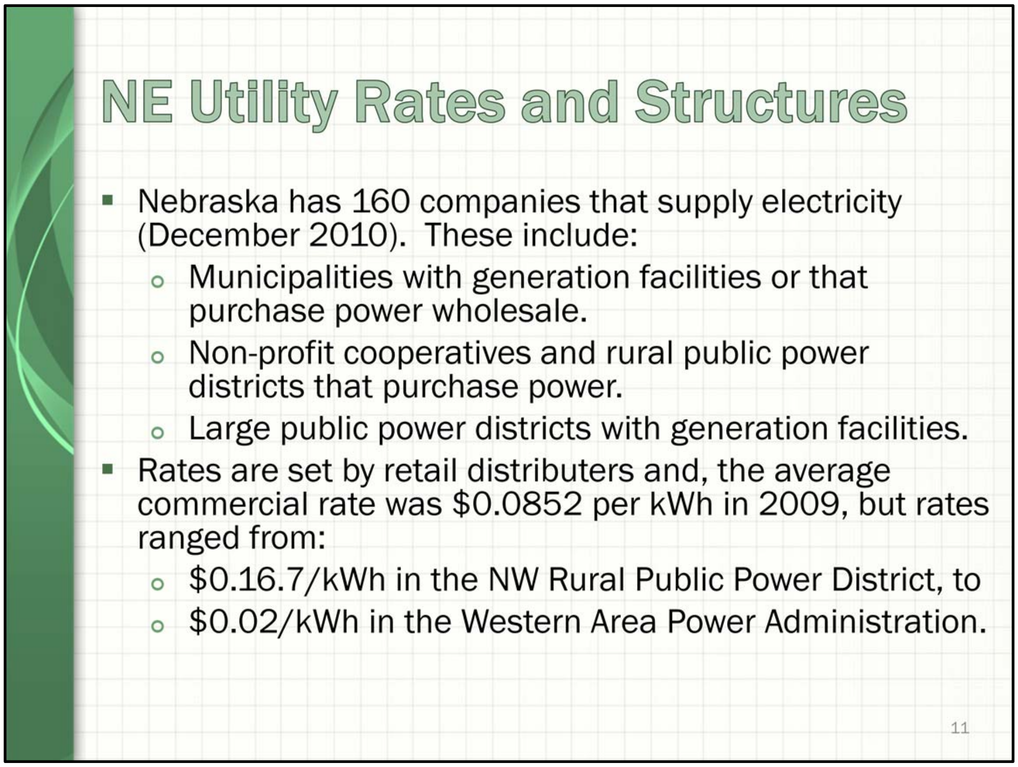
Sources for Nebraska light commercial buildings –

1. Commercial Energy Benchmarks (members.questline.com)
2. DOE CBECS Building Energy Handbook (buildingdatabook.eren.doe.gov)


Nebraska Commercial Energy Use – Summary
In most small to medium commercial buildings, heating ranks either 1st or 2nd in energy consumption, but not necessarily in energy cost.
Refrigeration requires the most energy in grocery and convenience stores. It ranks 4th in restaurants, but it is typically 2nd or 3rd in cost.
Refrigeration impacts HVAC loads as well.
Cooling is significant in offices and retail stores.
Ventilation contributes to both heating and cooling costs.
9



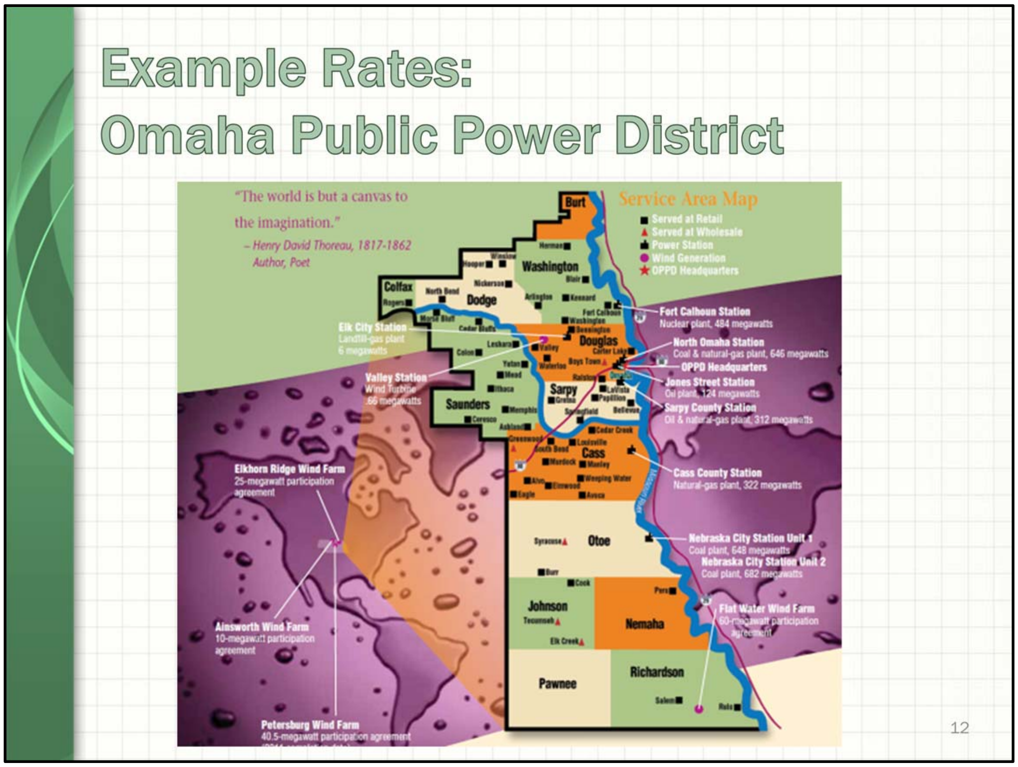
Taking a close look at utility bills over at least a one year period, and preferably more, will provide good insight into the opportunities for improvement. Each building and business are unique users of energy. Utility bills show consumption history and variations over time and how energy costs are distributed. This information is extremely valuable in understanding the potential impact of improvements and what costs might be appropriate for each specific application.



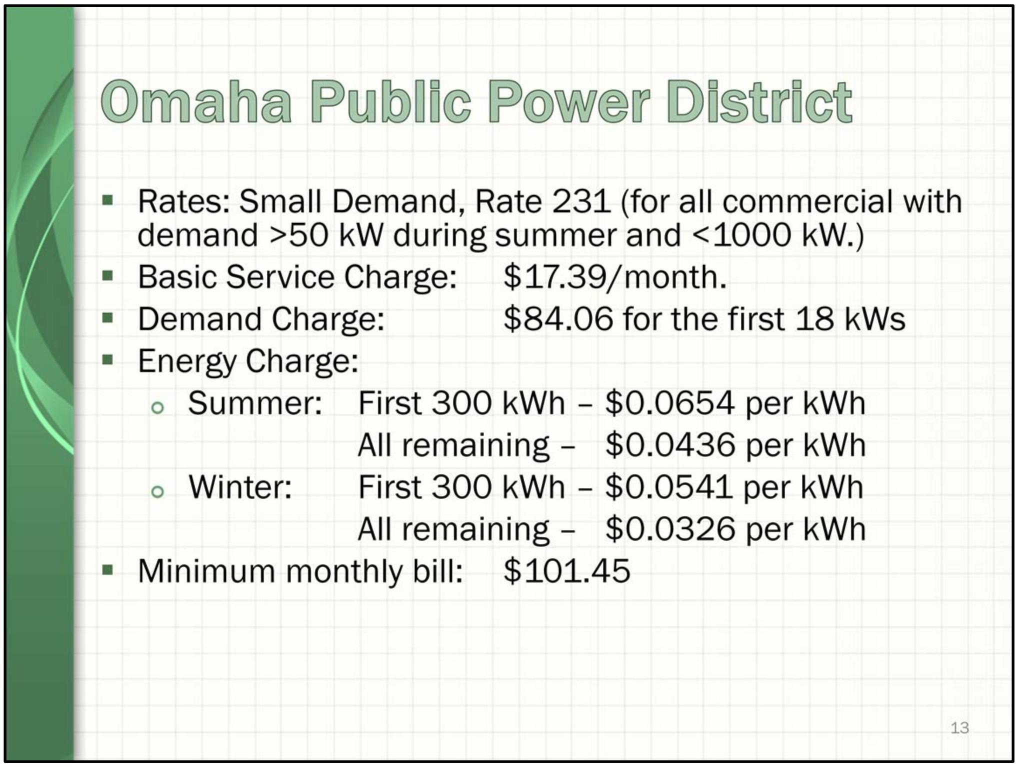
The state maintains a list of the suppliers and their average prices, at http://www.neo.ne.gov/statshtml/119.htm

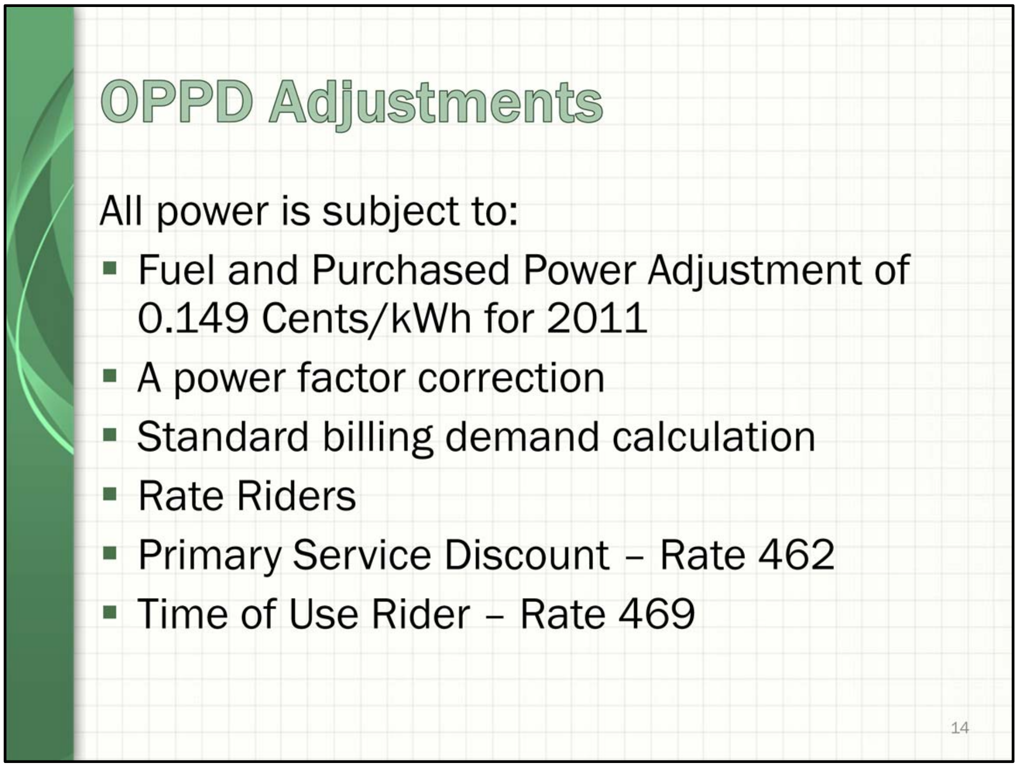
Nebraska's Electricity Rates - http://www.neo.ne.gov/statshtml/119.htm

Nebraska Power Review Board, list of power suppliers, http://www.nprb.state.ne.us/links.html

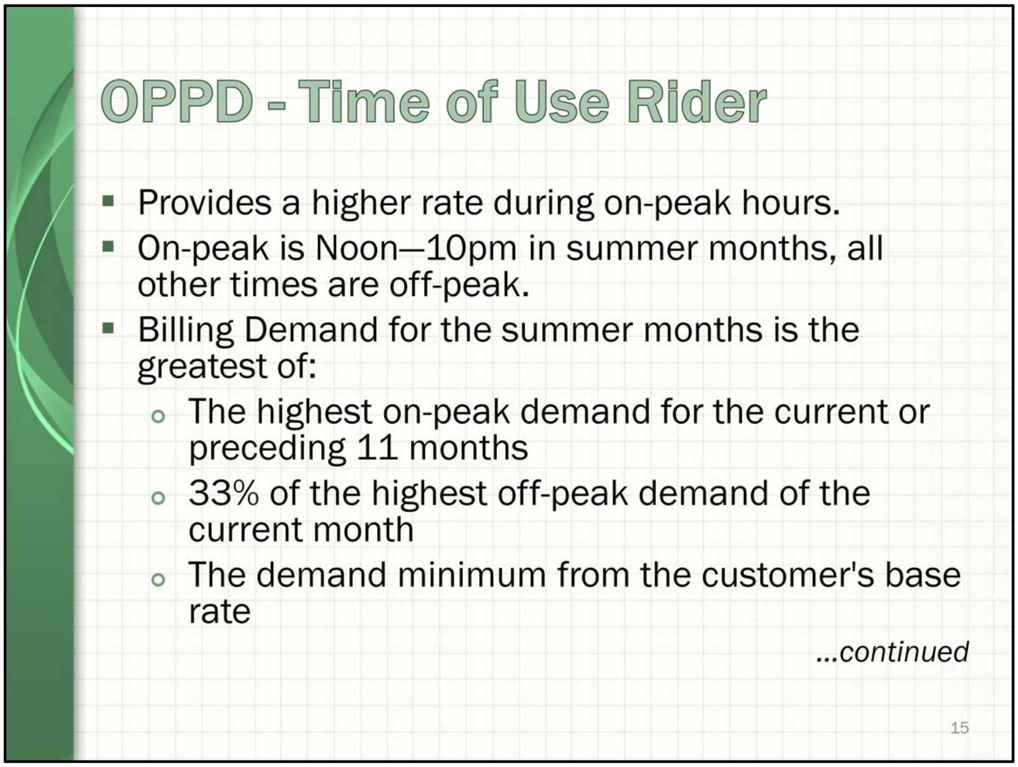


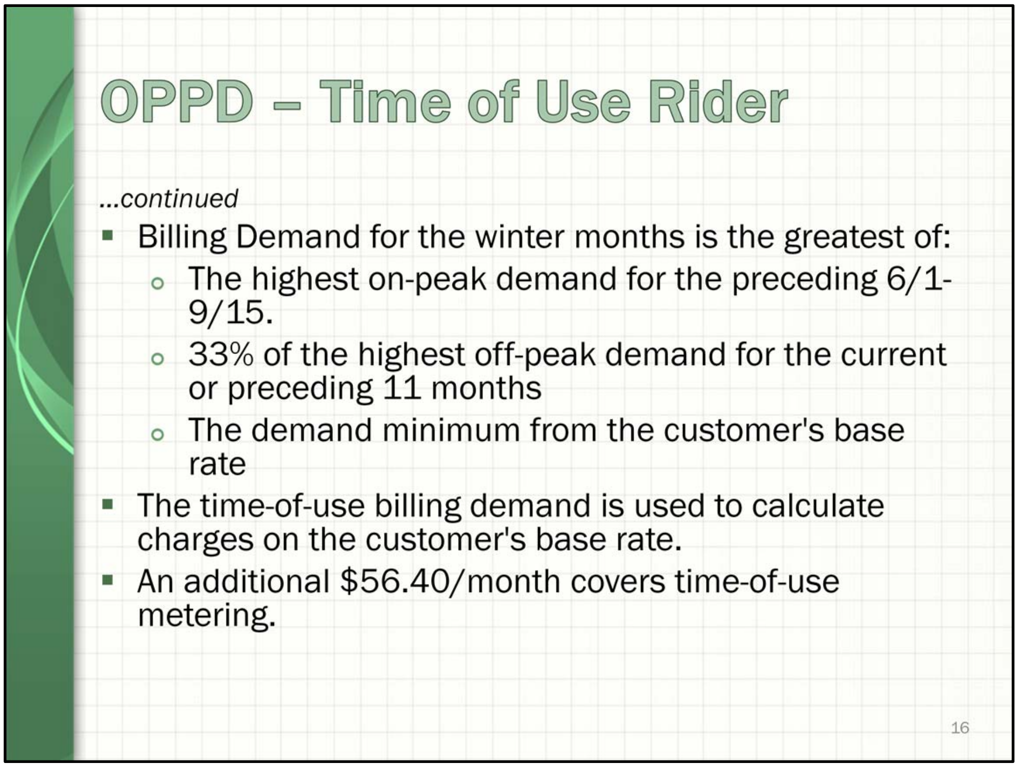
http://www.oppd.com/prodconsump10g/groups/web/documents/webcontent/22_006954.pdf

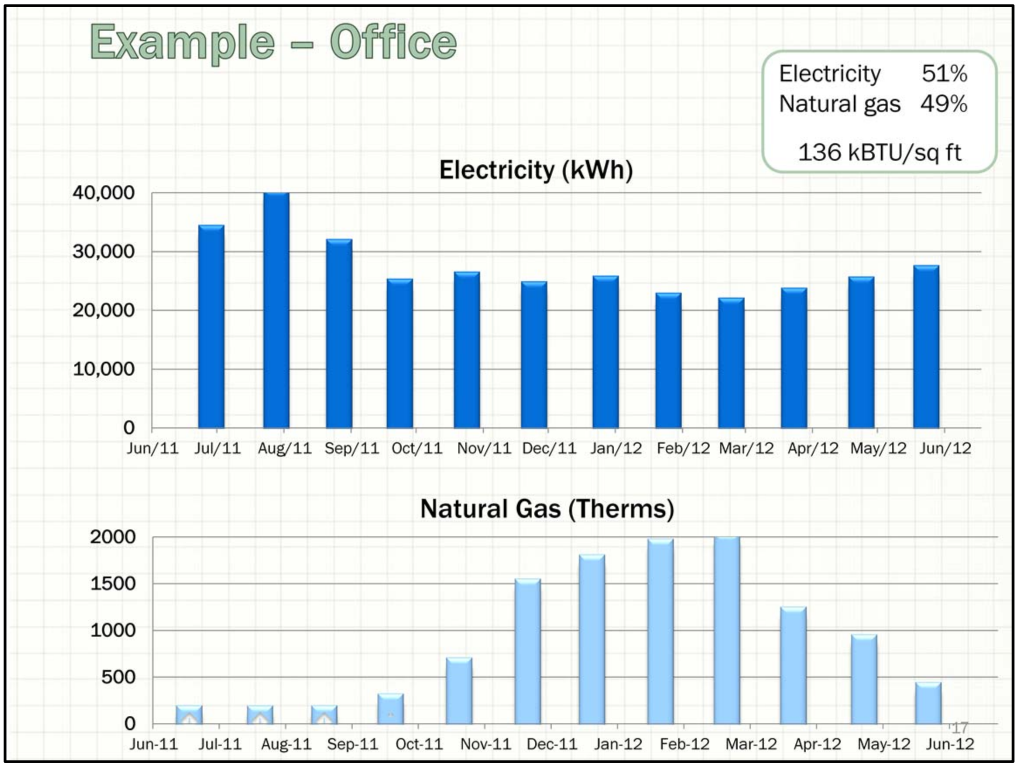

Omaha Public Power District
Rates: Small Demand, Rate 231 (for all commercial with demand >50 kW during summer and <1000 kW.)
Basic Service Charge: $17.39/month.
Demand Charge: $84.06 for the first 18 kWs
Energy Charge:
Summer: First 300 kWh – $0.0654 per kWh
All remaining – $0.0436 per kWh
Winter: First 300 kWh – $0.0541 per kWh
All remaining – $0.0326 per kWh
Minimum monthly bill: $101.45
13



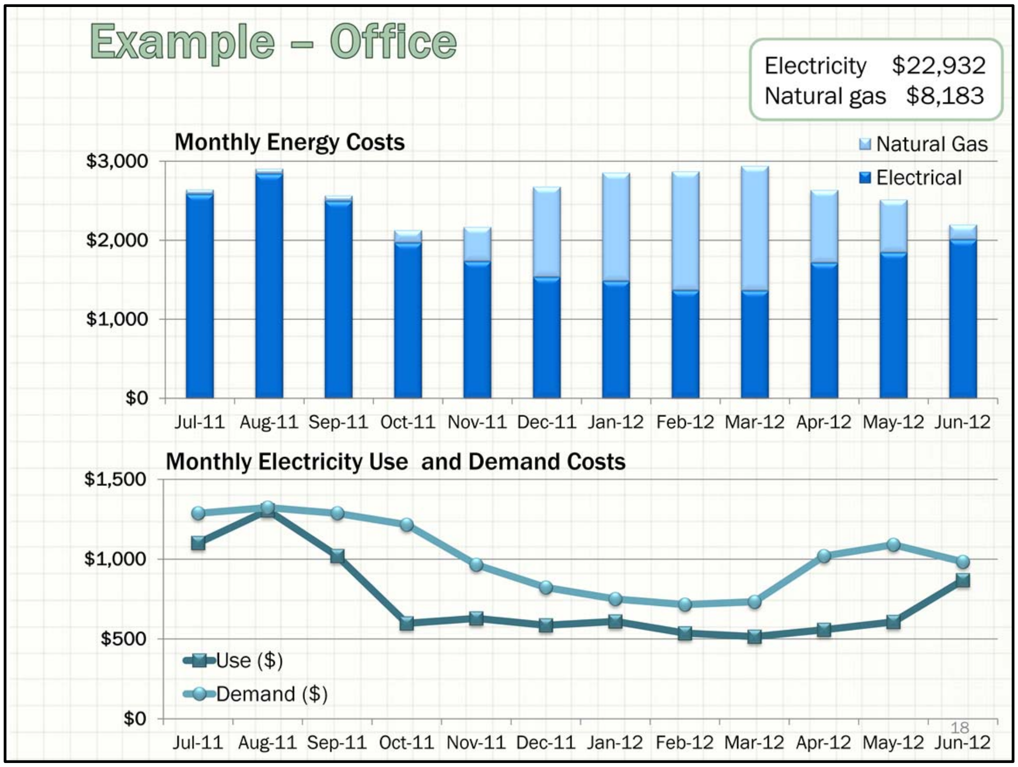
http://www.oppd.com/Rates/CommercialIndustrial/22_001501


OPPD - Time of Use Rider
Provides a higher rate during on-peak hours.
On-peak is Noon—10pm in summer months, all other times are off-peak.
Billing Demand for the summer months is the greatest of:
The highest on-peak demand for the current or preceding 11 months
33% of the highest off-peak demand of the current month
The demand minimum from the customer's base rate
...continued
15

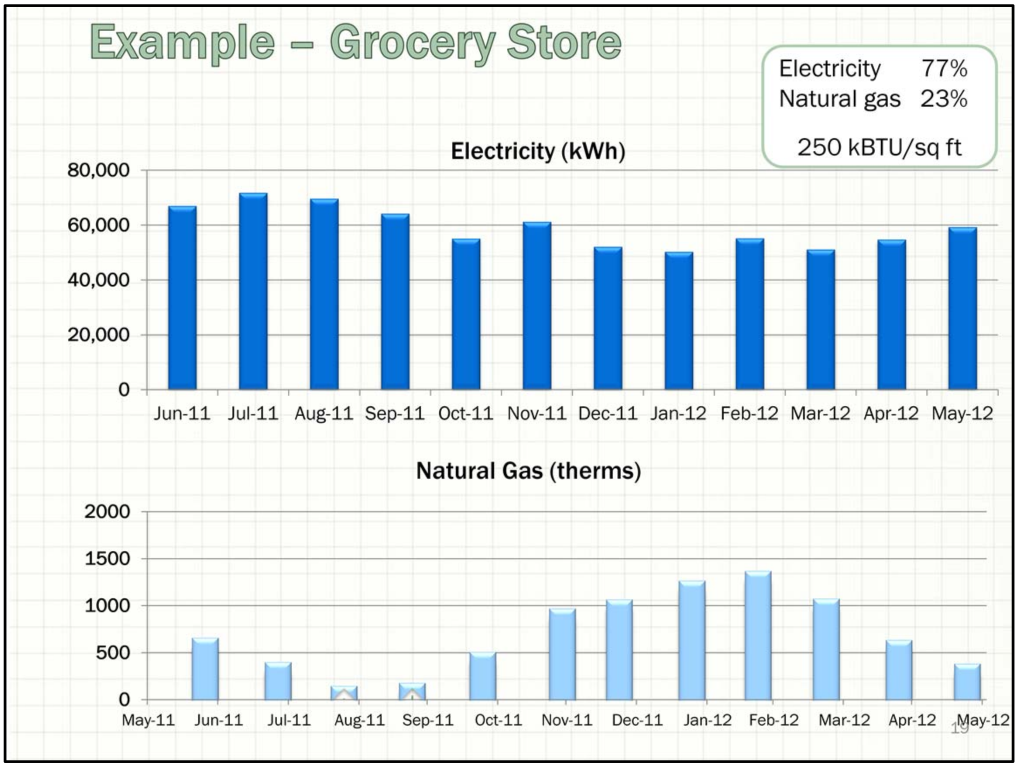

OPPD – Time of Use Rider
...continued
Billing Demand for the winter months is the greatest of:
The highest on-peak demand for the preceding 6/1-9/15.
33% of the highest off-peak demand for the current or preceding 11 months
The demand minimum from the customer's base rate
The time-of-use billing demand is used to calculate charges on the customer's base rate.
An additional $56.40/month covers time-of-use metering.
16



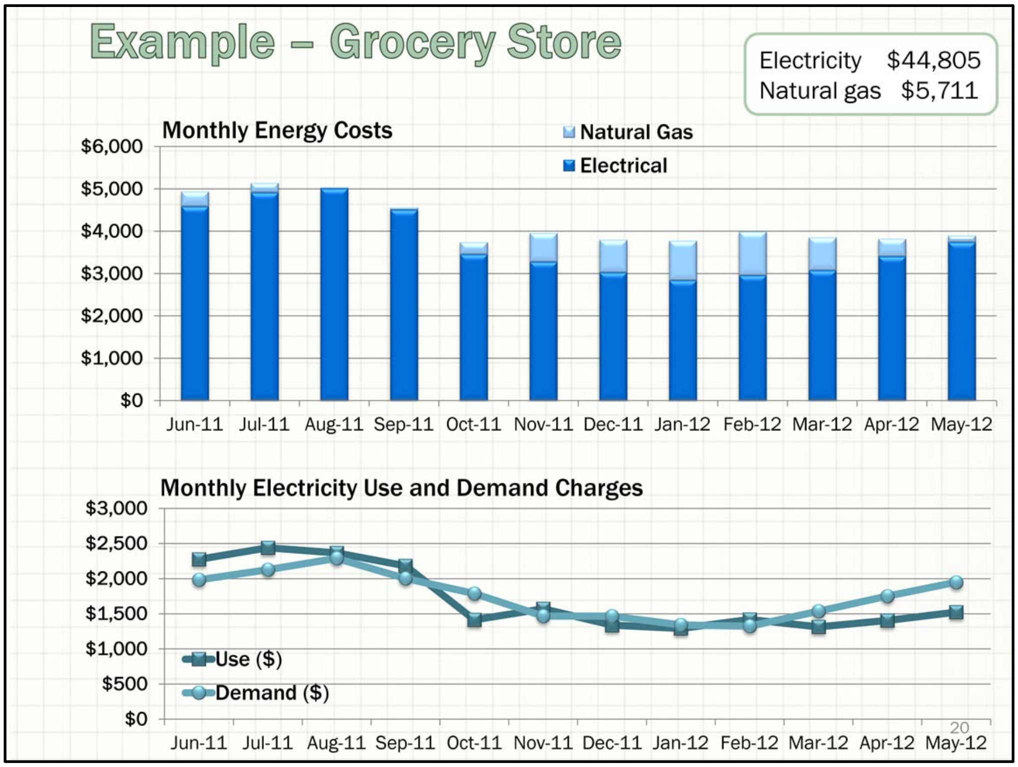
This is energy consumption data from a 15,094 sq ft office building in Lincoln, NE. The EUI, or energy intensity index, of 136 kBTU/sq ft is very high compared to the average shown earlier for Nebraska office buildings. Note the typical seasonal pattern of energy use but also the high electricity baseload of approximately 20,000 kWh per month. What might this data indicate about energy efficiency improvements for this building?



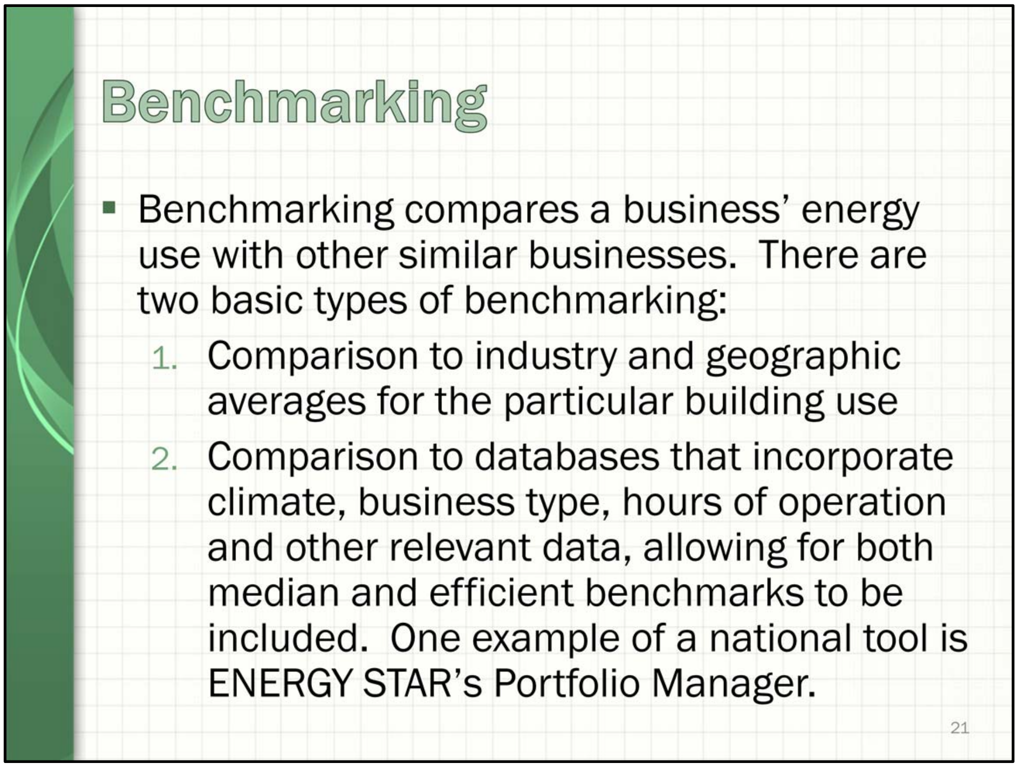
In this 15,094 sq ft office building, note the typical seasonal cost distribution between electricity and natural gas, with gas costs exceeding electricity in the winter months. The dominate costs however, are for base (non-seasonal) electricity charges of approximately $1,500 monthly (almost 60% of the total energy costs each year); this contributes to electricity being over 70% of the costs while being only just over 50% in consumption. Note also that electricity demand charges exceed use charges by a significant amount.



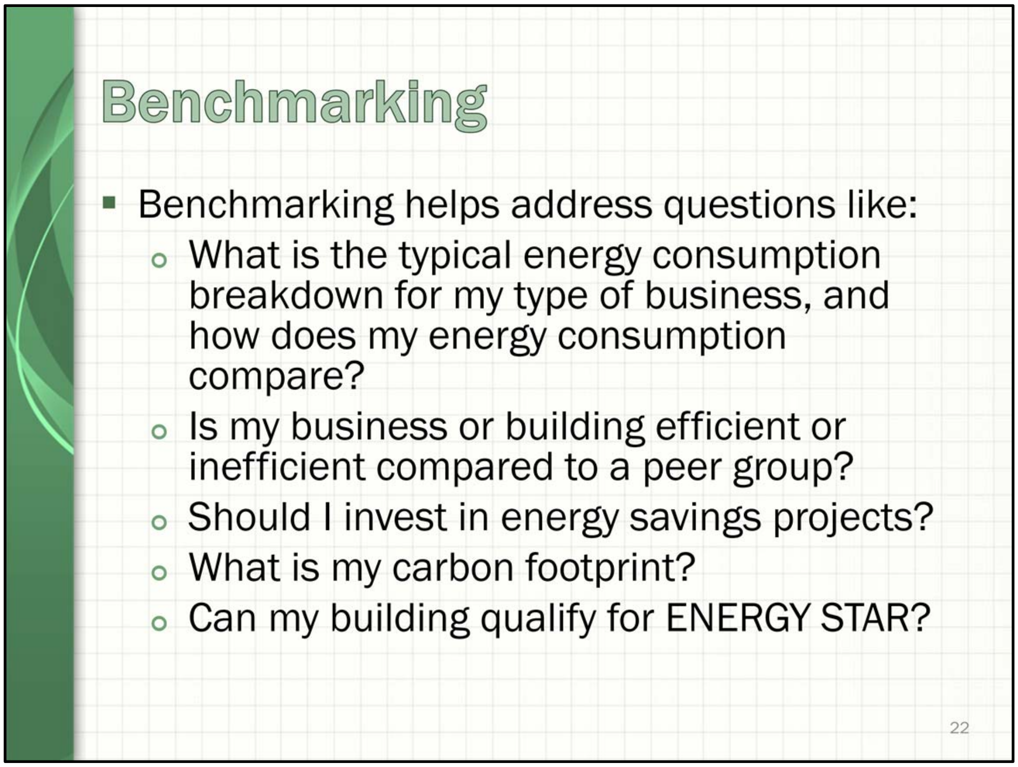
This is energy consumption data from a 12,512 sq ft grocery store in Lincoln, NE. How does the EUI, or energy intensity index, compare to the average shown earlier for Nebraska grocery stores? What might account for the high baseload electricity consumption?



How do these energy costs differ from the office building example?



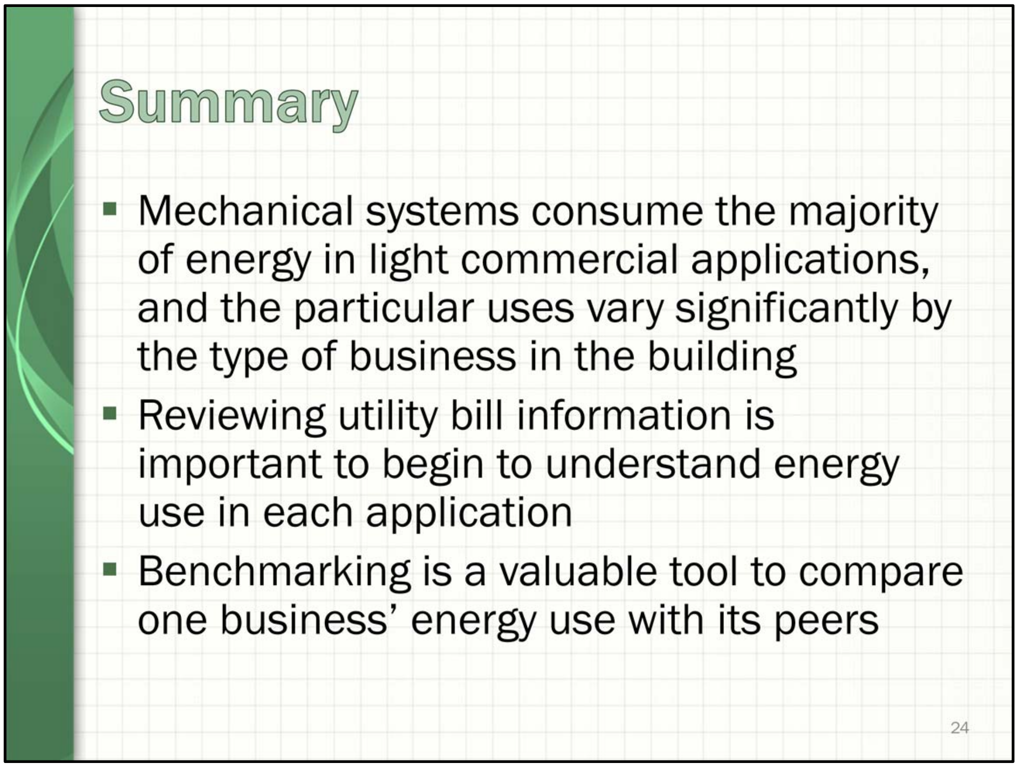
Tools such as the Department of Energy's CBECS database (http://www.buildingbenchmarks.com/) help businesses gather average consumption data for use in comparison. A more complete tool is Portfolio Manager (http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager); basic business information is entered, such as hours of operation, number of employees and the size of the conditioned space, along with monthly utility data, and statistics are used to predict median and energy efficient use that is relevant to the particular business. Portfolio Manager is also the tool used to verify ENERGY STAR level performance of commercial buildings.

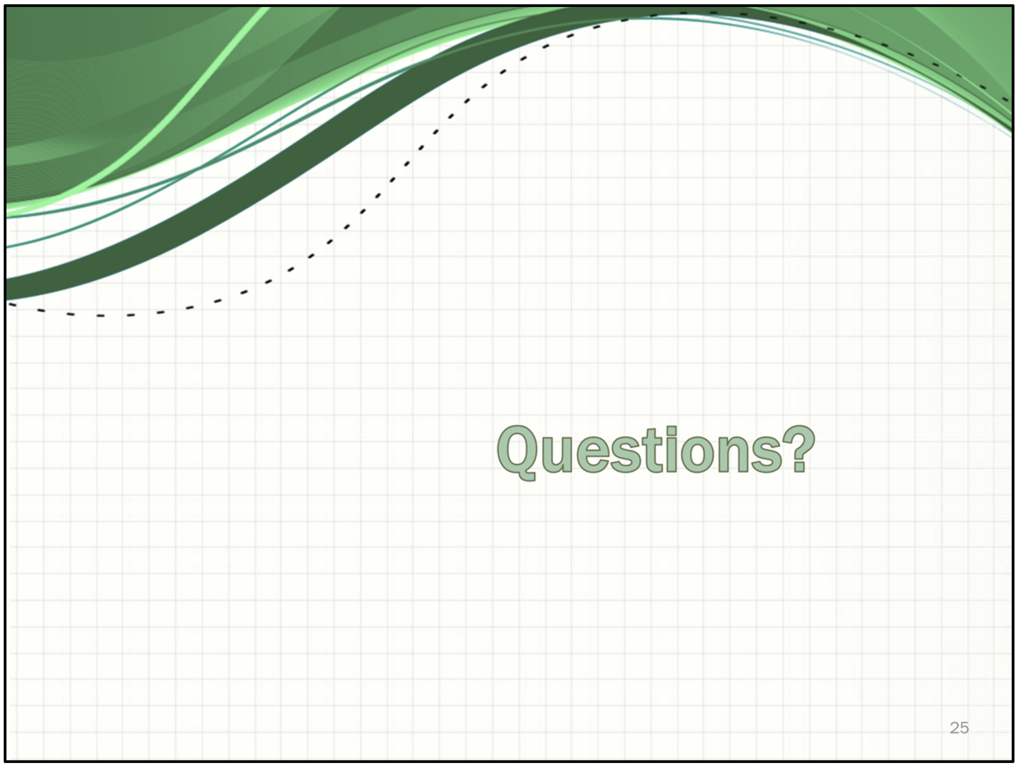

Benchmarking
Benchmarking helps address questions like:
What is the typical energy consumption breakdown for my type of business, and how does my energy consumption compare?
Is my business or building efficient or inefficient compared to a peer group?
Should I invest in energy savings projects?
What is my carbon footprint?
Can my building qualify for ENERGY STAR?
22

A Portfolio Manager Example

	Evaluation Periods		Comparisons		
Performance Metrics	Current (Ending date 05/31/12)	Baseline	Rating of 75	Target	National Median
Energy Performance Rating	12	12	75	N/A	50
Energy Intensity					
• Site (kBtu/ft^2)	136	136	63	N/A	86
• Source (kBtu/ft^2)	301	301	140	N/A	190
Energy Cost					
• $/year	$30,678	$30,678	$14,318	N/A	$19,359
• $/ft^2/year	$2.03	$2.03	$0.95	N/A	$1.28
Greenhouse Gas Emissions					
• $MtCO_2e$/year	294	294	137	N/A	186
• $kgCO_2e/ft^2$/year	19	19	9	N/A	12

The earlier office building used as an example was benchmarked using ENERGY STAR's Portfolio Manager (www.energystar.gov/istar/pmpam). The table above compiles the results. Note the difference in Site Energy Intensity (136 kBTU/sq ft) to the comparisons. The Rating of 75 column is the level that would qualify the building, with its particular use and data, as an ENERGY STAR building. Note also the differences in Energy Cost per sq ft per year.


Summary
Mechanical systems consume the majority of energy in light commercial applications, and the particular uses vary significantly by the type of business in the building
Reviewing utility bill information is important to begin to understand energy use in each application
Benchmarking is a valuable tool to compare one business’ energy use with its peers
24


Questions?
25

Assessment

Questions

For questions 1-3, use the following answers for building types:

a. office
b. retail
c. restaurant
d. grocery
e. gas station/convenience

1. On average, which types of small commercial buildings in Nebraska have the lowest and highest *energy use intensity* (measured in kBtu/sq ft)?

    a. Lowest (82 kBtu/sq ft): _________
    b. Highest (262 kBtu/sq ft): _________

2. On average, which types of small commercial buildings in Nebraska use the least and the greatest electric power, when expressed as a *% of total energy* consumption? (Note: The lowest % electricity will have the highest % natural gas and fuel oil.)

    a. Least (41%) ________
    b. Greatest (90%) ________

3. Which two types of buildings typically have the highest total electricity use¸ and in them, what mechanical system uses the most electricity?

    a. Building types _________
    b. Mechanical system _________

4. List two kinds of useful information that can come from analysis of utility bills.

    a. ____

    b. ____

True or false

5. In most small to medium commercial buildings in Nebraska, heating ranks either first or second in energy *consumption*, but not necessarily in energy *cost*.

Answers

For questions 1-3, use the following answers for building types:

a. office
b. retail
c. restaurant
d. grocery
e. gas station/convenience

1. On average, which types of small commercial buildings in Nebraska have the lowest and highest *energy use intensity* (measured in kBtu/sq ft)?

    - Lowest (82 kBtu/sq ft): **b. retail**
    - Highest (262 kBtu/sq ft): **c. restaurant**

2. On average, which types of small commercial buildings in Nebraska use the least and the greatest electric power, when expressed as a *% of total energy* consumption? (Note: The lowest % electricity will have the highest % natural gas and fuel oil.)

    - Least (41%) **c. restaurant**
    - Greatest (90%) **e. gas station/convenience**

3. Which two types of buildings typically have the highest total electricity use¸ and in them, what mechanical system uses the most electricity?

    - Building types **e. grocery or gas station/convenience**
    - Mechanical system **refrigeration**

4. List two kinds of useful information that can come from analysis of utility bills.

   Any two of the following:

   - **An understanding of annual costs (electricity use, electricity demand, natural gas and/or fuel oil) – pointing to where potential improvements could have the greatest impact**
   - **A calculation of annual energy intensity – which is used for benchmarking (compared to average energy use in similar buildings)**
   - **Identify how energy consumption varies monthly – break usage into base-load and seasonal loads that can help set targets for improvement**
   - **Separate electric power consumption and electric demand charges – it may be possible to reduce high demand charges with equipment scheduling or to help set priorities for improvement**

True or false

5. In most small to medium commercial buildings in Nebraska, heating ranks either first or second in energy *consumption*, but not necessarily in energy *cost*.

   True

3: Mechanical Systems Codes & Standards

Learning Objectives

By attending this session, participants will:

- ✓ Become familiar with the relevant parts of the 2009 International Energy Conservation Code (IECC)
- ✓ Become familiar with the relevant parts of the 2007 American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 90.1
- ✓ Learn the differences between the two codes

Key Terminology

ASHRAE 90.1

Codes

Complex mechanical systems

Dehumidify

Demand control ventilation

Energy recovery ventilators

IECC

Performance path

Prescriptive path

Regulations

Semi-heated space

Simple mechanical systems

Standards

Supplemental Materials

American Society of Heating, Refrigerating and Air-Conditioning Engineers http://www.ashrae.org/

International Code Council http://www.iccsafe.org/Pages/default.aspx

U.S. Department of Energy Building Energy Codes Program http://www.energycodes.gov/

Online Code Environment and Advocacy Network (OCEAN) www.bcap-ocean.org has a free checklist of code requirements, as well as other tools.

Evaluating Commercial Buildings for Energy Code Compliance:

- (PDF) http://www.energycodes.gov/becu/documents/Commercial_90_Percent_Eval_Inspect_Training.pdf

Commercial Mechanical Requirements of the 2009 IECC:

- (PDF) www.energycodes.gov/training/pdfs/2009_iecc_mechanical.pdf
- (webcast) www.youtube.com/watch?v=y-d_S7v3dro

Basics of Using COMcheck Software:

- http://www.energycodes.gov/comcheck
- (PDF) http://www.energycodes.gov/training/pdfs/comcheckbasics.pdf
- (webcast) http://www.youtube.com/watch?v=XrsC9g44vMQ
- Online version of COMcheck https://energycode.pnl.gov/COMcheckWeb

Building Code Studies:

- *Impacts of Standard 90.1-2007 for Commercial Buildings at State Level*. Sep 2009. (PDF) http://www.energycodes.gov/publications/techassist/commercial/Commercial_Nebraska.pdf
- *Nebraska-specific Advanced Commercial Building Energy Code Study, Final Report Documentation*. Nov 2009. (PDF, 19.5 MB) http://www.neo.ne.gov/home_const/iecc/documents/NebraskaEnergyStudyFinalReport.pdf

Classroom Props and Preparations

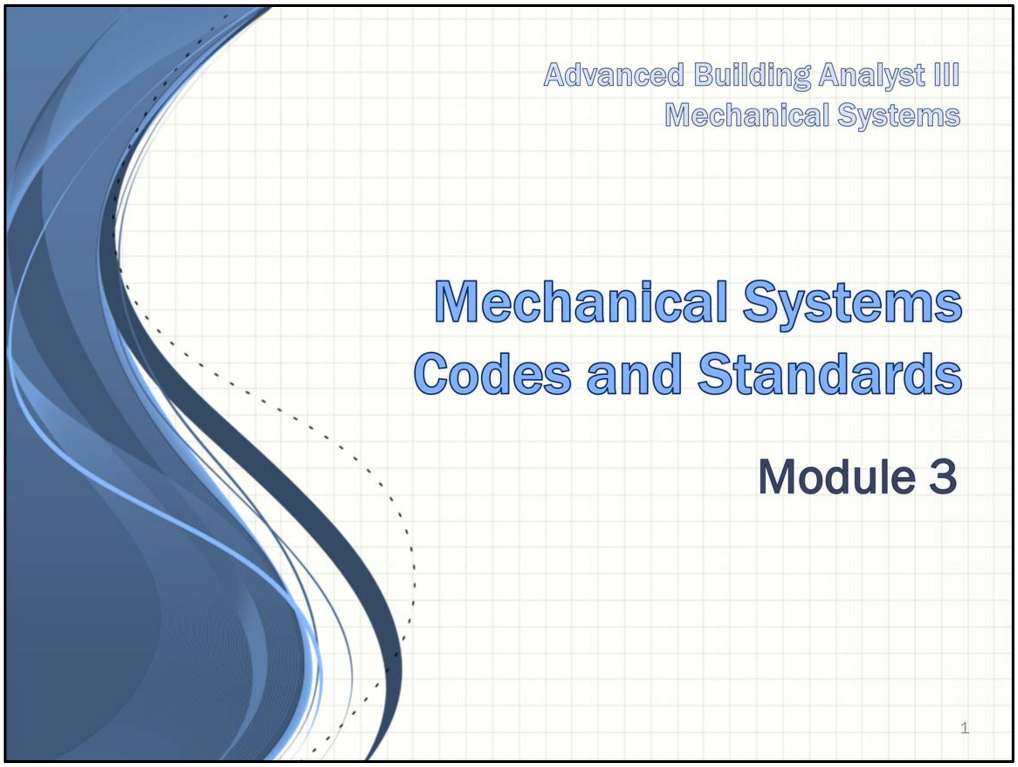
- Review presentation and select any sections to emphasize or omit if desired.
- Consider Activities –if using discussion questions, prepare for range of possible answers. If using COMcheck program, set building parameters for students to use, and vary them to achieve desired results.
- Review and print assessment questions.

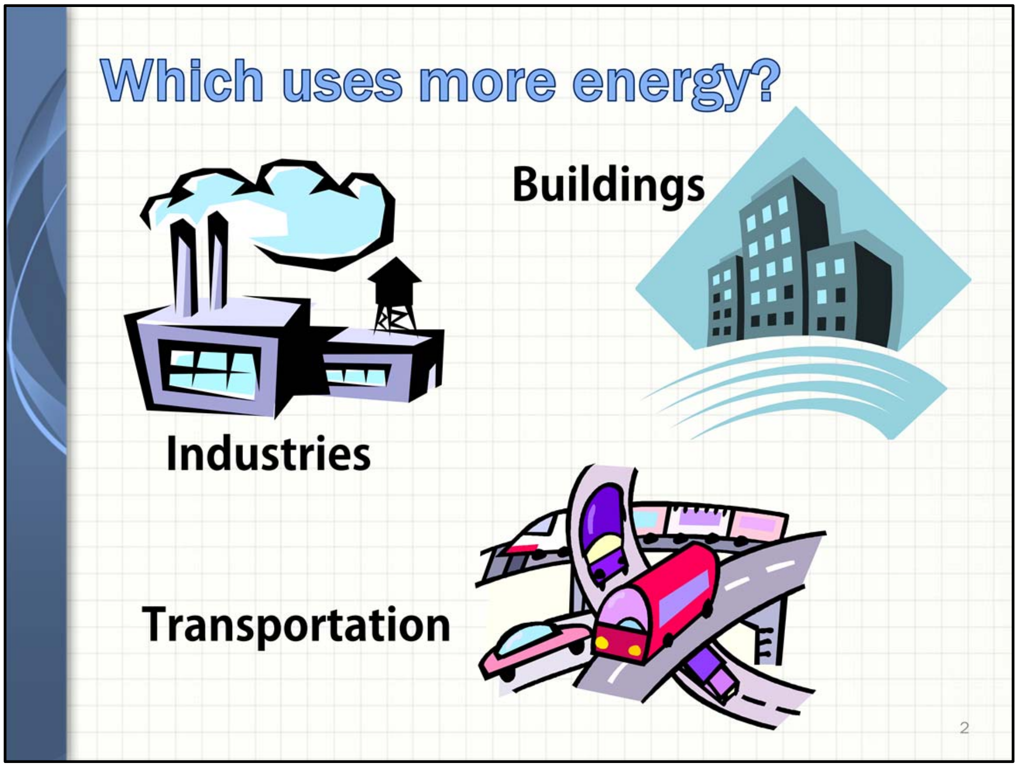
Possible Activities

1. Discuss the impact of codes on increasing energy efficiency. Refer to building code studies listed above.
2. For small retrofit projects that do not require compliance with energy codes, discuss whether the students would recommend or plan to follow IECC or ASHRAE 90.1 codes anyway? What would provide the greatest long-term benefit for the client, and what would they base their decision on?
3. If students have computers with internet access introduce them to the online version of COMcheck for a basic commercial building. It may be accessed at https://energycode.pnl.gov/COMcheckWeb/ .

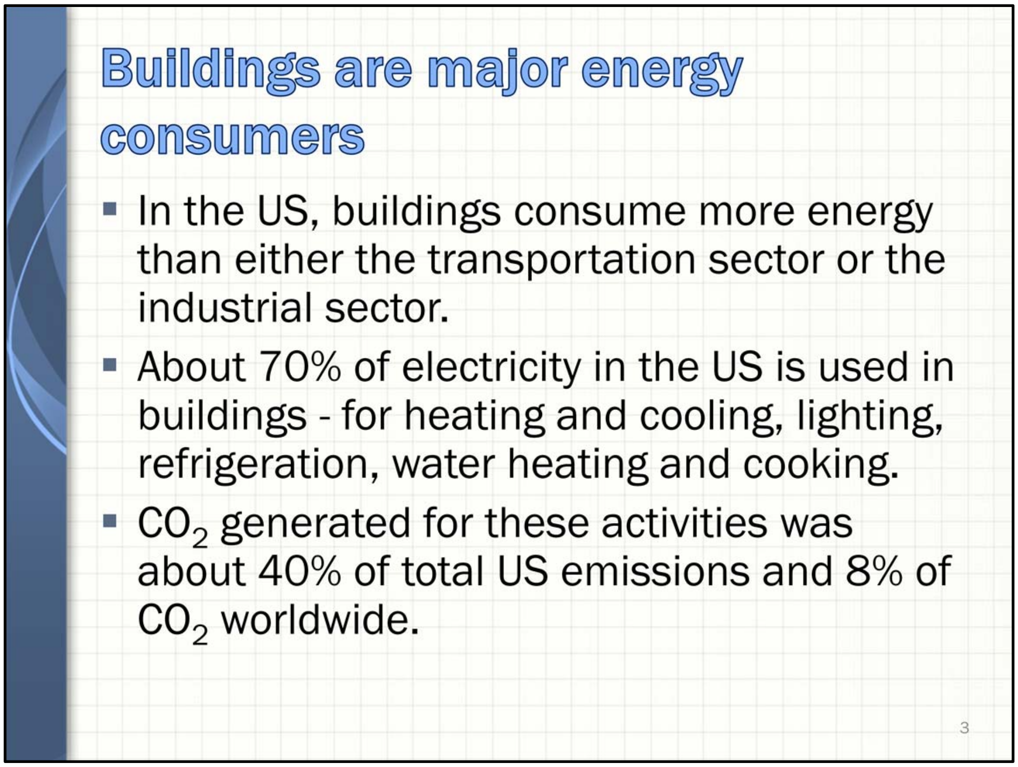
   Provide simple building description, (say, an 8,000 ft^2 office building—80 ft × 100 ft × 15 ft, with slab on grade, with typical construction …). Provide building envelope information and two options for HVAC systems. Ask students to input data and check compliance based on the 2009 IECC code. Students could be asked to determine the minimum EER needed for an air-cooled RTU with economizer to comply.

   This activity can be done in about 15 minutes, if input data is provided.


Advanced Building Analyst III
Mechanical Systems
Mechanical Systems
Codes and Standards
Module 3
1



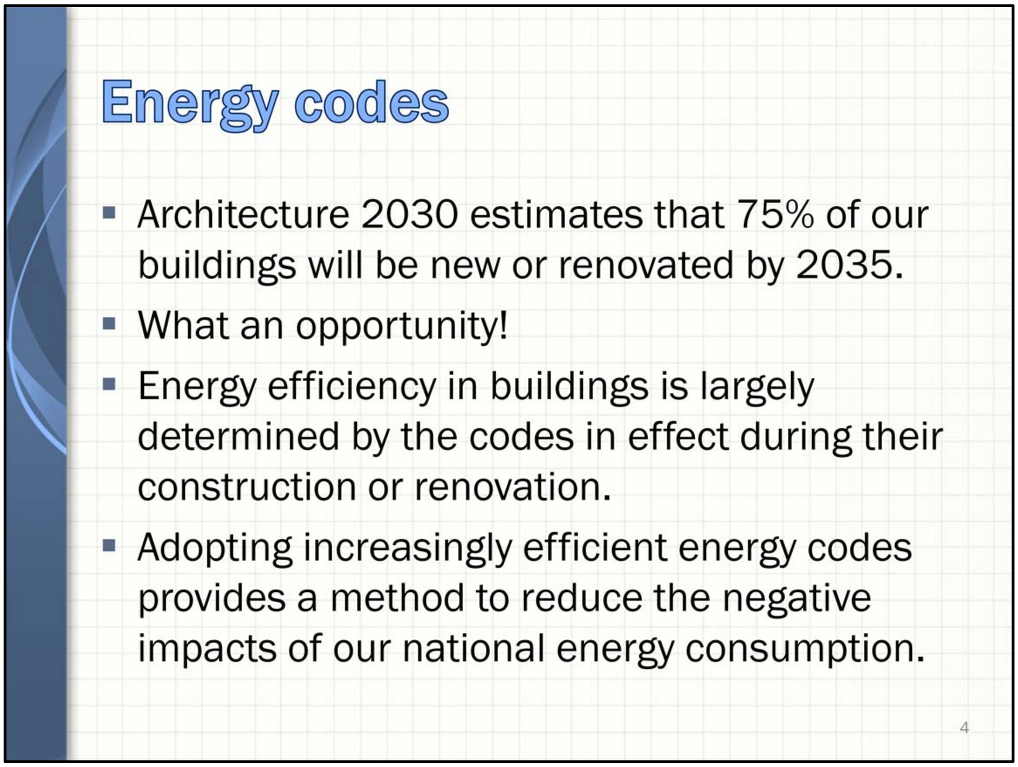
The answer is… buildings!



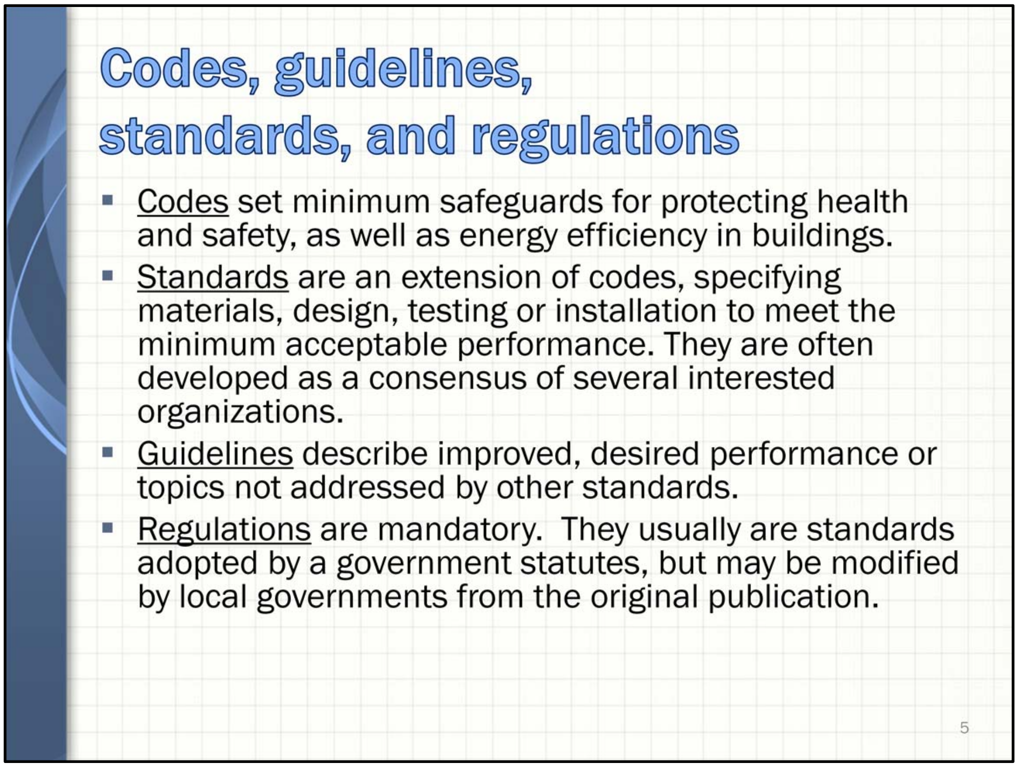
Buildings includes residential and commercial.

Statistics are from 2007 data.
http://www.energycodes.gov/becu/documents/BECU_Codes_101_Intro.pdf

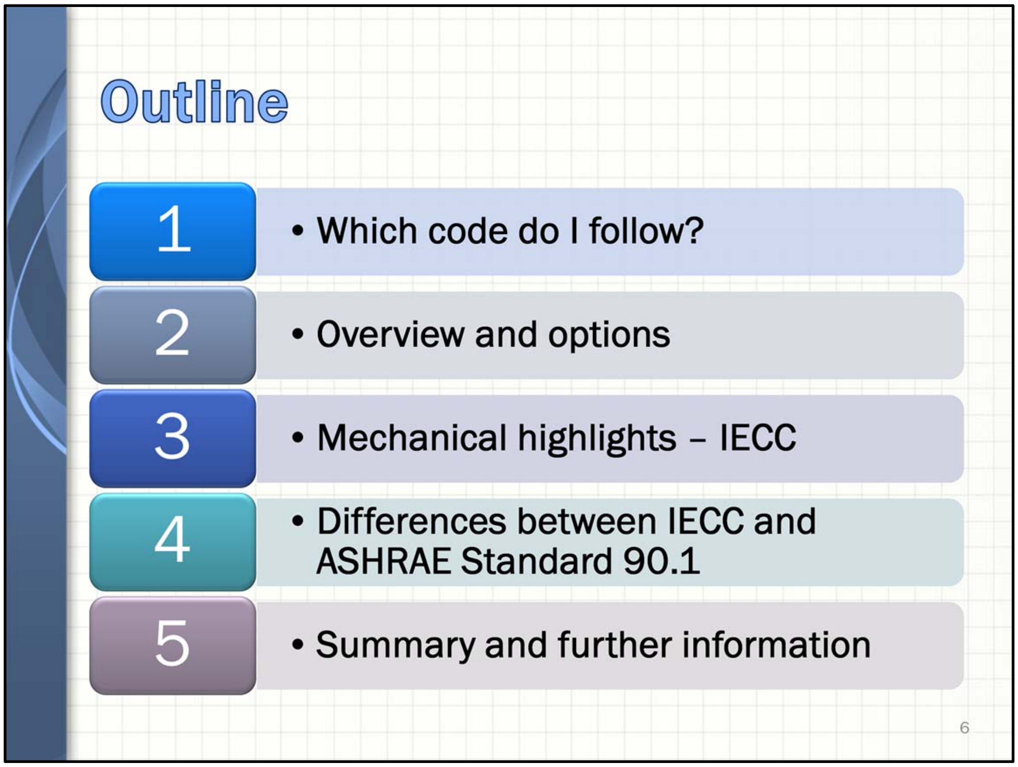
http://www.preservationnation.org/information-center/sustainable-communities/sustainability/green-lab/additional-resources/nthp_energy_codes_101.pdf

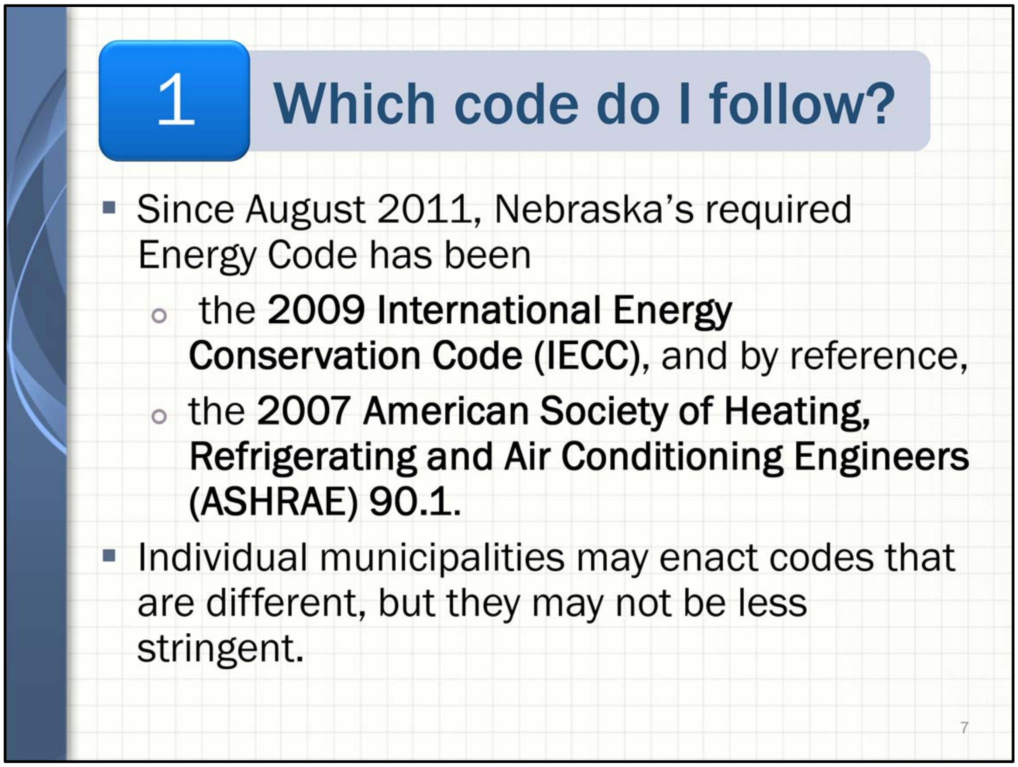


Architecture 2030, http://architecture2030.org/the_solution/buildings_solution_how



http://www.iccsafe.org/cs/Pages/default.aspx


Outline
1
• Which code do I follow?
2
• Overview and options
3
• Mechanical highlights – IECC
4
• Differences between IECC and ASHRAE Standard 90.1
5
• Summary and further information
6



Currently in Nebraska, the 2009 IECC code (a standard) is used as the basis for building energy regulations.

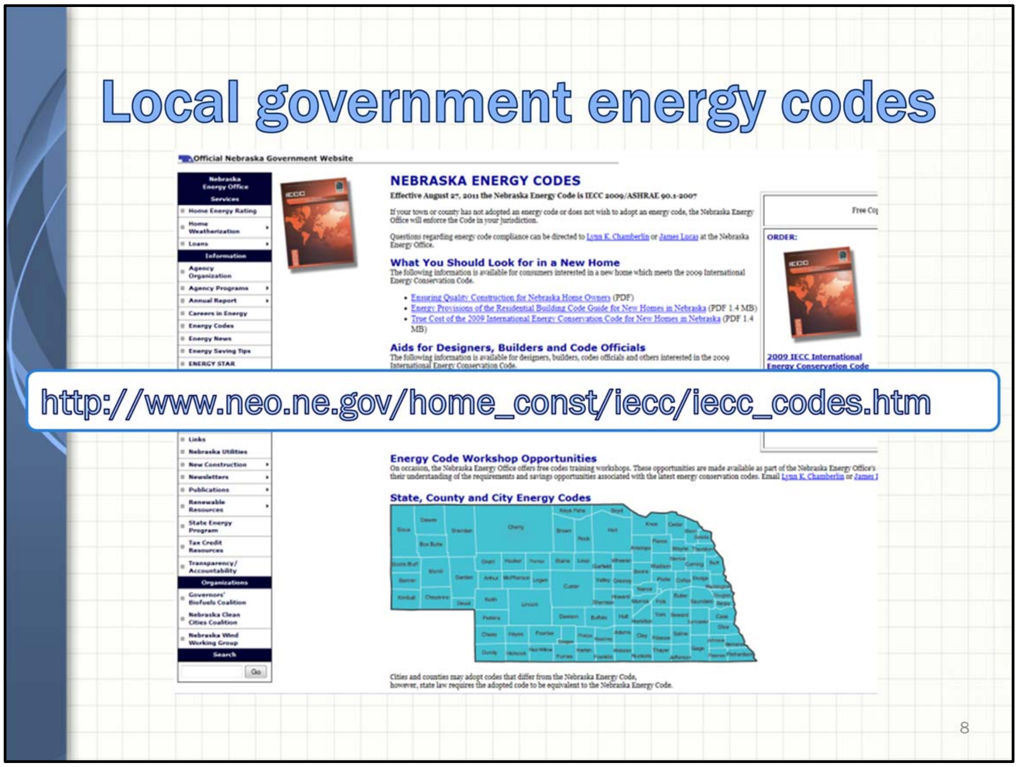
The IECC is developed by a non-profit agency, the International Code Council. The IECC code covers residential and commercial building design and construction. It frequently has been adopted by state and local governments.

ASHRAE 90.1 provides energy standards, developed by consensus of many in the industry, for all buildings other than single-family homes and multi-family buildings of 3 stories or less.

The IECC code adopted ASHRAE 90.1 by reference, meaning that complying with it satisfies the requirements of the IECC as well.

New editions of both standards are issued every 3 years. Currently in Nebraska, the 2009 IECC code is mandatory, as well as the sections of ASHRAE 90.1 that it references.

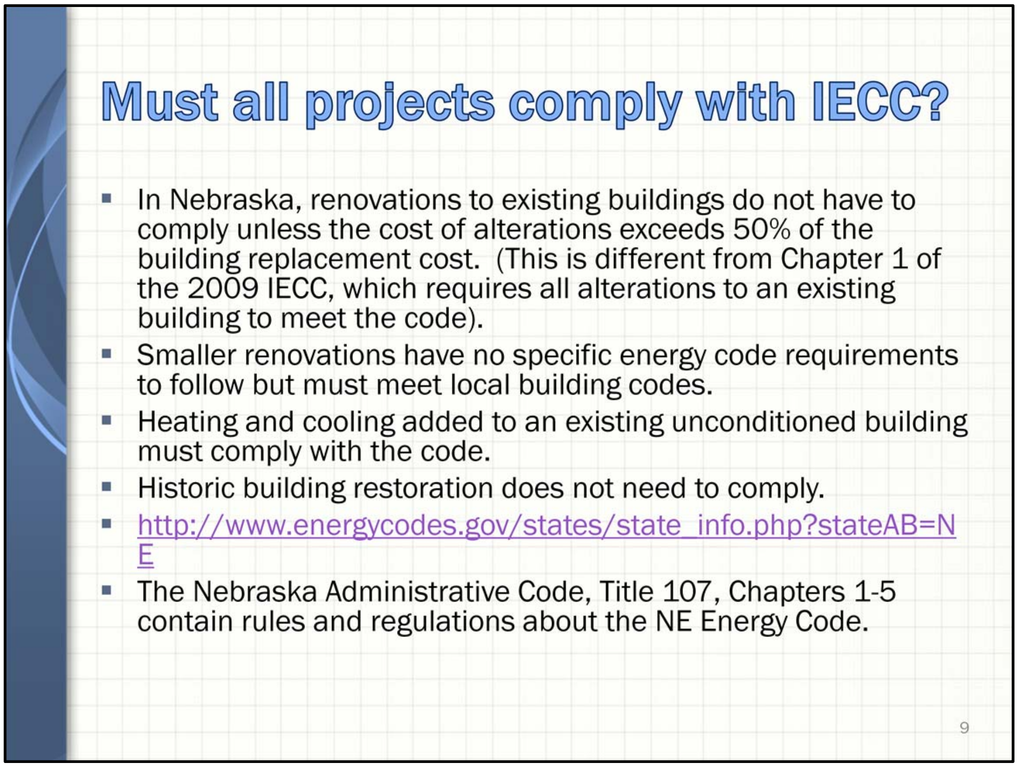
There are newer releases of both these codes now: 2010 ASHRAE, and 2012 IECC. However, Nebraska's cycle of approval for adoption requires several years. If you want to work "beyond current code" to a higher energy efficiency, you can refer to the newest versions of the codes.



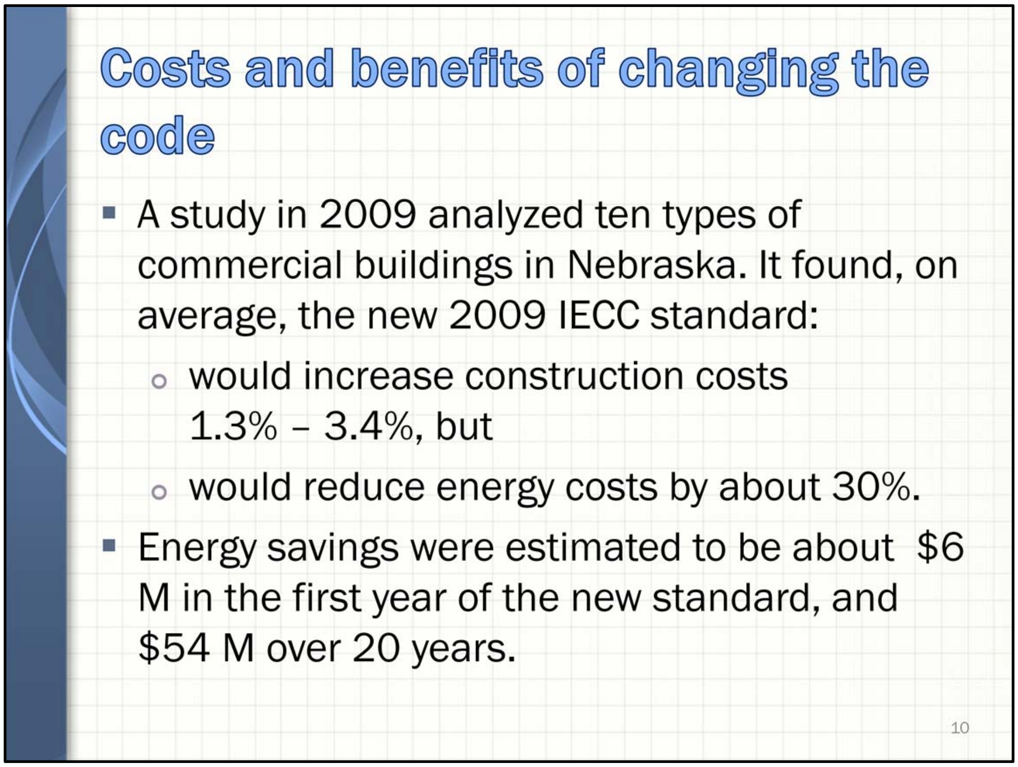
Nebraska's local government energy codes may be viewed from this interactive map on the State's website: http://www.neo.ne.gov/home_const/iecc/iecc_codes.htm

If a town or county has not or does not wish to adopt an energy code, the Nebraska Energy Office will enforce the Code in that jurisdiction.

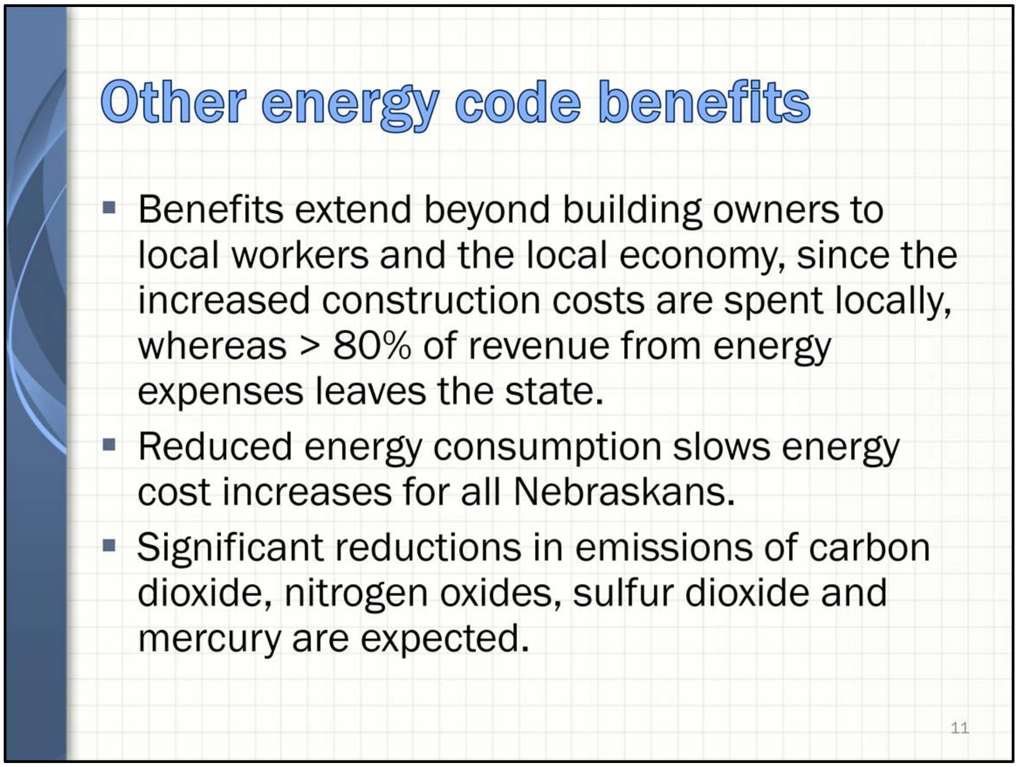
Status of State Energy Codes Nebraska - Building Energy Codes
www.energycodes.gov/states/state_info.php?stateAB=NE



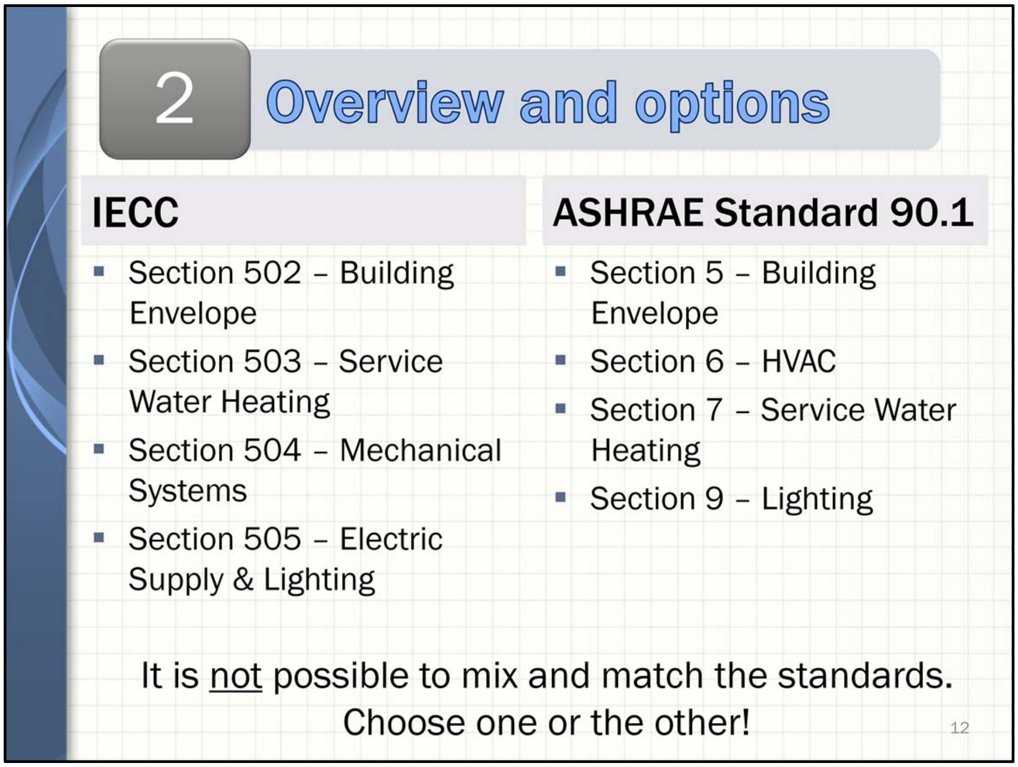
NE Admin. Code, Title 107 - http://www.sos.ne.gov/rules-and-regs/regsearch/Rules/Energy_Office/Title-107.pdf



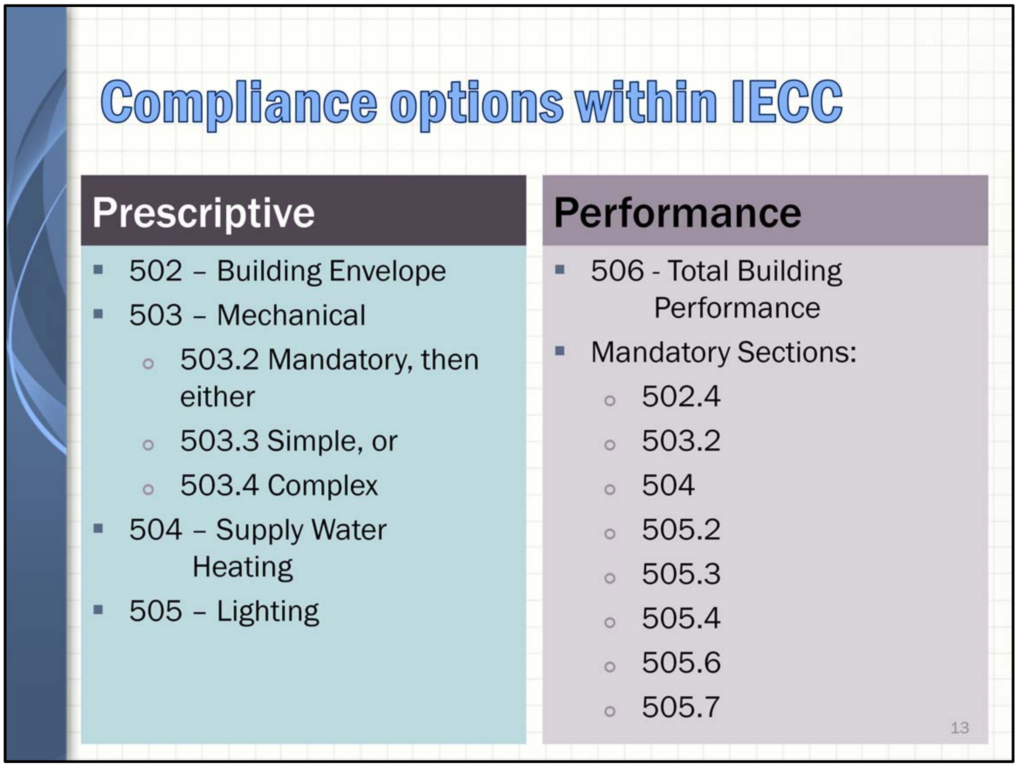
The study was specific for commercial buildings in Nebraska.
http://www.neo.ne.gov/home_const/iecc/documents/NebraskaEnergyStudyFinalReport.pdf



http://www.neo.ne.gov/home_const/iecc/documents/NebraskaEnergyStudyFinalReport.pdf



The IECC allows users to choose which of the Standards to follow. Previously, the IECC allowed some sections of ASHRAE to be substituted, but now you must follow one entirely. Documentation must be provided to the IECC. Plan review and construction inspection are required.

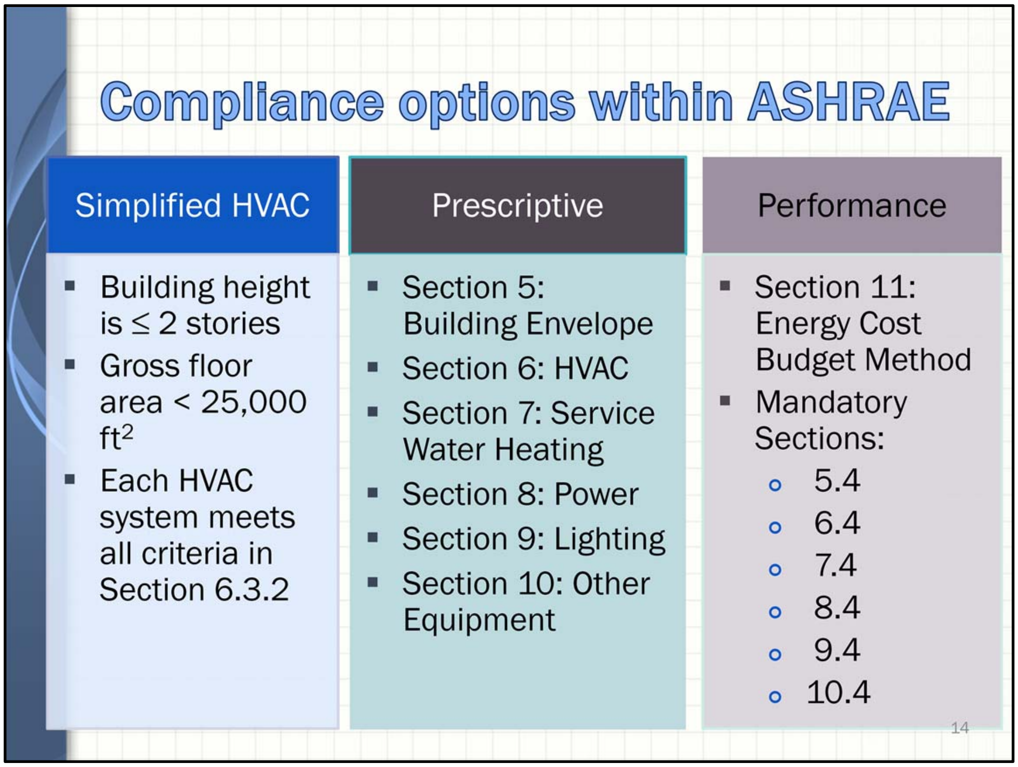


Prescriptive path – Follow the Code's "prescription" for design – meet the requirements for each system individually, like following a recipe.

A design that follows the Performance path, does not meet all the particulars for every element, but the overall building must be modeled and shown to perform as well or better than an equivalent standard building. Note that some provisions are mandatory under either option.

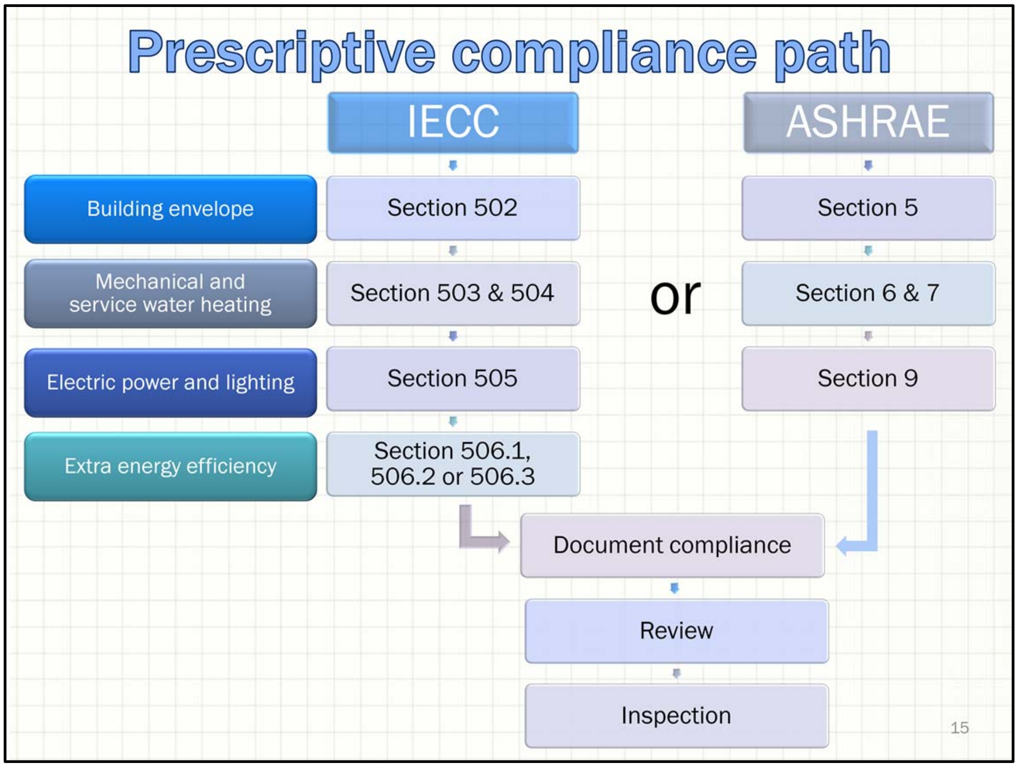
Use the prescriptive option for buildings with ≤ 40% of the total wall area in windows, and for buildings with ≤ 3% of gross roof area in skylights.

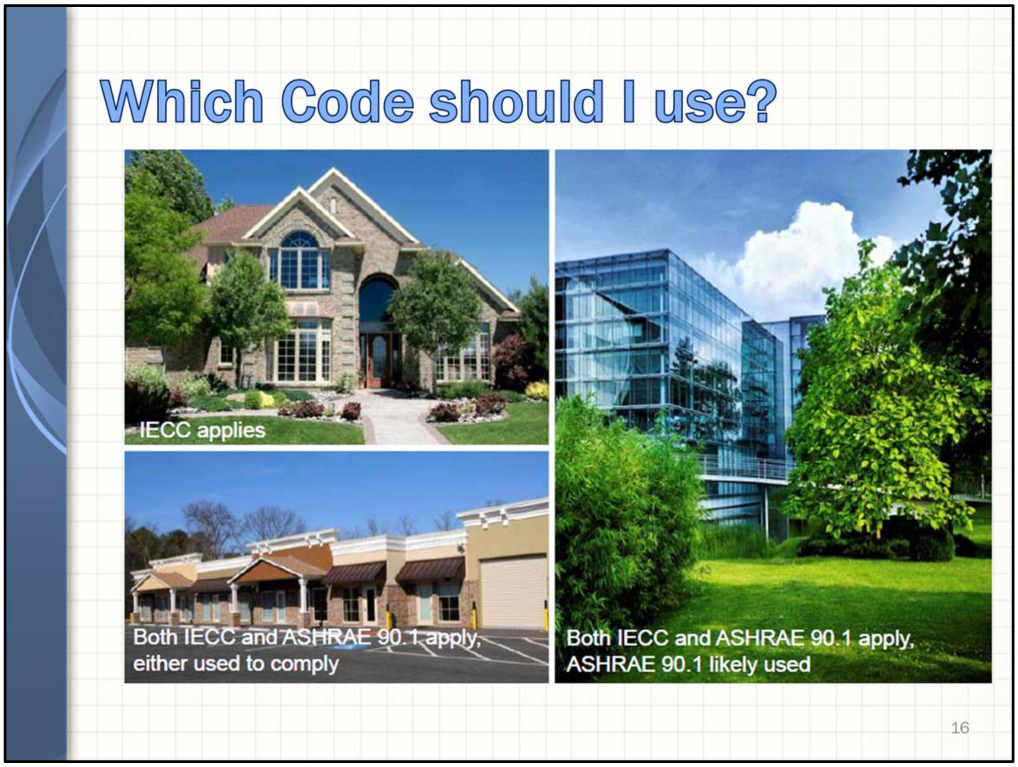
http://www.energycodes.gov/training/presentations.stm IECC 2009 Building Envelope



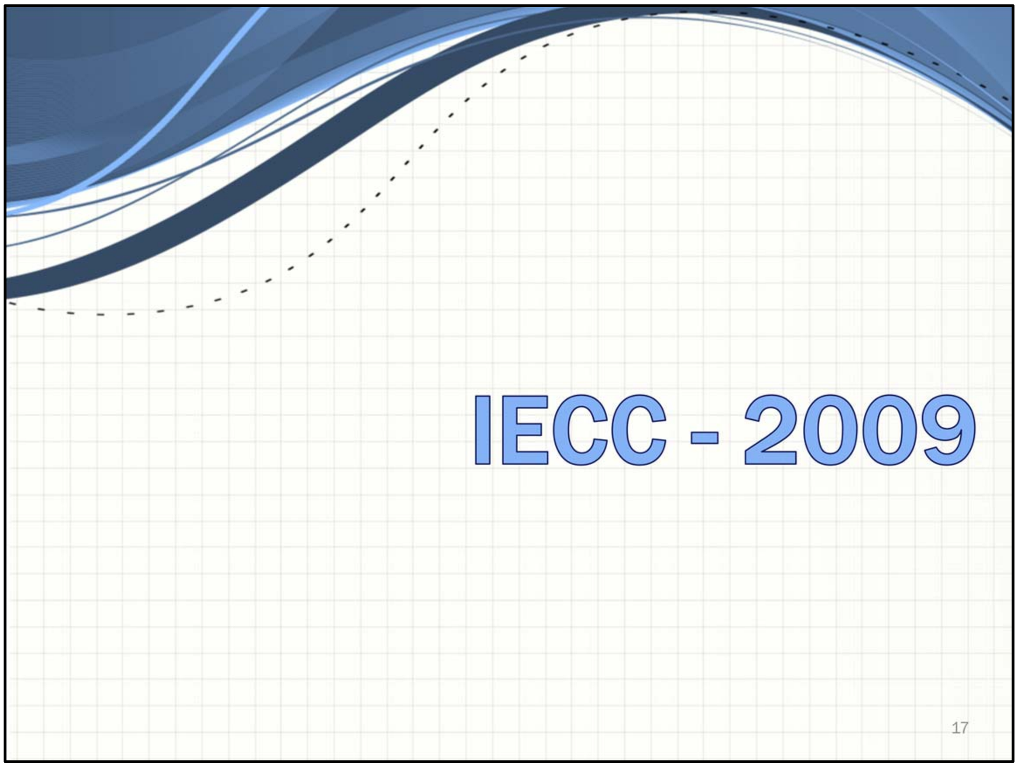
ASHRAE Standard 90.1 has a trade-off option for the building envelope requirements, rather than a simplified approach. Trade-offs in the mechanical systems had been allowed previously, but were eliminated in the 2007 version.

For the Performance Path, also see - Informative Appendix G Performance Rating Method. Again, notice that some provisions are mandatory under either option.


Prescriptive compliance path
IECC
ASHRAE
Building envelope
Section 502
Section 5
Mechanical and service water heating
Section 503 & 504
or
Section 6 & 7
Electric power and lighting
Section 505
Section 9
Extra energy efficiency
Section 506.1, 506.2 or 506.3
Document compliance
Review
Inspection
15



Photos from Building Energy Codes University, https://www.energycodes.gov/sites/default/files/becu/Commercial_90_Percent_Eval_Inspect_Training.pdf



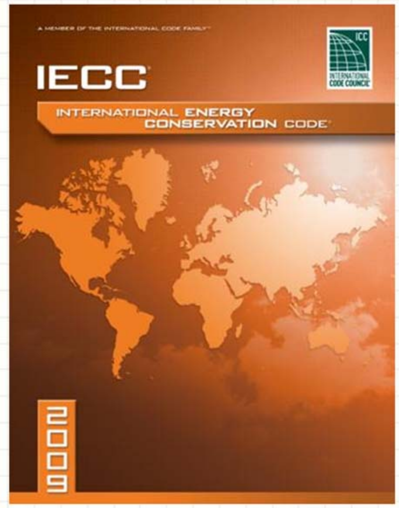
Introduced in 1998, the IECC addresses energy efficiency on several fronts, including cost savings, reduced energy usage, conservation of natural resources, and the impact of energy usage on the environment. Important changes in this sixth edition include:

- A comprehensive set of changes includes measures to improve the thermal envelope, HVAC systems, and electrical systems of residential buildings up to three stories in height.
- Commercial enhancements include required energy savings for windows, doors and skylights; thermal envelope efficiency; and increased efficiencies for installed HVAC equipment.

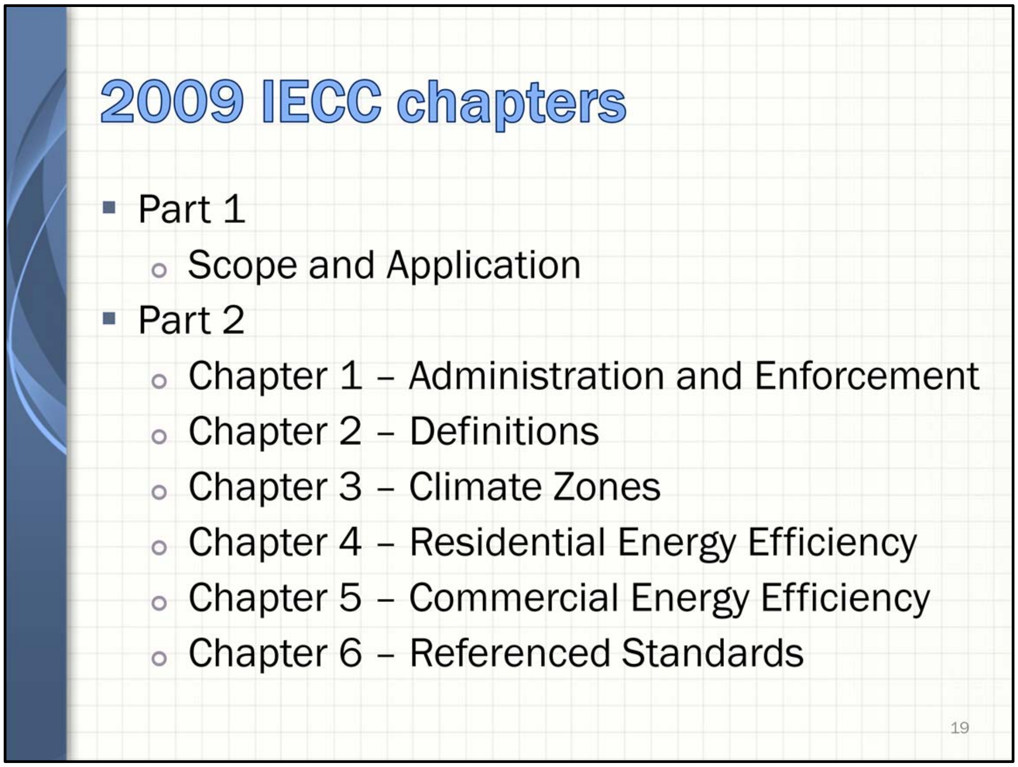
(116 pages) Sample Pages http://www.iccsafe.org/Store/Pages/Product.aspx?id=3800X12

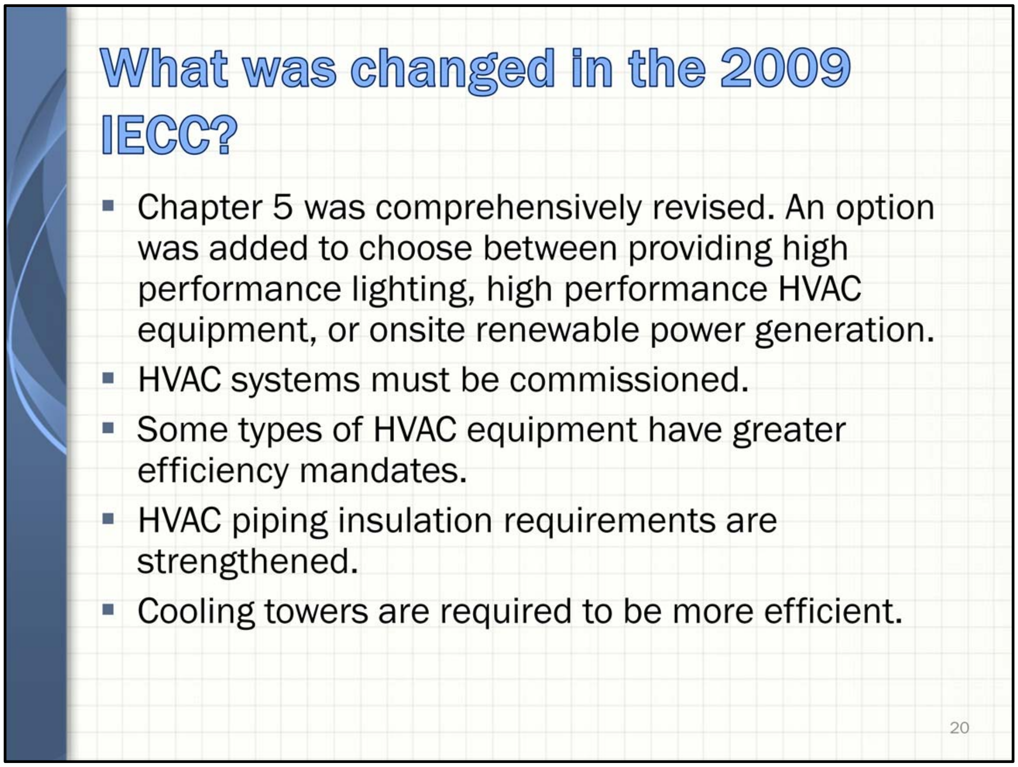
2009 IECC Non-Residential

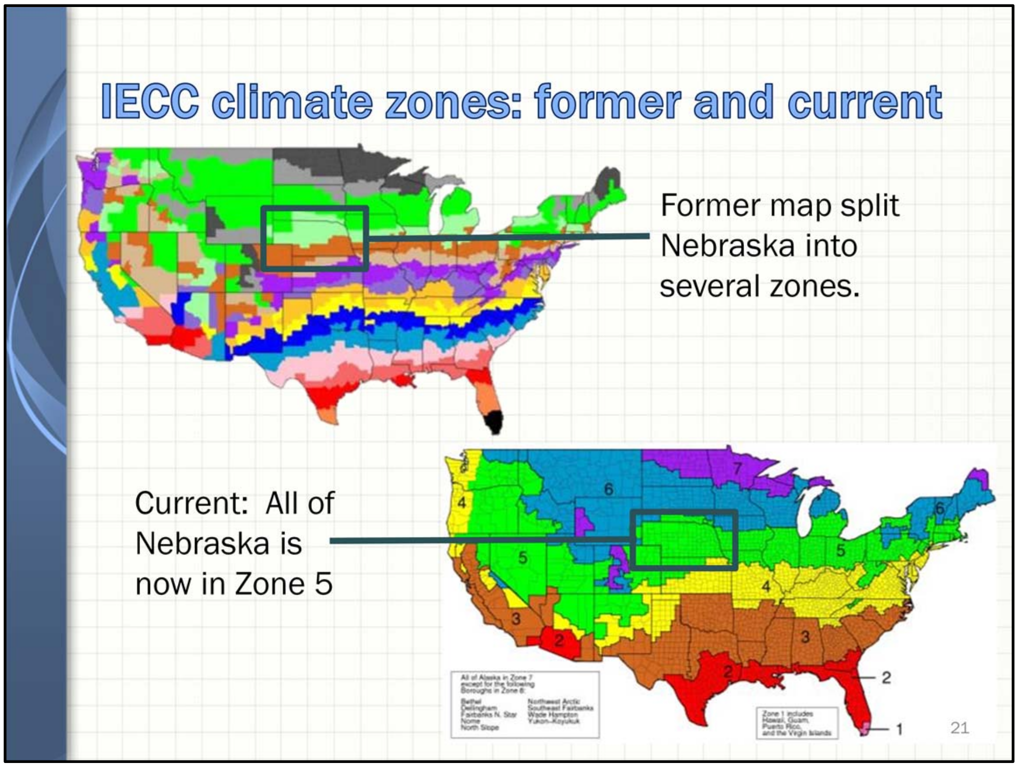
- Applies to all non-residential buildings
- Also applies to Residential buildings greater than 3 stories, including R-1 buildings, hotels and motels.
- It does *not* include R-2, R-3 or R-4 buildings.



18

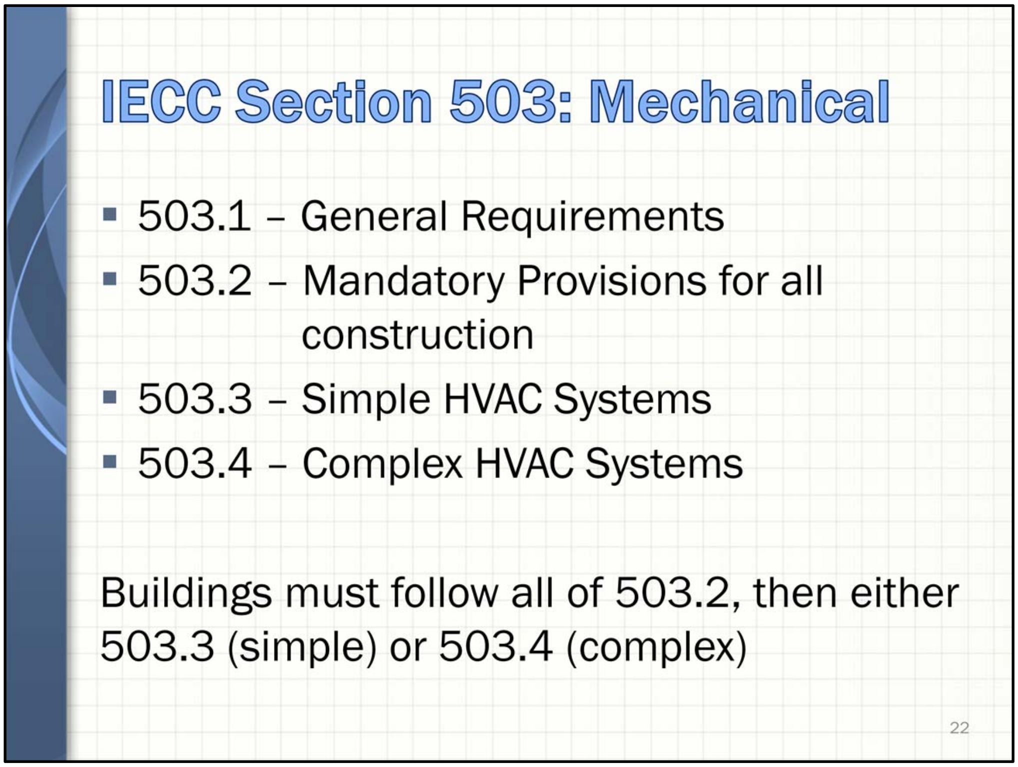

2009 IECC chapters
Part 1
Scope and Application
Part 2
Chapter 1 – Administration and Enforcement
Chapter 2 – Definitions
Chapter 3 – Climate Zones
Chapter 4 – Residential Energy Efficiency
Chapter 5 – Commercial Energy Efficiency
Chapter 6 – Referenced Standards
19


What was changed in the 2009 IECC?
Chapter 5 was comprehensively revised. An option was added to choose between providing high performance lighting, high performance HVAC equipment, or onsite renewable power generation.
HVAC systems must be commissioned.
Some types of HVAC equipment have greater efficiency mandates.
HVAC piping insulation requirements are strengthened.
Cooling towers are required to be more efficient.
20



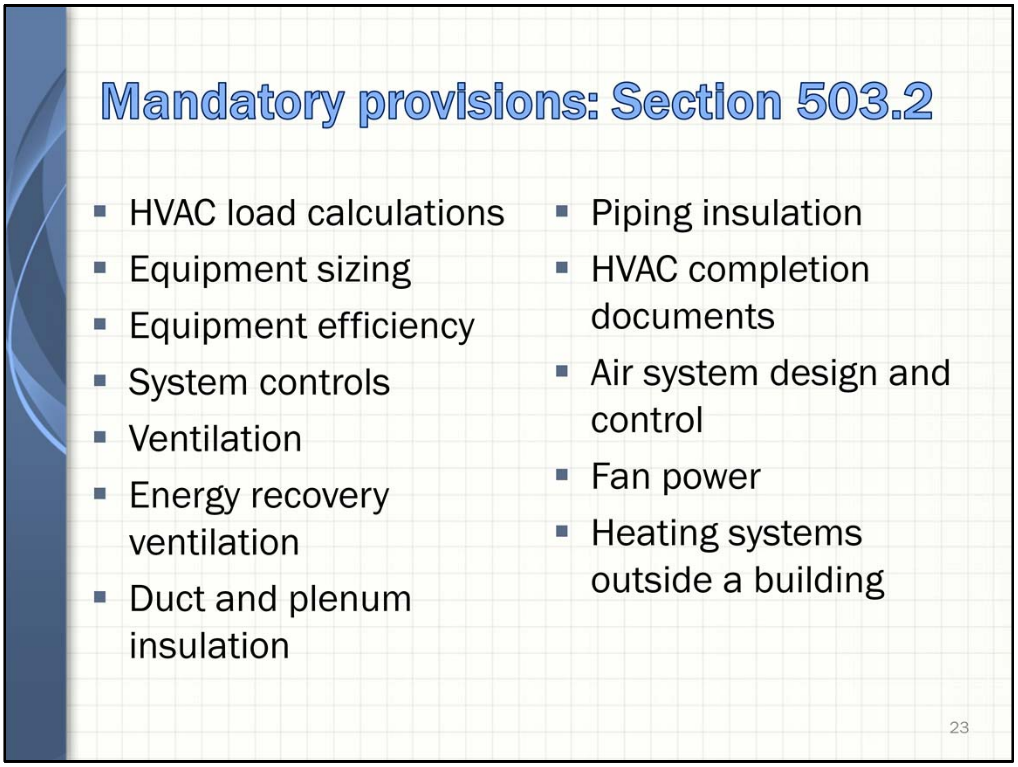
Climate zones for the 2004 Supplement to the IECC, the 2006 IECC, 2009 IECC, ASHRAE 90.1-2004, and ASHRAE 90.1-2007. The zones were revised in 2004.

Maps from the Building Energy Code Resource Center, http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article/1420

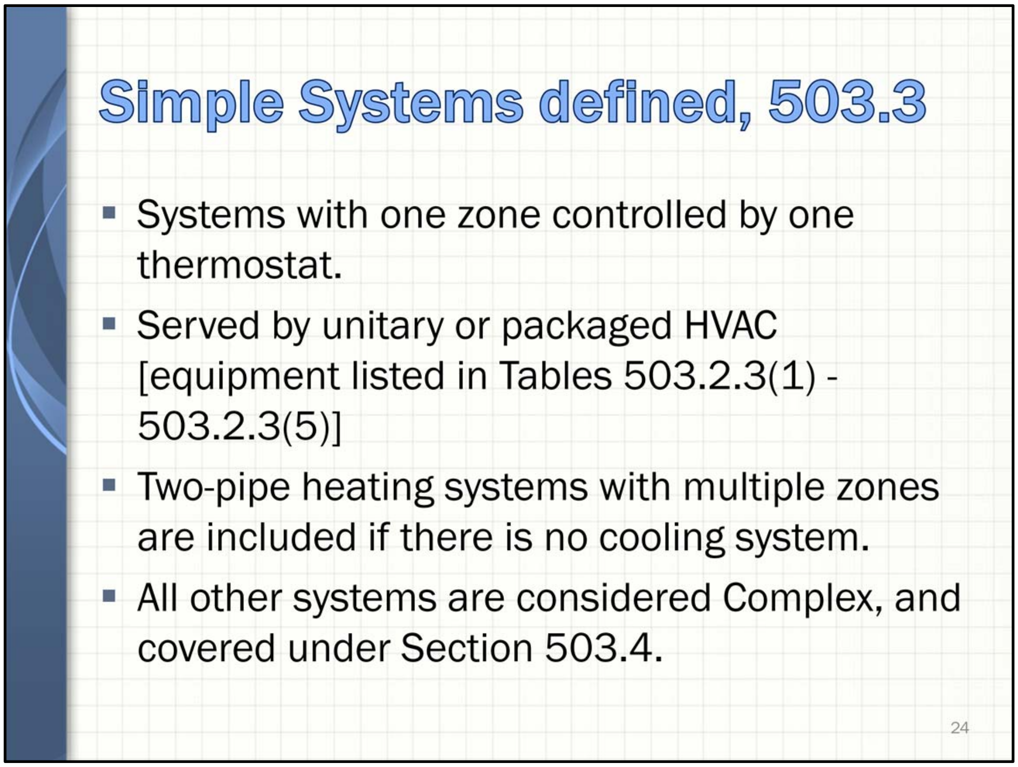


The mandatory provisions apply to all mechanical systems. They specify requirements for HVAC load calculations, equipment sizing, HVAC equipment efficiency, system controls, ventilation, and energy recovery ventilation requirements. They also include requirements for duct and plenum insulation, piping insulation, HVAC completion documents, air system design and control, fan power, and heating systems outside of a building.

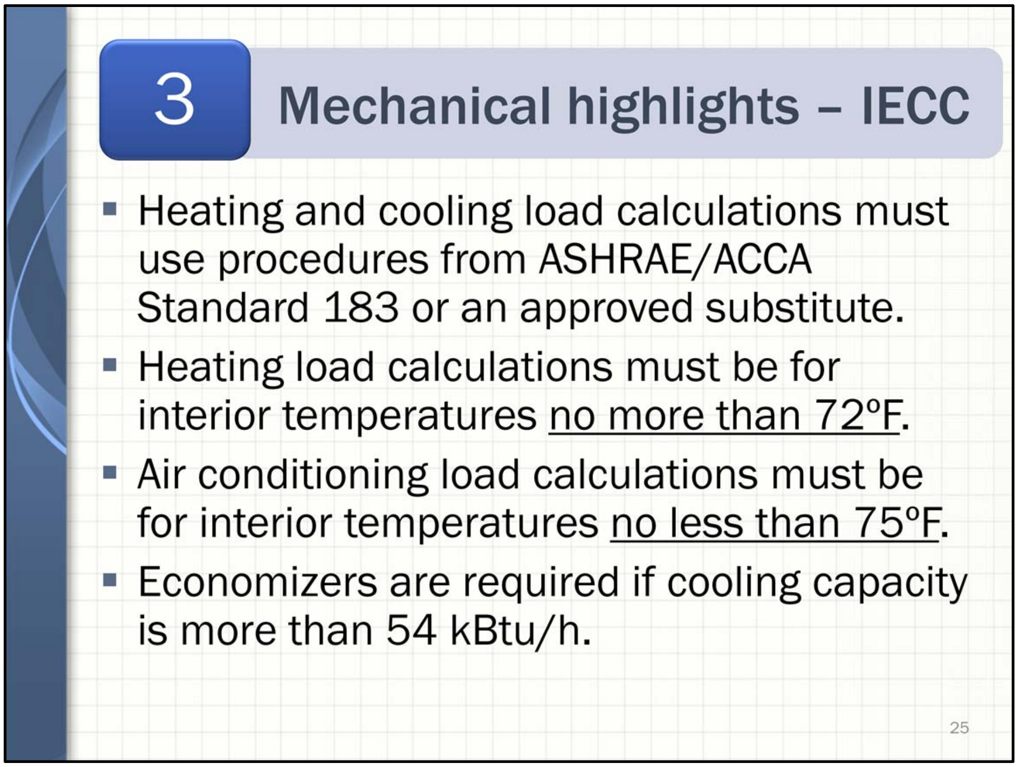
http://www.energycodes.gov/training/pdfs/2009_iecc_comm_mechanical_transcript.pdf



All of these are always mandatory, even if you are following the total building performance option. They are described in Section 503.2 of the 2009 IECC.

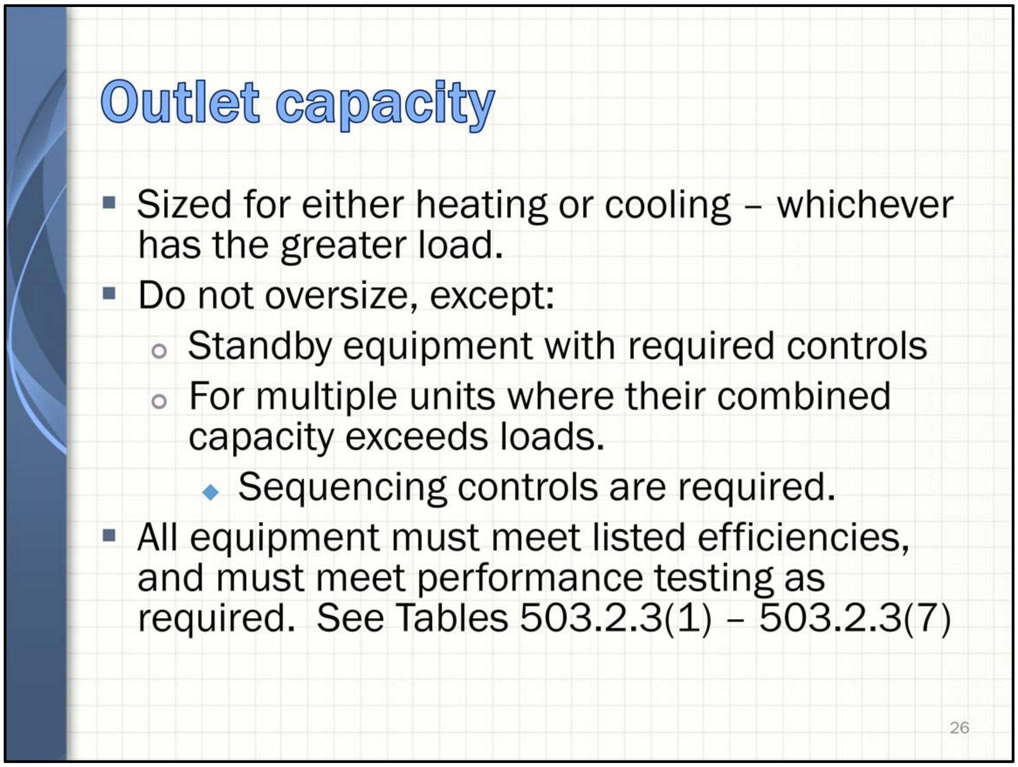

Simple Systems defined, 503.3
Systems with one zone controlled by one thermostat.
Served by unitary or packaged HVAC [equipment listed in Tables 503.2.3(1) - 503.2.3(5)]
Two-pipe heating systems with multiple zones are included if there is no cooling system.
All other systems are considered Complex, and covered under Section 503.4.
24

2009 IECC

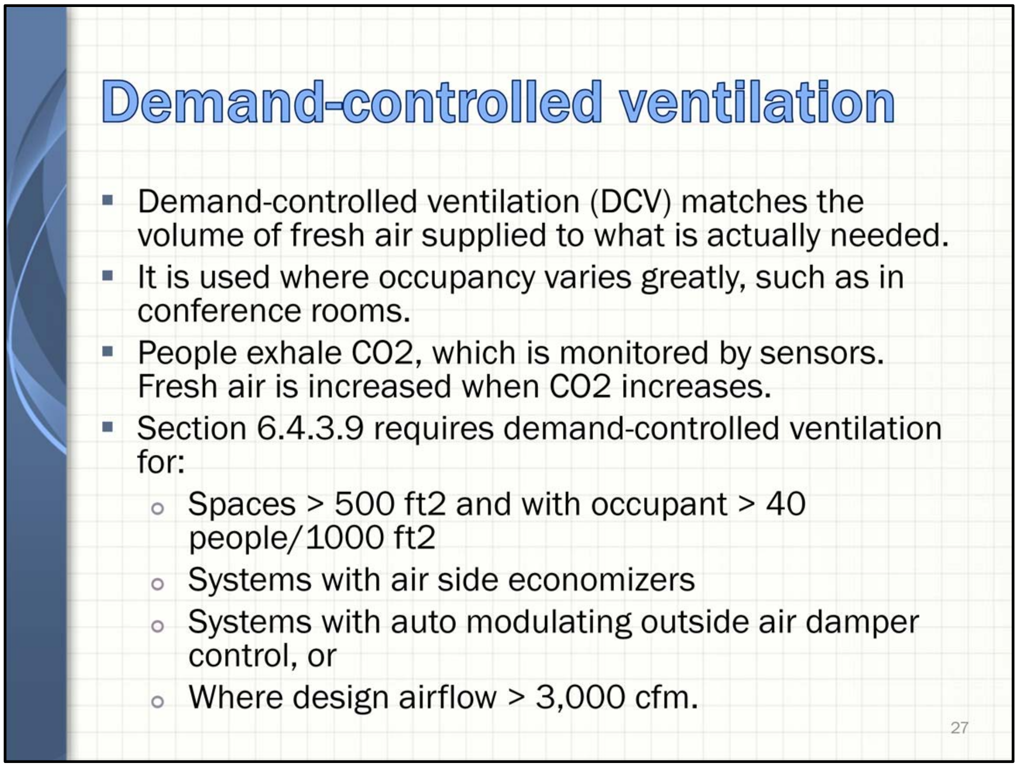


Interior design conditions specified in IECC Section 302, exterior conditions specified by ASHRAE.

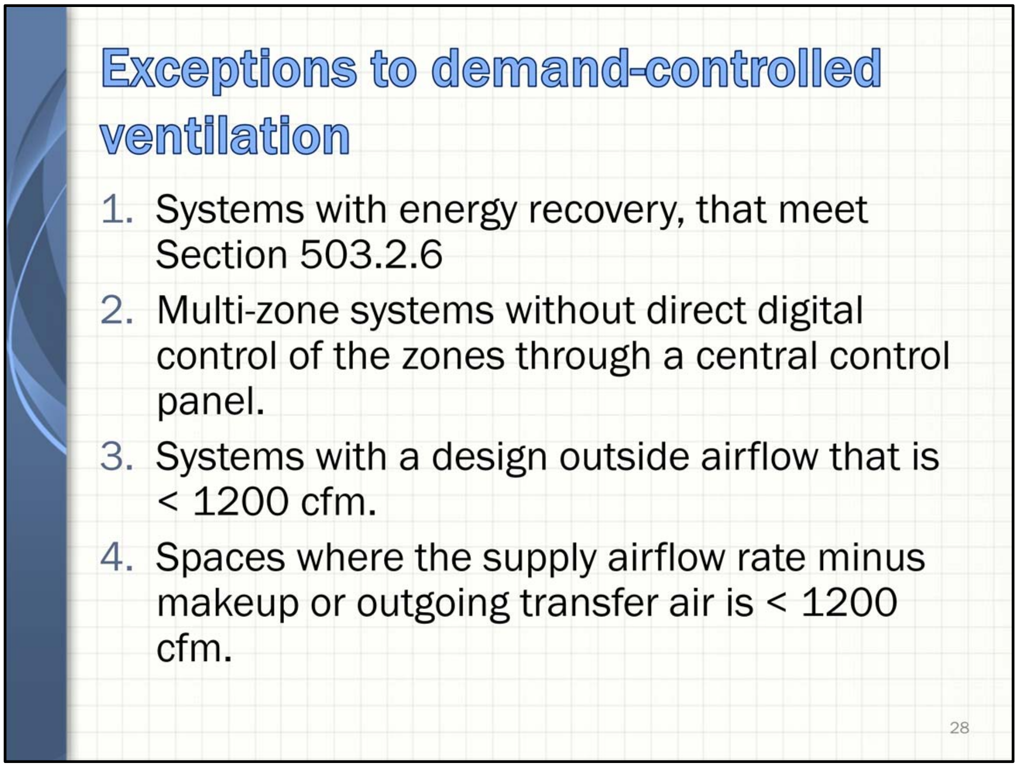
www.energycodes.gov/training/.../2009_iecc_comm_mechanical.ppt



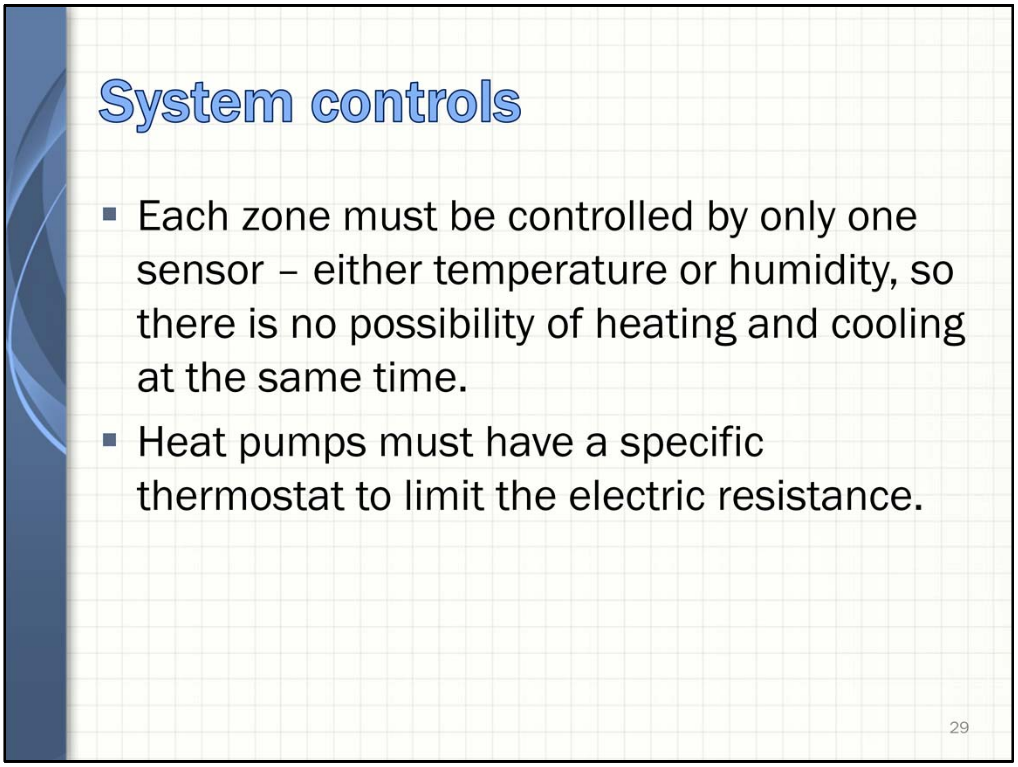
All HVAC equipment, such as furnaces, air conditioners, chillers, boilers, and heat pumps, must meet performance and minimum efficiencies. The exception is for water cooled centrifugal chillers, operating in non-standard conditions. An adjustment factor, k_{adjust} is used for this.



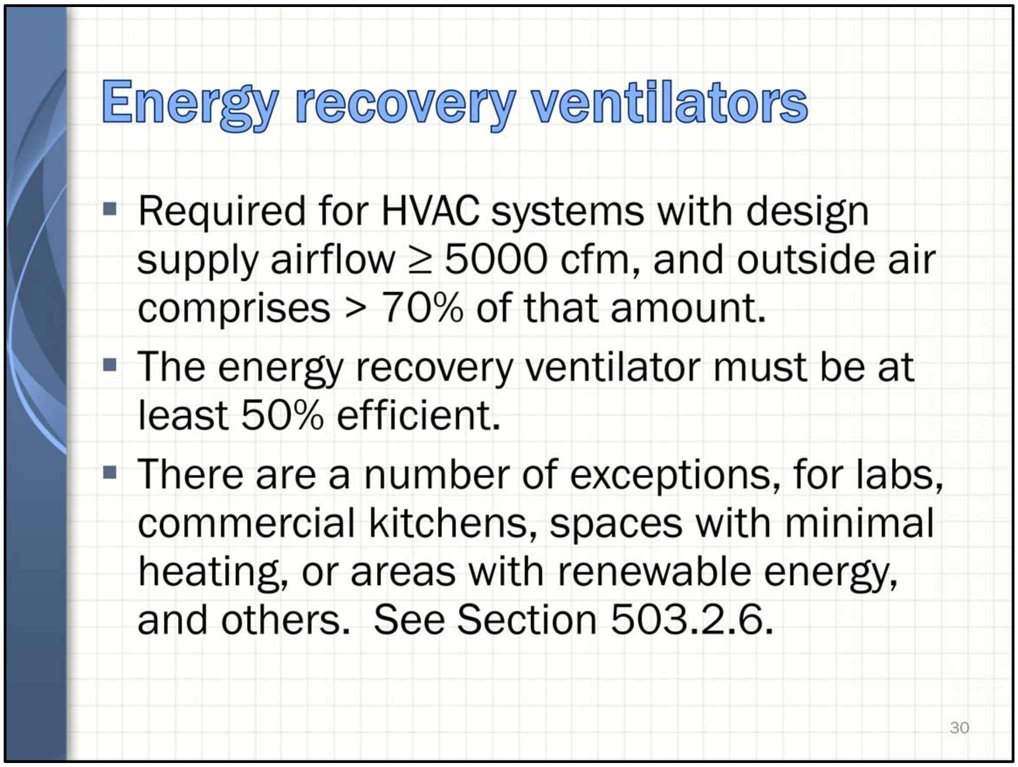
https://www.energycodes.gov/sites/default/files/becu/Commercial_90_Percent_Eval_Inspect_Training.pdf



From Section 503.2.5.1 of 2009 IECC.



http://www.energycodes.gov/training/pdfs/2009_iecc_comm_mechanical_transcript.pdf

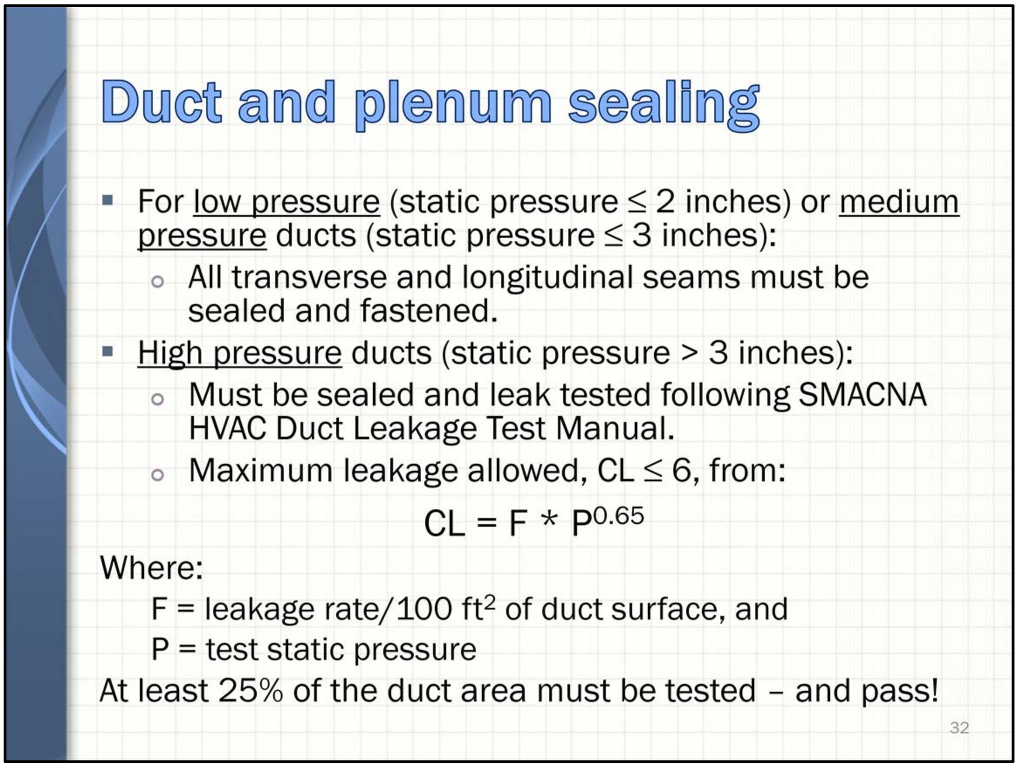

Energy recovery ventilators
Required for HVAC systems with design supply airflow ≥ 5000 cfm, and outside air comprises > 70% of that amount.
The energy recovery ventilator must be at least 50% efficient.
There are a number of exceptions, for labs, commercial kitchens, spaces with minimal heating, or areas with renewable energy, and others. See Section 503.2.6.
30

2009 IECC

Duct and plenum insulation

- Required for all supply and return ducts and plenums, unless they are in conditioned spaces.
- In an unconditioned interior space, use R-5 insulation.
- Outside the building, use R-8 insulation.
- Ducts supplying cooling air only do not require insulation to reduce energy losses, but may be advisable to prevent condensation.

31

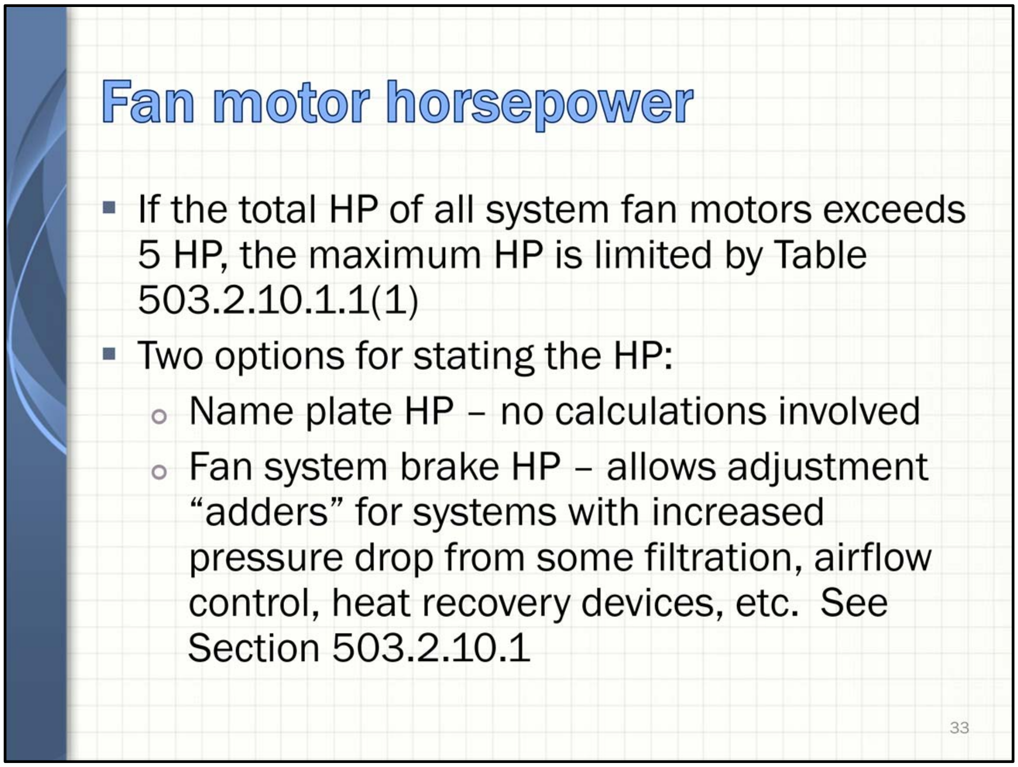


2009 IECC Section 503.2.7

Note: There is an exception for continuously welded and locking-type longitudinal seams on supply ducts with static pressure < 2 inches. ASHRAE Standard 90.1 has the same standard without this exception.

Standard 90.1 also does not set the maximum leakage at 6, but instead allows a variable amount. See Section 6.4.4.2.2

http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf

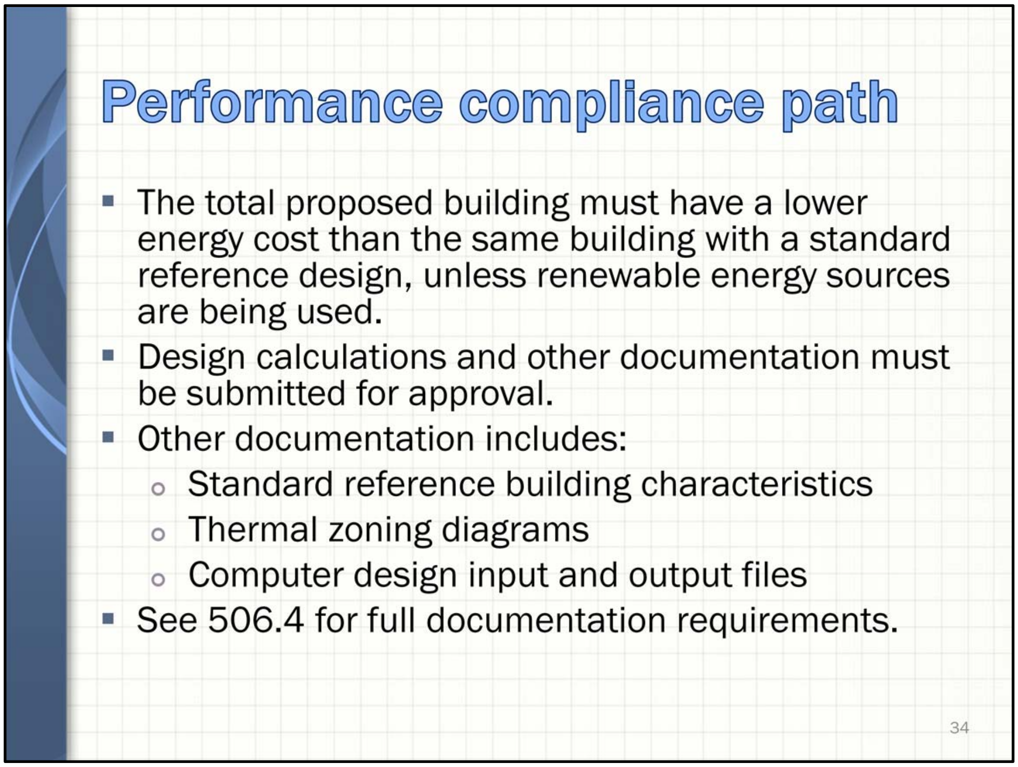


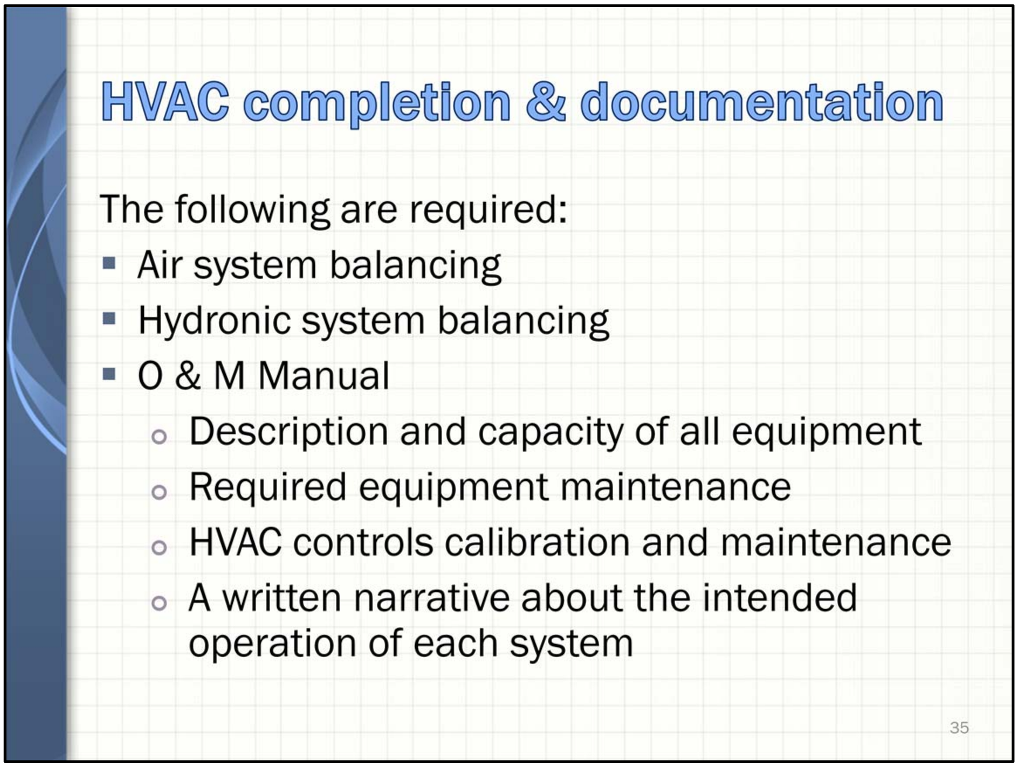
There are exceptions for hospital and lab systems, individual exhaust fans ≤ 1 hp, or fans with fume hoods.

"Brake horsepower (bhp) is the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, differential, water pump, and other auxiliary components such as power steering pump, muffled exhaust system, etc. *Brake* refers to a device which was used to load an engine and hold it at a desired RPM. During testing, the output torque and rotational speed were measured to determine the *brake horsepower*."

http://en.wikipedia.org/wiki/Horsepower

http://www.energycodes.gov/training/pdfs/2009_iecc_comm_mechanical_transcript.pdf


Performance compliance path
The total proposed building must have a lower energy cost than the same building with a standard reference design, unless renewable energy sources are being used.
Design calculations and other documentation must be submitted for approval.
Other documentation includes:
Standard reference building characteristics
Thermal zoning diagrams
Computer design input and output files
See 506.4 for full documentation requirements.
34



Section 503.2.9

Other topics – See http://www.energycodes.gov/training-courses/commercial-mechanical-requirements-2009-iecc,

Presentation slides at: http://www.energycodes.gov/sites/default/files/becu/2009_iecc_mechanical.pdf

- Piping insulation (503.2.8),
- Hydronic systems (503.4.3),
- Water Loop Heat Pump systems (5043.4.3.3),
- Part Load Control (503.4.3.4),
- Pump Isolation (503.4.3.5),
- Heat rejection equipment fan speed control (503.4.4),
- Multiple zone system airside req’mts (503.4.5),
- terminal devices for single duct VAV systems (503.4.5.1),
- dual duct and mixing vav systems, supply air temp reset controls (503.4.5.4),
- Heat recovery for service hot water heating (503.4.6),.
- Service Water heating, Section 504.

American Society of Heating, Refrigerating and Air Conditioning Engineers, in existence since 1894!

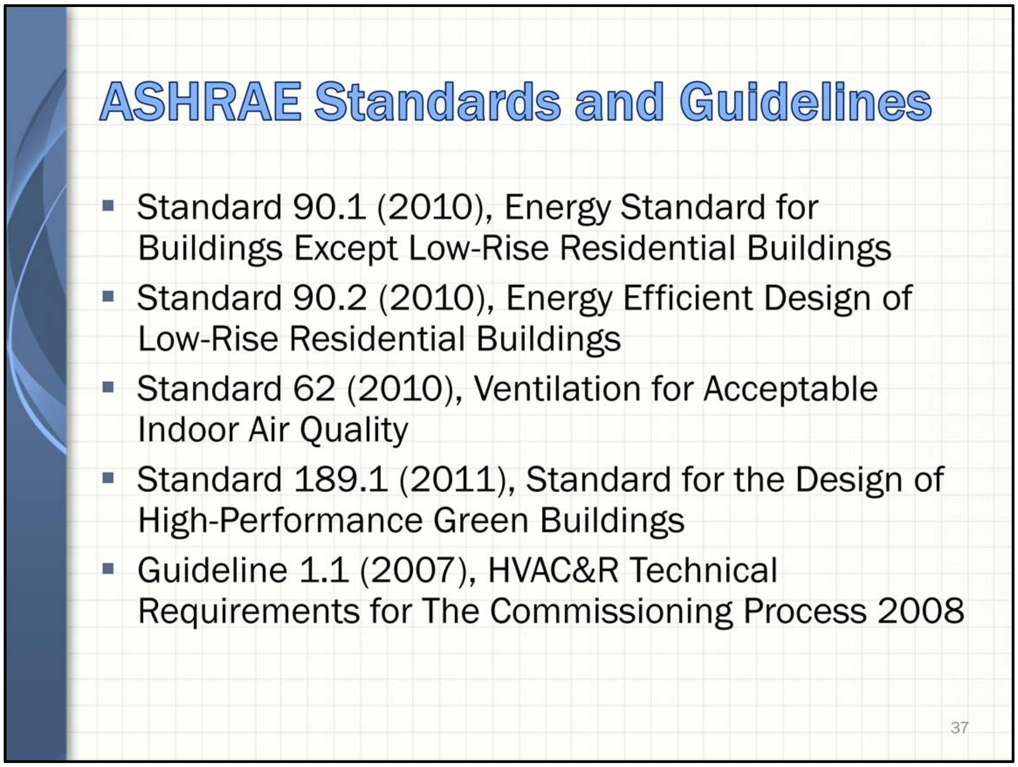
This is an international society (even though the name includes ‘American’) comprised of organizations and individuals involved in heating, ventilation, air conditioning, and refrigeration. The organization’s purpose is to exchange experience and develop standards and guidelines.

They publish *The ASHRAE Handbook* – 4 volumes, both on-line and in hard copy: *Fundamentals*, *HVAC Applications, HVAC Systems and Equipment*, and *Refrigeration*.

Rap video on You-tube: License to Chill: It's cool to be an HVAC engineer!

“*ASHRAE: Licensed to Chill* features a hot soundtrack accompanied by interviews with young members highlighting the importance of the HVAC&R industry to the world; the diverse and creative opportunities related to engineering as a career; and the difference the building industry makes related to sustainability.

"The video drives home the message that our industry truly engineers the world we live in, and that young people don't want to miss out on the chance to be a part of that," he said.” http://www.youtube.com/watch?v=P1sqBI9aPtA



There are a number of ASHRAE standards and guidelines that you should be aware of.

ASHRAE standards are generally accepted but not legally binding, unless they are adopted by state and local building codes. These are the latest versions of each. Standard 90.1 is also sponsored by the Illuminating Engineering Society of North America (IESNA) and approved by the American National Standards Institute (ANSI).

Standard 90.1-2010 (I-P Edition) -- Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI Approved; IESNA Co-sponsored)

Standard 62.1 See discussion paper: http://www.automatedbuildings.com/news/jan03/articles/ebtron/ebt.htm

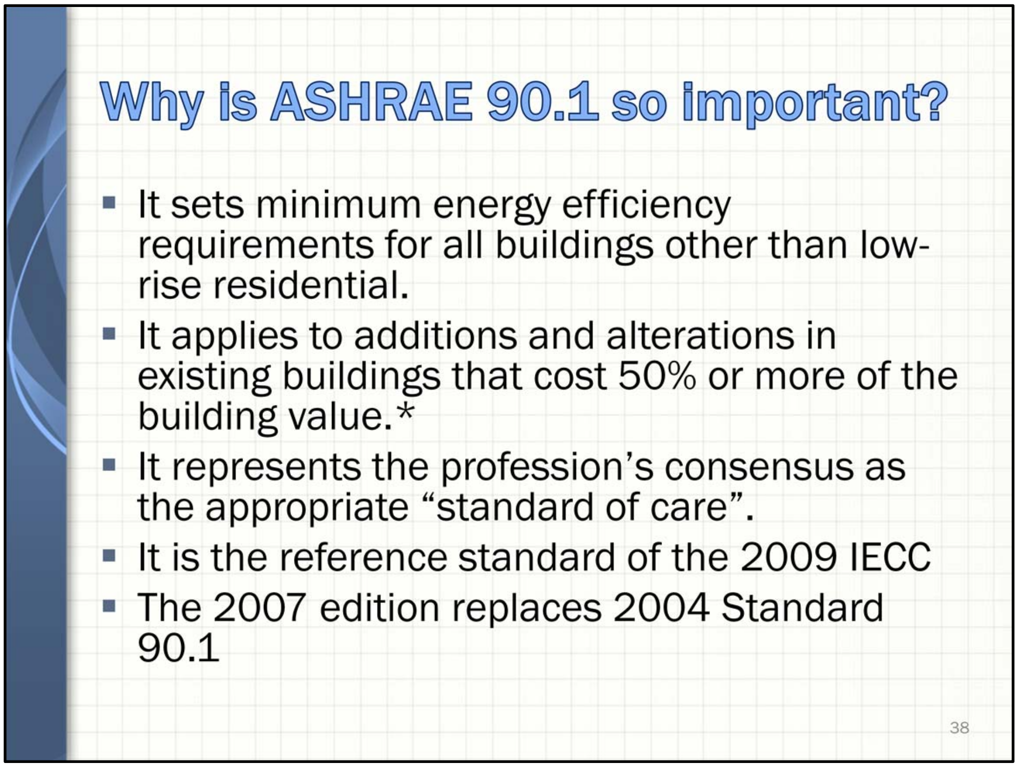
Standard 62.1-2010 -- Ventilation for Acceptable Indoor Air Quality (ANSI Approved)

Standard 62.2-2010 -- Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings (ANSI/ASHRAE Approved) 2010

Standard 170-2008 -- Ventilation of Health Care Facilities (ANSI/ASHRAE/ASHE Approved) 2008

Standard 189.1-2011 -- Standard for the Design of High-Performance Green Buildings (ANSI Approved; USGBC and IES Co-sponsored)

Guideline 1.1-2007 -- HVAC&R Technical Requirements for The Commissioning Process 2008

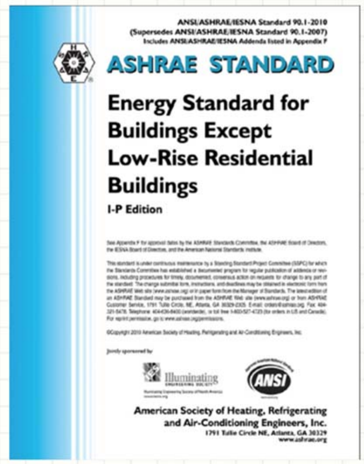


First, ASHRAE 90.1 is sometimes referred to as ANSI/ASHRAE/IESNA Standard 90.1 – 07. The American National Standards Institute (ANSI) and the Illuminating Engineering Society of North America (IESNA) are joint participants in developing the code.

* Nebraska sets the 50% threshold; most states require all modifications to meet the ASHRAE code. Even though it is not required for small alterations, we strongly recommend that it be carefully considered. In most cases the energy savings make it in the owner's interest to meet the ASHRAE code.

ASHRAE 90.1-2007

- Sections and titles:
  - 1 - Purpose
  - 2 - Scope
  - 3 - Definitions, Abbreviations, and Acronyms
  - 4 - Administration and Enforcement
  - 5 - Building Envelope
  - 6 - HVAC
  - 7 - Service Water Heating
  - 8 - Power
  - 9 - Lighting
  - 10 - Other Equipment
  - 11 - Energy Cost Budget Method
  - 12 - Normative References


ANSI/ASHRAE/IESNA Standard 90.1-2010
(Supersedes ANSI/ASHRAE/IESNA Standard 90.1-2007)
Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F

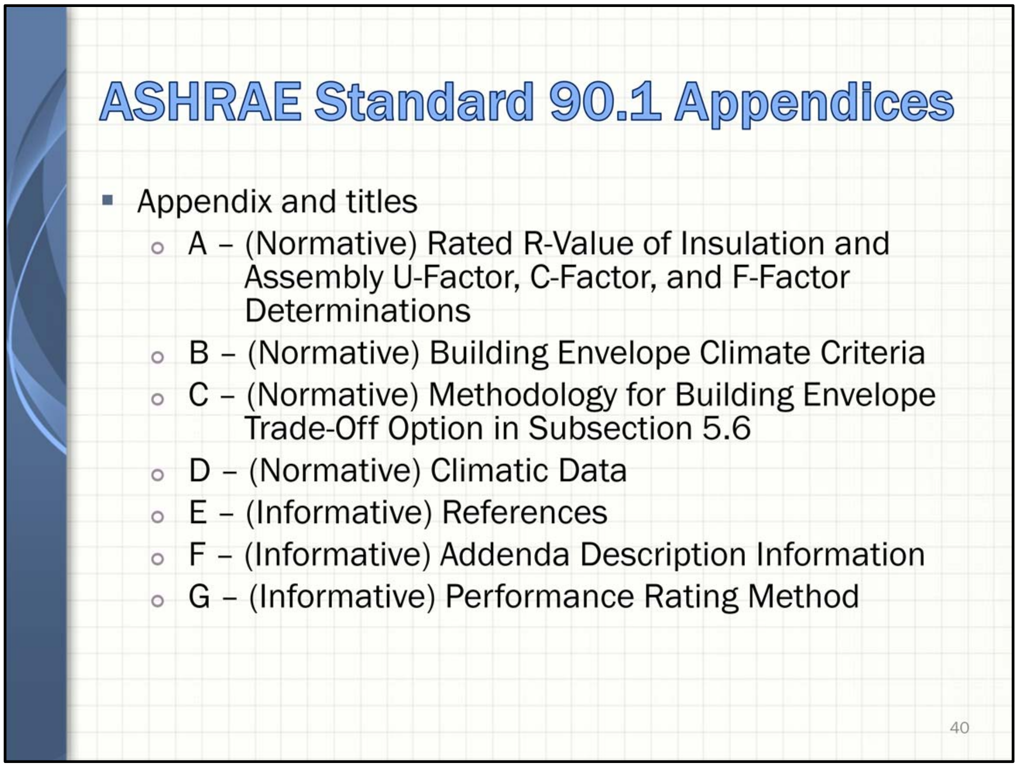
ASHRAE STANDARD

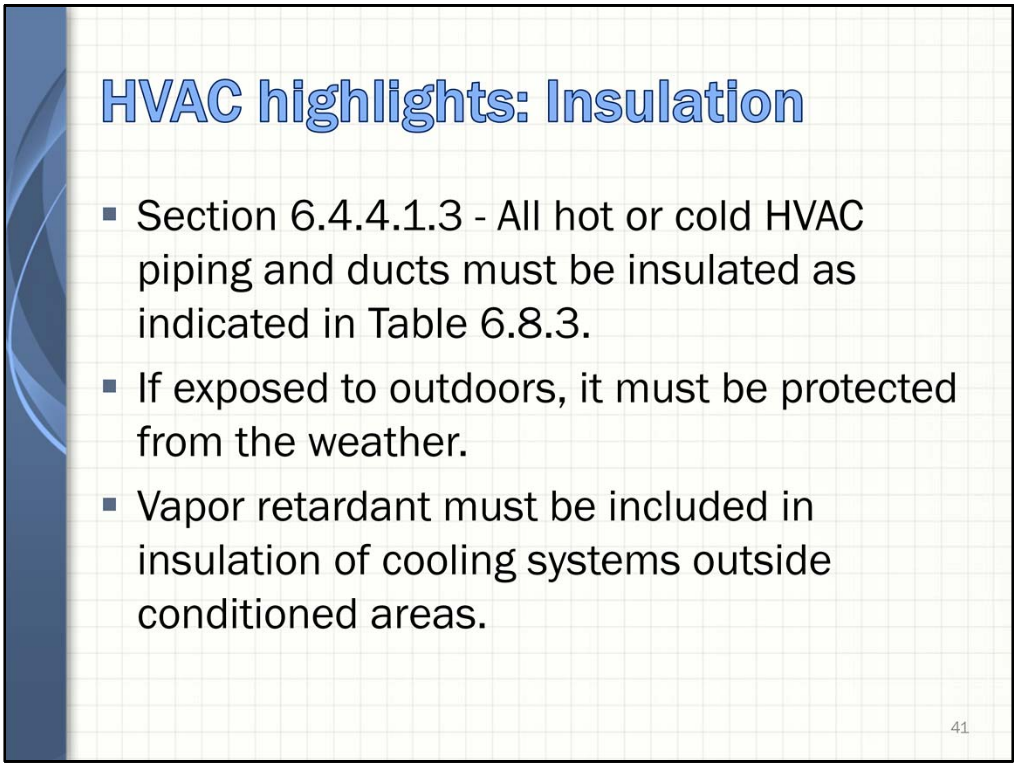
Energy Standard for Buildings Except Low-Rise Residential Buildings

I-P Edition

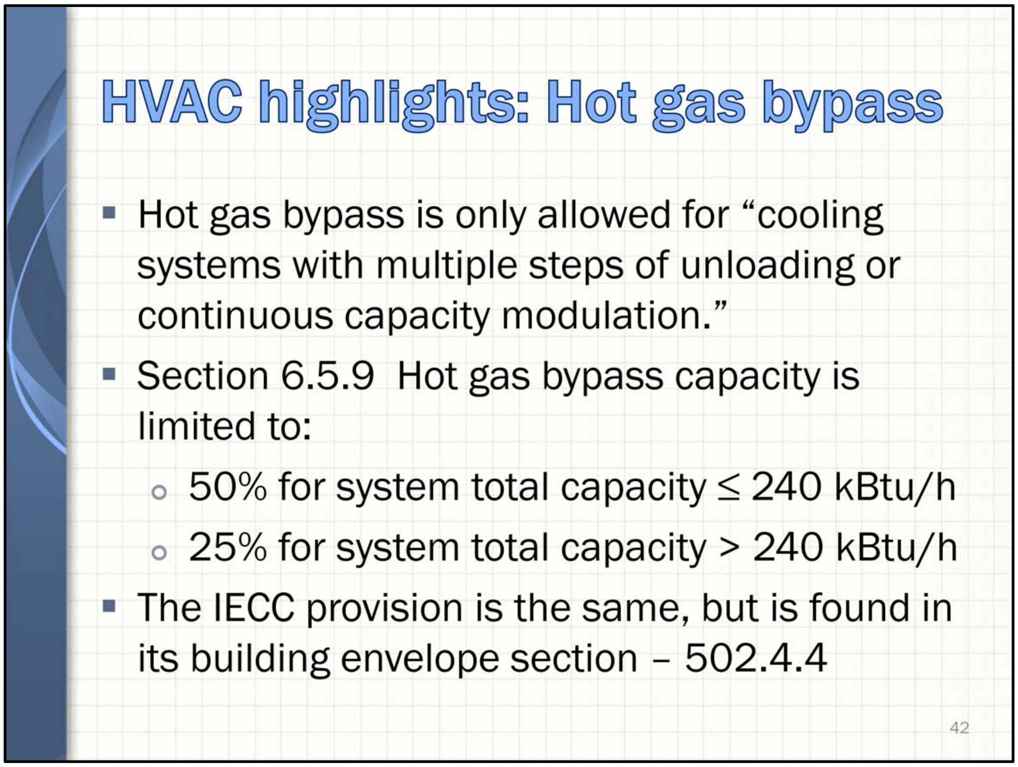
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle NE, Atlanta, GA 30329
www.ashrae.org

39


ASHRAE Standard 90.1 Appendices
Appendix and titles
A – (Normative) Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations
B – (Normative) Building Envelope Climate Criteria
C – (Normative) Methodology for Building Envelope Trade-Off Option in Subsection 5.6
D – (Normative) Climatic Data
E – (Informative) References
F – (Informative) Addenda Description Information
G – (Informative) Performance Rating Method
40

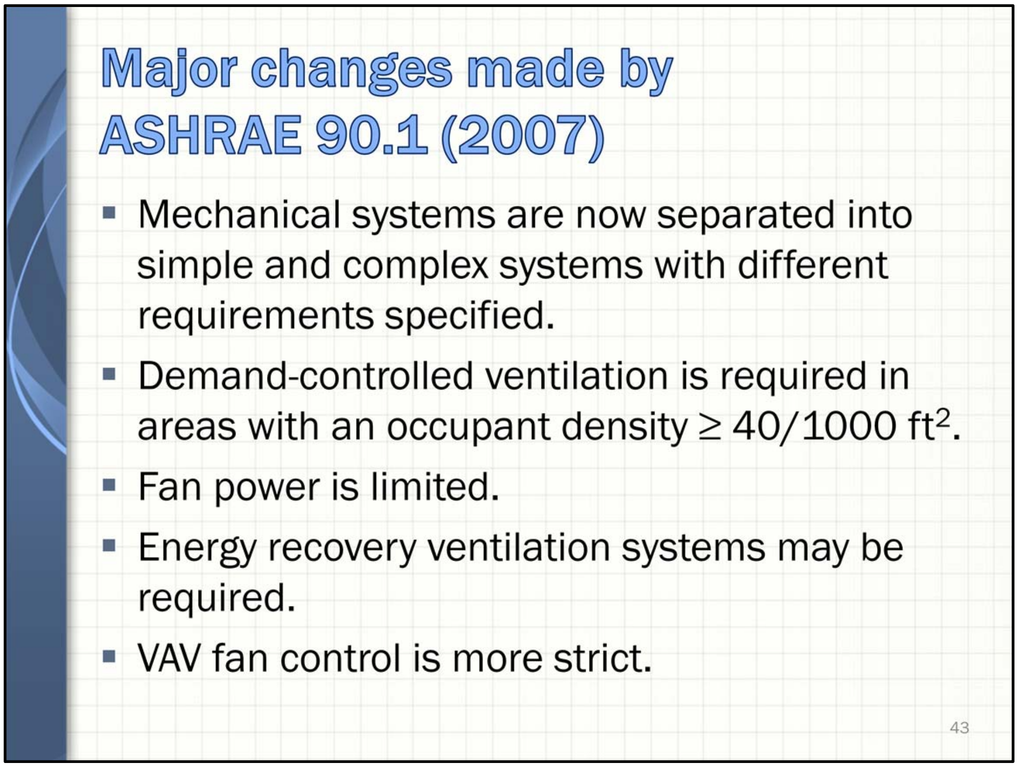


https://www.energycodes.gov/sites/default/files/becu/Commercial_90_Percent_Eval_Inspect_Training.pdf



https://www.energycodes.gov/sites/default/files/becu/Commercial_90_Percent_Eval_Inspect_Training.pdf

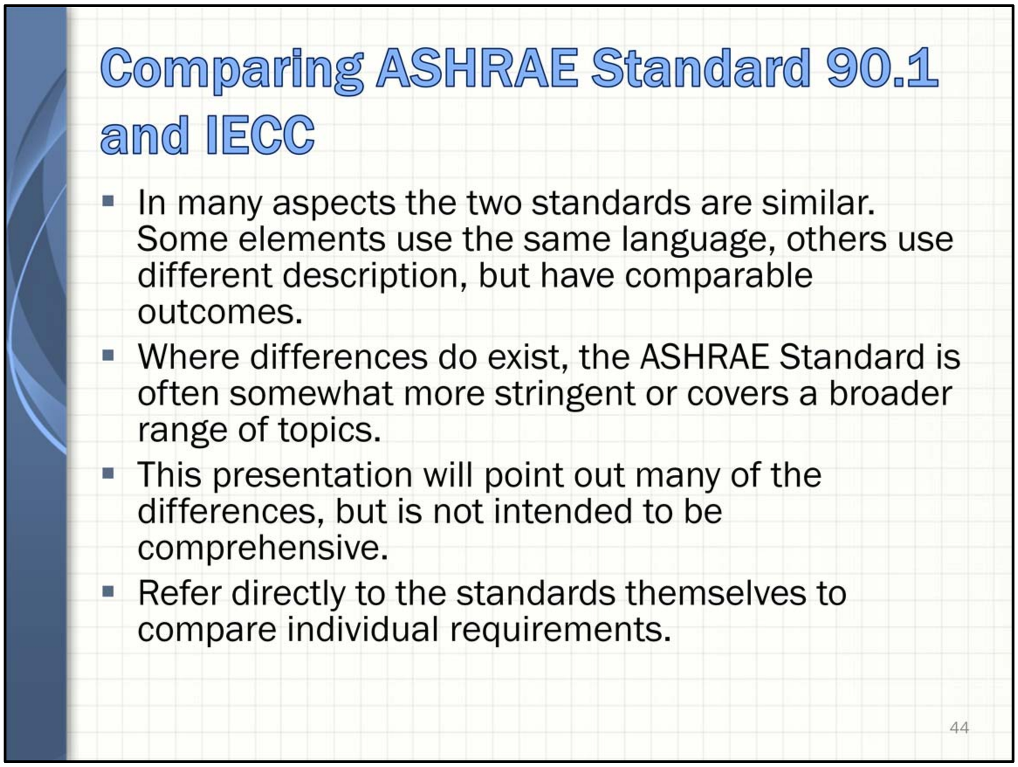
http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf

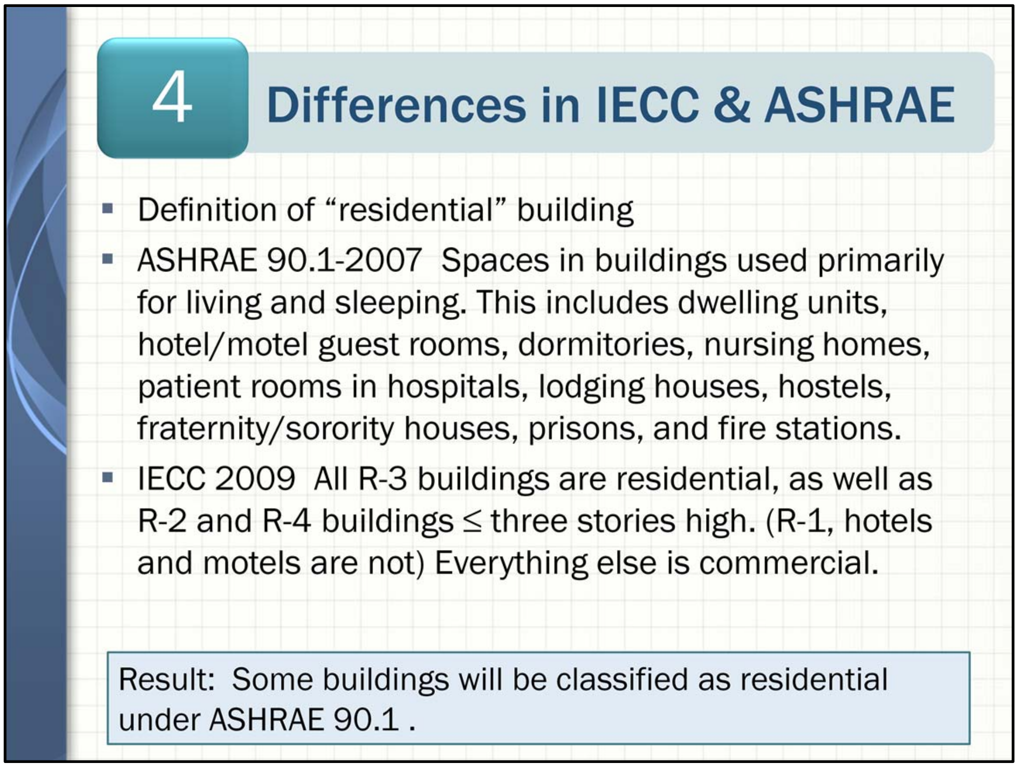


See
http://www.energycodes.gov/publications/techassist/commercial/Commercial_Nebraska.pdf
- especially beginning on pg 14

Changes from the 2003 IECC, and 2001 Standard 90.1 have affected areas other than mechanical systems. Some of them are:

- The changes in climate zones have resulted in more stringent building envelopes.
- Before all windows met the same standard – now there is some differentiation in requirements by frame type and location of fenestration.
- Stringent building insulation requirements
- Simplified fenestration requirements excluding orientation and window wall ratio
- Changes to lighting for retail desplays and outdoor lighting.


Comparing ASHRAE Standard 90.1 and IECC
In many aspects the two standards are similar. Some elements use the same language, others use different description, but have comparable outcomes.
Where differences do exist, the ASHRAE Standard is often somewhat more stringent or covers a broader range of topics.
This presentation will point out many of the differences, but is not intended to be comprehensive.
Refer directly to the standards themselves to compare individual requirements.
44

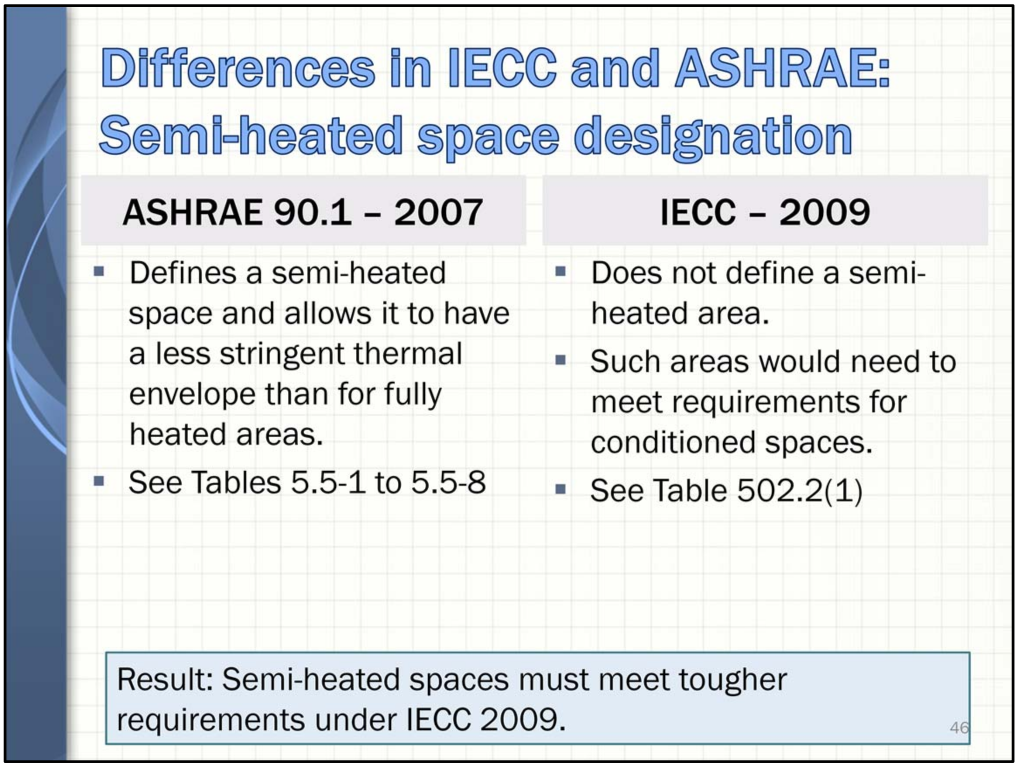


http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf http://www.scribd.com/doc/48719204/13/Semi-heated-space-designa3on

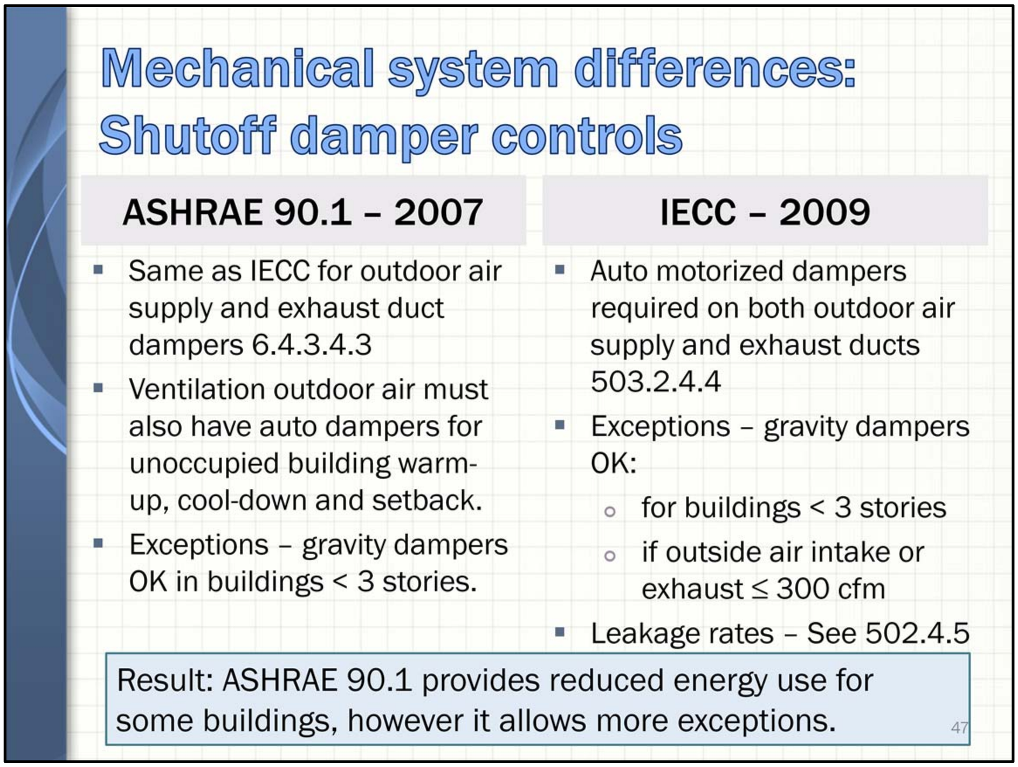
Buildings exempt from ASHRAE 90.1:

- Single or multi-family homes ≤ 3 stories high
- Pre-manufactured and modular homes
- Buildings using renewable energy supply (not fossil fuels or electricity).
- Areas of buildings and equipment where energy use is primarily for industrial, manufacturing or commercial processes.
- Alterations to historic buildings
- Alterations to buildings with energy consumption ≤ an equivalent building that meeting Sections 5-10

There are many differences in items affecting the building envelope. For a summary of them, see: http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf



http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf

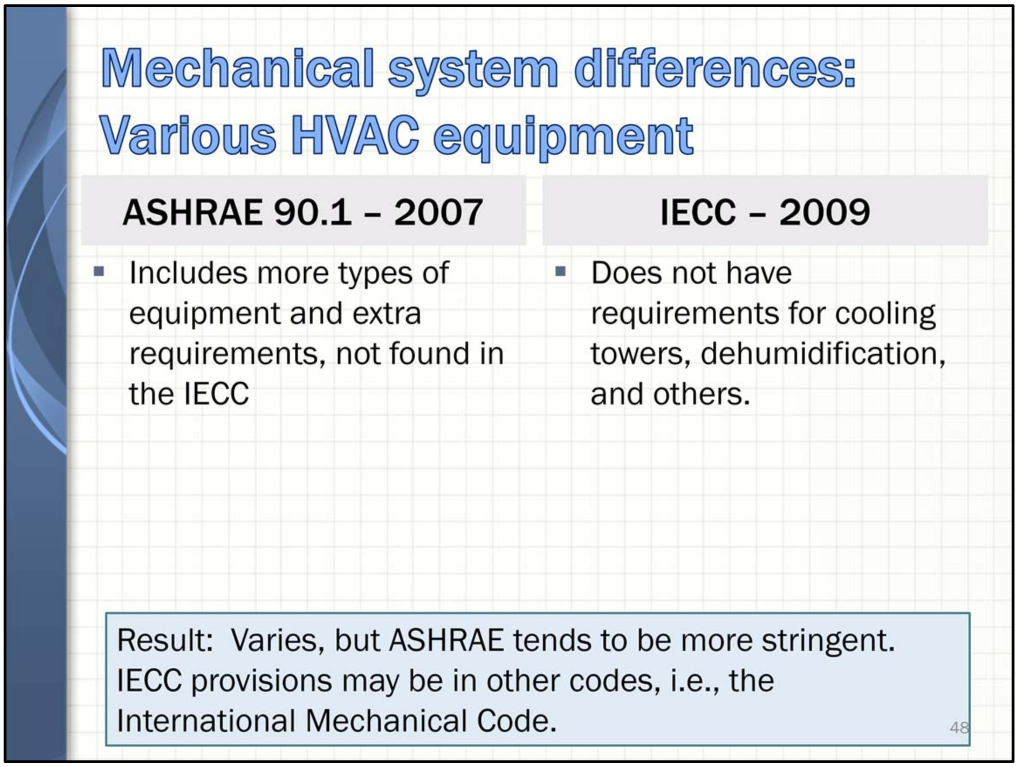


ASHRAE has different values for climate zones 1, 2, 6, 7, and 8https://www.energycodes.gov/sites/default/files/becu/Commercial_90_Percent_Eval_Inspect_Training.pdf

ASHRAE 6.4.3.4.3 Sets maximum air leakage rates for return air and outdoor air dampers:

- 10 cfm/ft^2 damper area for motorized
- 20 cfm/ft^2 damper area for non-motorized
- 40 cfm/ft^2/damper area for dampers < 24 in L or W

"In some cases the allowable damper leakage rates in Standard 90.1-07 are higher than those in the 2009 IECC. Thus, in some cases, the 2009 IECC is more stringent". *Comparison of Standard 90.1-07 and the 2009 IECC with Respect to Commercial Buildings*, pg 3, December 2009. Also see discussion on Pg. 24. http://www.energycodes.gov/publications/research/documents/codes/90-1_iecc_comparison_final_12-16-2009.pdf



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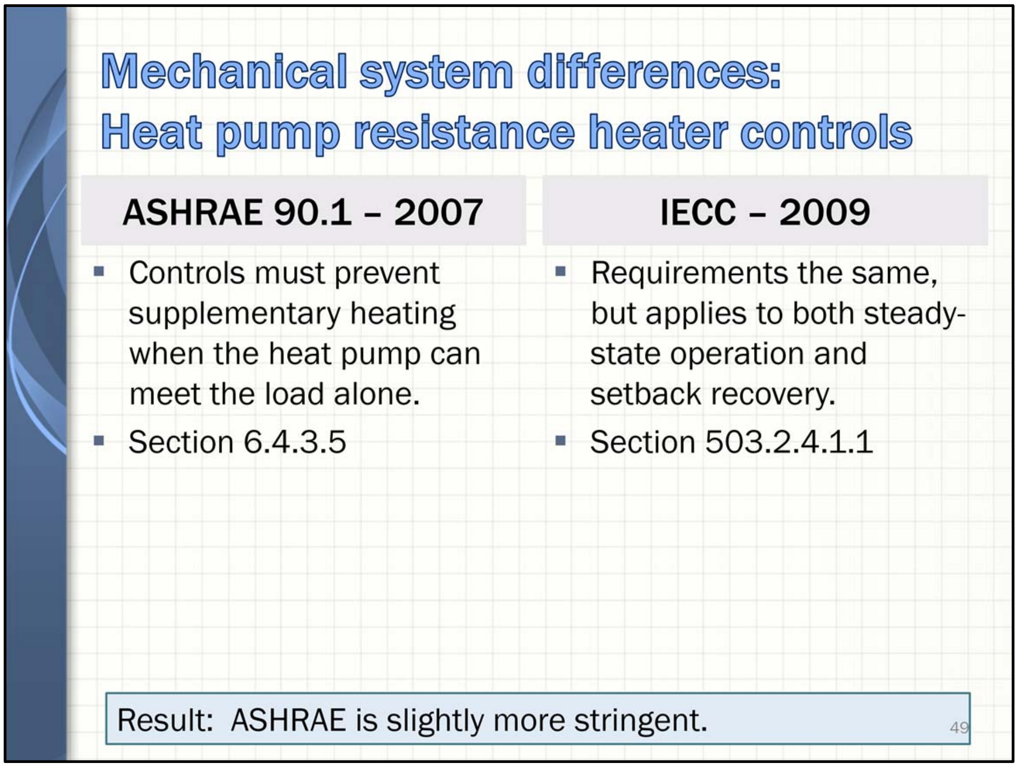

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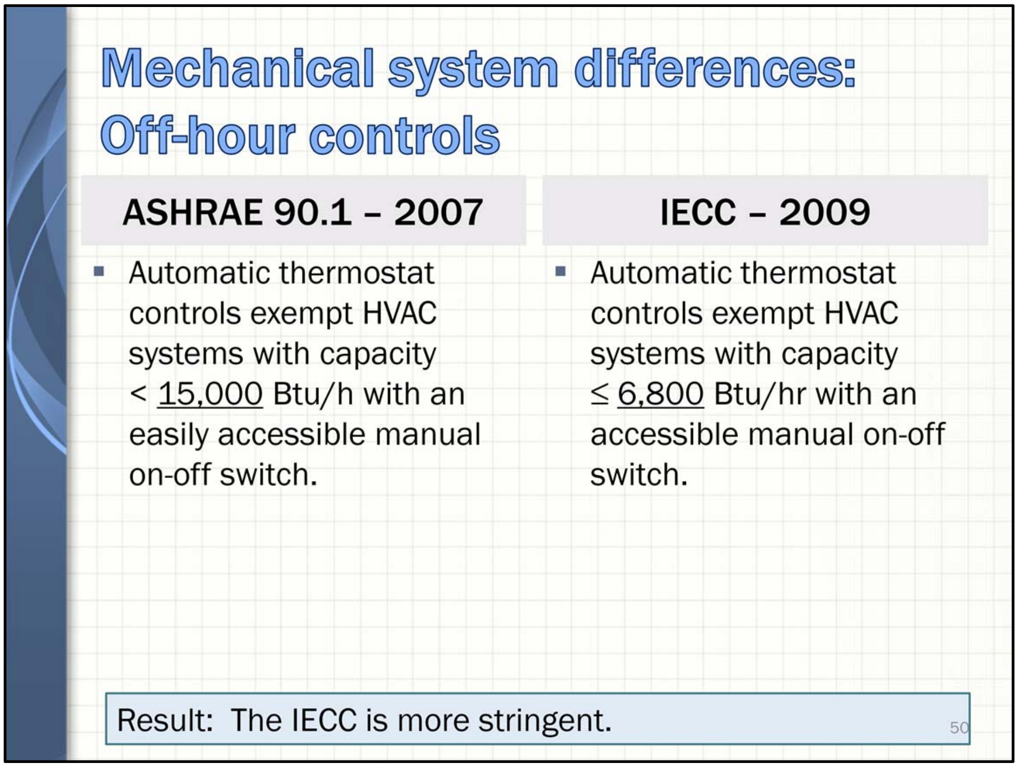

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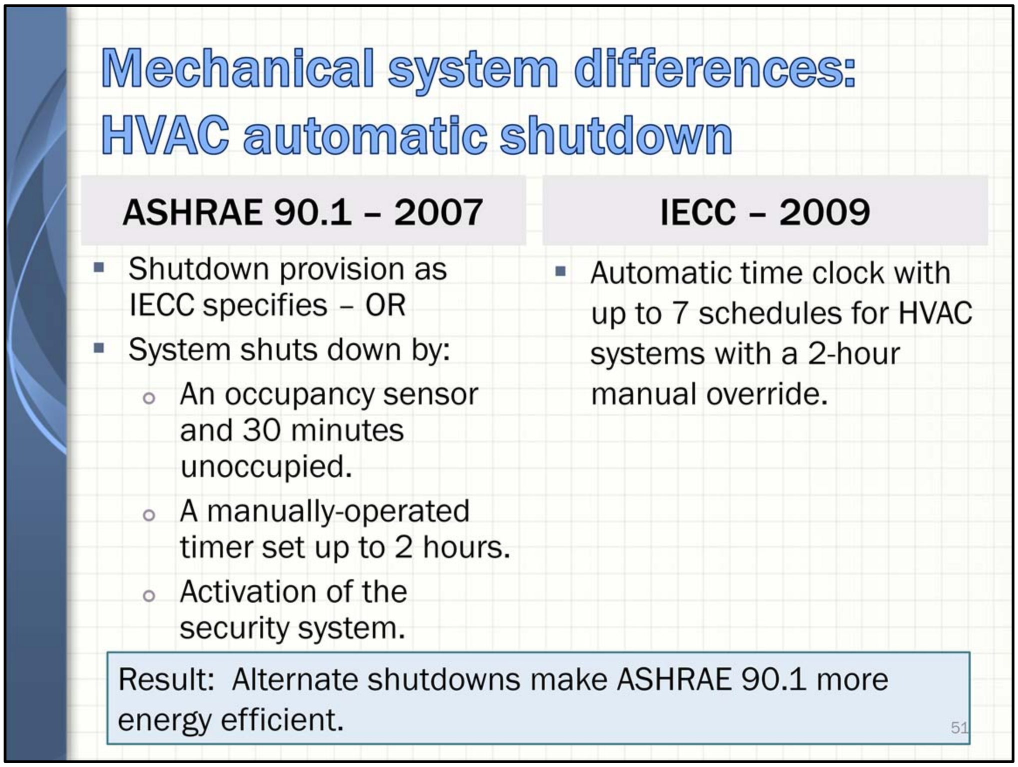

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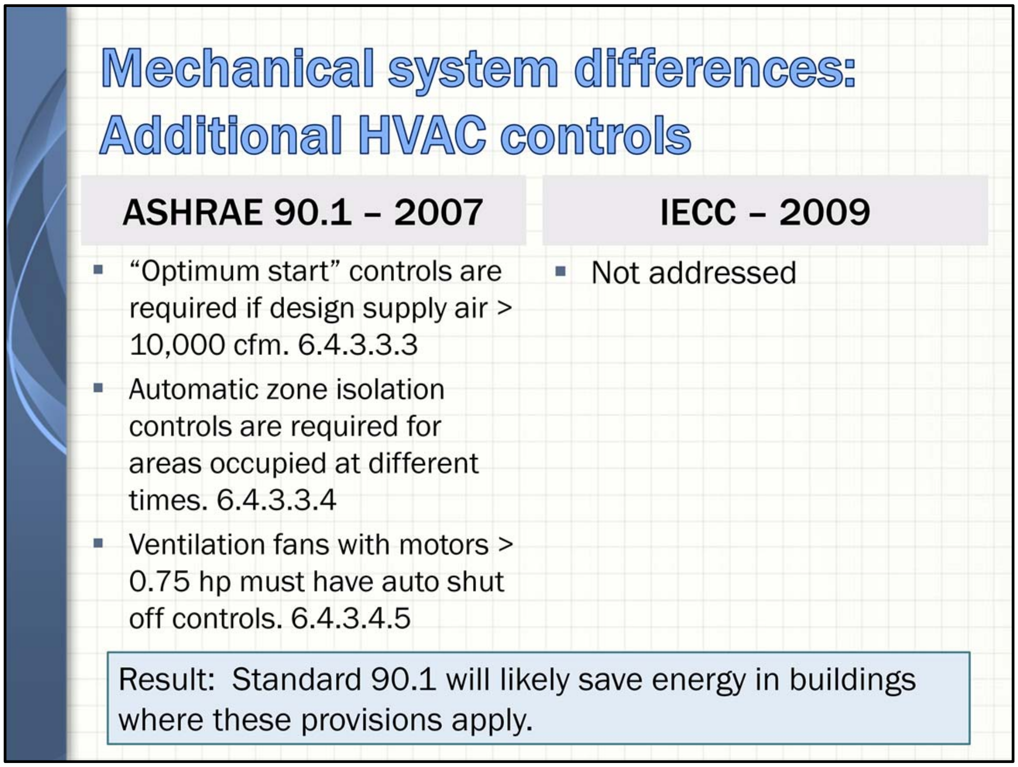

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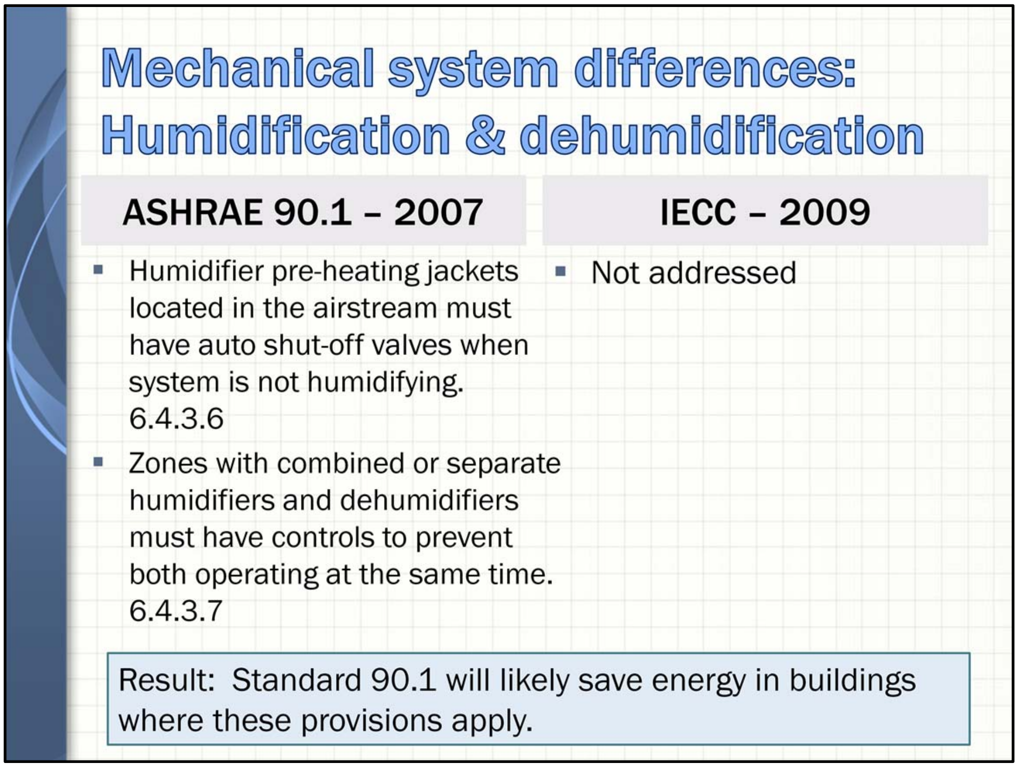

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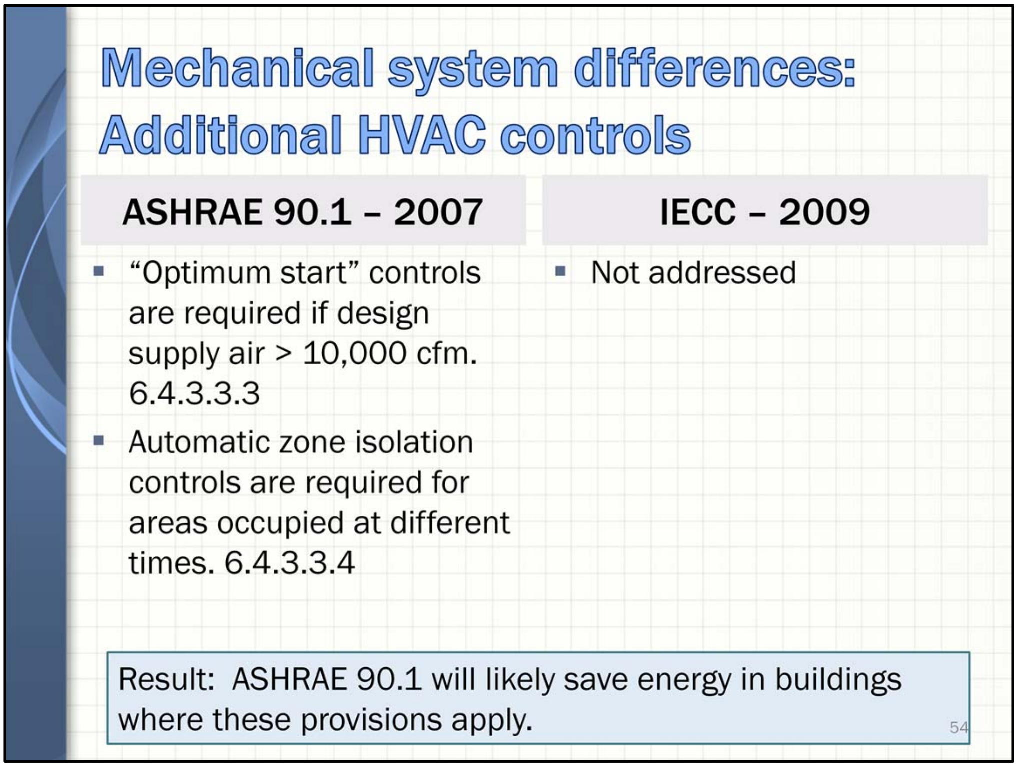

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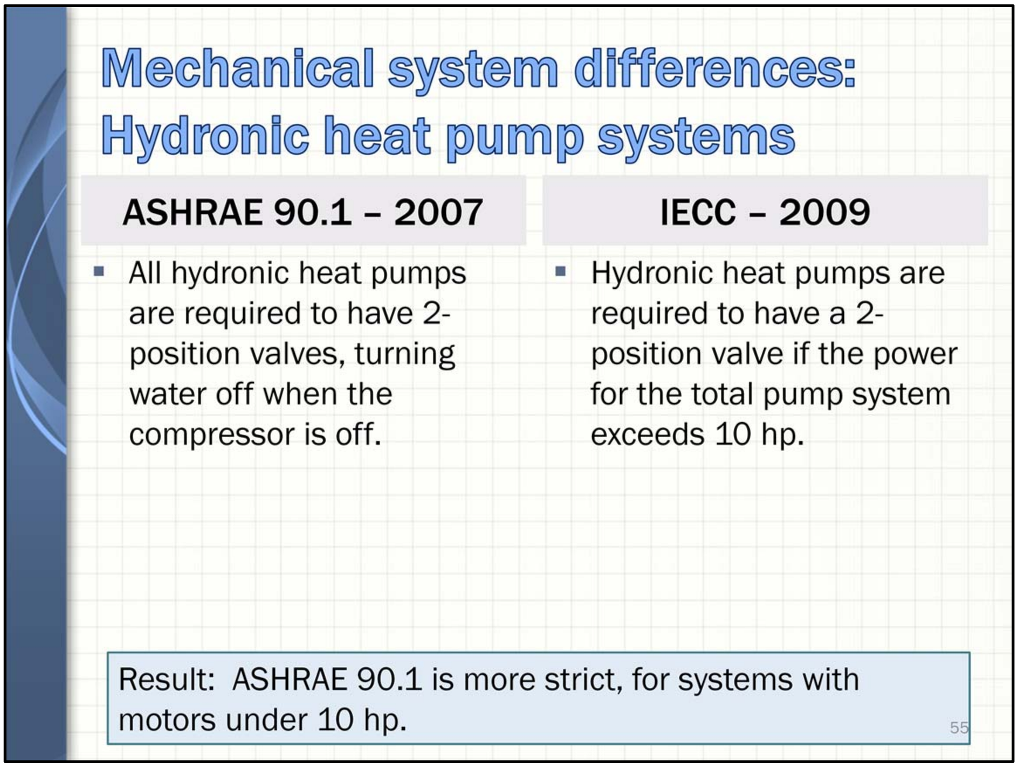

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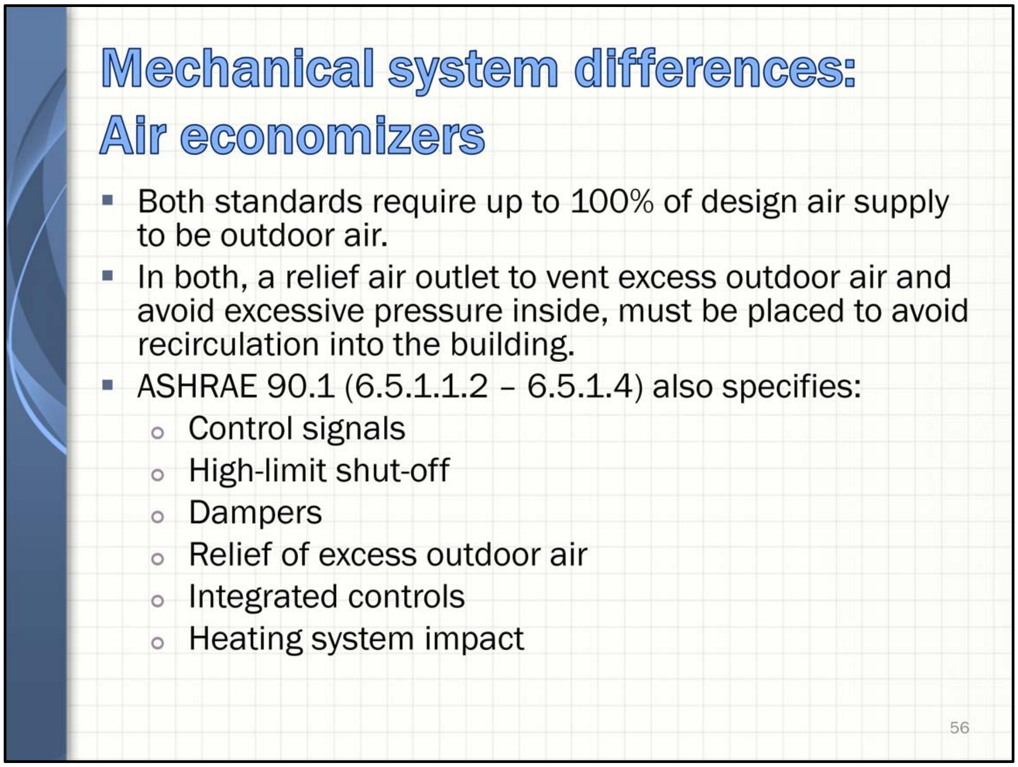
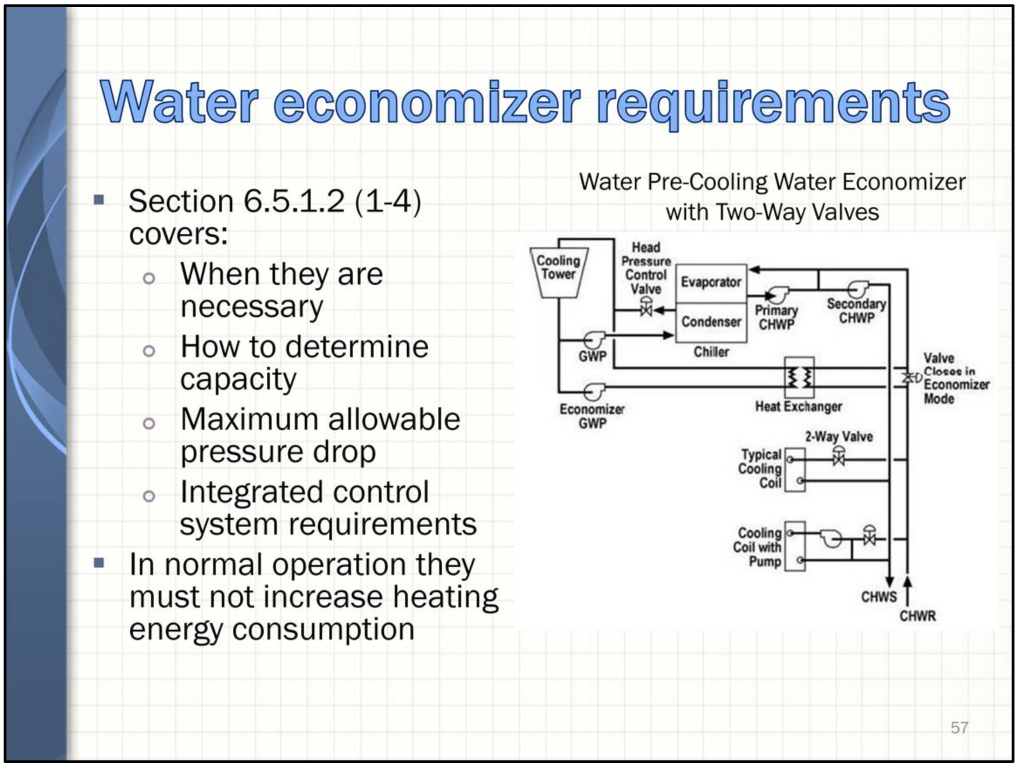


IECC 503.3.1 Also See "integrated economizers" in Standard 90.1 6.5.1.3 and IECC Section 503.3.1

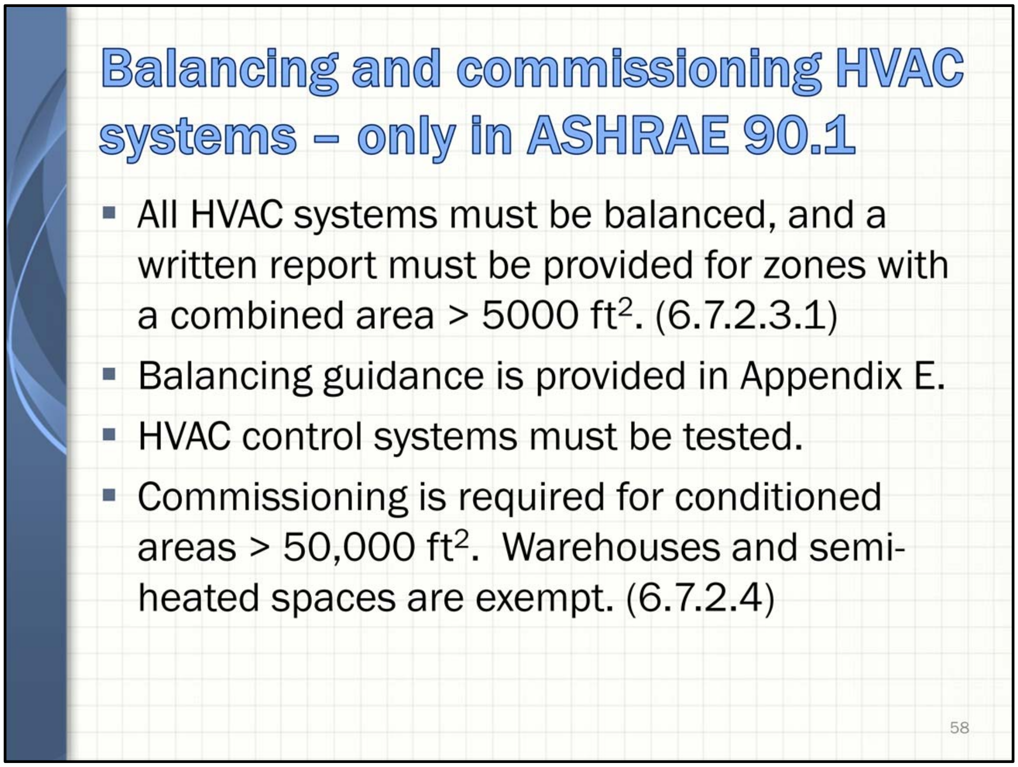
https://www.energycodes.gov/sites/default/files/becu/Commercial_90_Percent_Eval_Inspect_Training.pdf

http://www.energycodes.gov/sites/default/files/documents/90-1_iecc_comparison_final_12-16-2009.pdf



2009 IECC does not have equivalent requirements.

Diagram from US DOE Energy Efficiency & Renewable Energy, Building Energy Codes University, http://www.energycodes.gov/sites/default/files/documents/90-1_iecc_comparison_final_12-16-2009.pdf , slide 50



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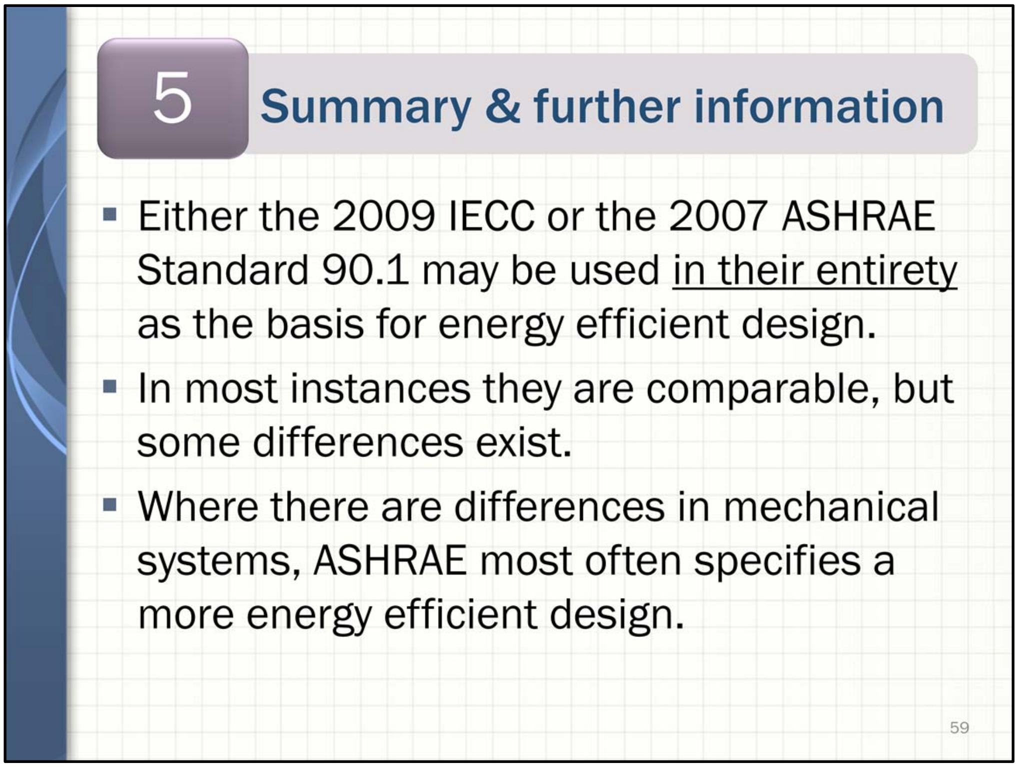

5
Summary & further information
Either the 2009 IECC or the 2007 ASHRAE Standard 90.1 may be used in their entirety as the basis for energy efficient design.
In most instances they are comparable, but some differences exist.
Where there are differences in mechanical systems, ASHRAE most often specifies a more energy efficient design.
59

http://www.neo.ne.gov/home_const/iecc/iecc_codes.htm

http://www.energycodes.gov/training/onlinetraining/2009comiecc.stm

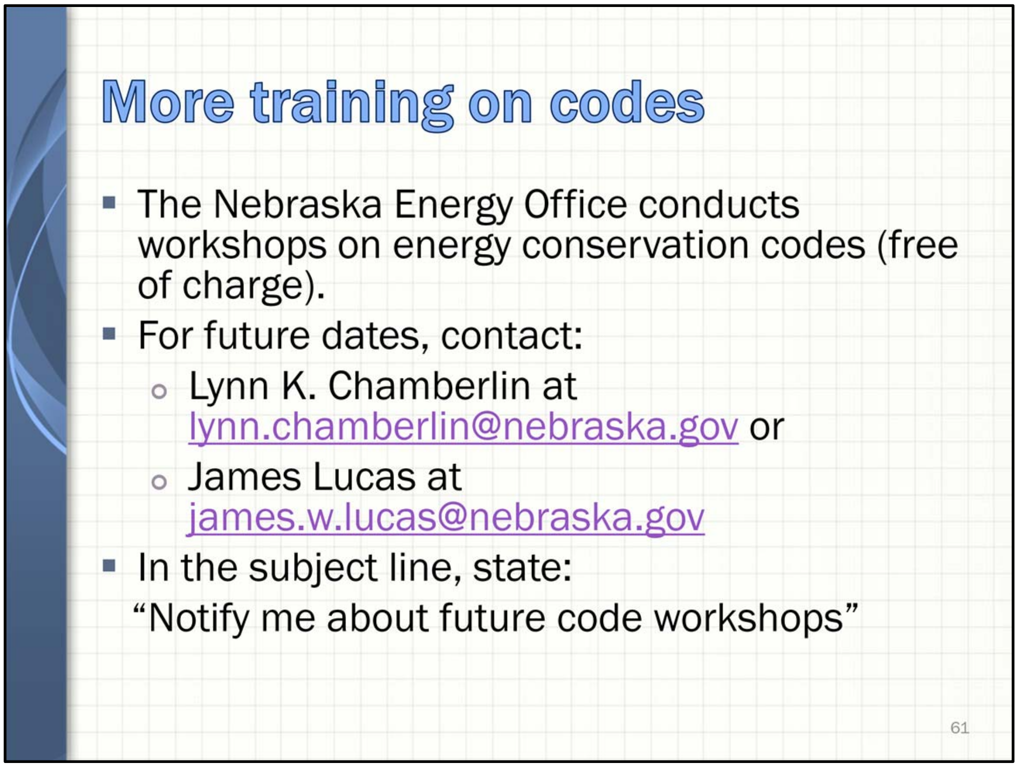
2009 IECC Commercial Envelope Requirements presentation slides (PDF 1.4 MB)

2009 IECC Commercial Envelope Requirements transcript (PDF 149 KB)

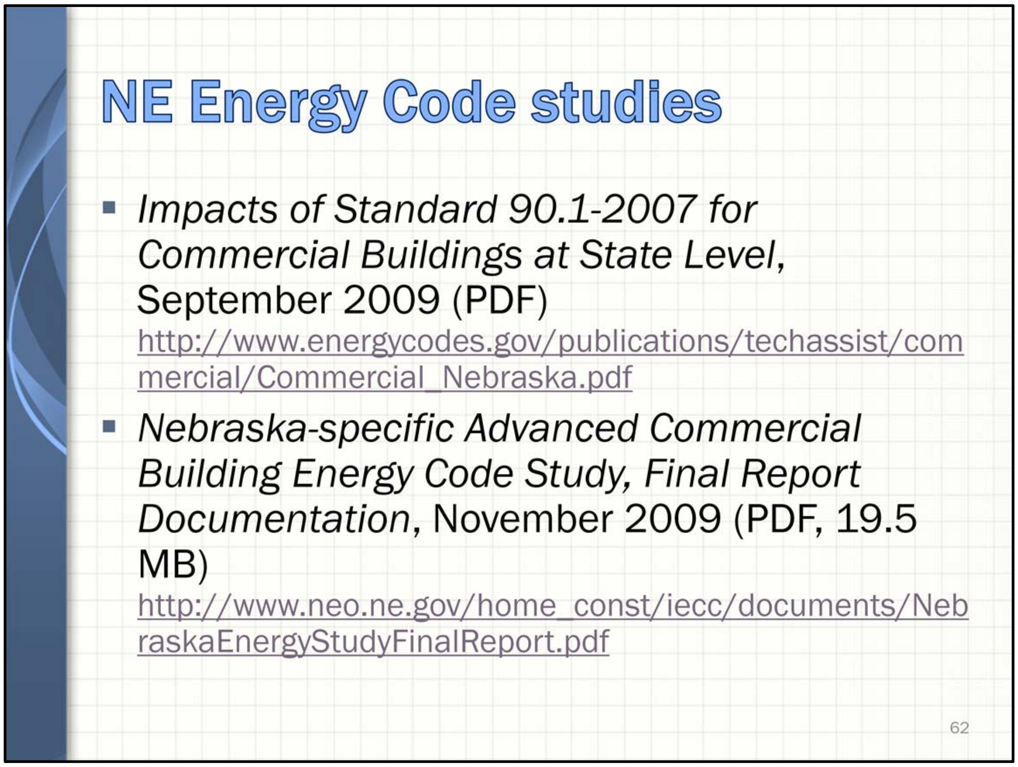
webcast - www.youtube.com/watch?v=WrFttIL1N9g

Commercial Lighting Requirements of 2009 IECC:
www.energycodes.gov/training/presentations.stm ;

Transcript of webcast:
http://www.energycodes.gov/training/pdfs/2009_iecc_comm_lighting_transcript.pdf

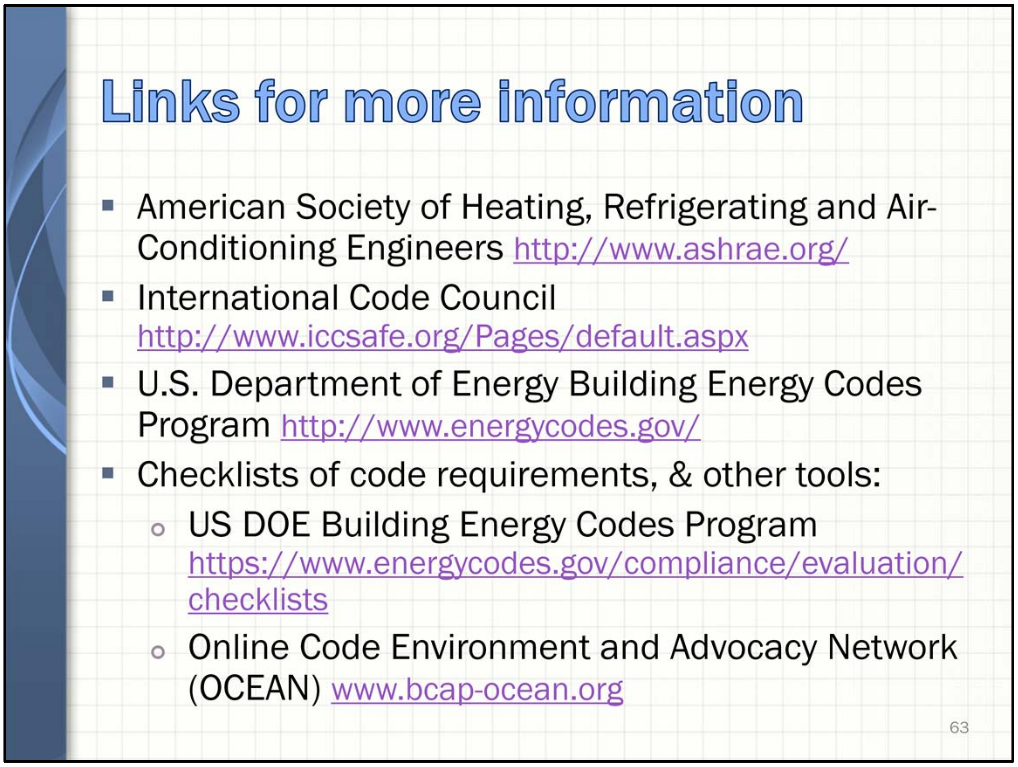


On occasion, the Nebraska Energy Office offers free codes training workshops. These opportunities are made available as part of the Nebraska Energy Office's continuing effort to assist local code officials, architects, engineers and others in their understanding of the requirements and savings opportunities associated with the latest energy conservation codes. Email Lynn K. Chamberlin or James Lucas to be notified about future training opportunities.



Studies on Residential Code Impacts:

- *Energy Impact Study of the 2009 IECC and 2012 IECC Energy Codes for Nebraska*, March 14, 2012 (PDF 0.17 MB), http://www.neo.ne.gov/home_const/iecc/documents/NEcodesreport3-14-12.pdf
- *Energy Impact Study of the 2003 IECC and 2009 IECC Energy Codes for Nebraska*, August 2009, http://www.neo.ne.gov/home_const/iecc/documents/NE_codes_report_6-30-09%5b1%5d.pdf
- *Life Cycle Cost Analysis of the 2000 International Energy Conservation Code for Nebraska*, August 2003, http://www.neo.ne.gov/reports/unl_mec_study.htm
- *International Energy Conservation Code Cost Impact Memo*, September 2009 (PDF), http://www.neo.ne.gov/home_const/iecc/documents/2009IECCcostimpact9-30-09.pdf



The DOE Building Energy Codes Program has 2009 IECC and ASHRAE Standard 90.1 checklists

The OCEAN checklist is at: http://bcap-ocean.org/sites/default/files/resources/commercial_checklist.pdf


Questions?
64

Assessment

Questions

1. IECC heating load calculations must be no more than _____º F for interior temperatures, and no less than ____º F. for air conditioning load calculations.
    a. 74 and 78
    b. 70 and 75
    c. 72 and 75
    d. 68 and 76
2. In Nebraska, ASHRAE 90.1 applies to additions and alterations in existing buildings that cost ____ or more of the building value.
    a. 100 %
    b. 75 %
    c. 50%
    d. Requires all additions and alterations to meet ASHRAE code

True or false

3. Nebraska is currently using the 2012 IECC.
4. It is possible to "mix and match" requirements from the IECC and the AHRAE Standard 90.1.
5. Economizers are required if cooling capacity exceeds 20 kBtu/h.
6. Energy recovery ventilation that is at least 50% efficient is required for individual fan systems if the design supply airflow is ≥ 5000 cfm, with a minimum of 70% outside air (with some exceptions).
7. Fan motor horsepower is limited when the *total HVAC system power* exceeds 2 hp (with some exceptions).
8. Both standards require HVAC systems with zones that exceed a combined area of 5000 ft^2 to be balanced and a written report to be provided.

9. While there are differences in the mechanical systems code requirements of both standards, ASHRAE most often specifies the more energy efficient design.

10. The Nebraska Energy Office conducts free workshops on the energy conservations codes.

Answers

1. IECC heating load calculations must be no more than _____º F for interior temperatures, and no less than ____º F. for air conditioning load calculations.

   b. 72 and 75

2. In Nebraska, ASHRAE 90.1 applies to additions and alterations in existing buildings that cost ____ or more of the building value.

   c. 50%

True or false

3. Nebraska is currently using the 2012 IECC.

   False (Nebraska is currently using the 2009 IECC.)

4. It is possible to "mix and match" requirements from the IECC and the AHRAE Standard 90.1.

   False (Either code must be followed in its entirety.)

5. Economizers are required if cooling capacity exceeds 20 kBtu/h.

   False (They are required if cooling capacity exceeds 54 kBtu/h.)

6. Energy recovery ventilation that is at least 50% efficient is required for individual fan systems if the design supply airflow is ≥ 5000 cfm, with a minimum of 70% outside air (with some exceptions).

   True

7. Fan motor horsepower is limited when the *total HVAC system power* exceeds 2 hp (with some exceptions).

   False (It's limited when total system power exceeds 5 hp.)

8. Both standards require HVAC systems with zones that exceed a combined area of 5000 ft^2 to be balanced and a written report to be provided.

   True

9. While there are differences in the mechanical systems code requirements of both standards, ASHRAE most often specifies the more energy efficient design.

    True

10. The Nebraska Energy Office conducts free workshops on the energy conservations codes.

    True

4: Improvements in HVAC

Learning Objectives

By attending this session, participants will:

- ✓ Understand that people are the key to success in obtaining the best balance of comfort, indoor air quality, and energy costs
- ✓ Be able to identify the most typical improvements in daily operations and occupant maintenance to improve energy efficiency and be prepared to share this information with others
- ✓ Understand the importance of preventive maintenance and the tasks to include that have the greatest impact on comfort, indoor air quality, and energy costs
- ✓ Understand the basics of HVAC retro-commissioning upgrades and the typical cost-effective applications for light commercial buildings in Nebraska

Key Terminology

Economizer	Heat recovery ventilation (HRV)
Demand-controlled ventilation (DCV)	Variable speed control

References and Supplemental Materials

Small HVAC System Design Guide. California Energy Commission, Oct 2003. www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-12.PDF

Flex Your Power (CA) Business Case Study. Bank of America www.fypower.org/pdf/CS_Biz_BofA.pdf

Comprehensive Building Tune-up. Puget Sound Energy www.pse.com/savingsandenergycenter/ForBusinesses/Documents/CaseStudy_TheWestinBellevue.pdf

Small Commercial Rooftops: Field Problems, Solutions, and the Role of Manufacturers. Jacobs et al. National Conference on Building Commissioning. 2003. http://bbistaff.com/bbi/report_1_files/2003_Jacobs_CEC%20Rofftop%20Unit%20study.pdf

Puget Sound Energy Case Study http://pse.com/savingsandenergycenter/ForBusinesses/Documents/CaseStudy_KidsCountry.pdf

Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat. U.S. Department of Energy PNNL-20955. Dec 2011.

"Airside Economizers." *Trane Engineers Newsletter* Volume 35-2. 2006 http://www.trane.com/commercial/uploads/pdf/673/admapn020en_0406.pdf

What's Cookin' in the Kitchen? Energy Savings! Energy Impact Illinois. May, 2011. http://energyimpactillinois.org/cases/whats-cookin-in-the-kitchen-energy-savings

Small Commercial HVAC - Surveying the Frontier of Energy Efficiency. Lee DeBaillie, L. Energy Center of Wisconsin. 2010

Retrocommissioning and Other Control Based Measures. Elliot, K. CRN Summit. Jul 2011

Retrocommissioning Should Involve Operating Staff, Retrocommissioning Tips and Tricks, Facilities.net www.facilitiesnet.com/powercommunication/article/Retrocommissioning-Should-Involve-Operating-Staff--11180

Encouraging Sustainable Behaviors in the Workplace. 2011 Behavior, Energy & Climate Change Conference. Navigant Consulting Inc

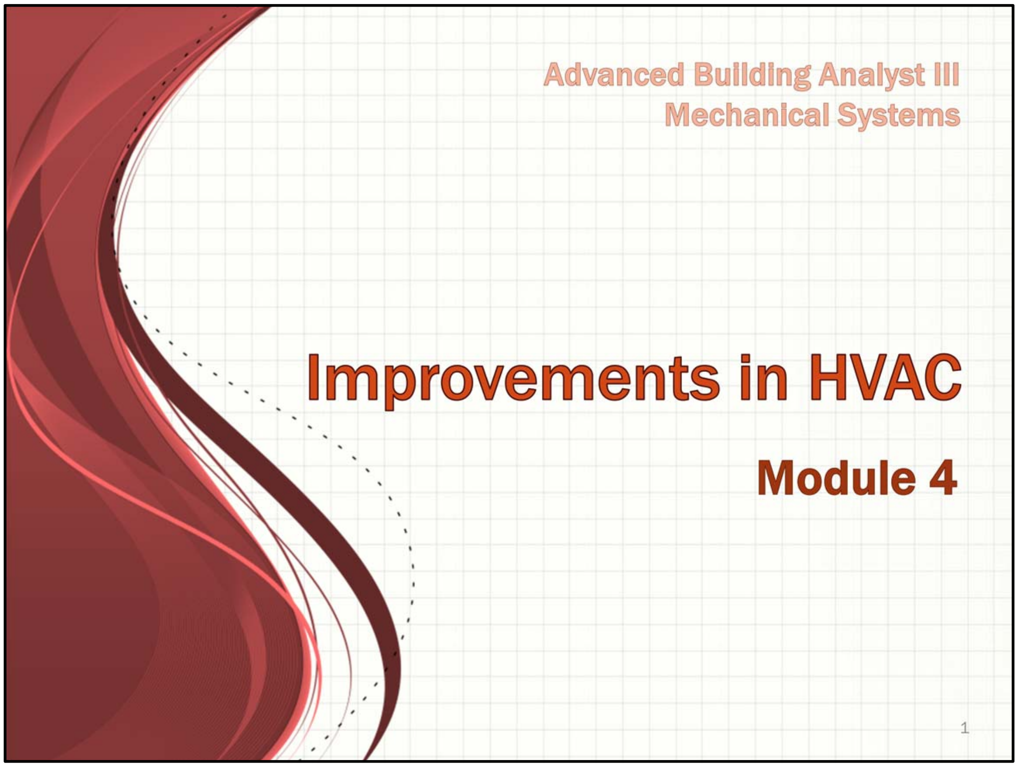
Managing energy use of pumps. Electrical Energy Efficiency Starter Kit. EcoSmart Electricians, National Electrical and Communications Association. http://www.ecosmartelectricians.com.au/starter-kit/c01_71.html

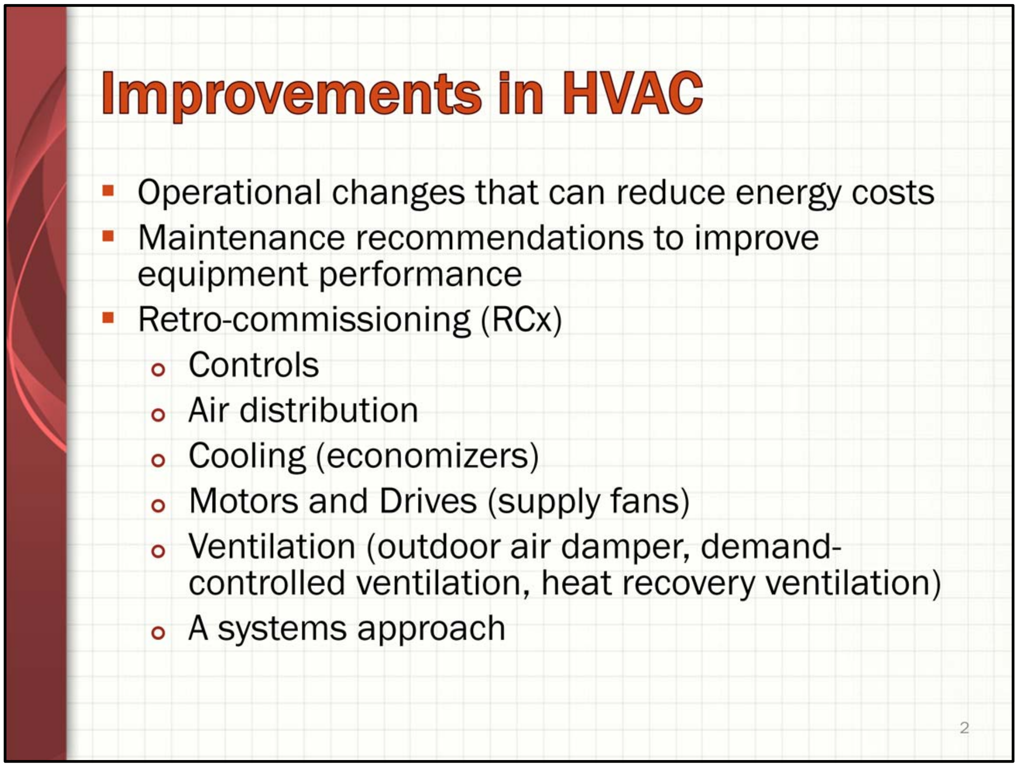
Classroom Props and Preparations

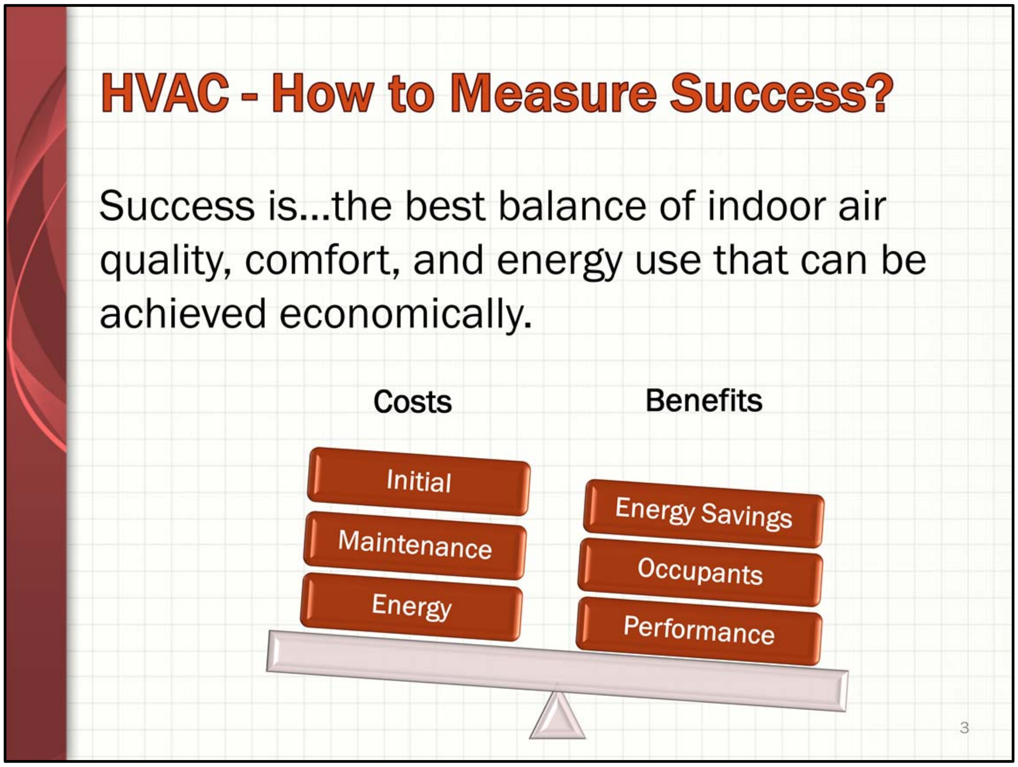
- Review the case studies provided in the references and the slides

Possible Activities

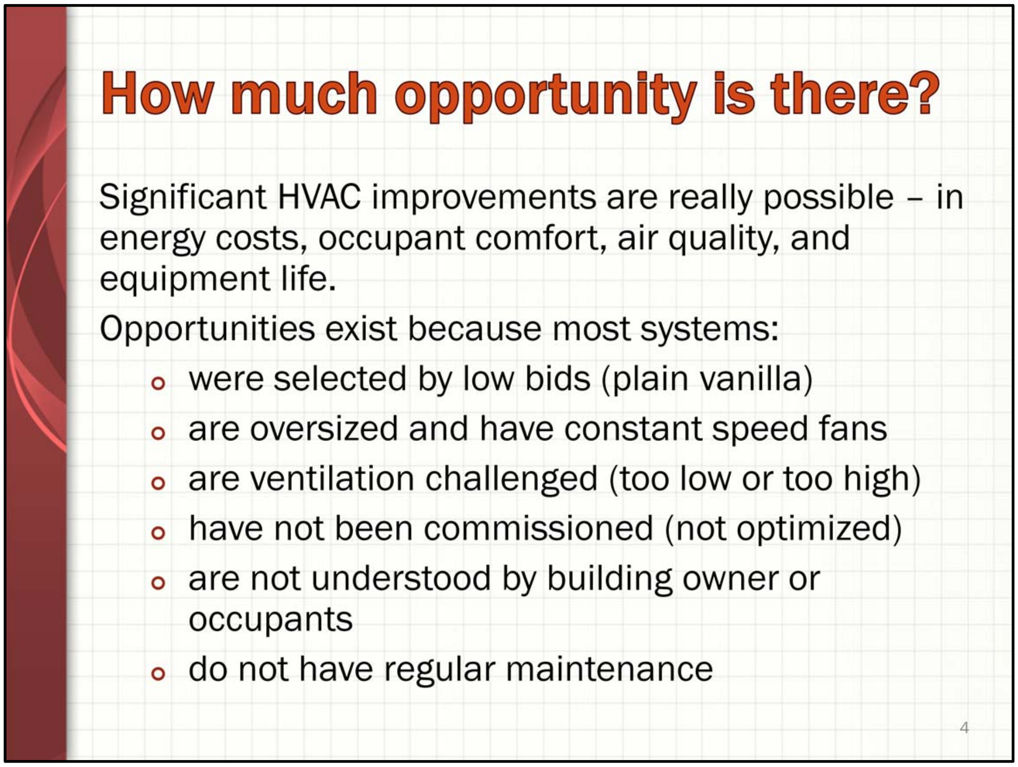
1. **Small group discussion on preventative maintenance (PM)**: Many studies have highlighted the impact of preventive maintenance on mechanical system performance. Discuss the reasons that businesses do not regularly contract for PM programs and ideas that may improve the acceptance of PM.
2. **Small group discussion on economizers**: Engineers in Nebraska have highlighted economizers as a means to lower cooling costs in many light commercial applications and ASHRAE 90.1 Section 6.4.3.9 requires them for new systems greater than 135kBtu/h for Climate Zone 5A. Discuss where economizers may be a good fit and where they may not be a good fit (e.g. type and age of equipment, local climate, equipment access for maintenance, equipment failure, and other factors).
3. **Small group discussion on retro-commissioning upgrades**: The studies included in this module by the Pacific Northwest National Laboratory and the Energy Center of Wisconsin demonstrate the impact of upgrade packages tailored for light commercial applications. Companies are now offering retrofit packages with a variety of performance claims. Discuss ways to assess when retrofit packages are appropriate for a particular application and the challenges of this assessment.

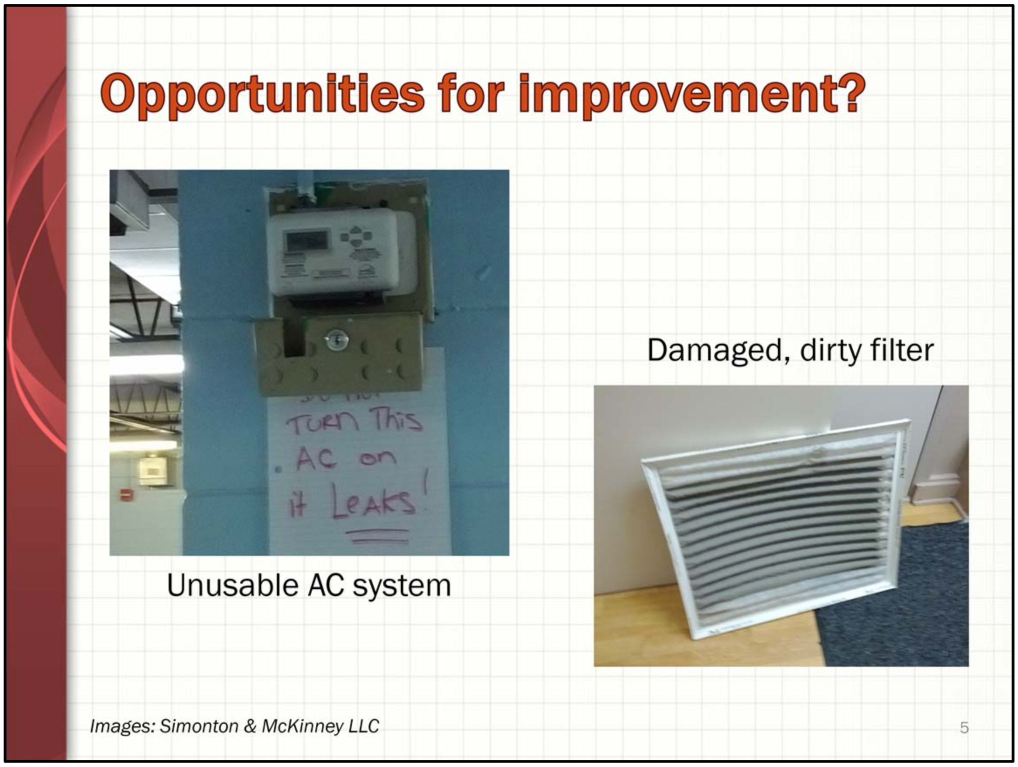

Advanced Building Analyst III
Mechanical Systems
Improvements in HVAC
Module 4
1


Improvements in HVAC
Operational changes that can reduce energy costs
Maintenance recommendations to improve equipment performance
Retro-commissioning (RCx)
Controls
Air distribution
Cooling (economizers)
Motors and Drives (supply fans)
Ventilation (outdoor air damper, demand-controlled ventilation, heat recovery ventilation)
A systems approach
2

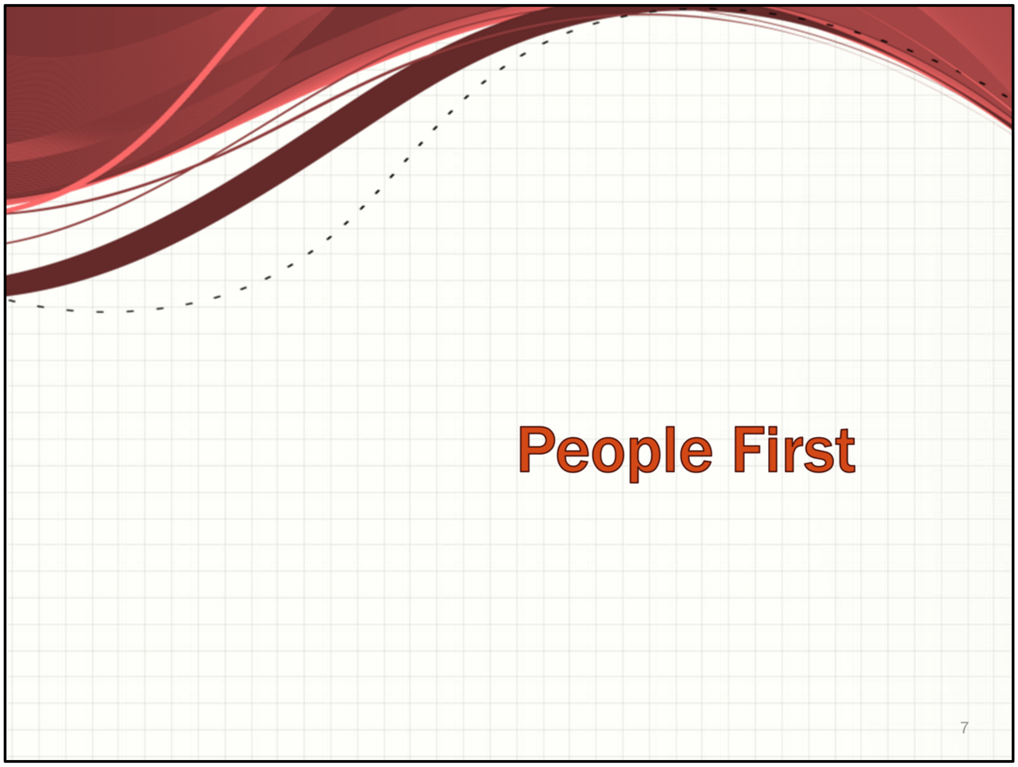


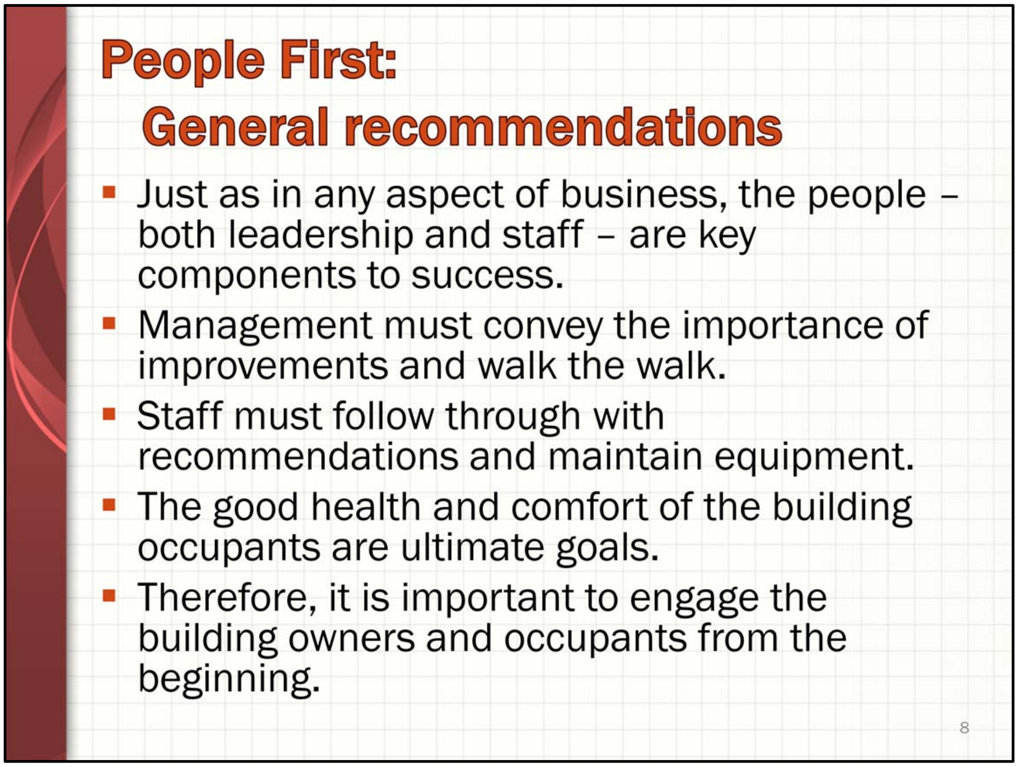
Each application is unique, requiring assessment of costs, benefits, and goals to determine the best game plan for success. Applying economic value to tangible benefits, including productivity, can be challenging but will provide a clearer picture of the impact. Including intangibles such as impact on business reputation can be included as additional factors when weighing options.


How much opportunity is there?
Significant HVAC improvements are really possible – in energy costs, occupant comfort, air quality, and equipment life.
Opportunities exist because most systems:
were selected by low bids (plain vanilla)
are oversized and have constant speed fans
are ventilation challenged (too low or too high)
have not been commissioned (not optimized)
are not understood by building owner or occupants
do not have regular maintenance
4


Opportunities for improvement?
TURN This
AC on
it Leaks!
Unusable AC system
Damaged, dirty filter
Images: Simonton & McKinney LLC
5


Opportunities for Improvement?
83.3 °F
54.0
Escaping AC supply air
Duct compressed by ladder
Dirty fan and coils
Photos: Simonton & McKinney LLC
6


People First
7


People First:
General recommendations
Just as in any aspect of business, the people – both leadership and staff – are key components to success.
Management must convey the importance of improvements and walk the walk.
Staff must follow through with recommendations and maintain equipment.
The good health and comfort of the building occupants are ultimate goals.
Therefore, it is important to engage the building owners and occupants from the beginning.
8

Get staff on board reducing energy use through communication and discussions positively and proactively.

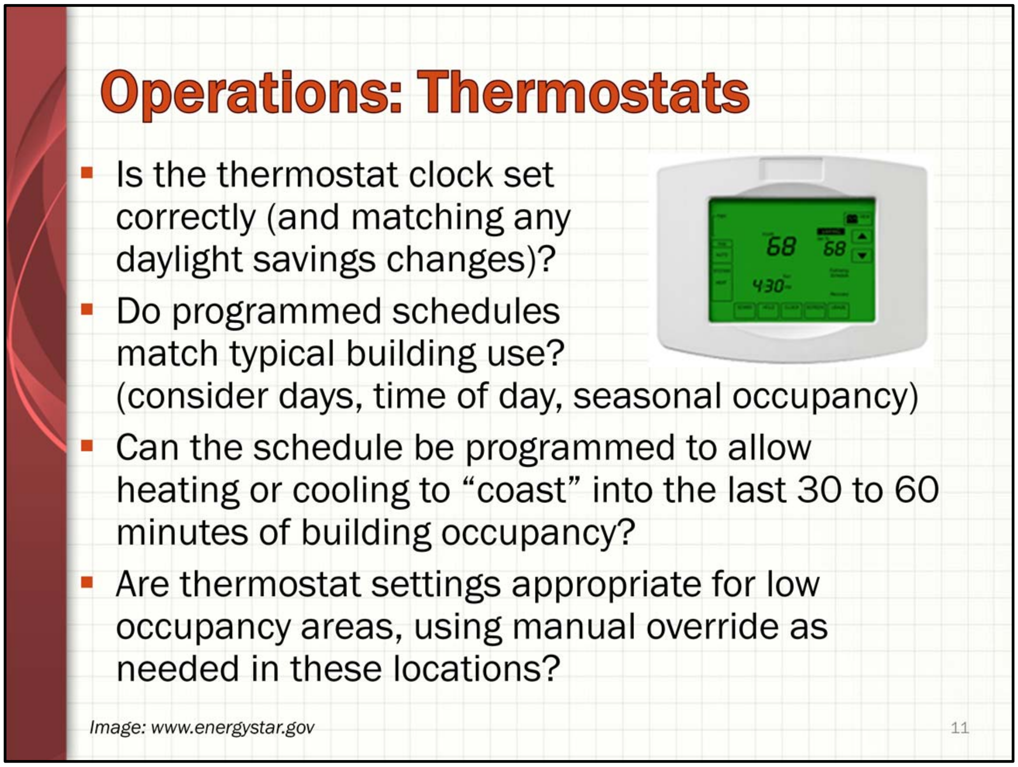
Gather staff input and demonstrate their contributions and recommendations are valued.

Set SMART goals – specific, measurable, attainable, realistic, and time-bound.

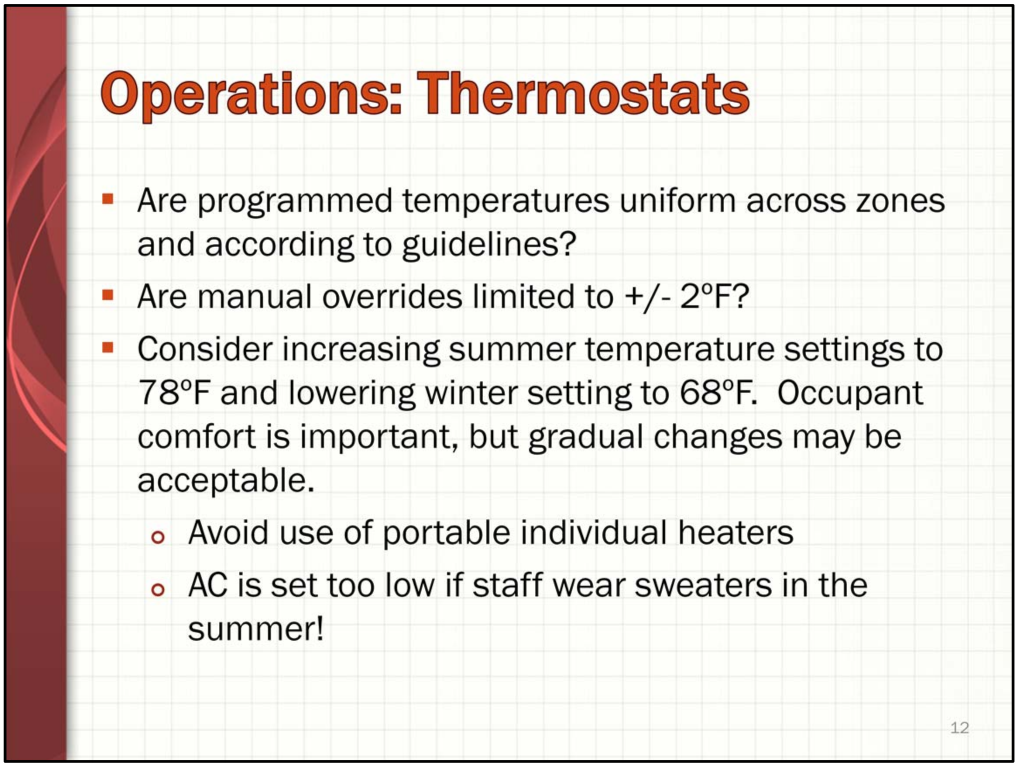
Use traditional best practices.

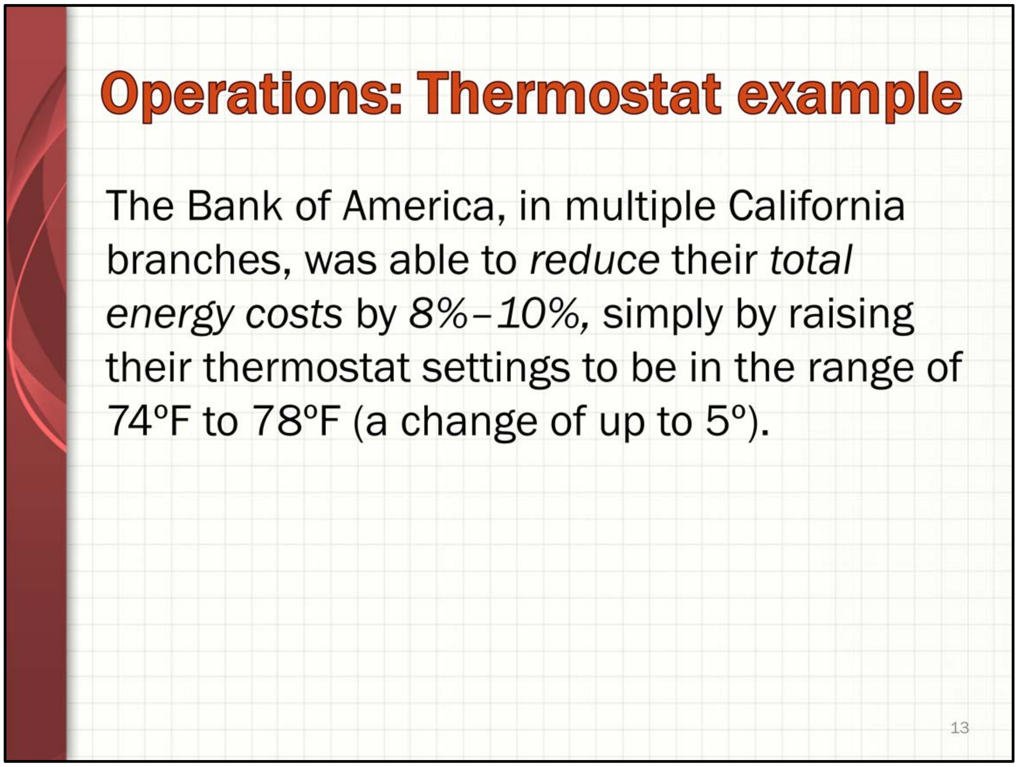
Follow-up and recognize contributions, reward performance, and celebrate successes.


Operations
10

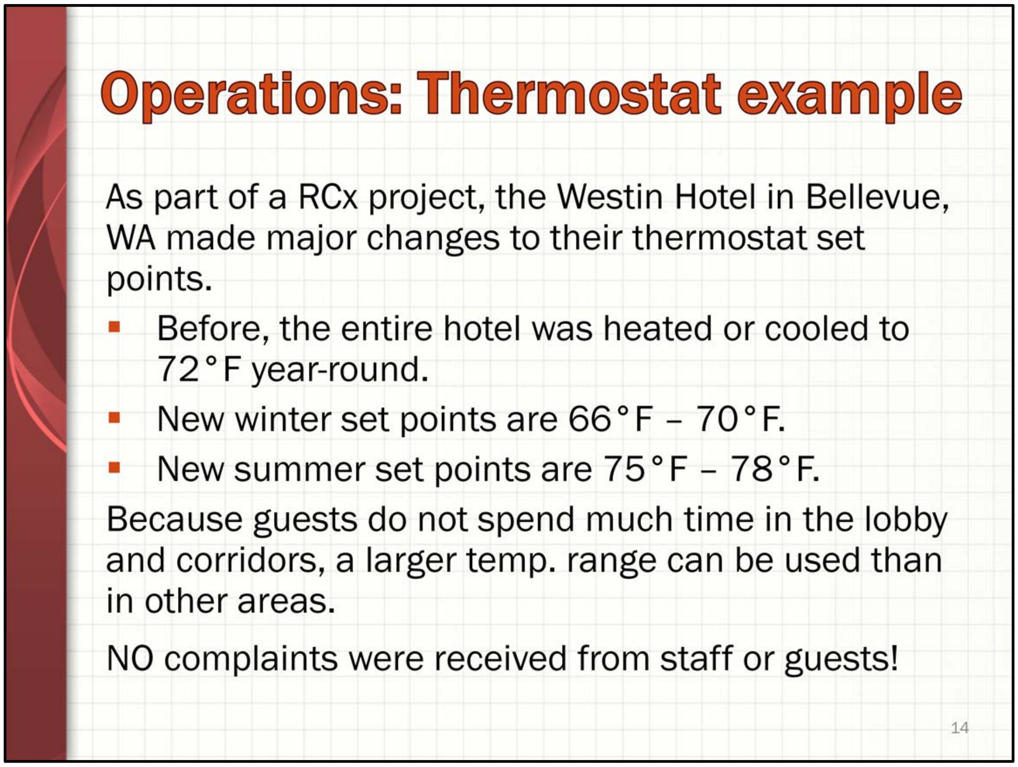


Control settings have a great impact on HVAC energy consumption. Times of operation, temperature settings during occupancy, setback temperature settings, control of areas with highly variable use, and ventilation (i.e. Fan On control when system is not calling for heating or cooling) are all important to best match building use and energy efficiency.

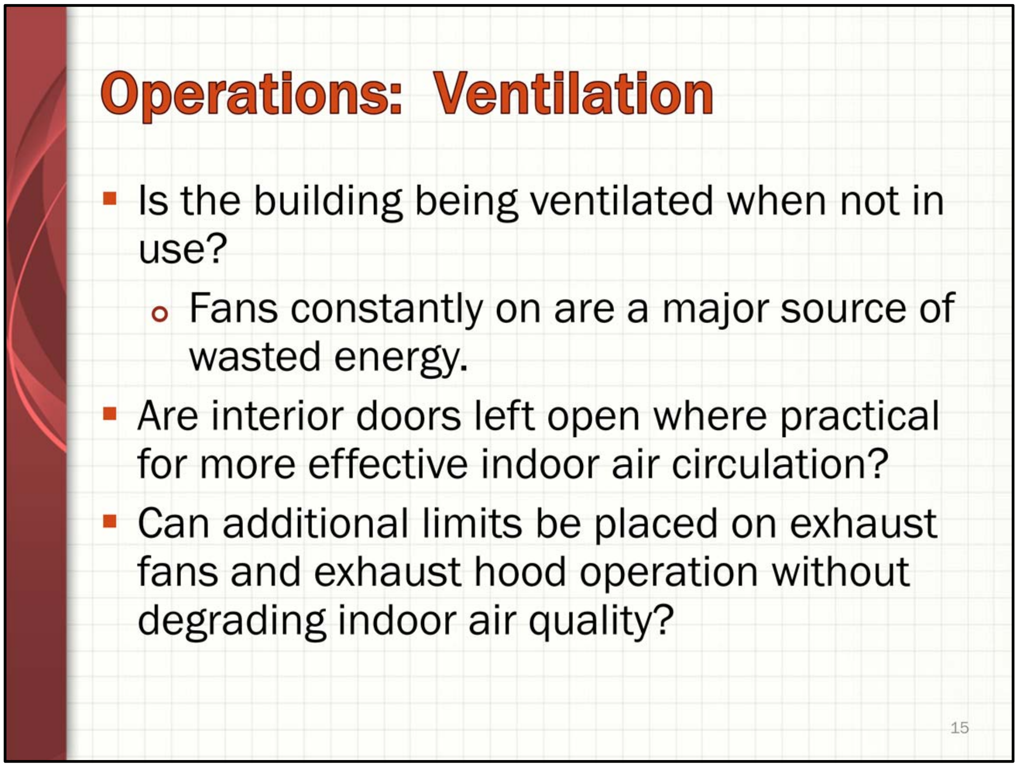

Operations: Thermostats
Are programmed temperatures uniform across zones and according to guidelines?
Are manual overrides limited to +/- 2°F?
Consider increasing summer temperature settings to 78°F and lowering winter setting to 68°F. Occupant comfort is important, but gradual changes may be acceptable.
Avoid use of portable individual heaters
AC is set too low if staff wear sweaters in the summer!
12

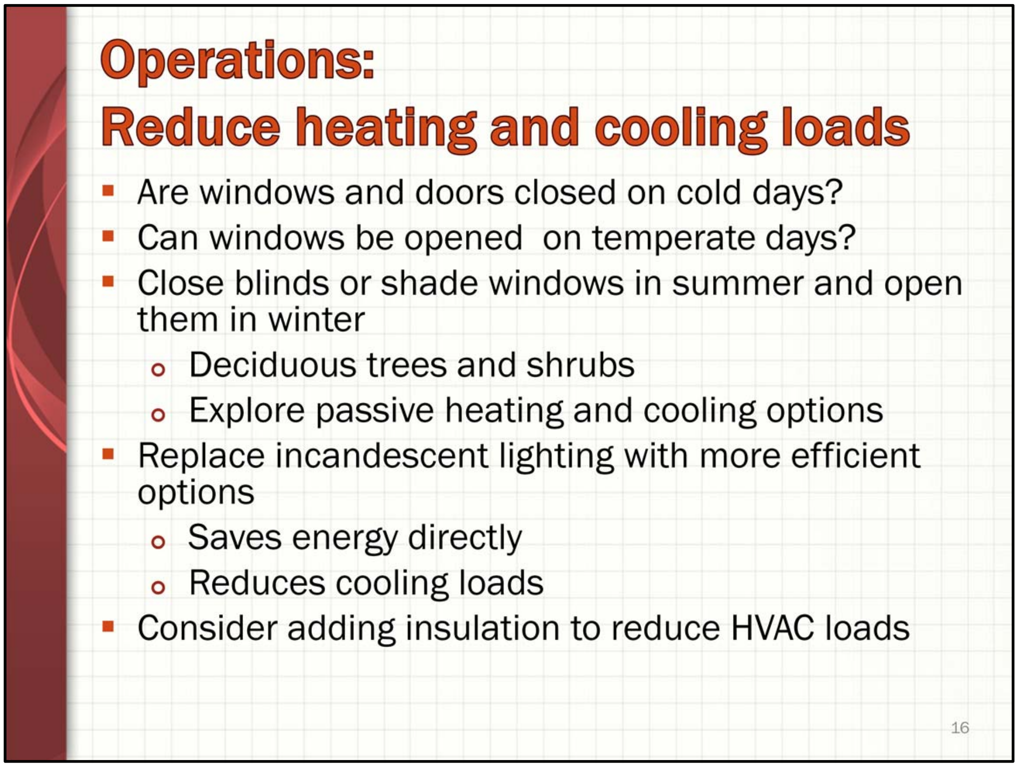


Flex Your Power Business Case Study, http://www.fypower.org/pdf/CS_Biz_BofA.pdf



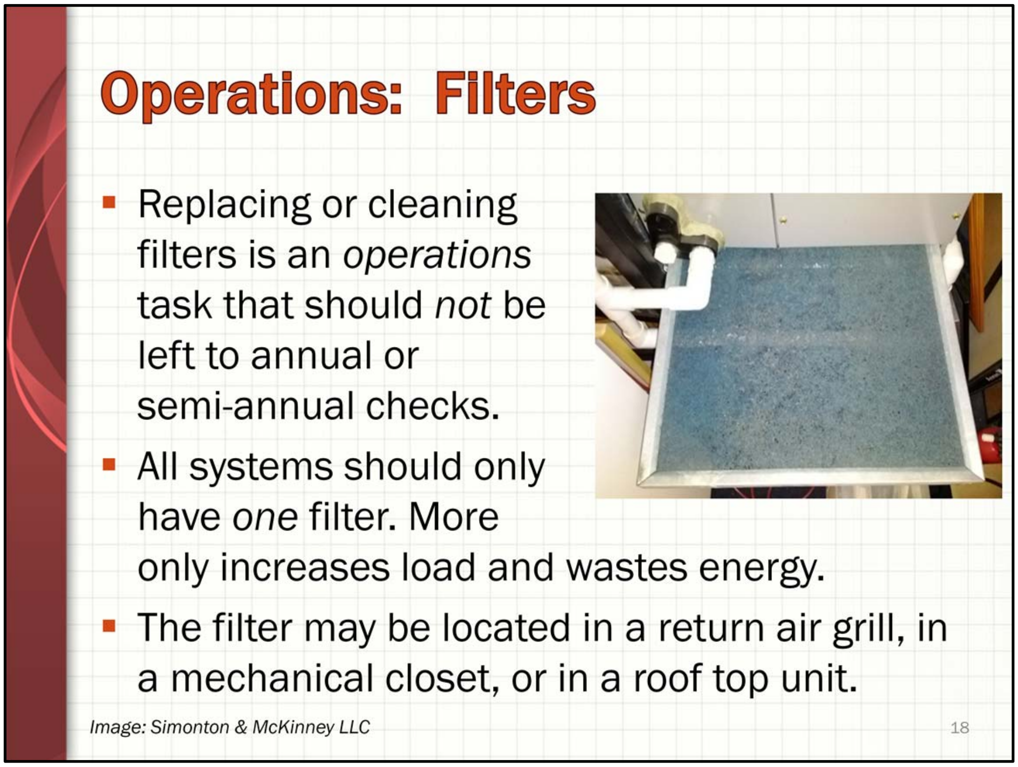
In addition, HVAC control settings for conference and ballrooms were re-set to "unoccupied" as the default condition, and other control changes were made to the heating and cooling system. While they are not able to separate the savings from the thermostat setting changes alone, the total energy savings are ranging between 10 – 20%. (from Puget Sound Energy, http://pse.com/savingsandenergycenter/ForBusinesses/Documents/CaseStudy_TheWestinBellevue.pdf)


Operations: Ventilation
Is the building being ventilated when not in use?
Fans constantly on are a major source of wasted energy.
Are interior doors left open where practical for more effective indoor air circulation?
Can additional limits be placed on exhaust fans and exhaust hood operation without degrading indoor air quality?
15



There are also other ways to impact HVAC energy consumption. Small actions together can add up to reducing the heating and cooling loads of the building.

Air filters have a very significant impact on indoor air quality and on energy efficiency. Filters are frequently neglected, become clogged, and lead to poor filtration and higher loading of the supply fan and the entire system due to reduced airflow.



Filters in commercial systems may be in the roof top unit (RTU), may be in an air-handler unit (AHU) in a mechanical closet, or may be in return grilles.

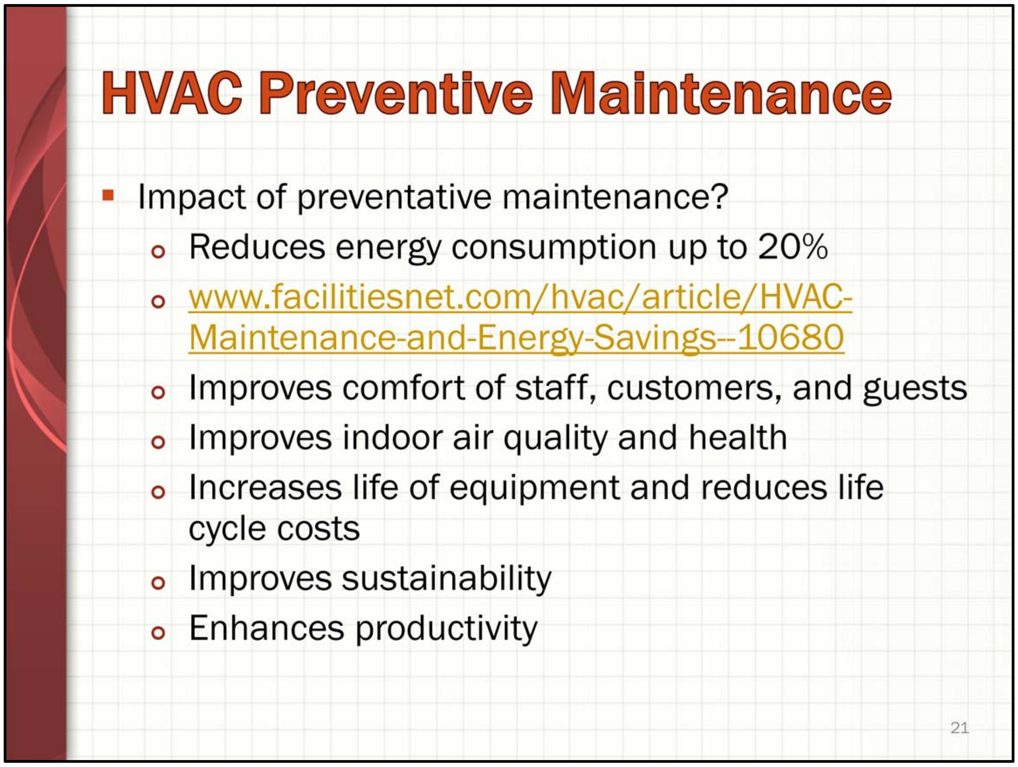
Operations: Condensers

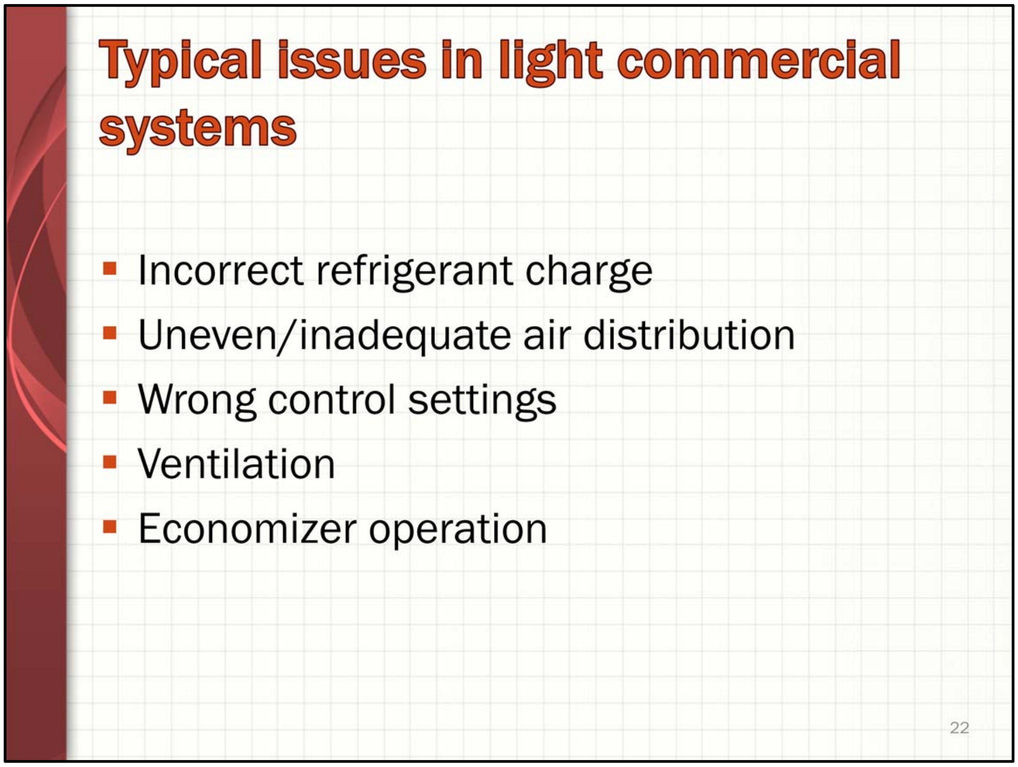
- Are the condensers (the outside AC unit) free of debris?
- Are the condensers shaded if possible?
- Clean condensers and area around unit.
- Investigate options for shading.

Image: B. Haldeman, University of Florida

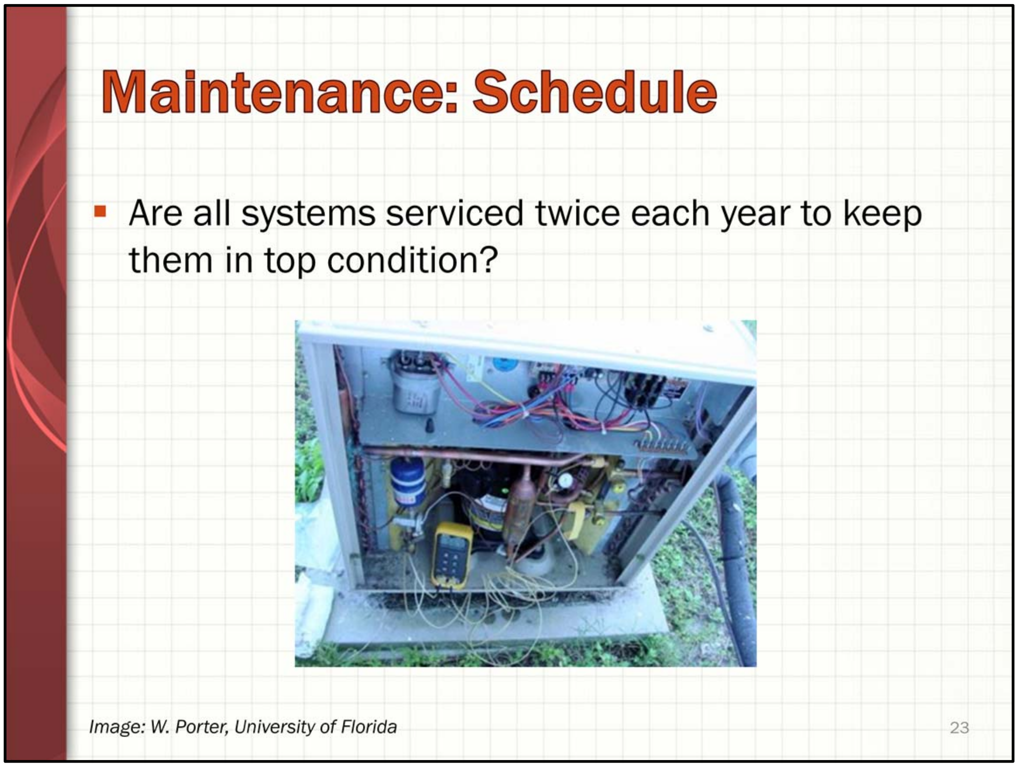
19


Preventive Maintenance
20

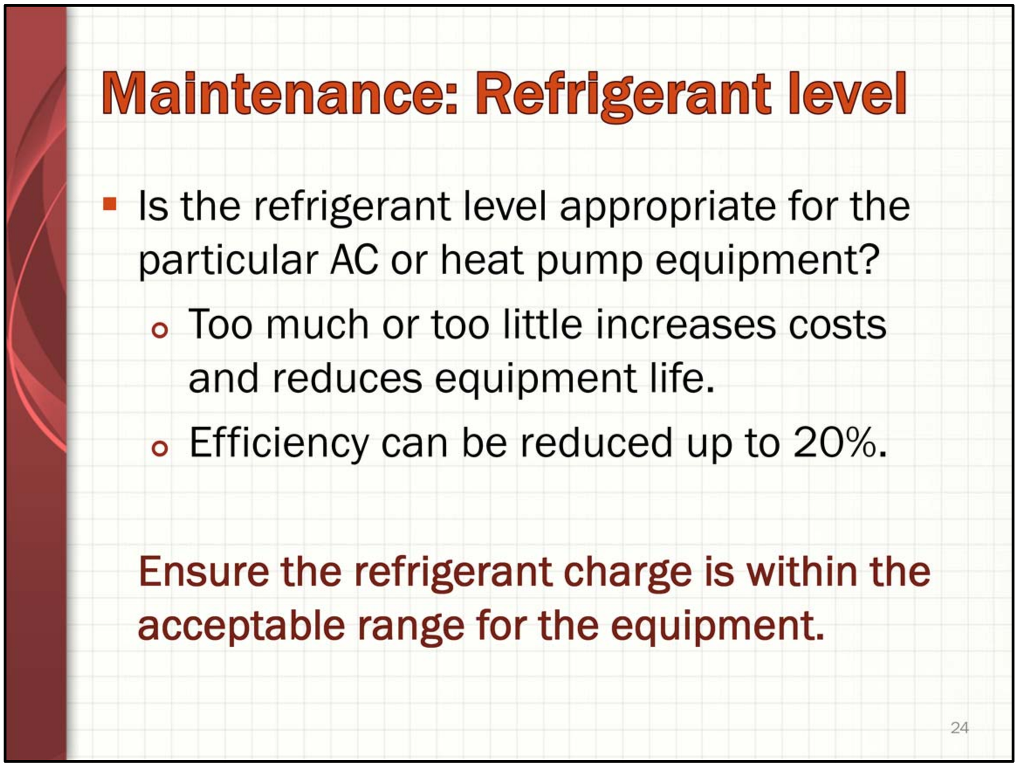

HVAC Preventive Maintenance
Impact of preventative maintenance?
Reduces energy consumption up to 20%
www.facilitiesnet.com/hvac/article/HVAC-Maintenance-and-Energy-Savings--10680
Improves comfort of staff, customers, and guests
Improves indoor air quality and health
Increases life of equipment and reduces life cycle costs
Improves sustainability
Enhances productivity
21



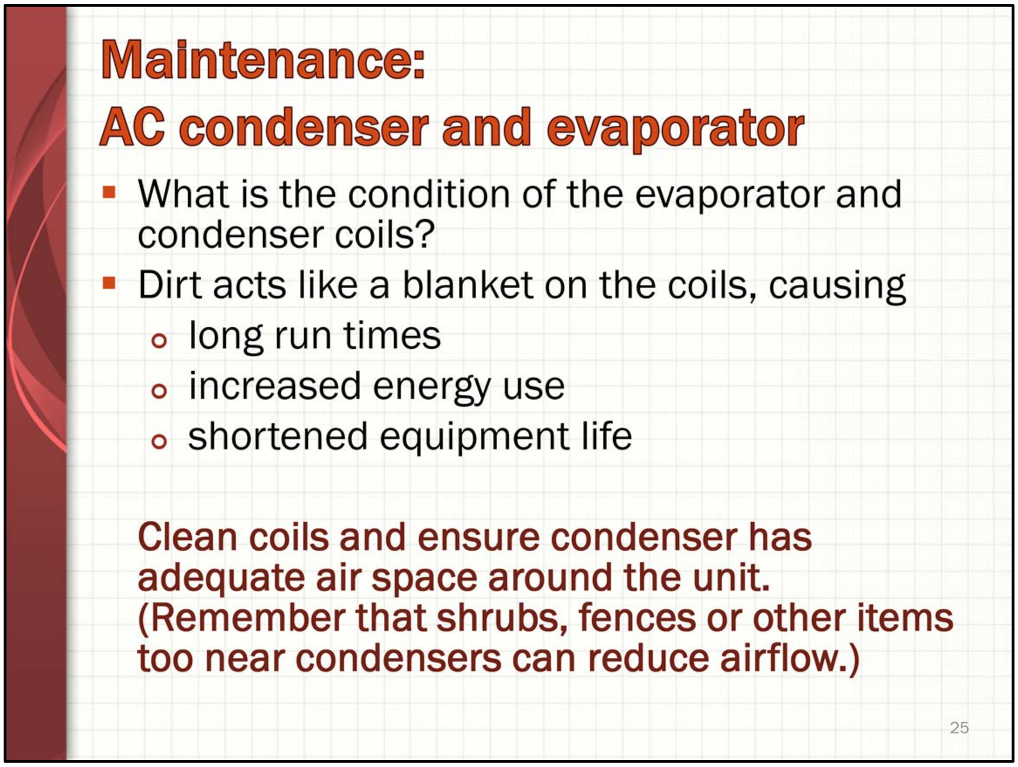
(CA Energy Commission – *Small HVAC Design Guide* (2003))



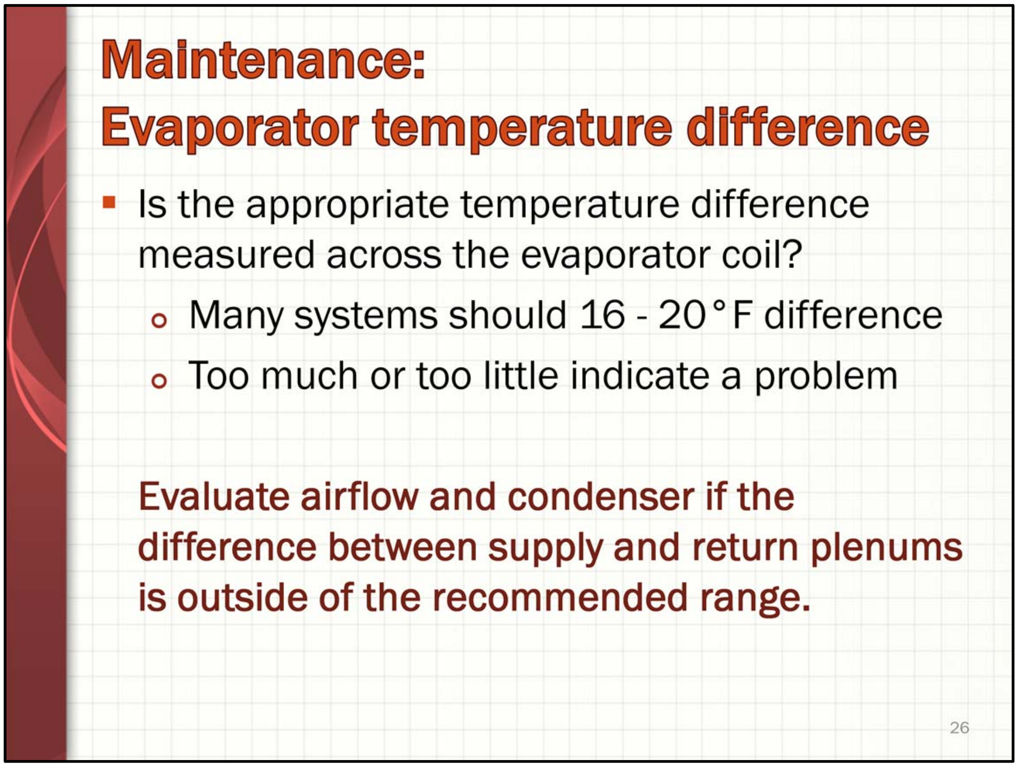
Scheduling professional maintenance, at least once a year and preferably twice, will keep the equipment in its best operating condition, impacting comfort, air quality, energy consumption, and equipment service life.



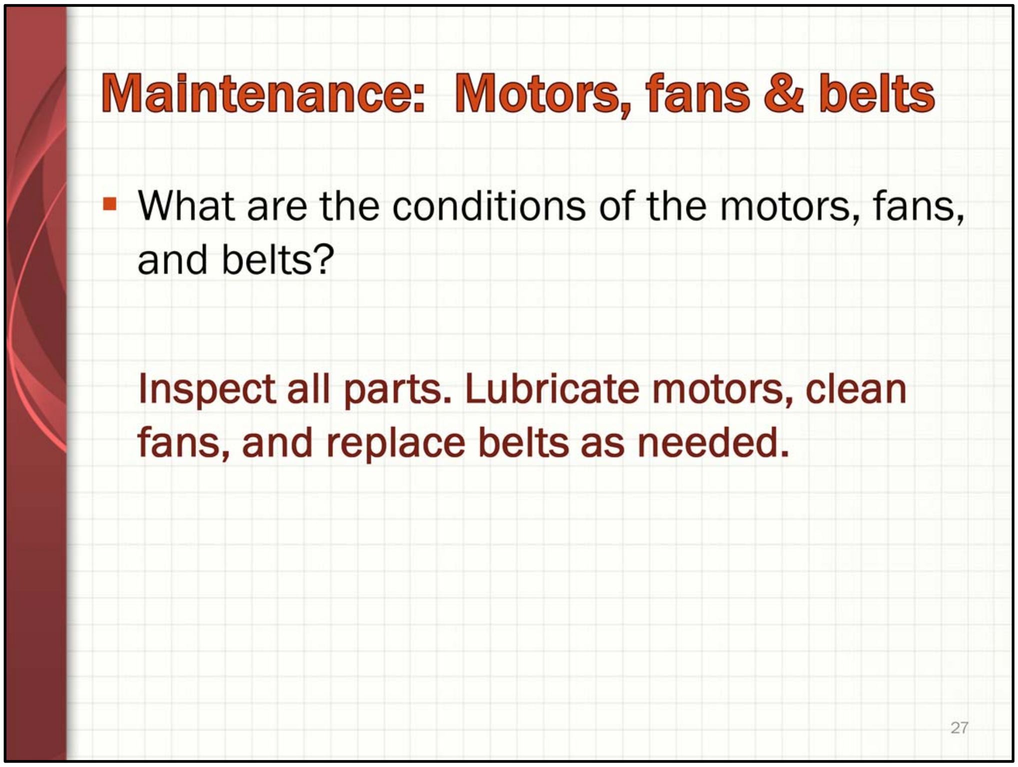
Too much or too little refrigerant will make system less efficient increasing energy costs and reducing the life of the equipment. Data from 74 commercial roof top units in California have shown that nearly half of the systems were operating with an incorrect refrigerant charge (Jacobs, 2003). Improperly charged units can negatively impact the equipment's efficiency by as much as 20%.



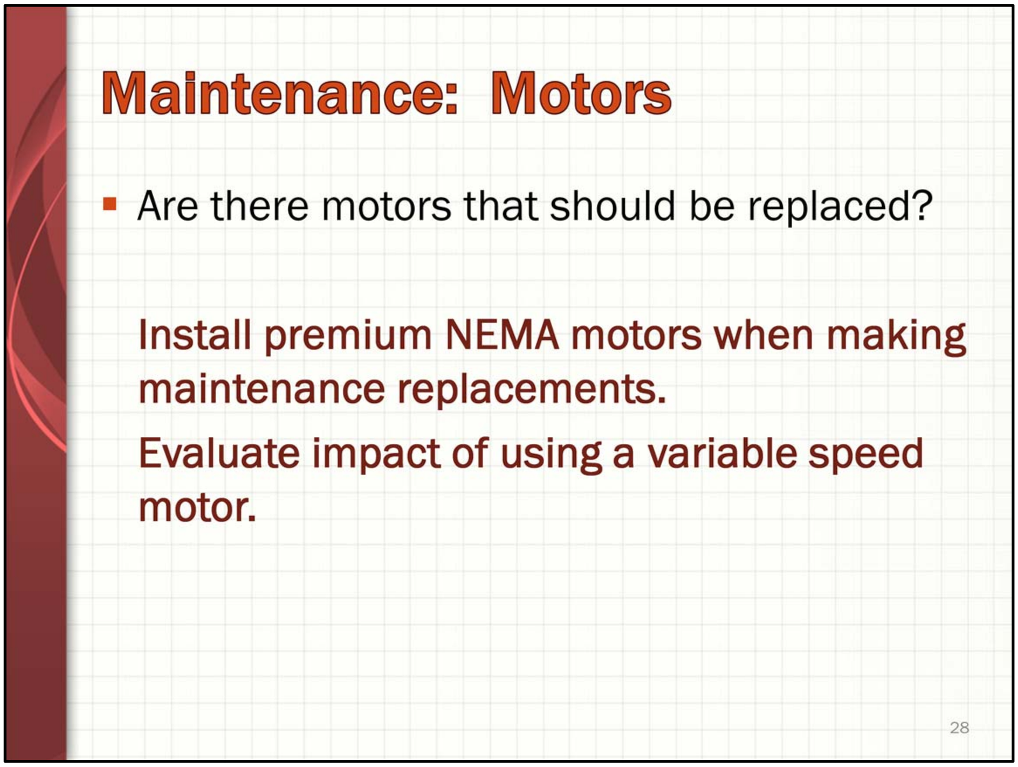
Dirty coils reduce the system's ability to cool cause the system to run longer, increasing energy costs and reducing the life of the equipment. Fencing, shrubbery, or other issues near condensers should be addressed to ensure effective airflow.



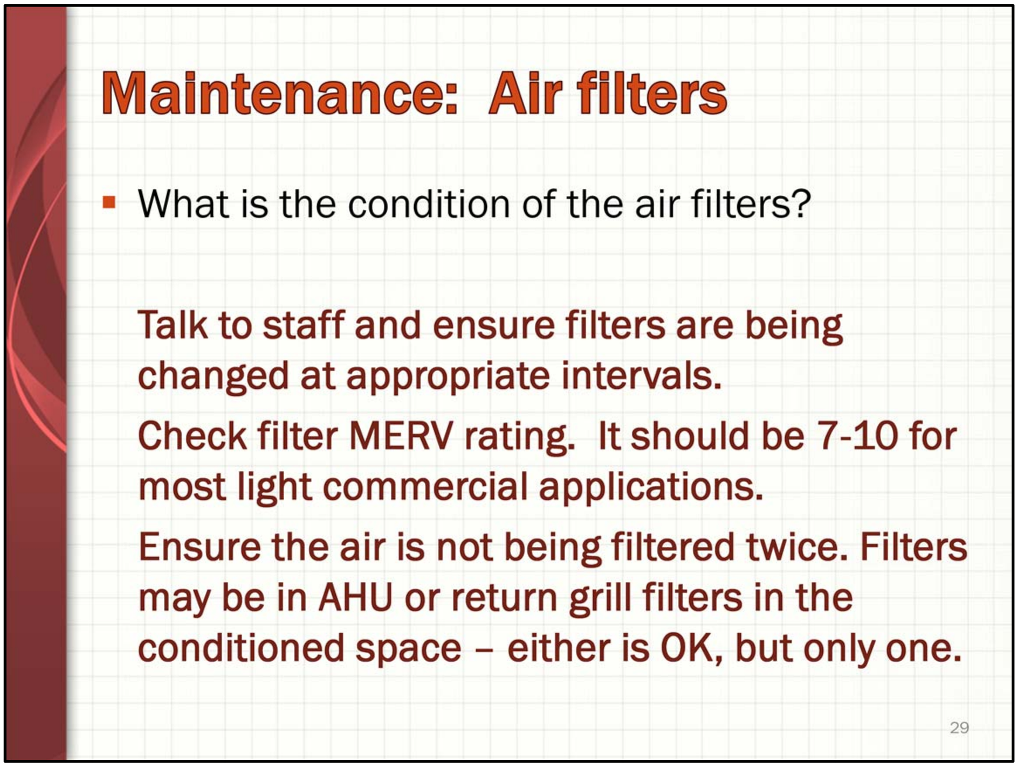
Many systems should be in the 16 – 20°F, with temperatures outside this range indicating issues to be addressed, such as refrigerant charge and airflow being blocked.



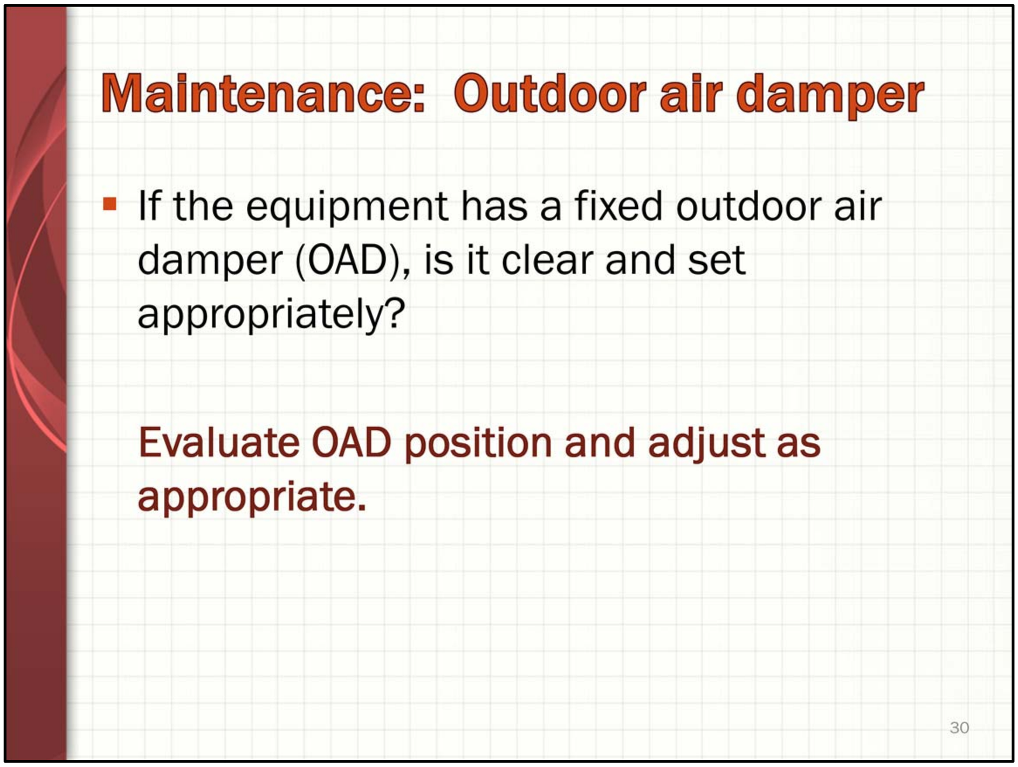
Parts that lack lubrication cause friction in motors, increasing the amount of electricity used, and may impact demand as well. Belts that are loose or frayed reduce drive efficiency. Dirty blowers can reduce system efficiency by up to 15 percent. Many older motors are not sealed and require lubrication.



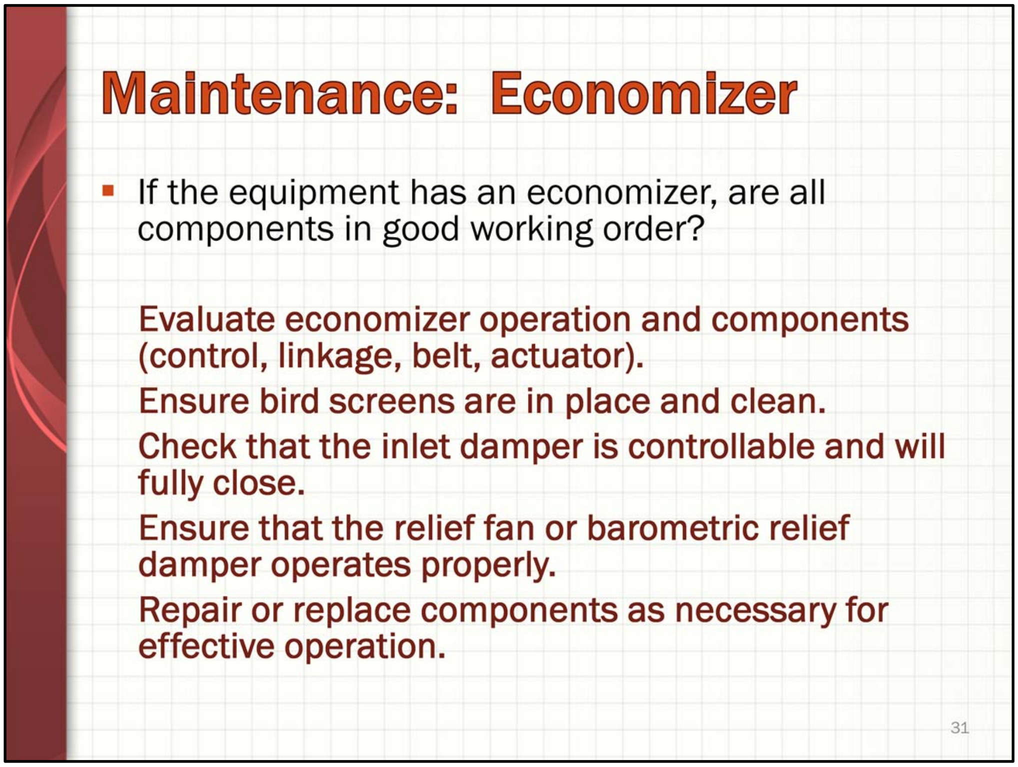
Specify National Electrical Manufacturers Association (NEMA) premium motors on HVAC equipment when motors must be replaced, and consider the option to include variable frequency drives (VFD) on condenser and evaporator fans when appropriate for the specific equipment. Premium efficiency models can save 35 to 45% on motor operation annually. And VFDs, with frequently lower startup current, will reduce peak demand as well.



Dirty filters overwork the equipment, result in lower indoor air quality, and add to energy costs. Bowed filters indicate high air velocity and/or high return pressure, both indicating air flow issues. Double filtration, e.g. with filters in an air handler and filters also in filter-backed return grilles, also reduce airflow and increase the load on the supply fan.

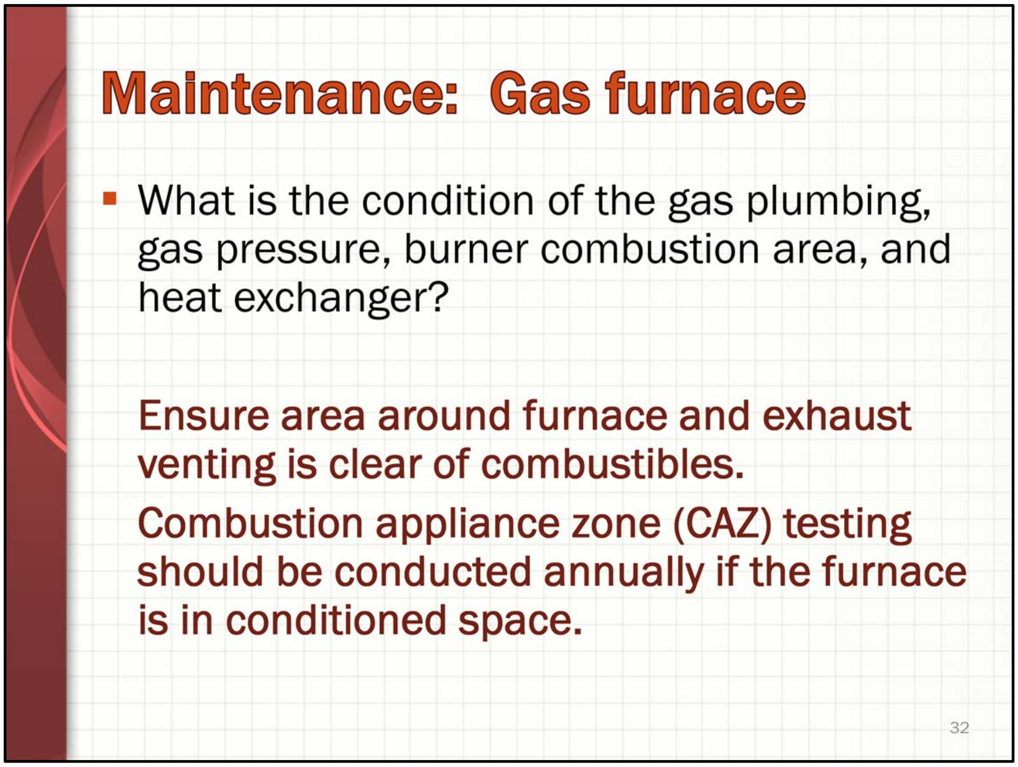


A blocked or closed OAD does not allow fresh air ventilation. An OAD that is set for a larger opening than is required for proper ventilation and building pressurization increases energy consumption.

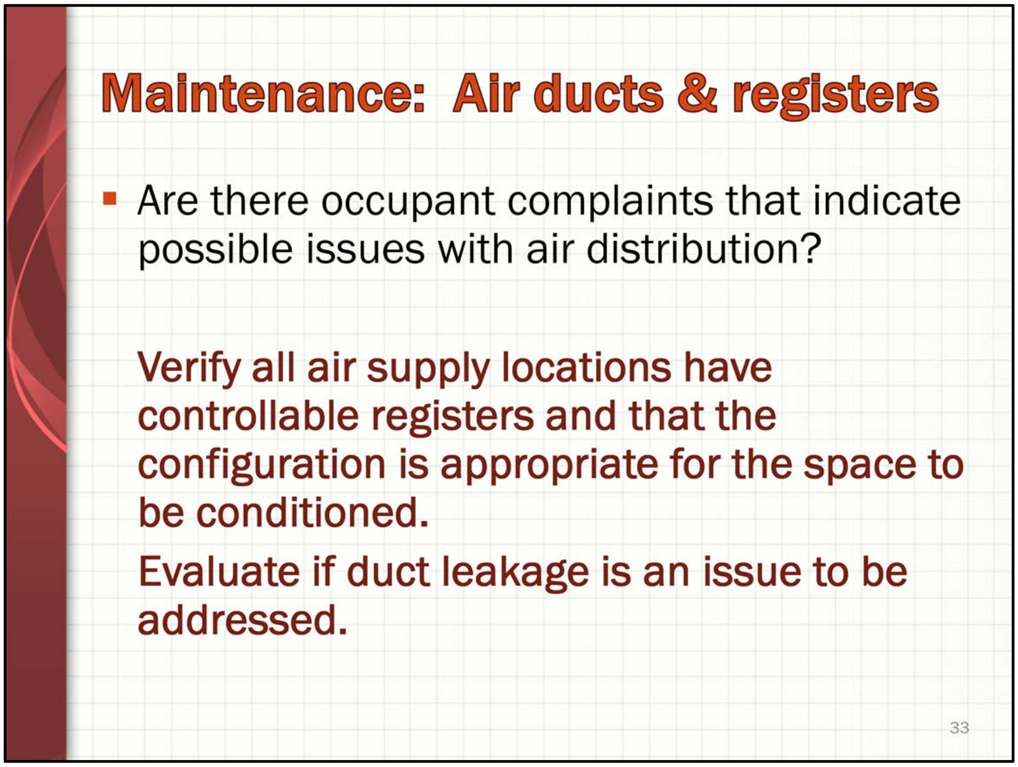


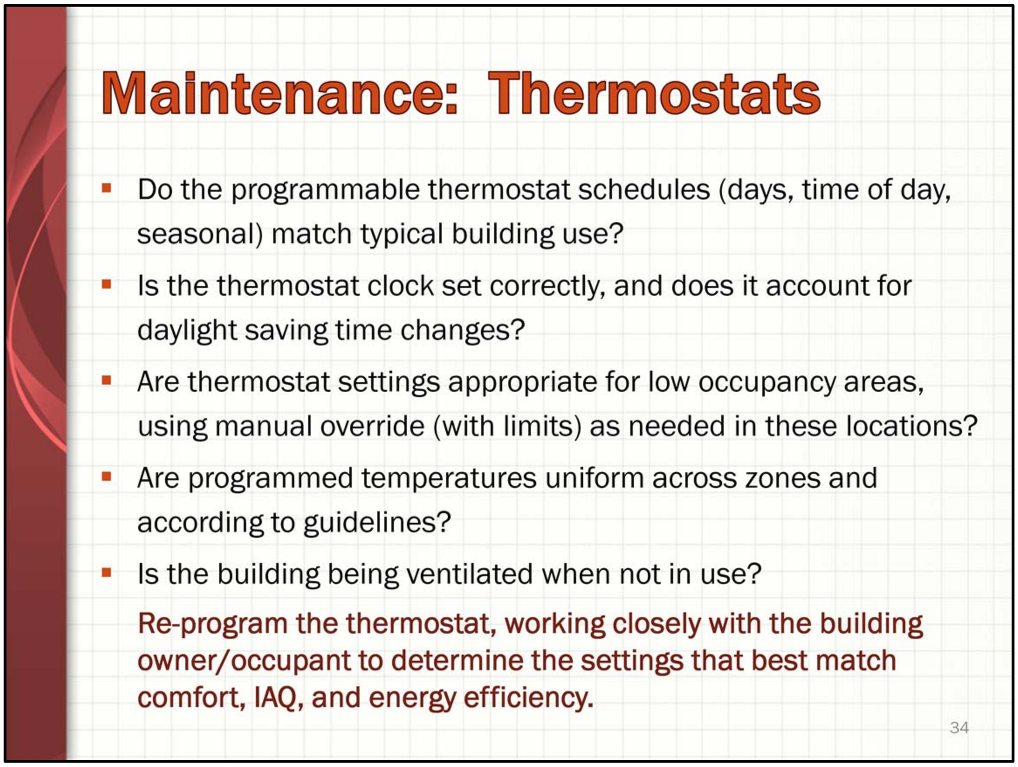
Airside economizer dampers are prone to failure, especially in packaged roof top units. They can fail due to lack of maintenance, failed control components, or improper control settings. A study found that 64% of installed roof top units have failed economizers.* An LES engineer estimates that approximately half of economizers in the Lincoln area need service (2012). The result of failure or components needing maintenance is higher-than-necessary energy bills. Likewise the return damper in the mixing box must also open and close properly.

* "Upstream Solutions to Downstream Problems: Working with the HVAC and Efficiency Communities to Improve Field Performance of Small Commercial Rooftop Units." Jacobs, P.C., Higgins, C., Shwom, R. *2004 ACEEE Summer Study on Energy Efficiency in Buildings – Proceedings.* Available online at: http://www.eceee.org/conference_proceedings/ACEEE_buildings/2004/Panel_6/p6_18/paper

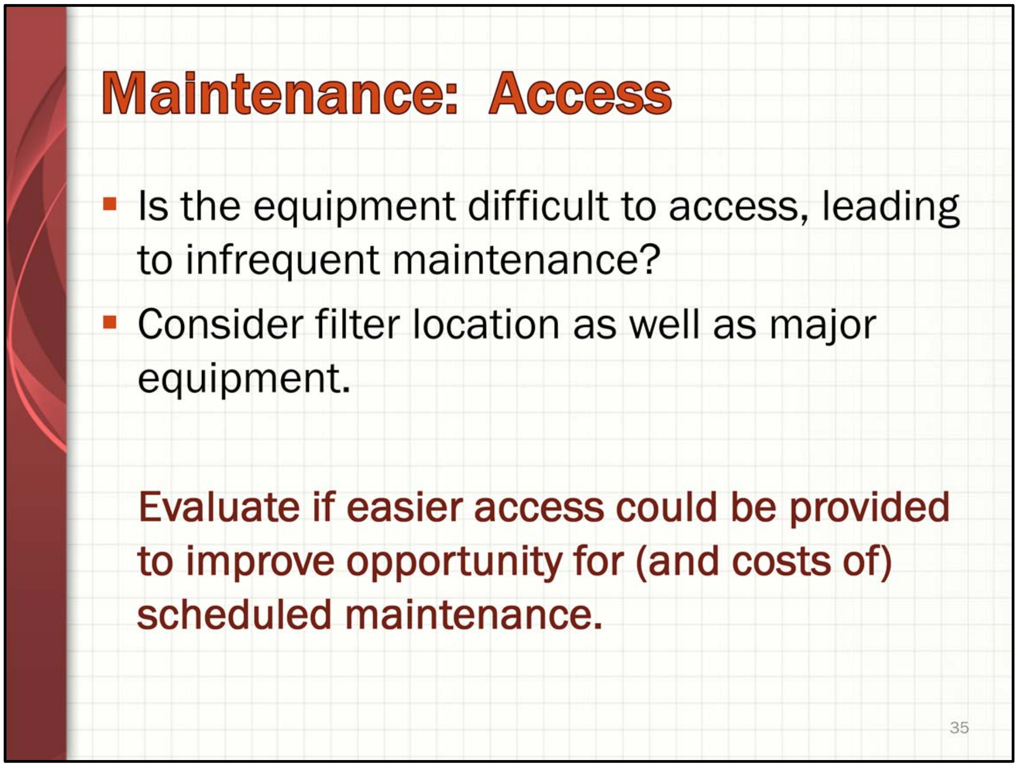


Leaky connections are a fire hazard and can contribute to health problems. A dirty burner or cracked heat exchanger causes improper burner operation. Either can cause the equipment to operate less safely and efficiently.


Maintenance: Air ducts & registers
Are there occupant complaints that indicate possible issues with air distribution?
Verify all air supply locations have controllable registers and that the configuration is appropriate for the space to be conditioned.
Evaluate if duct leakage is an issue to be addressed.
33

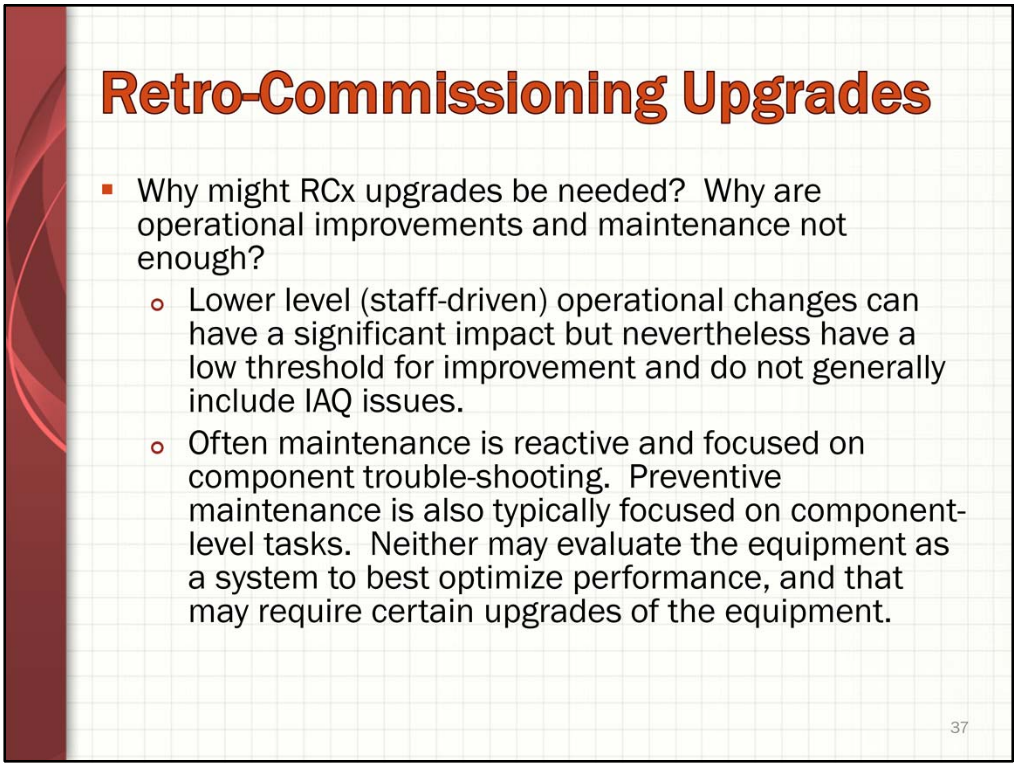


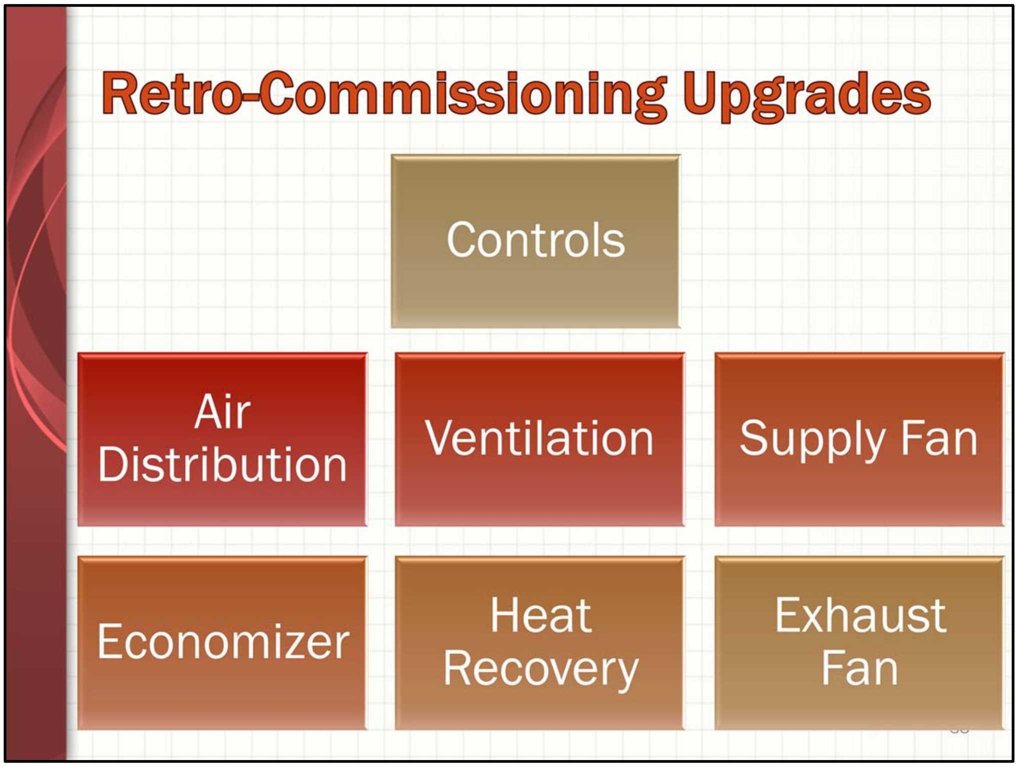
Does this sound familiar? It was already covered under operations, but is so important that it needs repeating.

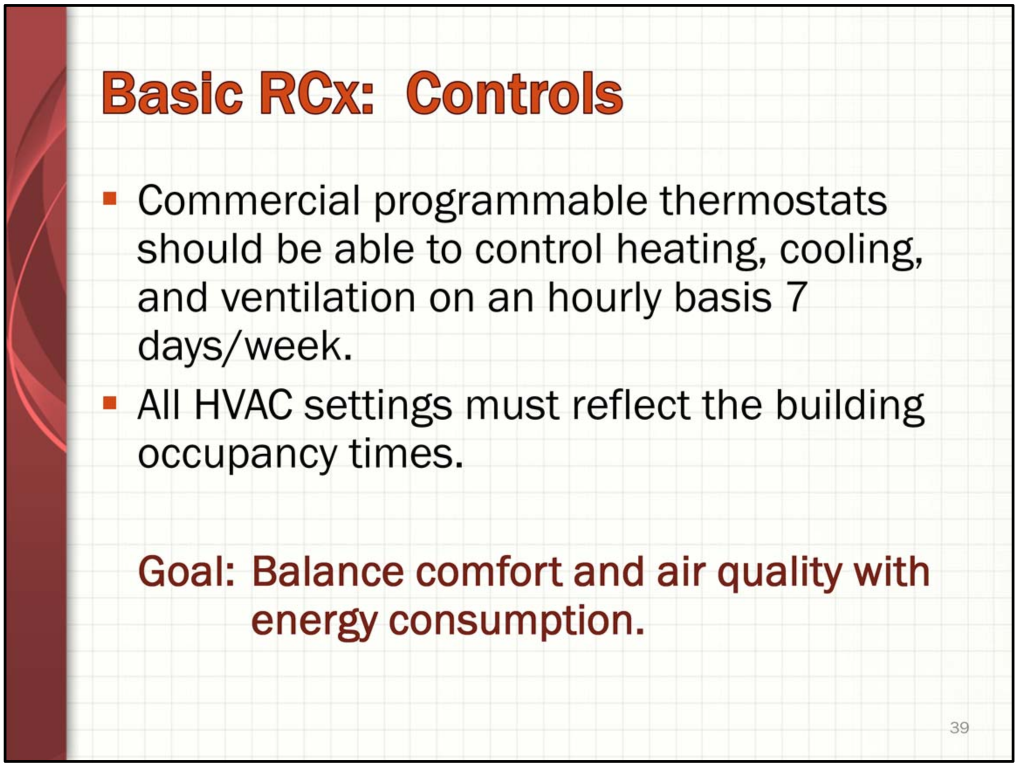


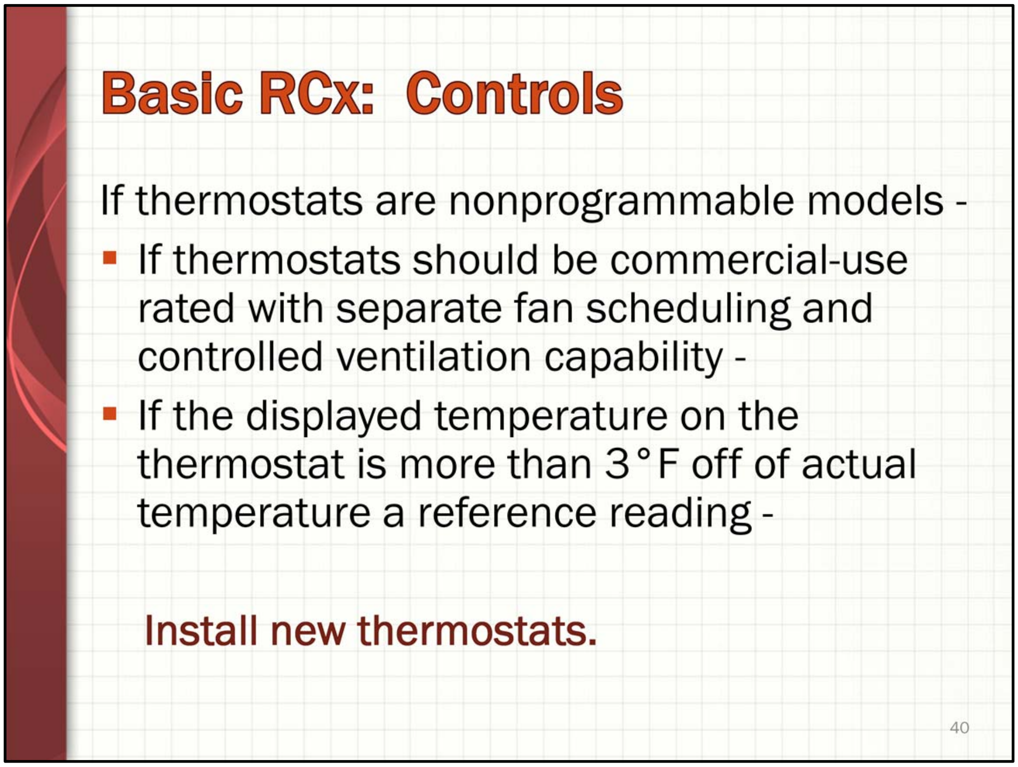
Improving access will lead to reduced equipment failures and reduced energy costs. If practical, provide easier access, particularly to the filter locations. To have a filter that is in a location that is easy to get to is very important for ongoing maintenance. It is also important that the cabinet or plenum that holds the filter is easy to open and close.


Retro-Commissioning Upgrades
36


Retro-Commissioning Upgrades
Why might RCx upgrades be needed? Why are operational improvements and maintenance not enough?
Lower level (staff-driven) operational changes can have a significant impact but nevertheless have a low threshold for improvement and do not generally include IAQ issues.
Often maintenance is reactive and focused on component trouble-shooting. Preventive maintenance is also typically focused on component-level tasks. Neither may evaluate the equipment as a system to best optimize performance, and that may require certain upgrades of the equipment.
37

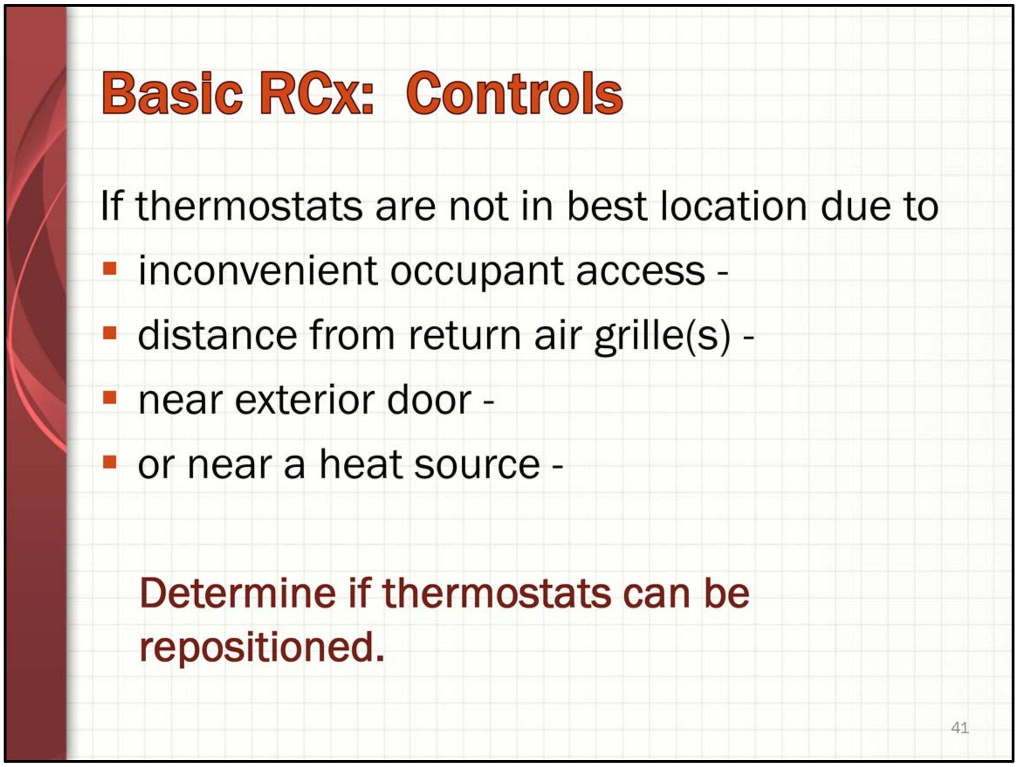

Retro-Commissioning Upgrades
Controls
Air Distribution
Ventilation
Supply Fan
Economizer
Heat Recovery
Exhaust Fan


Basic RCx: Controls
Commercial programmable thermostats should be able to control heating, cooling, and ventilation on an hourly basis 7 days/week.
All HVAC settings must reflect the building occupancy times.
Goal: Balance comfort and air quality with energy consumption.
39



Older style (nonprogrammable) thermostats do not allow for efficient control. Programmable thermostats that are typically used in homes cannot control ventilation. At a minimum the thermostat should have the ability to schedule the supply fan separately from the heating and cooling cycles.

Unlike older models that used mercury switches, the electronic sensors in standalone, digital thermostats generally cannot be recalibrated. However, these temperature sensors can drift over time. Many programmable thermostats have a +/- 4°F offset that can be used to adjust for this drift and enable a closer indication to actual room temperature. Check the thermostat display with an accurate temperature gauge and adjust for drift as appropriate. This may help reduce staff overriding control setpoints.



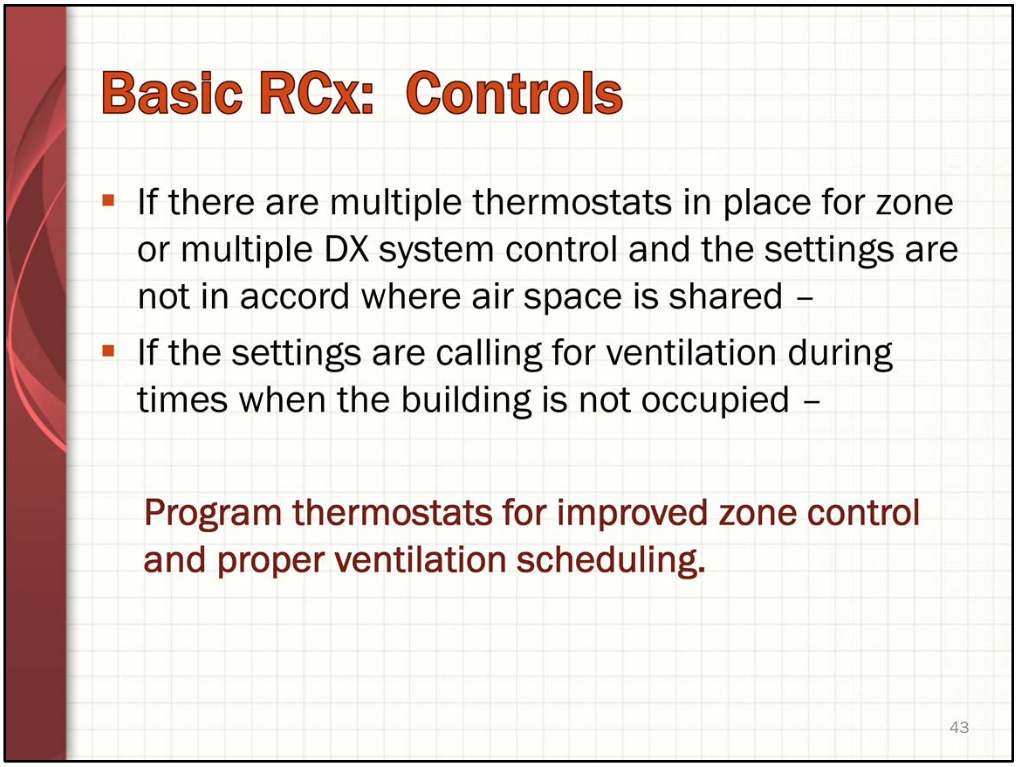
Pay attention to locations with multiple zones and thermostats and returns that are close to one another. Based on many factors (heating or cooling load, occupancy patterns, duct pressures, thermostat variation, etc), the zones that share air distribution may conflict with one another.

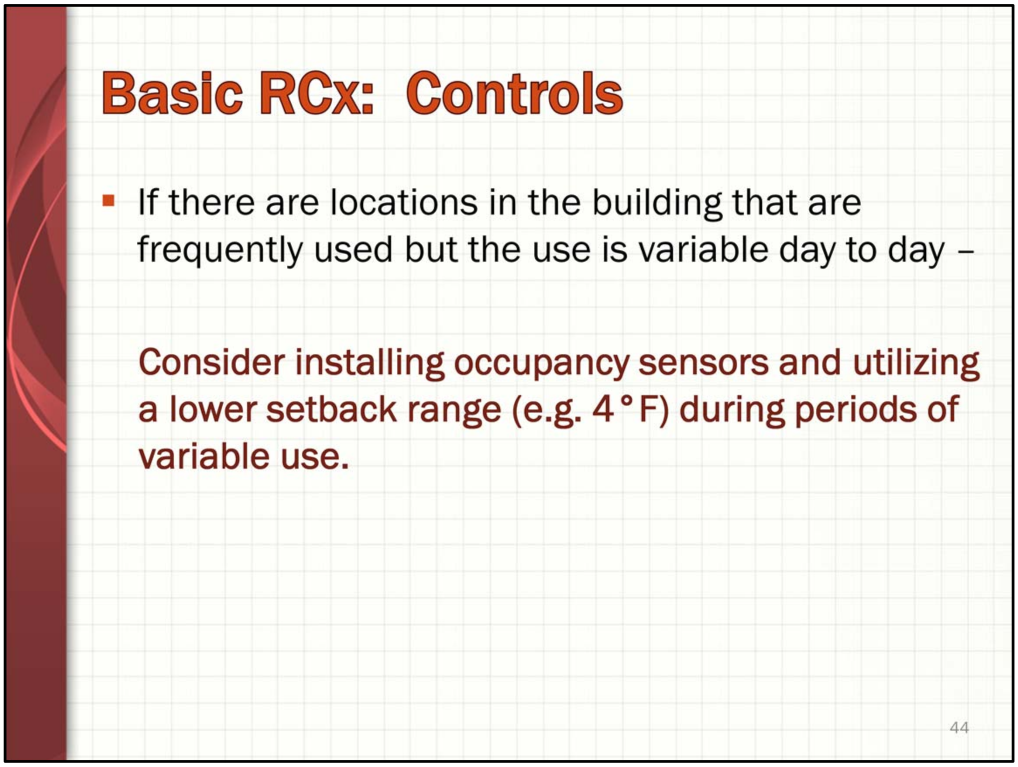
Basic RCx: Controls

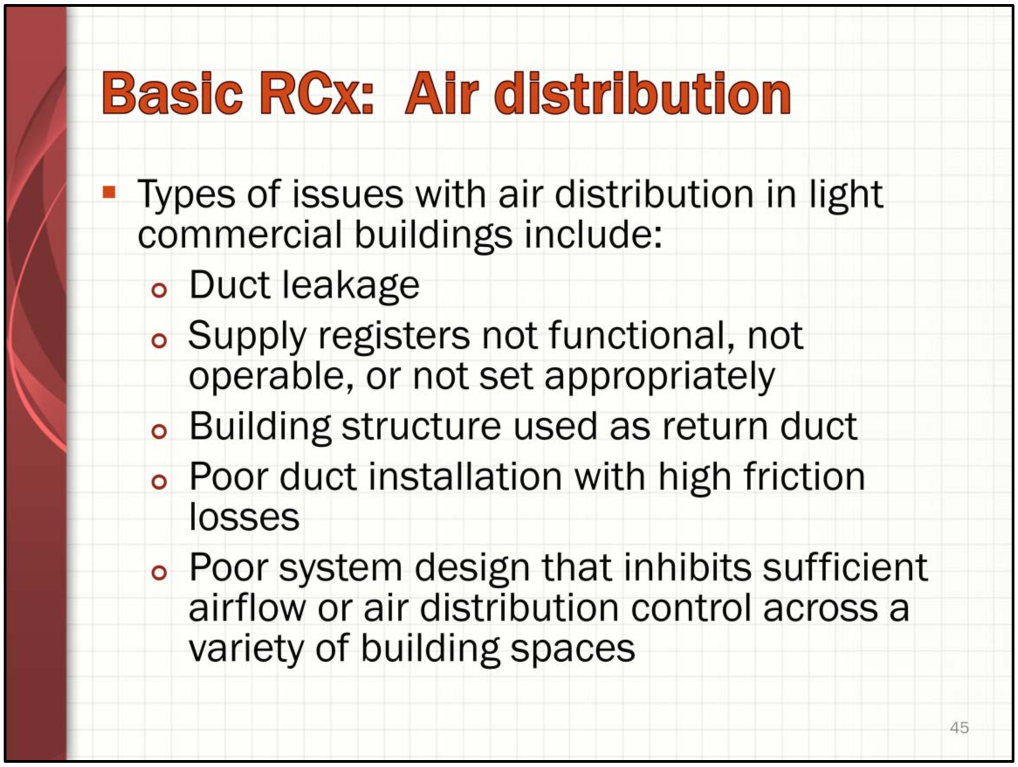
- If the settings do not match the times and days of building operation -
- If the settings do not account for space that is not regularly used -
- If the settings do not include appropriate setback temperatures (e.g. 84ºF/62ºF) –

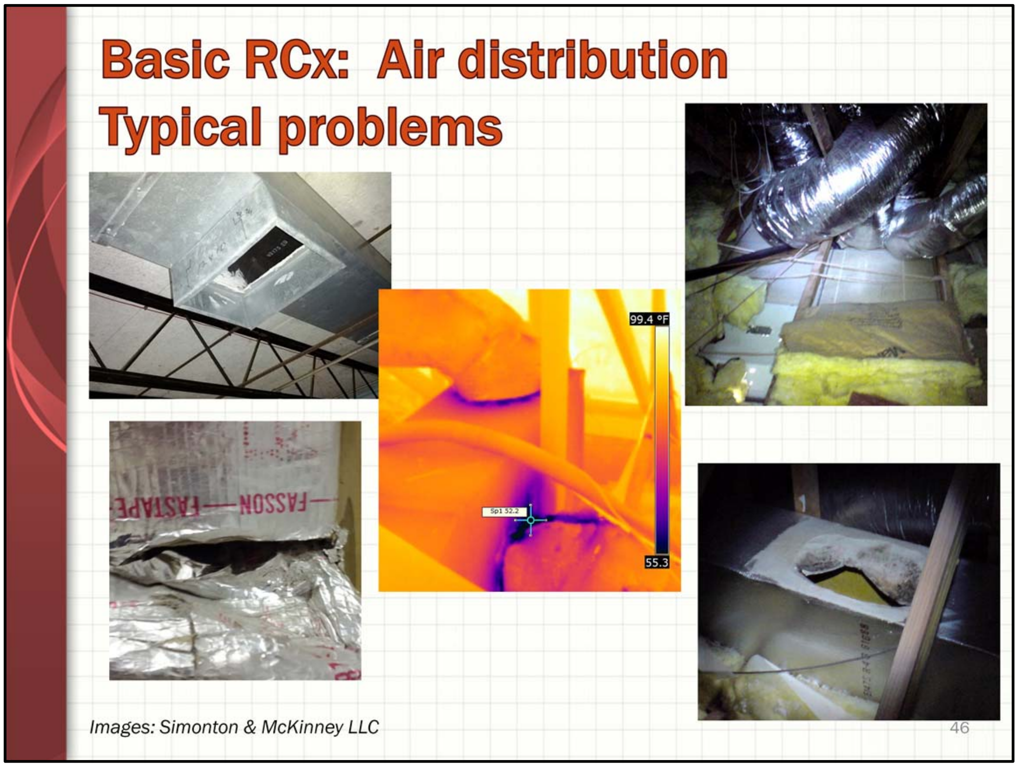
Program thermostats for typical occupancy times and days, space utilization and setback temperatures.

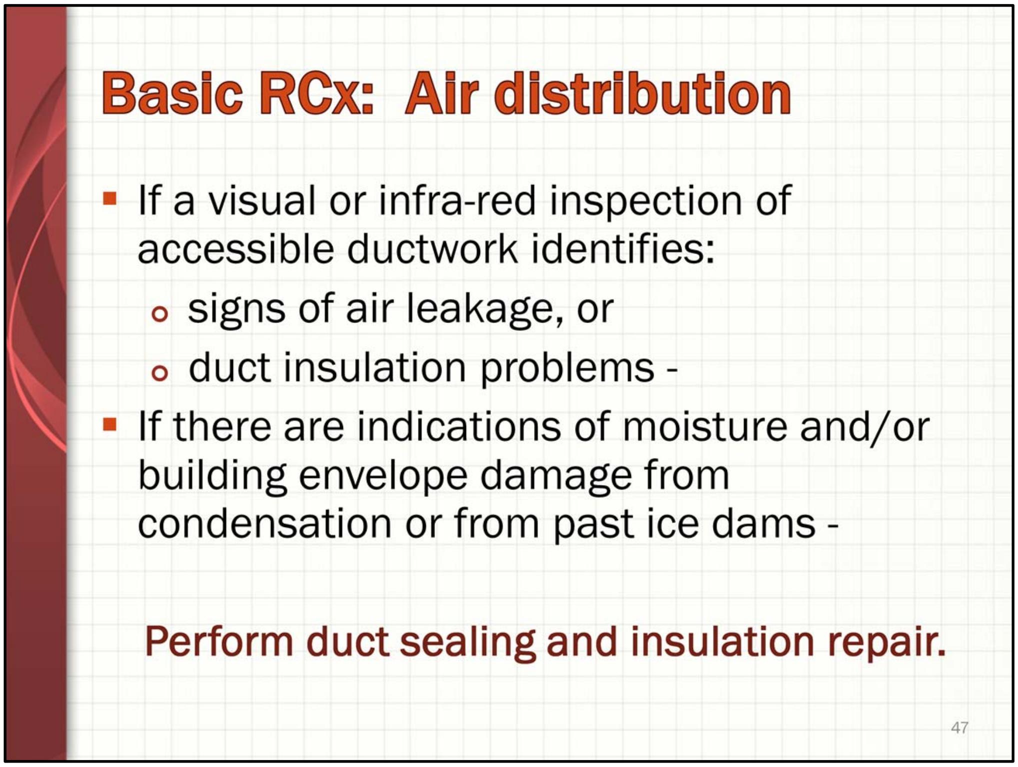
42


Basic RCx: Controls
If there are multiple thermostats in place for zone or multiple DX system control and the settings are not in accord where air space is shared –
If the settings are calling for ventilation during times when the building is not occupied –
Program thermostats for improved zone control and proper ventilation scheduling.
43

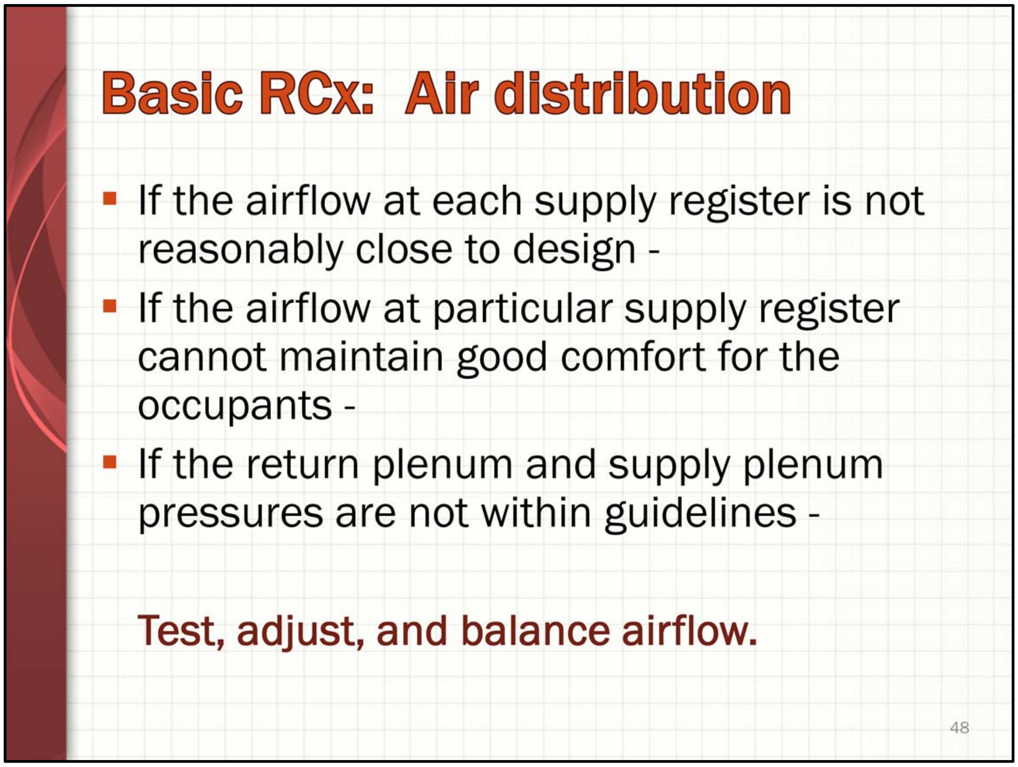

Basic RCx: Controls
If there are locations in the building that are frequently used but the use is variable day to day –
Consider installing occupancy sensors and utilizing a lower setback range (e.g. 4 °F) during periods of variable use.
44


Basic RCx: Air distribution
Types of issues with air distribution in light commercial buildings include:
Duct leakage
Supply registers not functional, not operable, or not set appropriately
Building structure used as return duct
Poor duct installation with high friction losses
Poor system design that inhibits sufficient airflow or air distribution control across a variety of building spaces
45

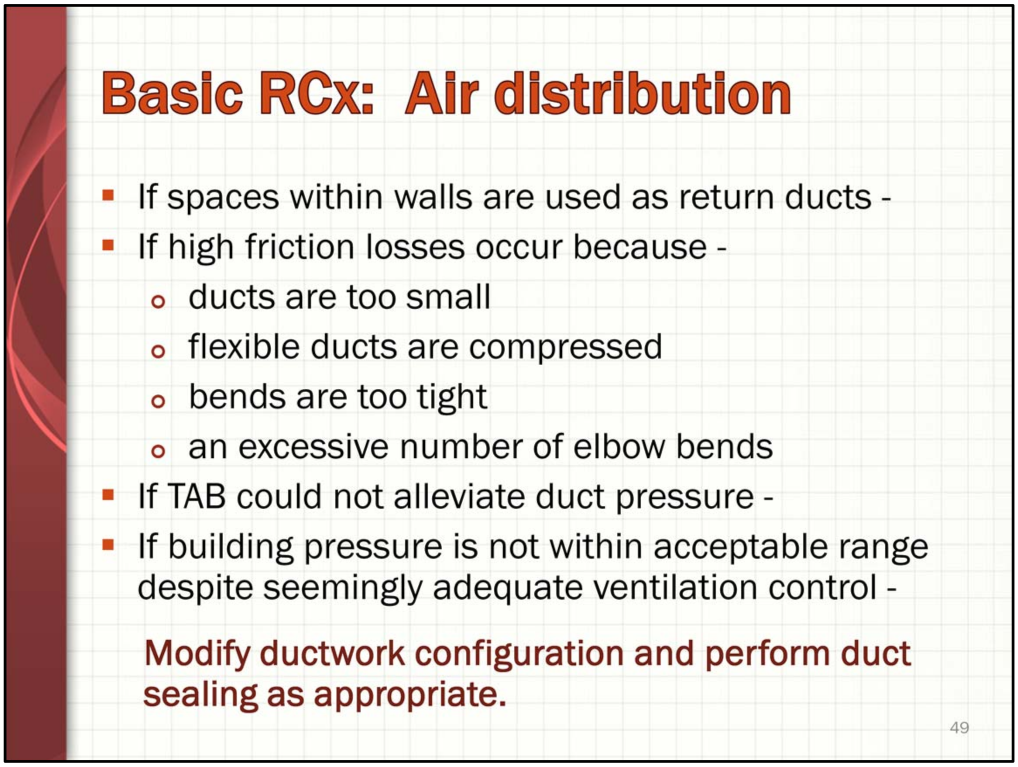

Basic RCx: Air distribution
Typical problems
99.4 °F
55.3
FASSON—FASTAPE
Images: Simonton & McKinney LLC
46



Duct leaks result in loss of efficiency, loss of system capacity, higher operational costs, and reduced comfort for building occupants. In certain environments and buildings duct leaks result in moisture-related structural damage. Leaks in returns can result in spread of contaminants and lower indoor air quality.



A balanced system with duct pressures within guidelines and supply registers providing the appropriate airflow to each area results in improved comfort and reduced operating costs.



Older buildings may utilize walls or other building spaces for return air, leading to contaminants entering the air distribution system and lowering both air quality and system efficiency. Poor installation, particularly with flexible duct drops and restrictions, results in higher fan pressures and reduced airflow.

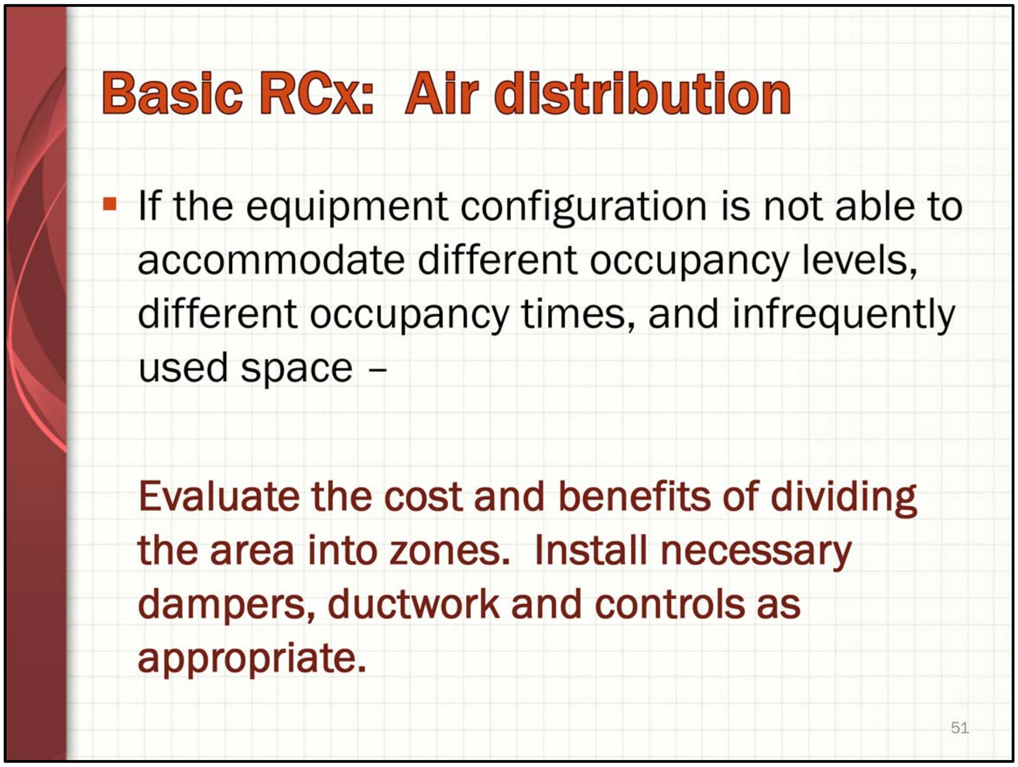
TAB = test, adjust and balance

Compressed flexible ducts

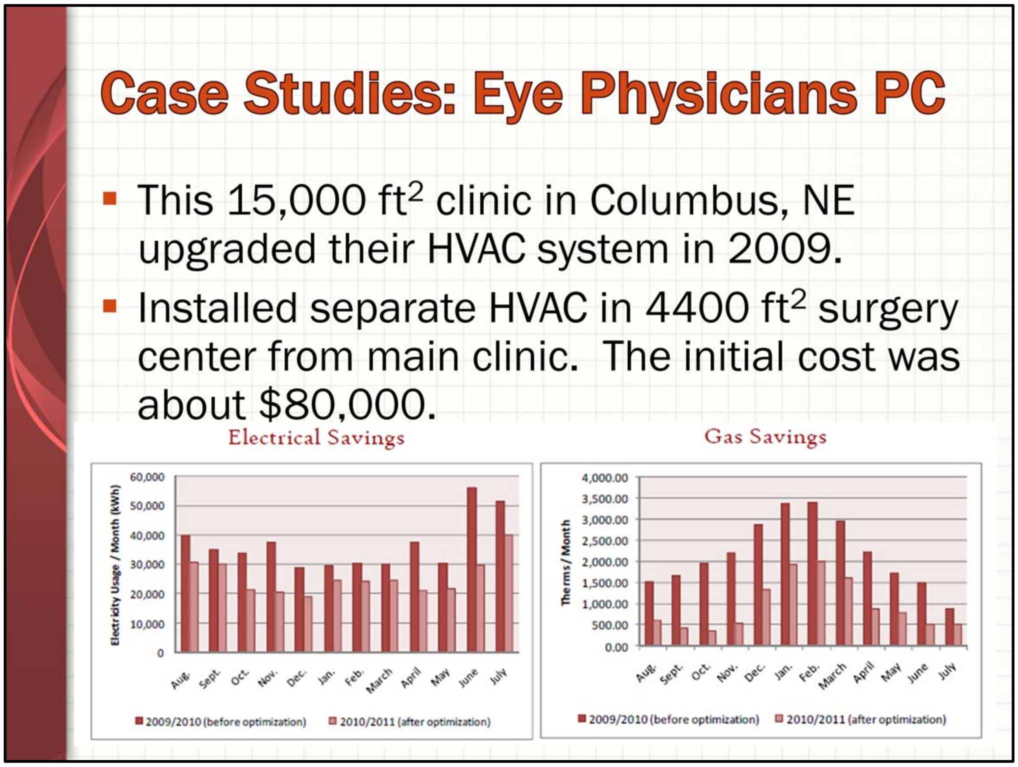
Image: C. Miller, University of Florida

Image: Simonton & McKinney LLC

50



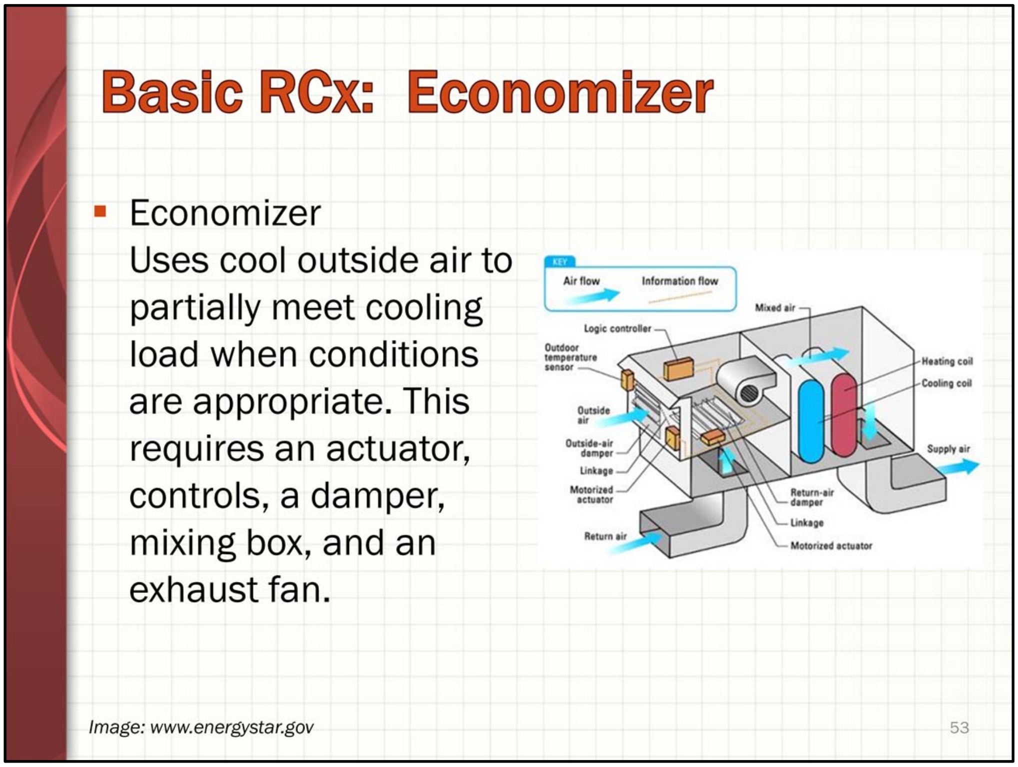
Total equipment capacity may be within design guidelines, but controlling different loads in various parts of a building may be difficult without zone controls.



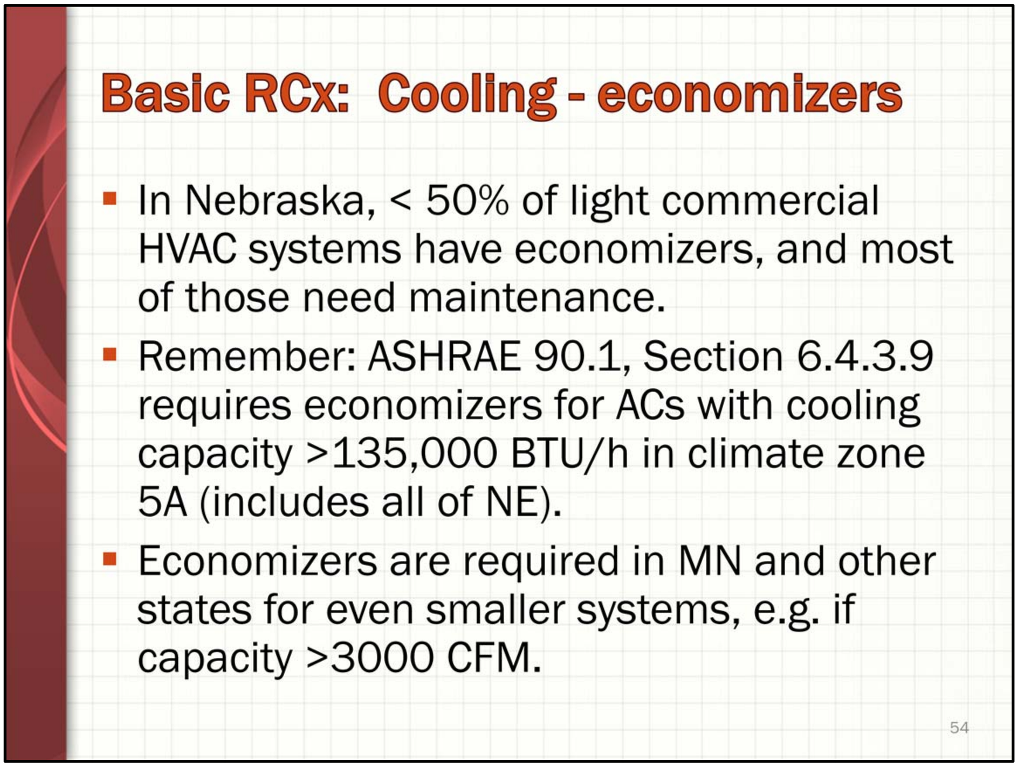
The surgery center had specific requirements for temperature, humidity and air filtering that was not necessary for the majority of the building. The former system was very noisy with high airflow. The initial payback period was estimated at 5 years, but larger than anticipated energy savings are reducing the period to about 3 years.

www.cmiomaha.com

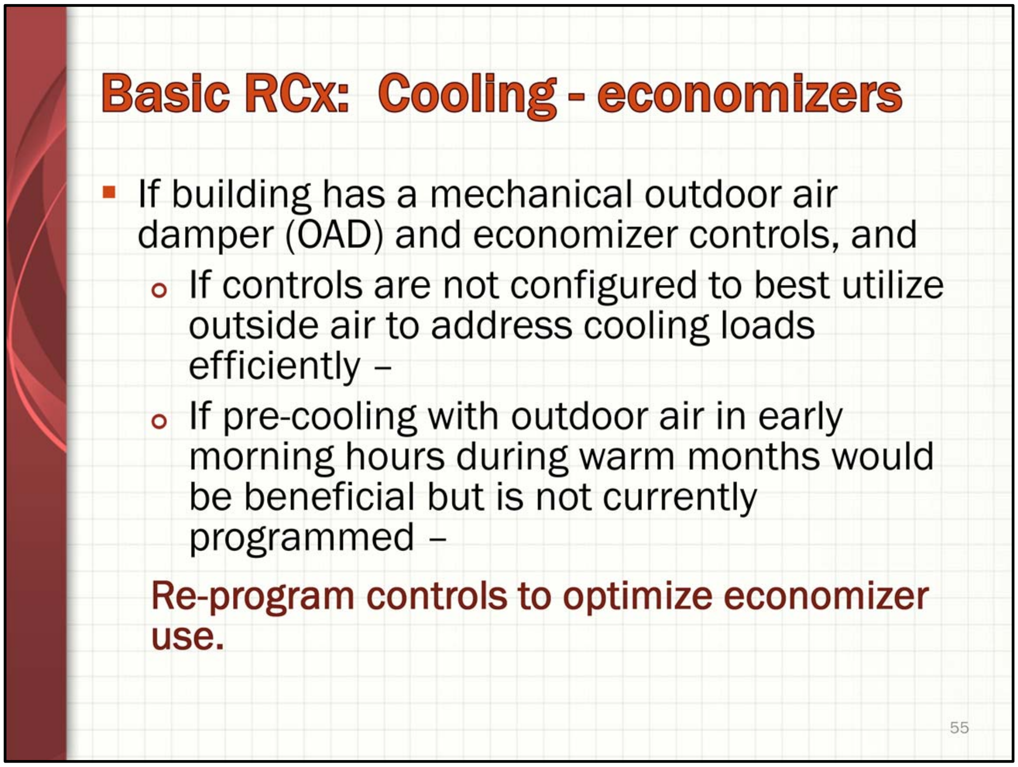
Data used by permission of Marsha Mulley, Office Manager



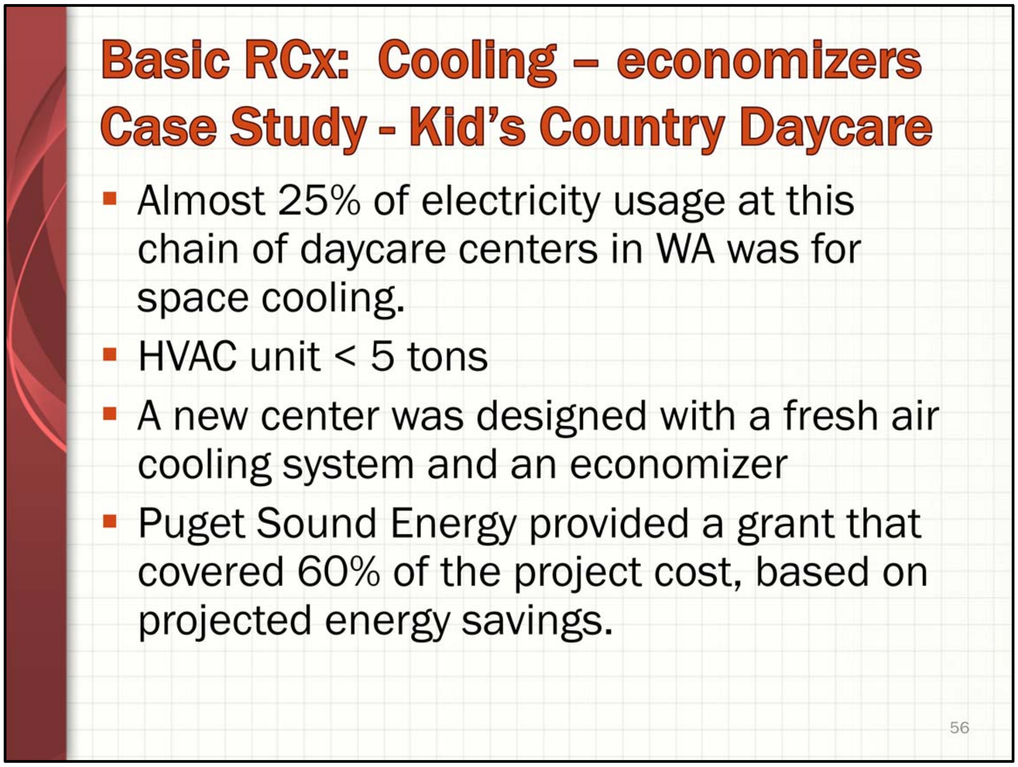
Often available at a low incremental cost, economizers draw in fresh air from the outside when the temperature outside is lower than the temperature inside. An economizer system uses large quantities of outside air to meet the cooling load rather than operating the mechanical cooling system. This involves providing the following: additional controls to evaluate outside versus indoor air, dampers to allow up to 100% outside air to be brought into the building, a mixing box that combines outside air and return air, and an exhaust or relief fan.

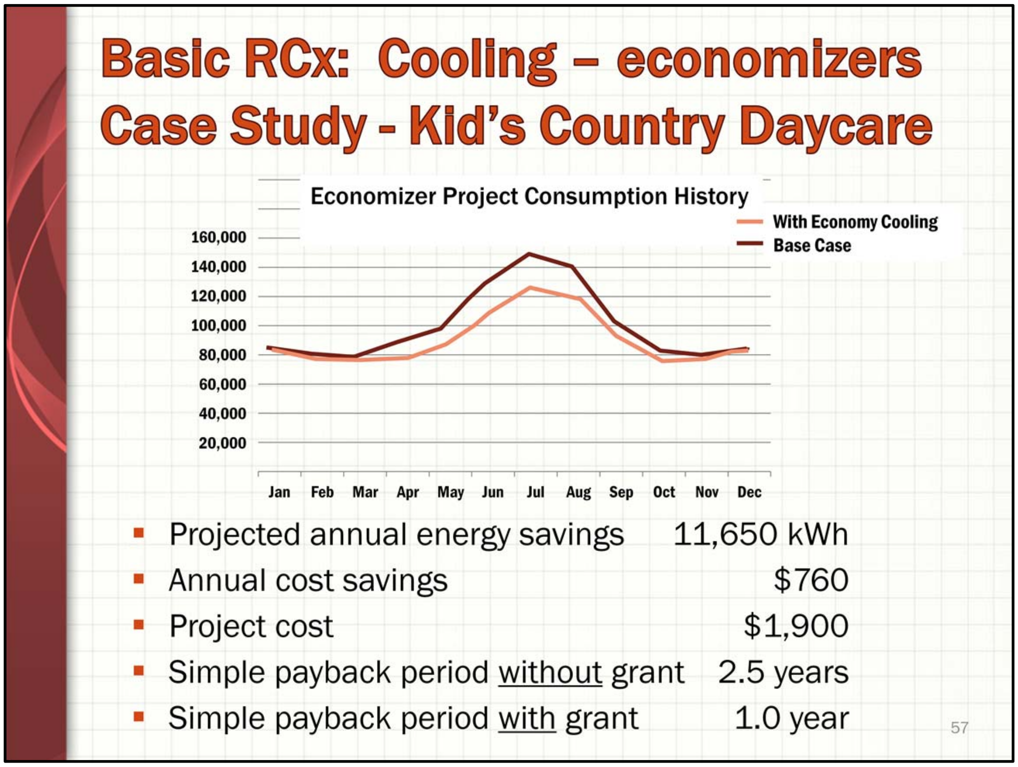


NE economizer estimate from LES, 06-2012



Very often economizers are not well maintained and need service. See the preventive maintenance section for particular PM measures to ensure good performance of an existing economizer.

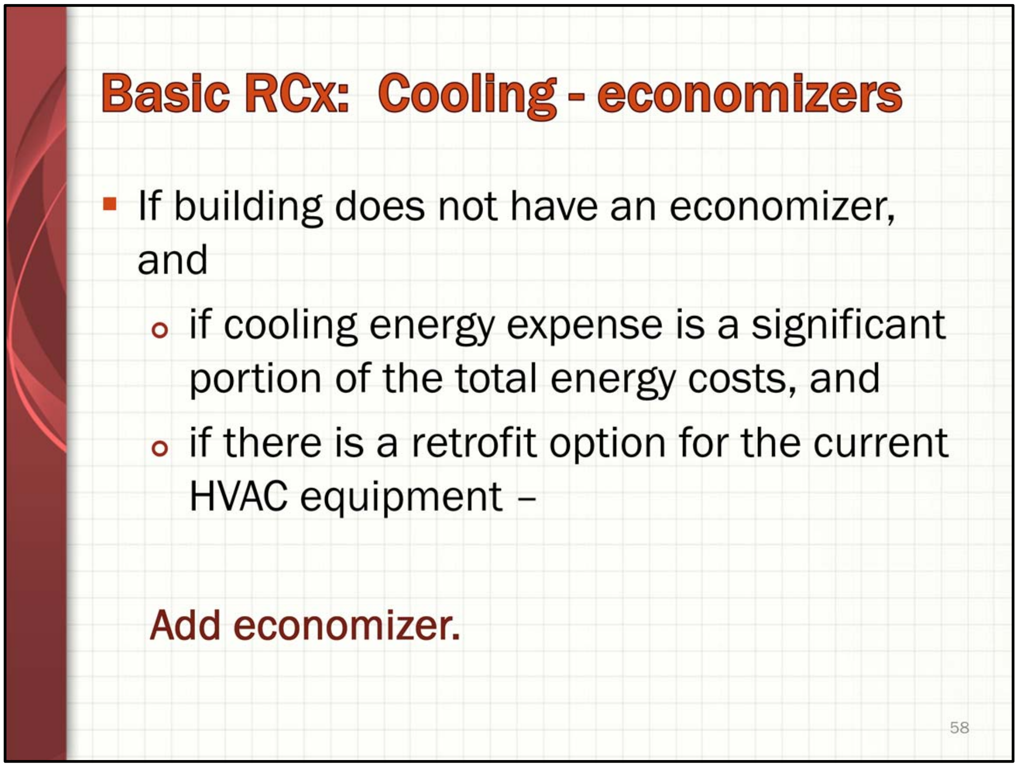

Basic RCx: Cooling – economizers
Case Study - Kid's Country Daycare
Almost 25% of electricity usage at this chain of daycare centers in WA was for space cooling.
HVAC unit < 5 tons
A new center was designed with a fresh air cooling system and an economizer
Puget Sound Energy provided a grant that covered 60% of the project cost, based on projected energy savings.
56



In addition to energy savings, maintenance costs have been reduced because the new compressor runs for shorter periods.

The building also uses automated controls, exceeds requirements of Washington State's Energy Code and has not reduced the comfort or safety of the occupants.

http://pse.com/savingsandenergycenter/ForBusinesses/Documents/CaseStudy_KidsCountry.pdf



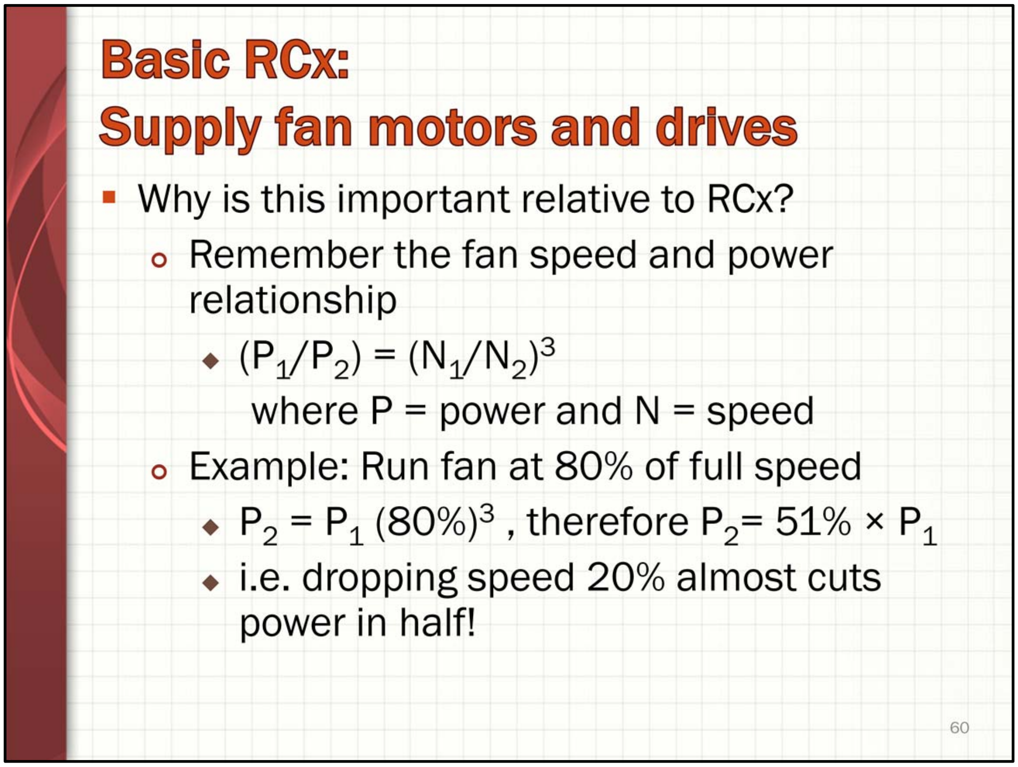
See Trane *Engineers Newsletter* Vol 35-2 – Airside Economizers for a good overview of economizer equipment and operations. The link www.fscc-online.com/HIW-Economizers%20(Spring'99)/hiw-economizers.html provides a quick overview. Integrated economizer control, using a more sophisticated control unit to utilize outdoor air for cooling simultaneously with condenser operation, may not be cost effective and may cause equipment operation issues on simple DX systems (PNNL-20955 *Energy Savings and Economics of Advanced Control Strategies for Packaged Air-Conditioning Units with Gas Heat*, Dec 2011).

Basic RCx: Supply fan motors and drives

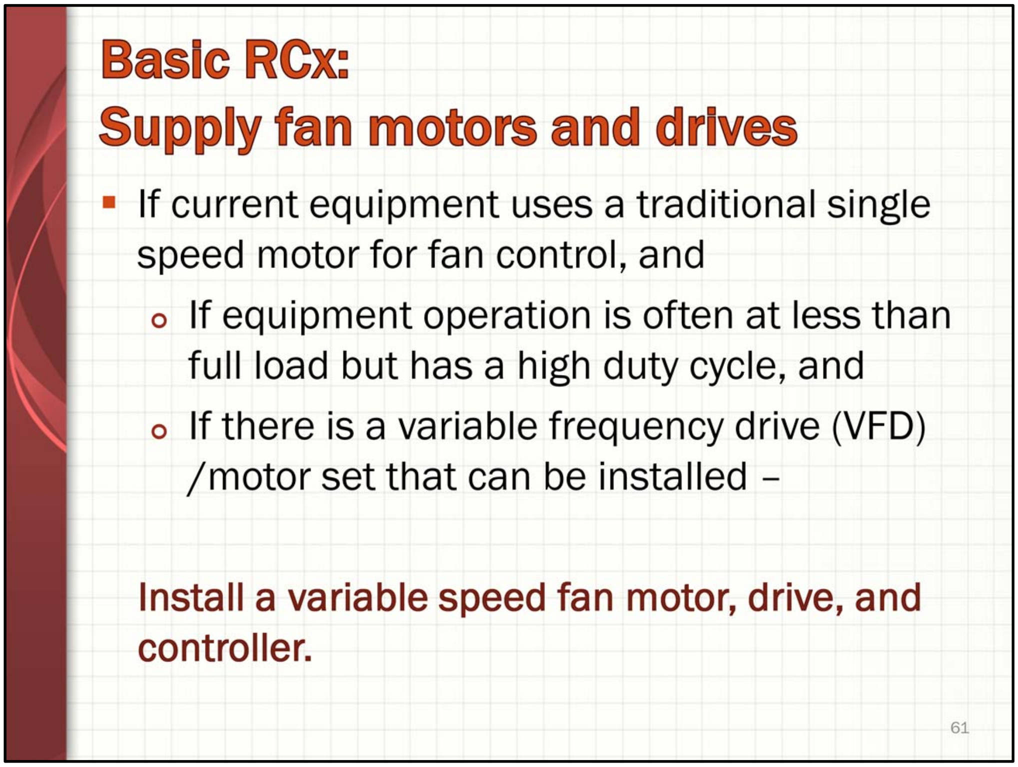
- Supply fans in light commercial systems have a longer duty cycle to handle ventilation needs than residential systems.
- Some state and local codes (e.g. CA, MN) require these fans to operate at least 55 min/hour when occupied.
- ASHRAE 90.1 6.4.3.10b, effective 01/01/12 requires supply fans be controlled by two-speed motors or variable-speed drives for DX equipment ≥ 110,000 Btu/hr serving single zones.

Image: iStockphoto

59

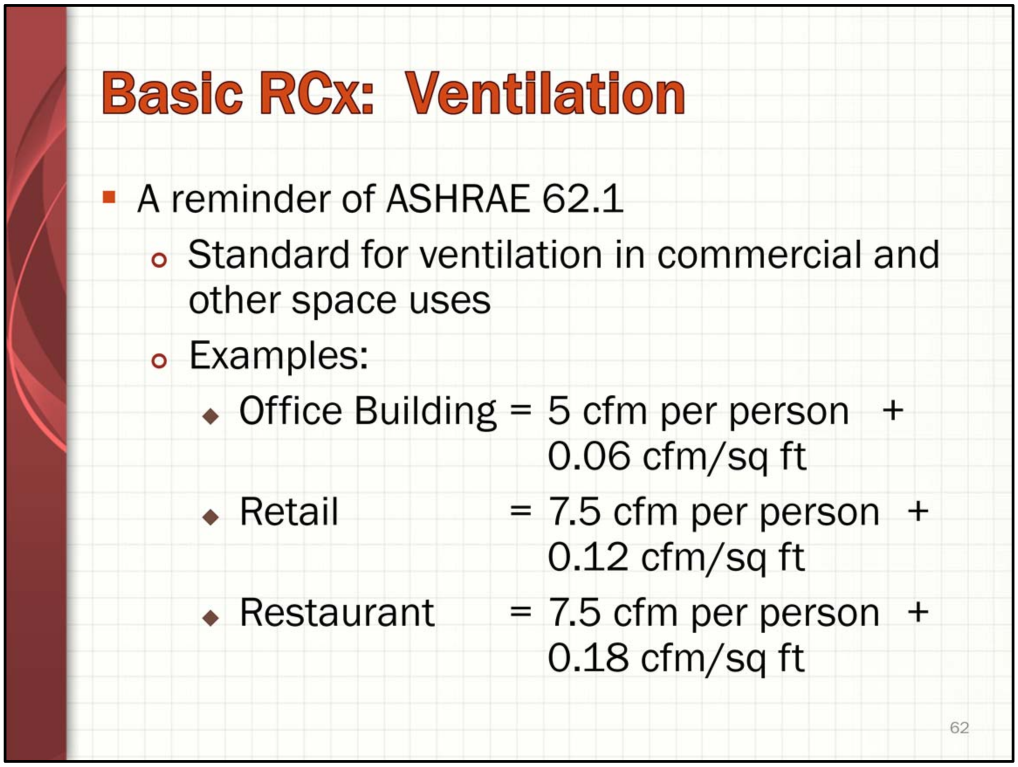


For long duty cycle applications, like supply fans, reducing motor speed to better match current loading has a big impact on power needs and therefore energy consumption. With ventilation, dampers and variable speed motors can be controlled together to best meet makeup air needs using the most efficient operation of the equipment.



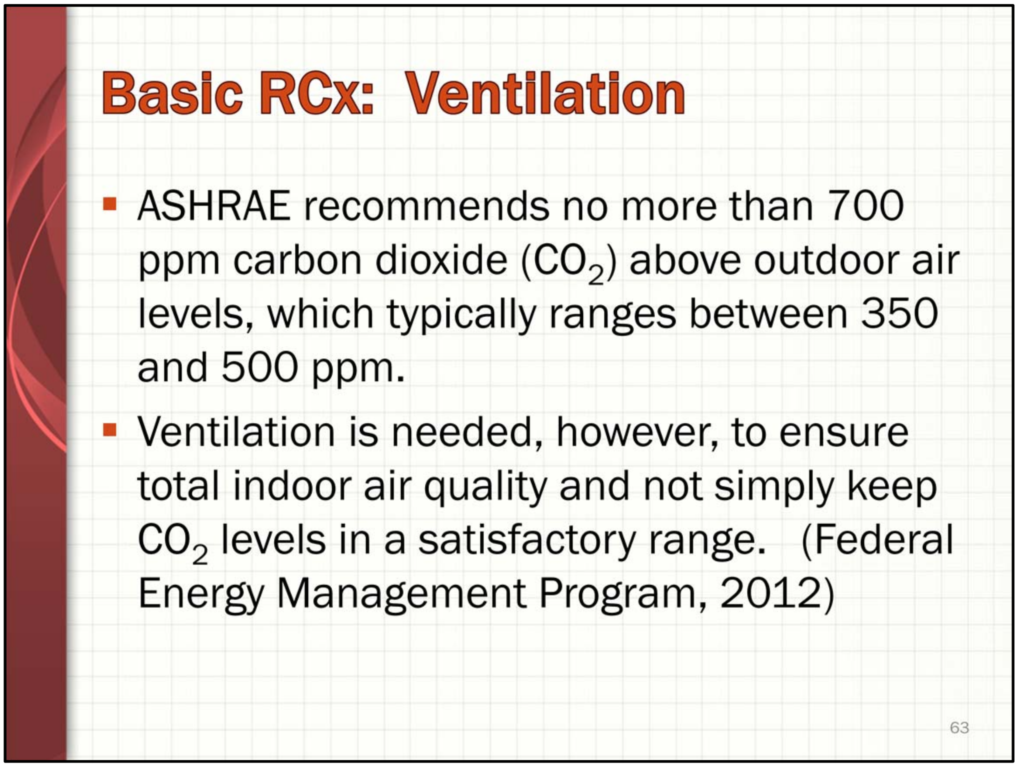
There are variable speed motor and drive packages available to fit a variety of HVAC applications (roof top unit [RTU] and split systems); sources include motor manufacturers such as Baldor and Yaskawa America.

For applications where the equipment has a high duty cycle near full load, NEMA premium-rated or ECM (electrically commutated) motors may be a good option.

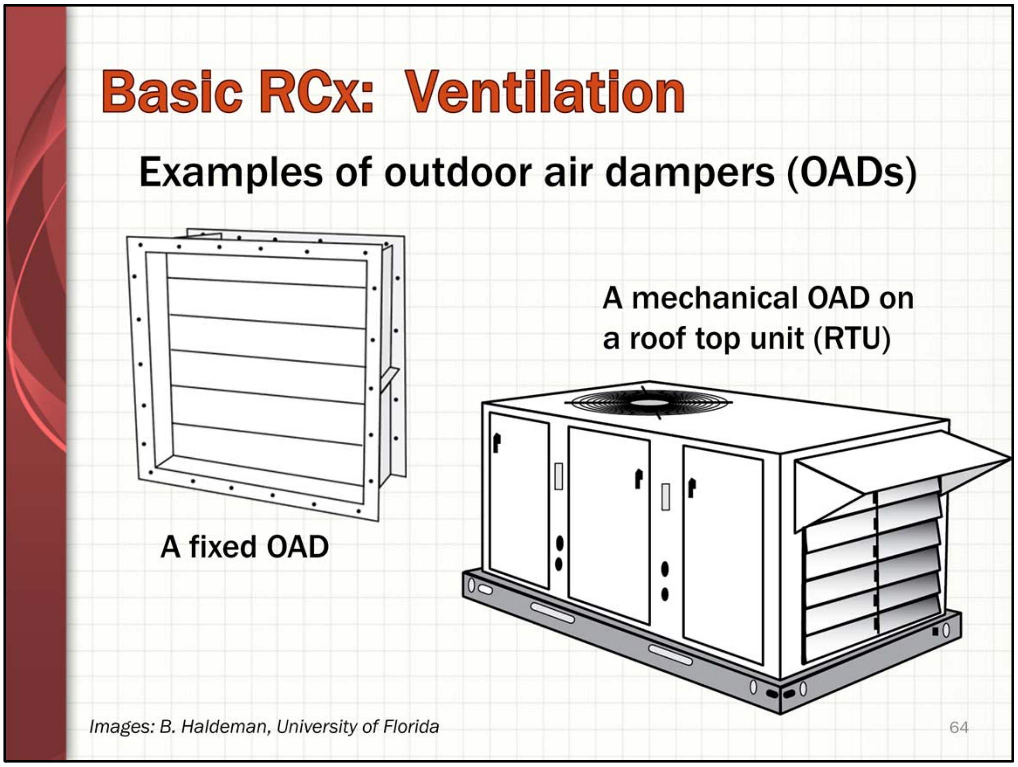


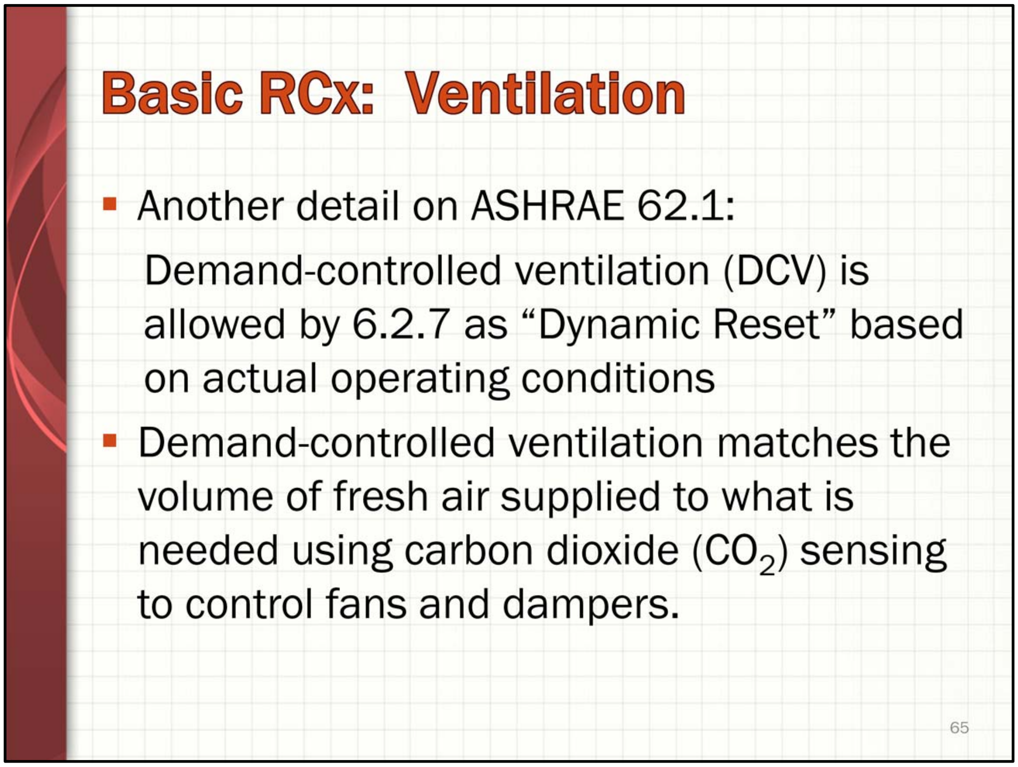
Building codes require a minimum amount of fresh air be provided to ensure adequate air quality. To comply, ventilation systems often operate at a fixed rate based on an assumed occupancy and the floor area. The result is there can be more fresh air coming into buildings than is necessary. In light commercial applications, particularly with split systems, there may be insufficient control of ventilation air, and less ventilation air than required by code and for good indoor air quality.

Typical roof top units (RTUs) with a constant speed supply fan and fixed outdoor air dampers (OADs) will not adjust for variable ventilation loads. Ventilation air must be conditioned, resulting in higher energy consumption and costs than is necessary with appropriate ventilation. In humid climates, excess ventilation also can result in uncomfortable humidity, and mold and mildew growth, making the indoor air quality (IAQ) worse rather than better.

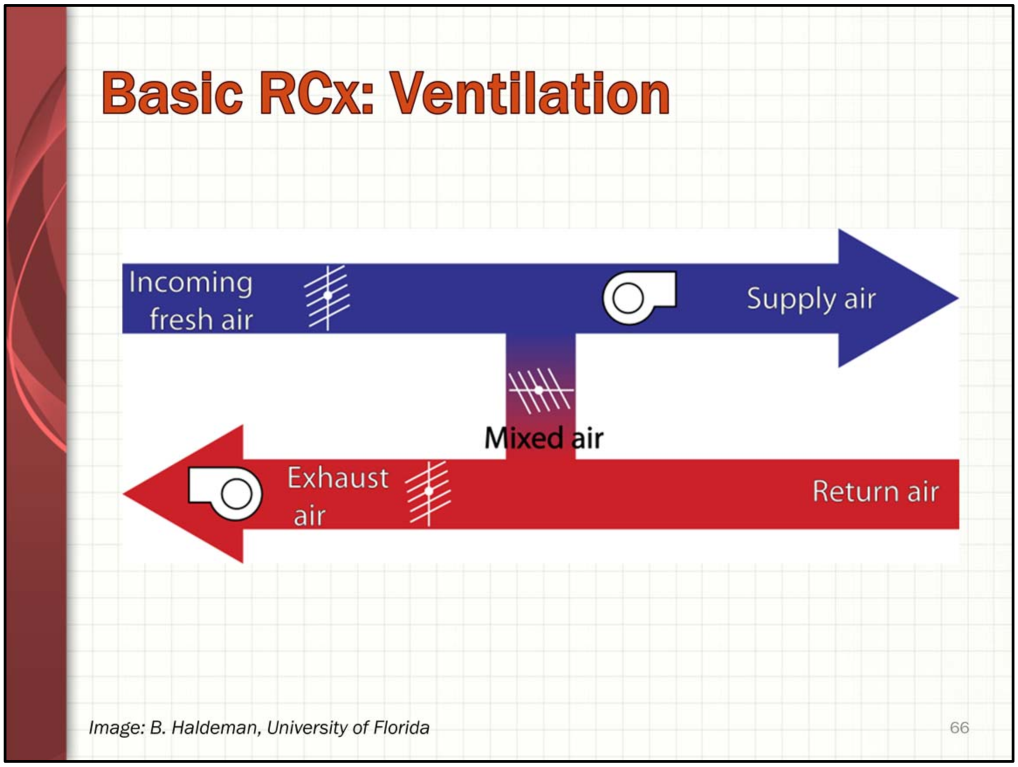


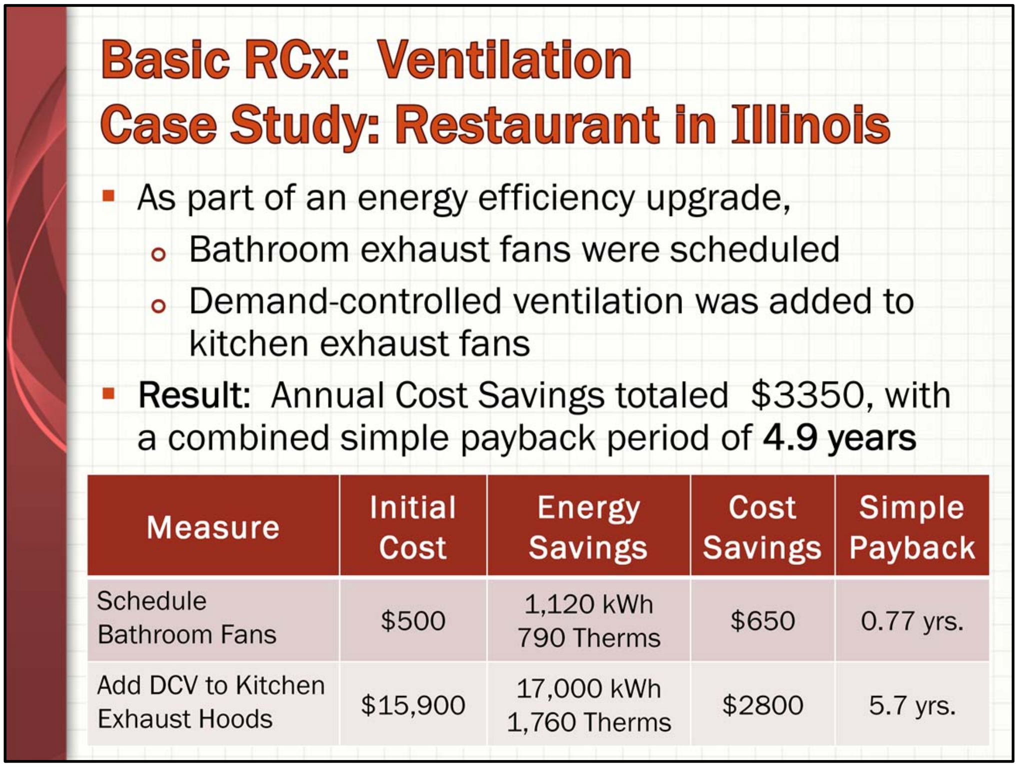
A lack of adequate fresh air can make building occupants drowsy, uncomfortable, and if working, less productive. Nationwide Insurance has participated in studies that indicate employees lose productivity at levels above 600ppm CO_2. (K. Smith, Crystal Air & Water, 2012)


Basic RCx: Ventilation
Examples of outdoor air dampers (OADs)
A mechanical OAD on a roof top unit (RTU)
A fixed OAD
Images: B. Haldeman, University of Florida
64



People exhale carbon dioxide (CO_2) and this can be used to measure ventilation required for good indoor air quality. Demand-controlled ventilation uses sensing to monitor CO_2 levels in the air inside a building, and an air-handling system to regulate the amount of ventilation air admitted.


Basic RCx: Ventilation
Incoming fresh air
Supply air
Mixed air
Exhaust air
Return air
Image: B. Haldeman, University of Florida
66

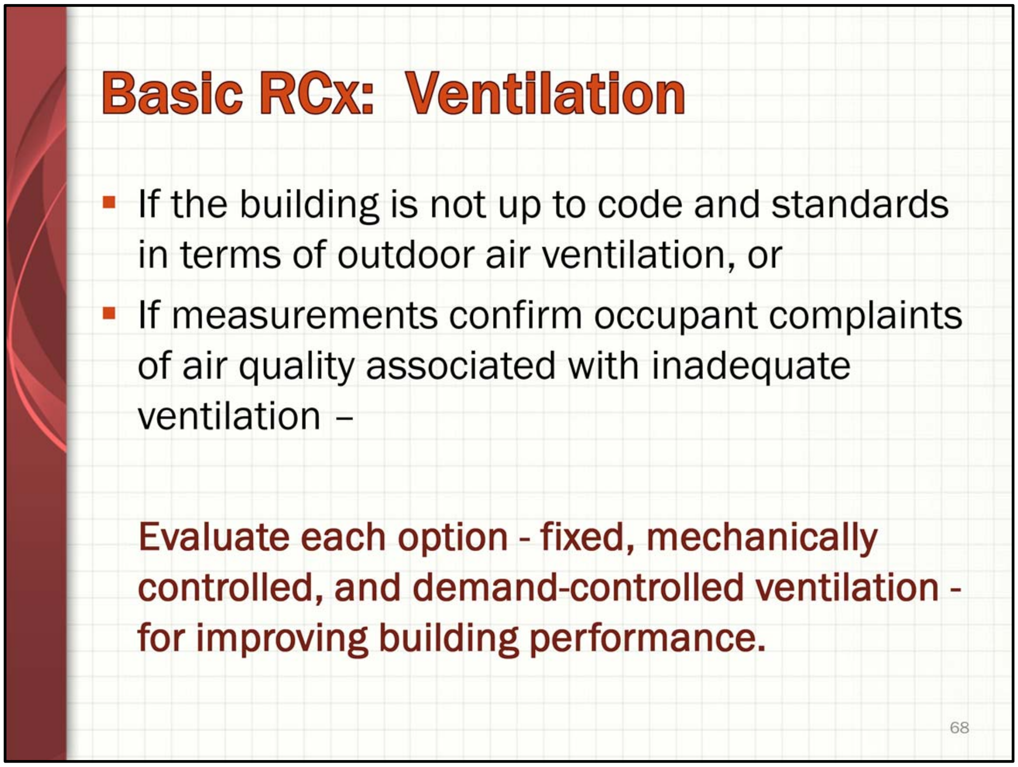


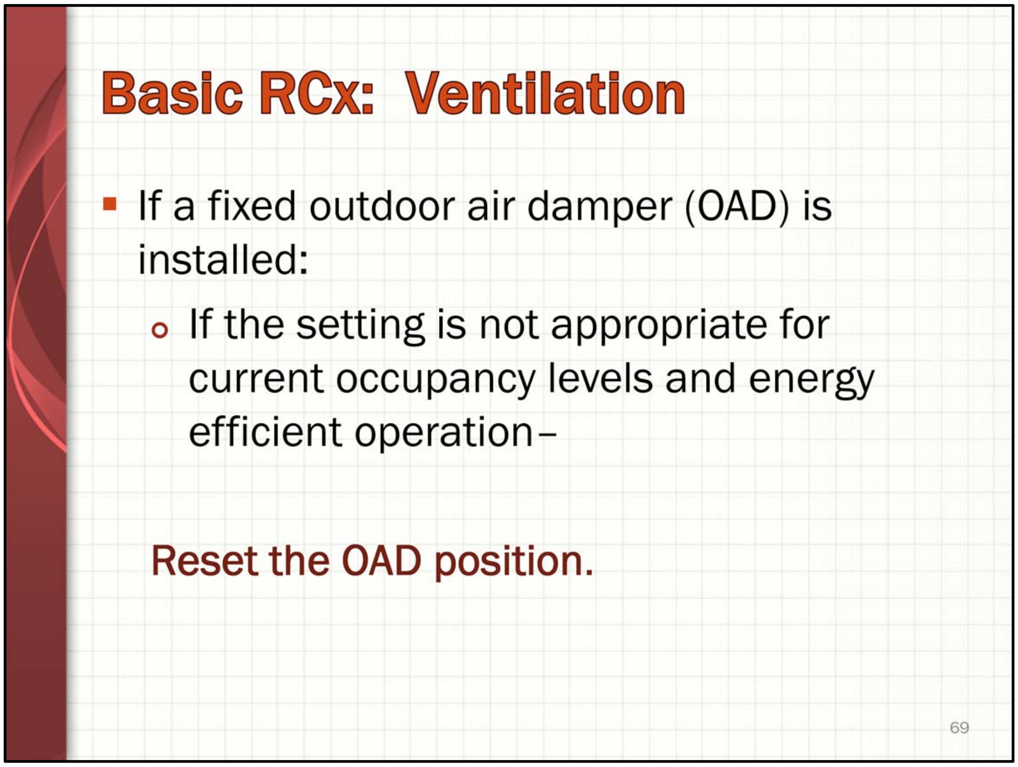
Energy Impact Illinois http://energyimpactillinois.org/cases/?reload=y

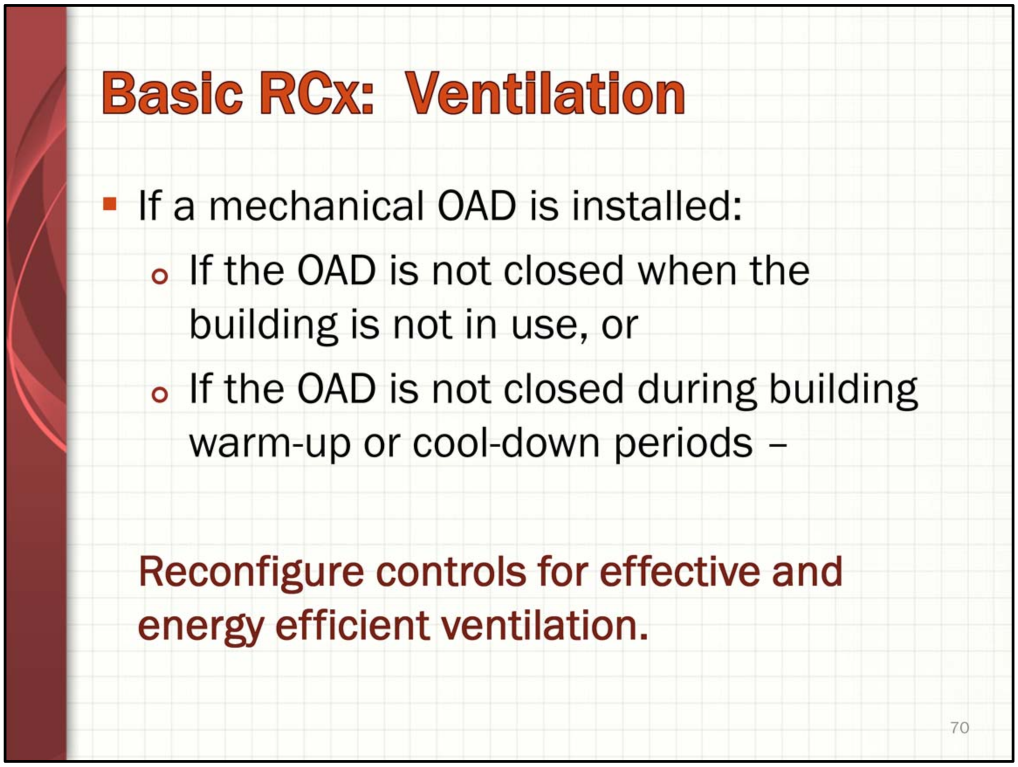
What's Cookin' in the Kitchen? Energy Savings! May 26, 2011

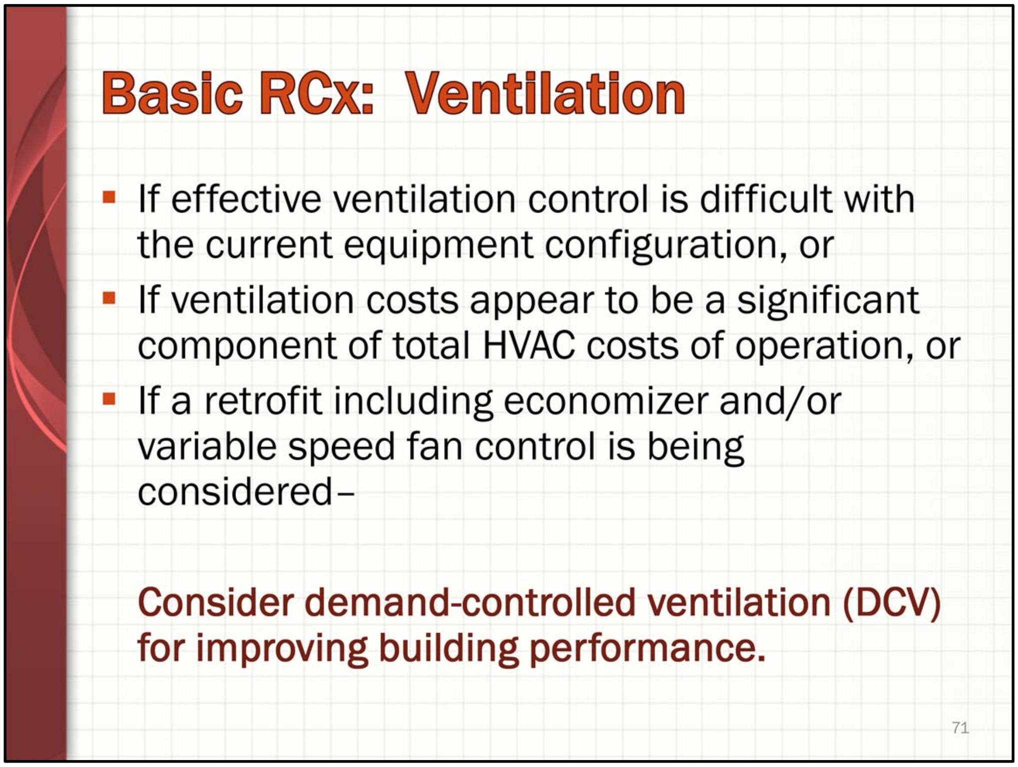
A quaint breakfast restaurant located in the historic town of Lemont, Illinois: the owner of this commercial kitchen was not comfortable with the energy usage of his kitchen equipment. Consequently, he applied for a free investment grade energy efficiency audit of his facility in the winter of 2011 the restaurant's energy usage was assessed.

(Numbers were rounded from original document.)

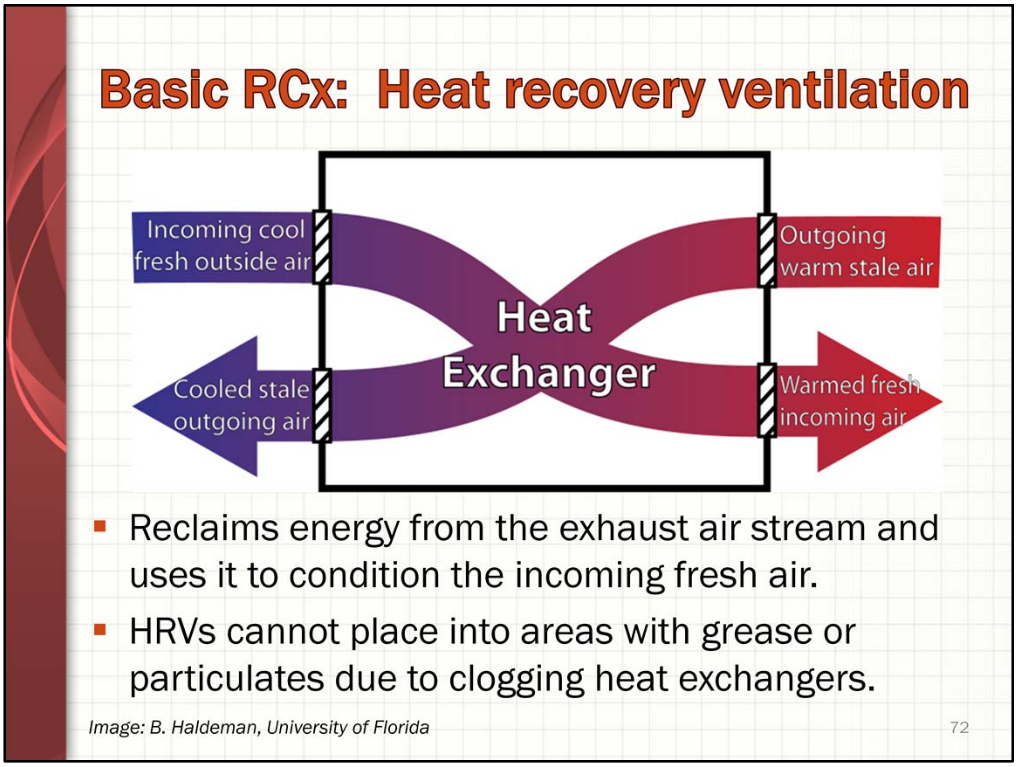

Basic RCx: Ventilation
If the building is not up to code and standards in terms of outdoor air ventilation, or
If measurements confirm occupant complaints of air quality associated with inadequate ventilation –
Evaluate each option - fixed, mechanically controlled, and demand-controlled ventilation - for improving building performance.
68


Basic RCx: Ventilation
If a fixed outdoor air damper (OAD) is installed:
If the setting is not appropriate for current occupancy levels and energy efficient operation–
Reset the OAD position.
69

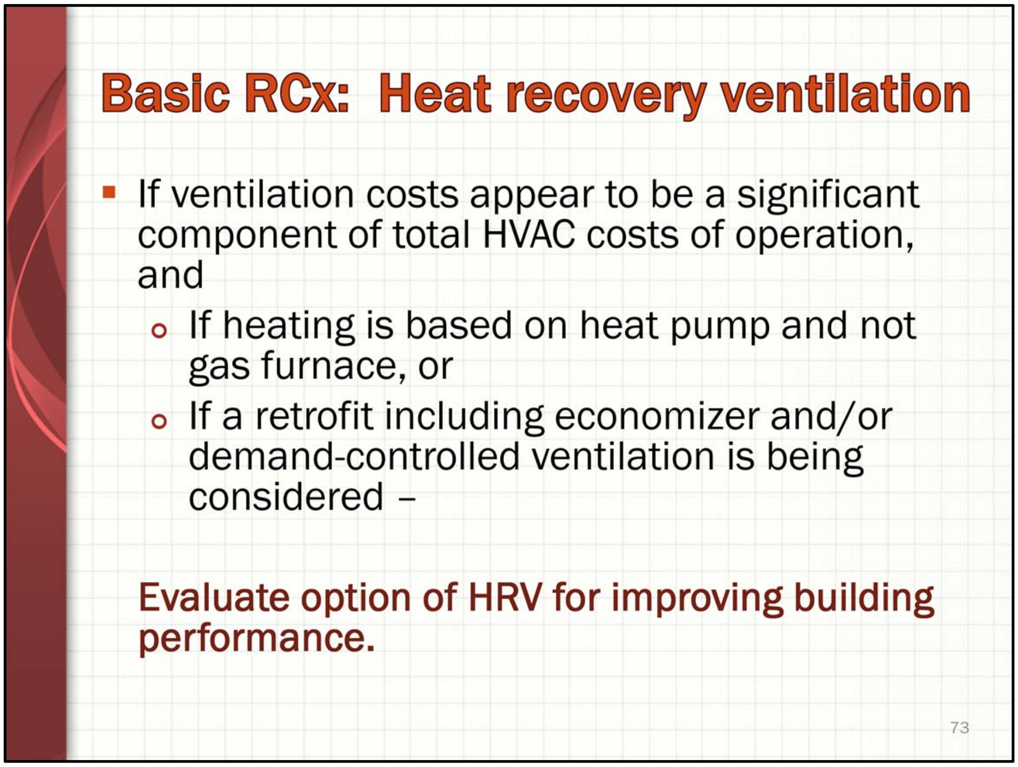

Basic RCx: Ventilation
If a mechanical OAD is installed:
If the OAD is not closed when the building is not in use, or
If the OAD is not closed during building warm-up or cool-down periods –
Reconfigure controls for effective and energy efficient ventilation.
70



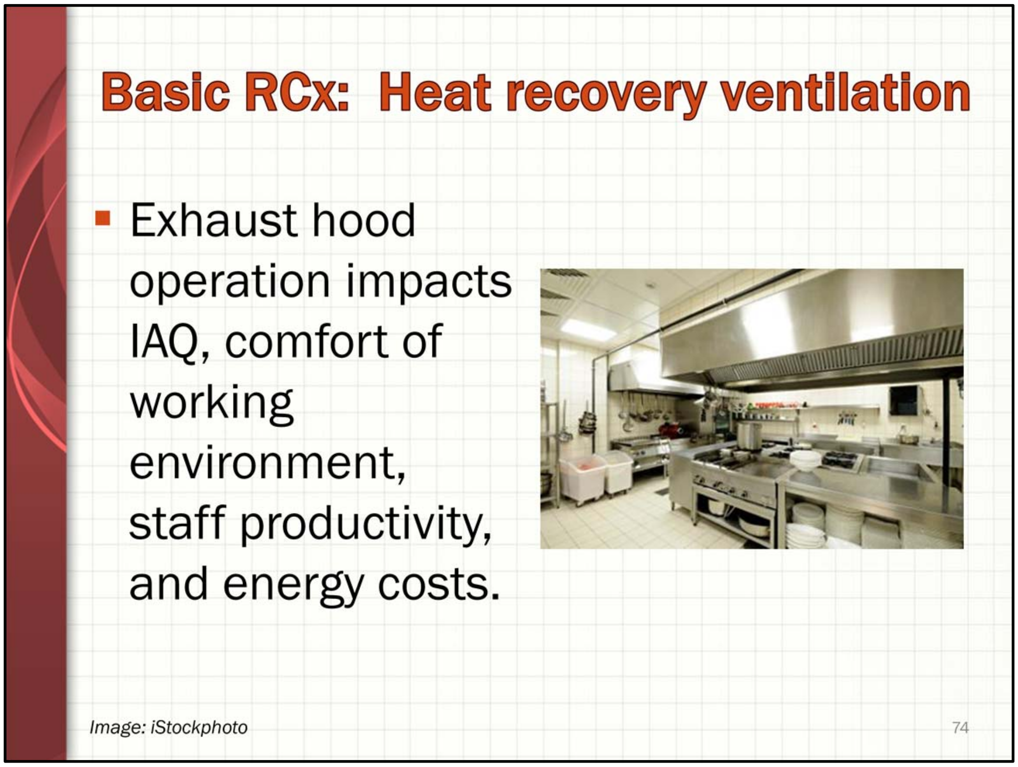
Demand-controlled ventilation saves energy by avoiding the heating, cooling, and dehumidification of more ventilation air than is needed. If configured with variable speed fan control, energy consumption is reduced further by lowering motor energy use.

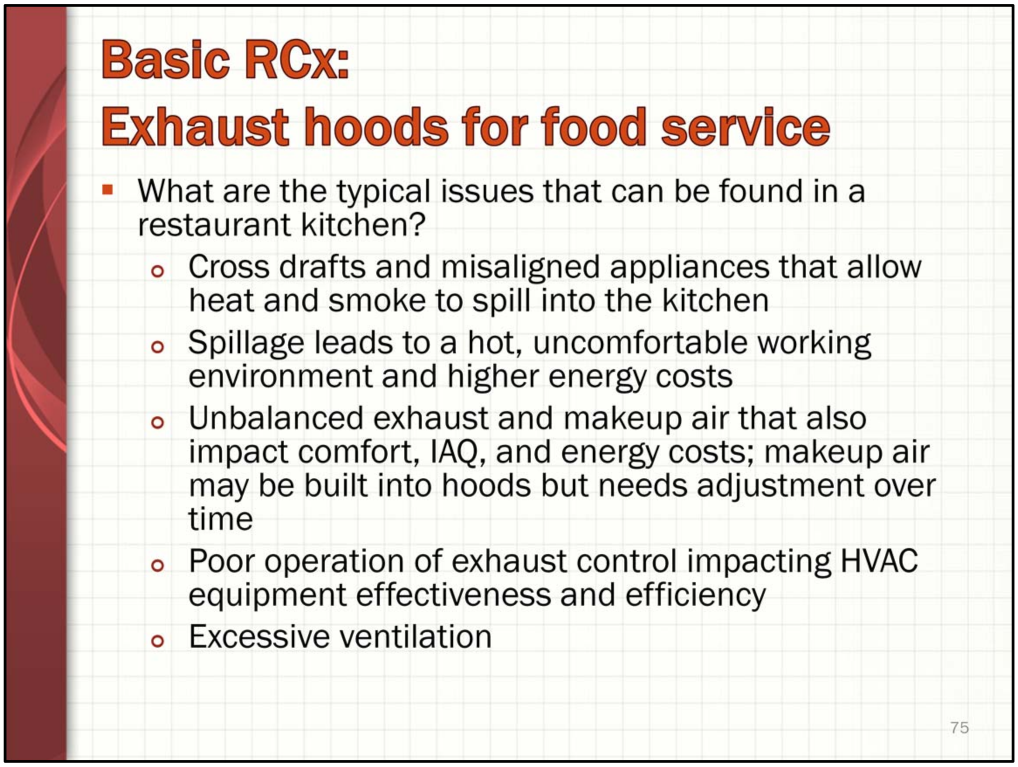


For maximum benefit, energy recovery designs should provide as close to balanced outdoor and exhaust airflows as is practical, taking into account the need for building pressurization and any exhaust that cannot be incorporated into the system. Exhaust for energy recovery units may be taken from spaces requiring exhaust (using a central exhaust duct system for each unit) or directly from the return air stream (as with a unitary accessory or integrated unit). Where economizers are used with an energy recovery unit, the energy recovery system should be controlled in conjunction with the economizer and provide for the economizer function. Where energy recovery is used without an economizer, the energy recovery system should be controlled to prevent unwanted heat, and an outdoor air bypass of the energy recovery equipment should be used. In cold climates, manufacturer's recommendations for frost control should be followed. (AEDG Design Guides, 1999)



Conditioning the ventilation air with an HRV improves heat pump performance by raising the inlet temperature of the entering air in the wintertime. Also, a packaged retrofit that includes a systems approach can improve building performance more cost-effectively.


Basic RCx: Heat recovery ventilation
Exhaust hood operation impacts IAQ, comfort of working environment, staff productivity, and energy costs.
Image: iStockphoto
74



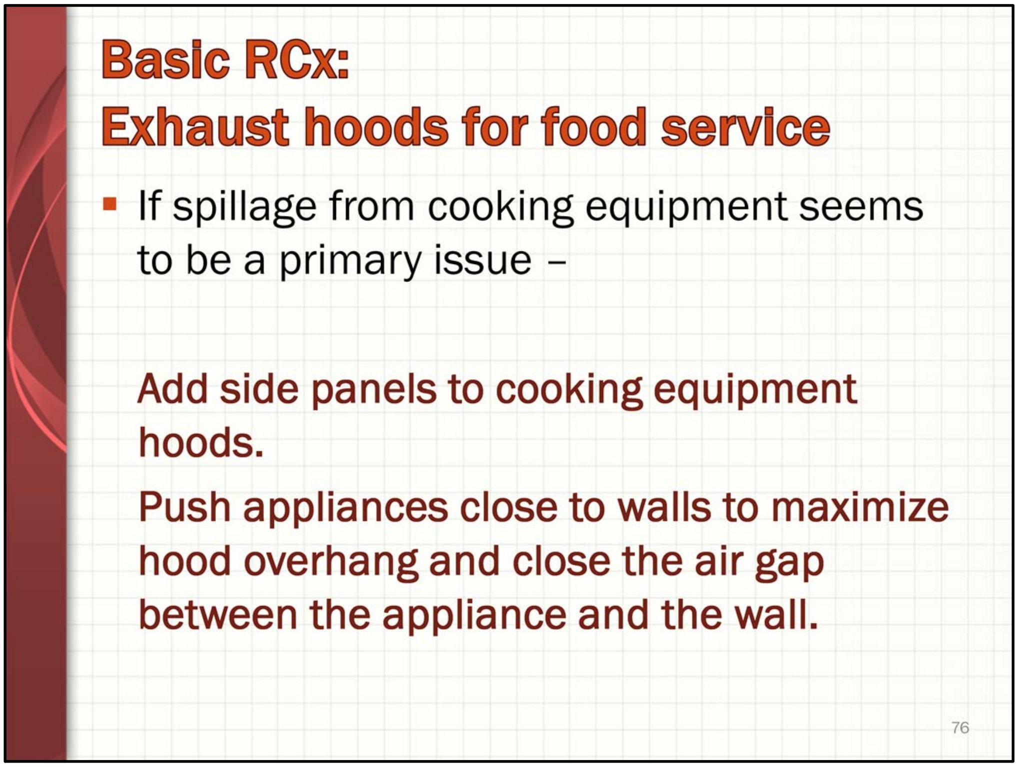
Time, lack of maintenance, broken belts, and poor commissioning all lead to kitchen exhaust systems that are out of balance, potentially moving too much or too little air, spilling, and higher energy costs. Problems with exhausts impact the HVAC operation as well.

On average, commercial kitchens exchange indoor air for fresh air 20 times/hr or more.

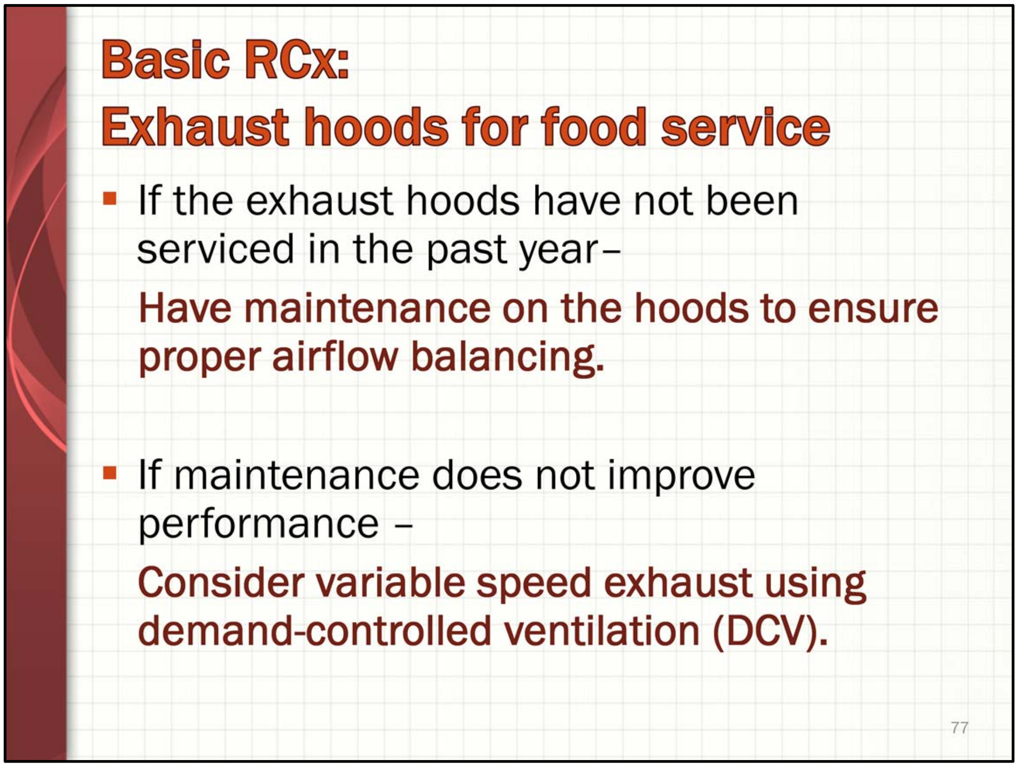
Exhaust fans often operate at full speed even when no one is cooking

About one-quarter of restaurant energy expense goes to conditioning make-up air from exhaust hoods.

http://www.focusonenergy.com/files/document_management_system/business_programs/kitchenventilation_factsheet.pdf



A 4-foot deep hood is somewhat typical for restaurant exhaust, but you'll capture more smoke and heat with a 5- or 6-foot deep hood.



Balance in airflow is important, because either too much or too little exhaust will waste energy and money. Air flow is likely out of balance if you notice either a suction when opening doors, or that doors sometimes swing open on their own.

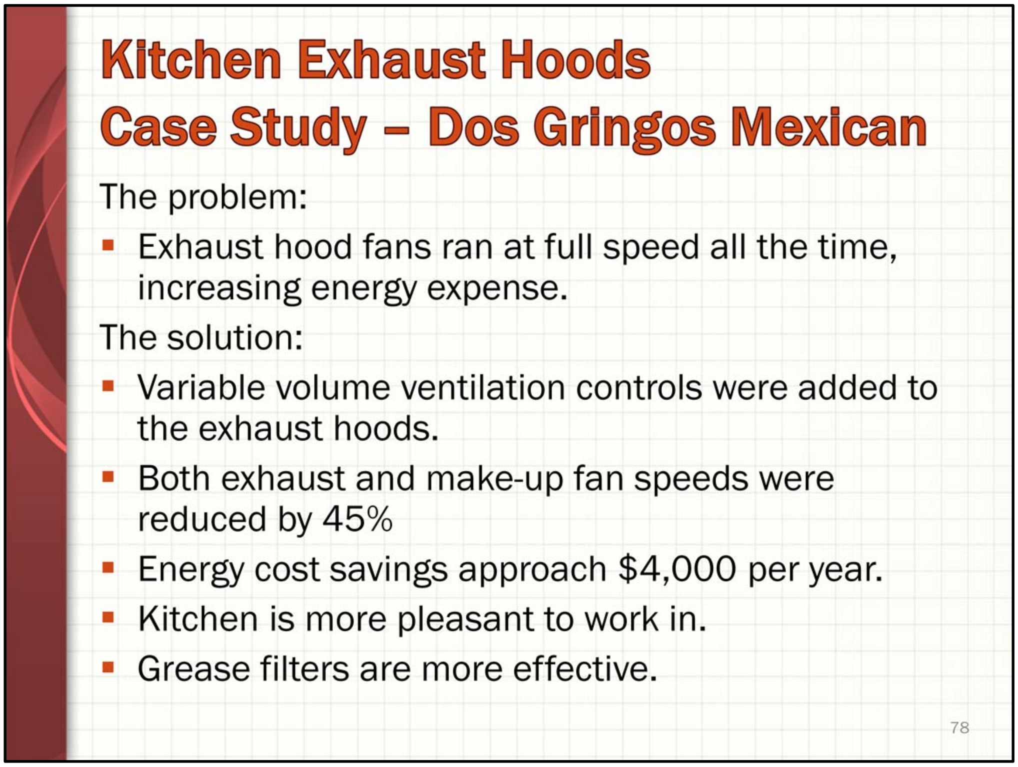
Commercial kitchen exhaust hoods are generally either on or off, suitable for periods of peak kitchen usage or when the kitchen is unoccupied. But in off-peak hours, less ventilation is needed. Variable-speed exhaust fans have sensors to match ventilation to actual demand. They can be retrofitted to existing kitchen hoods as well as new construction. They are typically able to reduce energy use by exhaust hoods from 30% to 50.

Benefits of DCV:

- sensors match exhaust air to cooking levels
- suitable for retrofit as well as new applications
- expect to save 30% - 50% of exhaust energy
- reduces noise levels in kitchen
- reduces load on AC compressors and extends life
- extends life of fan belts and AC filters

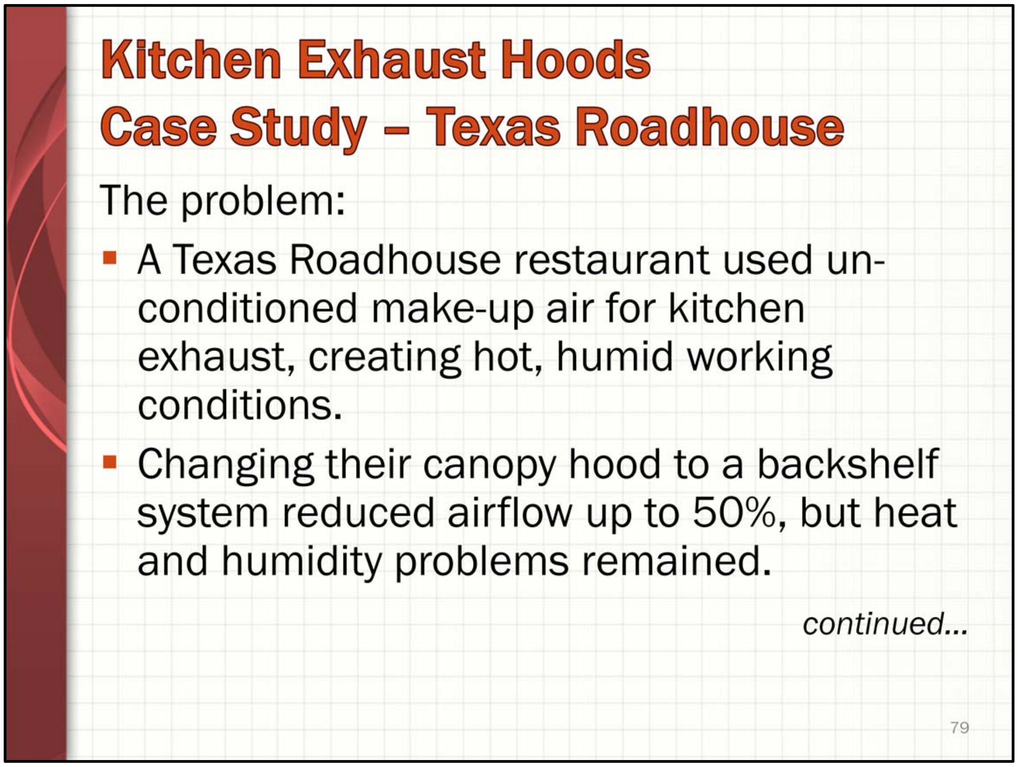
http://www.fypower.org/bpg/module.html?b=institutional&m=Food_Service&s=Ventilation

http://www.focusonenergy.com/files/document_management_system/business_programs/kitchenventilation_factsheet.pdf

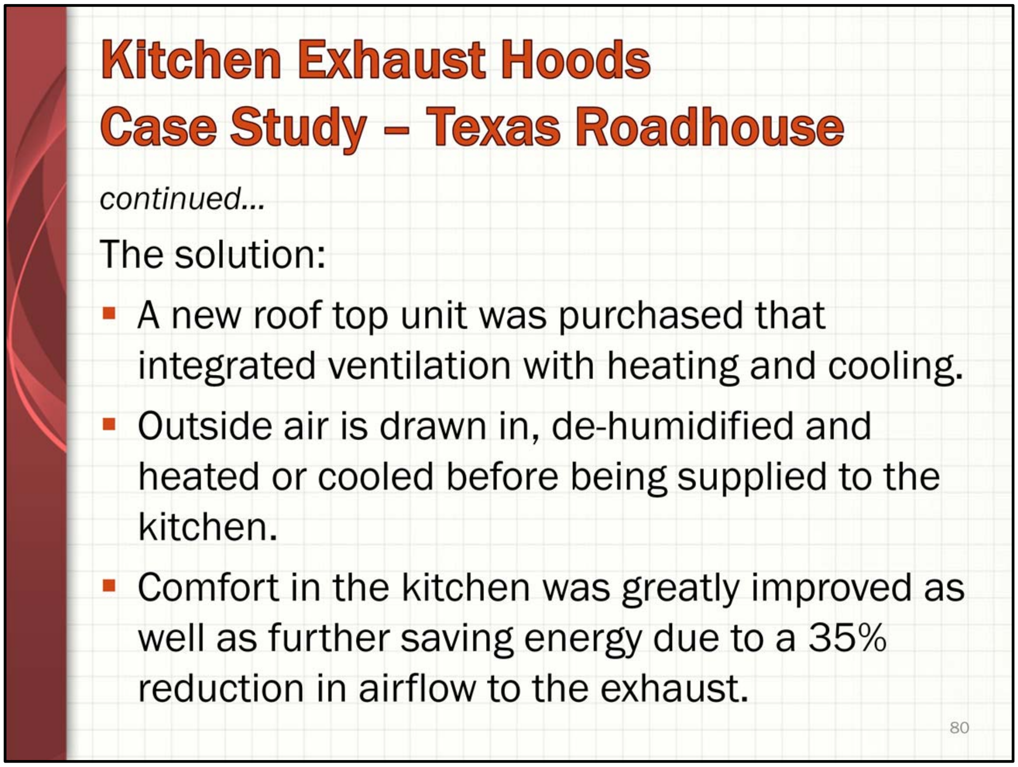


The payback period was not calculated, but with an incentive the restaurant received, the owner stated the payback period was “negligible”.

http://www.focusonenergy.com/files/document_management_system/business_programs/kitchenventilation_factsheet.pdf

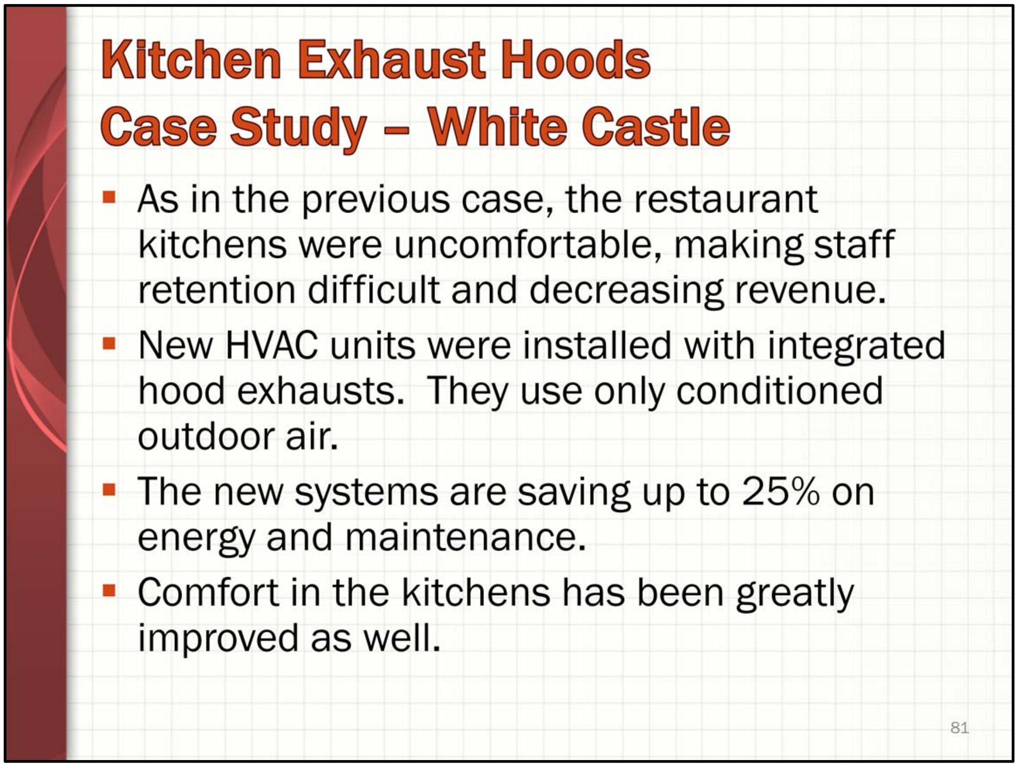


http://www.trane.com/Commercial/CaseStudies/CaseStudyDetails.aspx?studyId=11

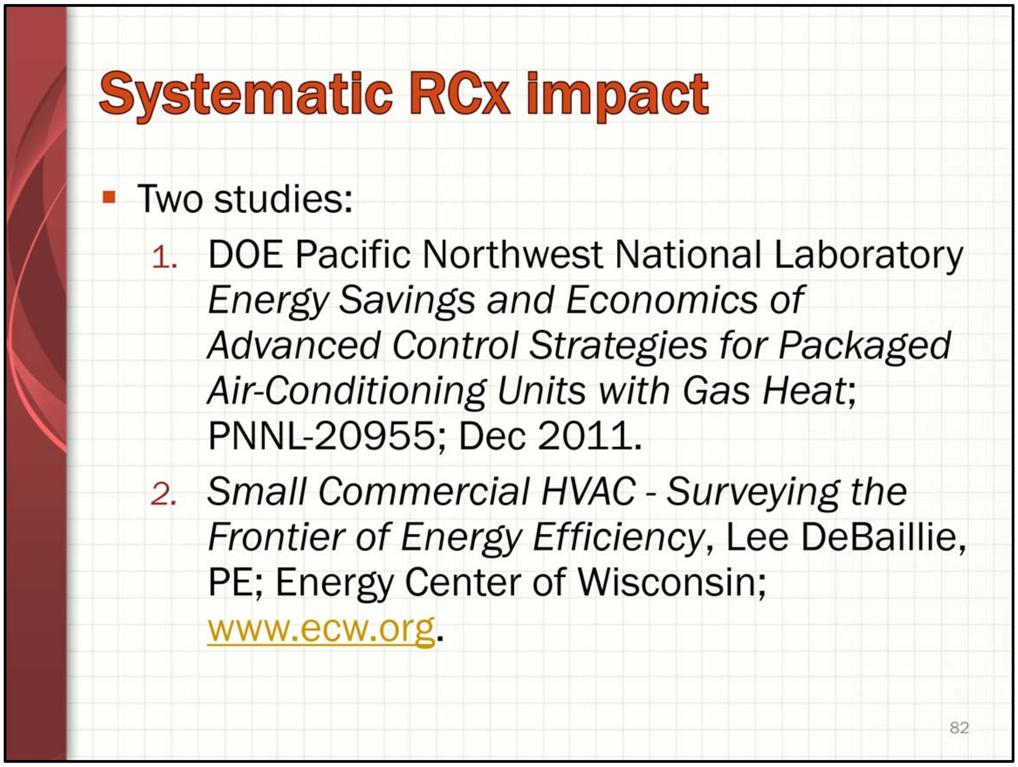


"Solving the MUA Dilemma: Keeping Cooks in the Kitchen," a 2003 ASHRAE Journal article, states that omitting makeup air (MUA) often increases kitchen comfort.

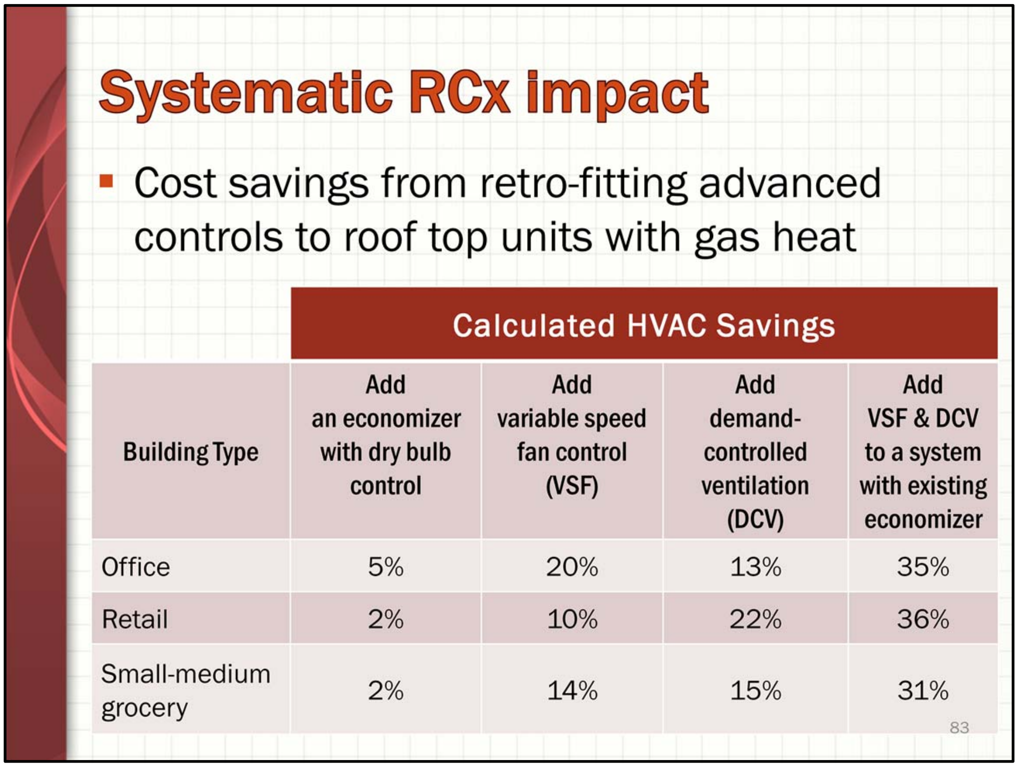
See ASHRAE Journal, July 2007, Stephen Brown, "Dedicated Outdoor Air System for Commercial Kitchen Ventilation" at *65.105.2.10/File%20Library/docLib/.../Brown--**July**07-Feature.pdf*



http://www.trane.com/Commercial/CaseStudies/CaseStudyDetails.aspx?studyId=32



The goal of retro-commissioning is to optimize existing system performance with low-cost improvements, rather than relying on major equipment replacement, that result in improved indoor air quality, comfort, and energy conservation and efficiency. Inherent in the retro-commissioning process is viewing all the components of the HVAC equipment as a system and evaluating improvements, either by tuning up or by selectively augmenting with new components, together to achieve the goal of optimizing system performance.



	Calculated HVAC Savings			
Building Type	Add an economizer with dry bulb control	Add variable speed fan control (VSF)	Add demand-controlled ventilation (DCV)	Add VSF & DCV to a system with existing economizer
Office	5%	20%	13%	35%
Retail	2%	10%	22%	36%
Small-medium grocery	2%	14%	15%	31%

Data is based on a simulation study by Pacific Northwest National Laboratory, Dec. 2011, for Climate Zone 5A (includes all of Nebraska)

The base system has no economizer, except as noted for the 4th option.

Certain caveats on the above data include –

- The energy use intensities (EUI) for the base, or reference, case seems low for Climate 5A compared to certain benchmarks, particularly heating. This, however, should tend to make the savings estimates conservative.
- The assumed equipment efficiency (energy efficiency ratio [EER], heating seasonal performance factor [HSPF], and energy factor [EF]) of the reference case of the different components are reasonable but many buildings will have lower efficiencies in operation, again tending to make the estimates conservative.
- There has not been a validation of the simulation results; this work is ongoing.

See details of assumed building geometry, envelope, HVAC (efficiency, schedule, ventilation, and set points) and loads for each type of building in Appendix A of the report.

http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20955.pdf

Systematic RCx impact

	Building Electric (kWh)	Electric Savings (kWh)	Building Gas (Therms)	Gas Savings (Therms)	Total Energy Cost	Cost Savings
Baseline building	50,447	—	7,427	—	$11,586	—
Fans off unoccupied	48,158	2,289	5,579	1,848	$9,879	$1,707
Fix economizer	48,052	106	5,579	0	$9,868	$11
Improve EER from 9.5 to 12	47,404	648	5,579	0	$9,803	$65
Duct resistance 1.5” to 1.0”	44,323	3,081	5,964	-115	$9,587	$216
Variable speed supply fan	38,958	5,365	5,683	11	$9,042	$545
Demand-controlled ventilation	39,056	-98	4,404	1,279	$8,029	$1,013
Heat Recovery Ventilation	40,457	-1,401	3,406	998	$7,371	$658

84

The data is from a simulation study by Lee Debaille of the Energy Center of Wisconsin.

The reference building is a 5,000 sq ft retail store:

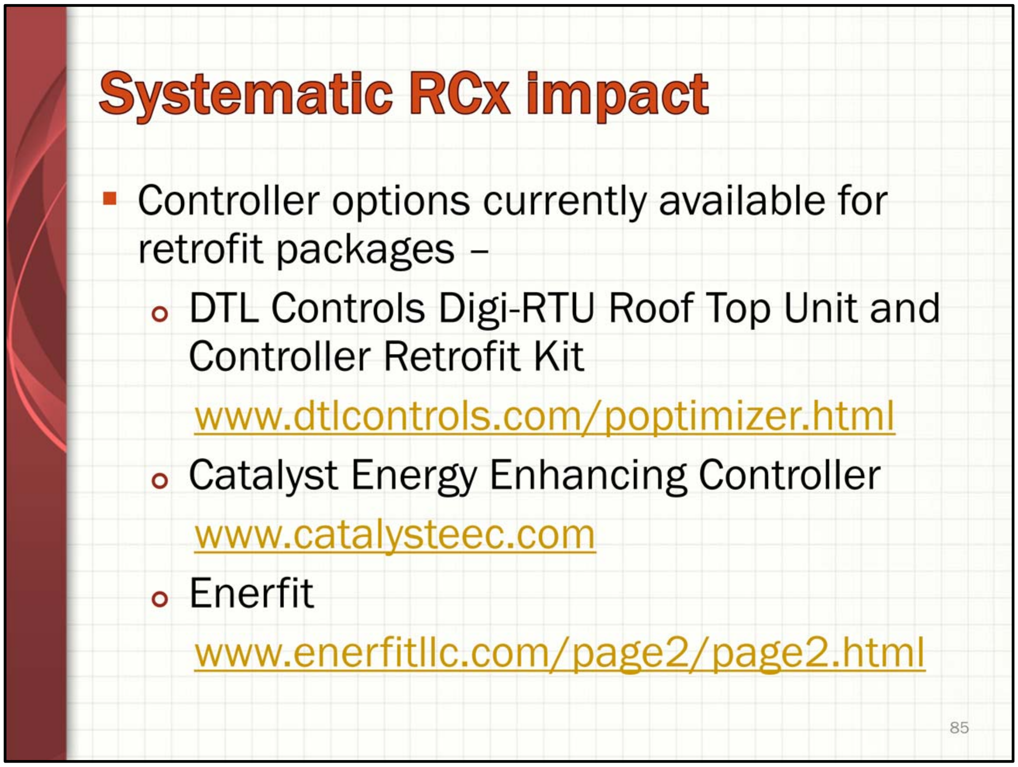
- located in Grand Rapids MN (Climate zone 7)
- building envelope built to MN code (2011)
- hours of operation: 7 a.m. to 7 p.m. Monday through Saturday; 10 a.m. to 4 p.m. Sunday

The building is assumed to have:

- a roof top unit (RTU)
- direct expansion (DX) cooling (EER 9.5)
- gas-fired heating

Utility costs:

- Electricity $0.10/kWh
- Natural Gas $0.80/therm.



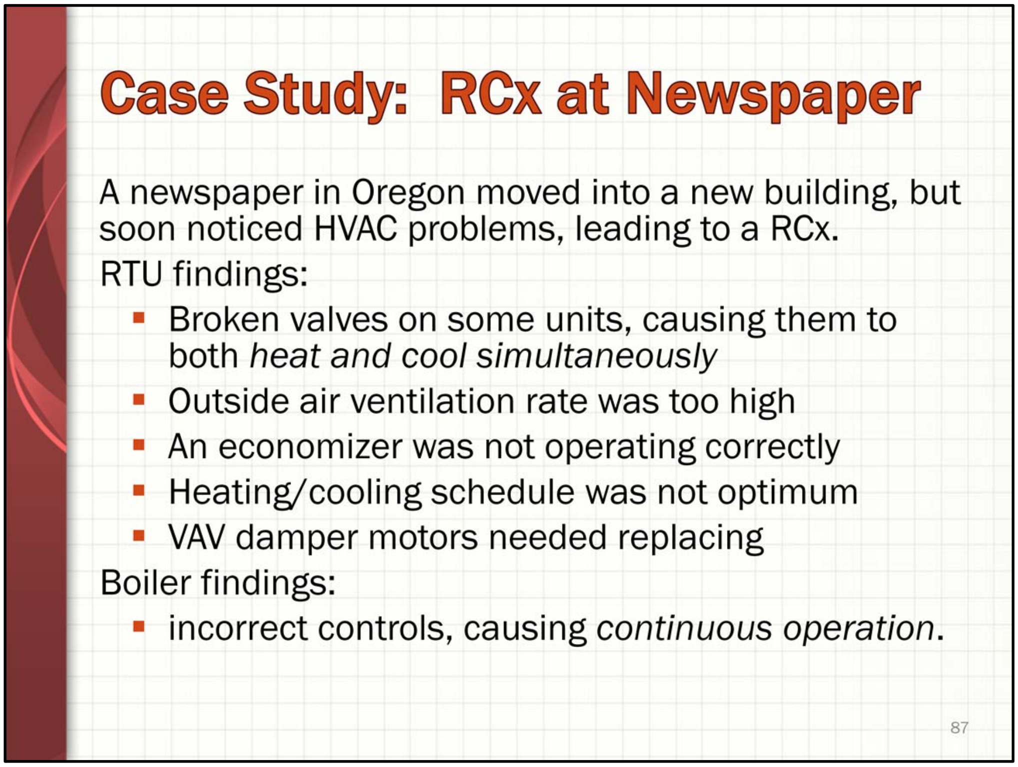
Packages require variable speed control of supply fan installed. Packages include sensing and control equipment along with custom configuration and commissioning for temperature, humidity, and ventilation control. In 2012 OPPD is evaluating options that may be included into an incentive program.

Systematic RCx impact

Company	Annual energy savings claims	Approximate cost	Payback claims
Catalyst	25 – 40%	$4,000 (15T)	~ 2 years
Enerfit	50 – 70%	$4,700 (20T)	1 – 3 years
Digi-RTU	45 – 64%	$3,000 – 10,000 (< 20T)	< 1 year (large RTUs) < 4 years (small RTUs)

86

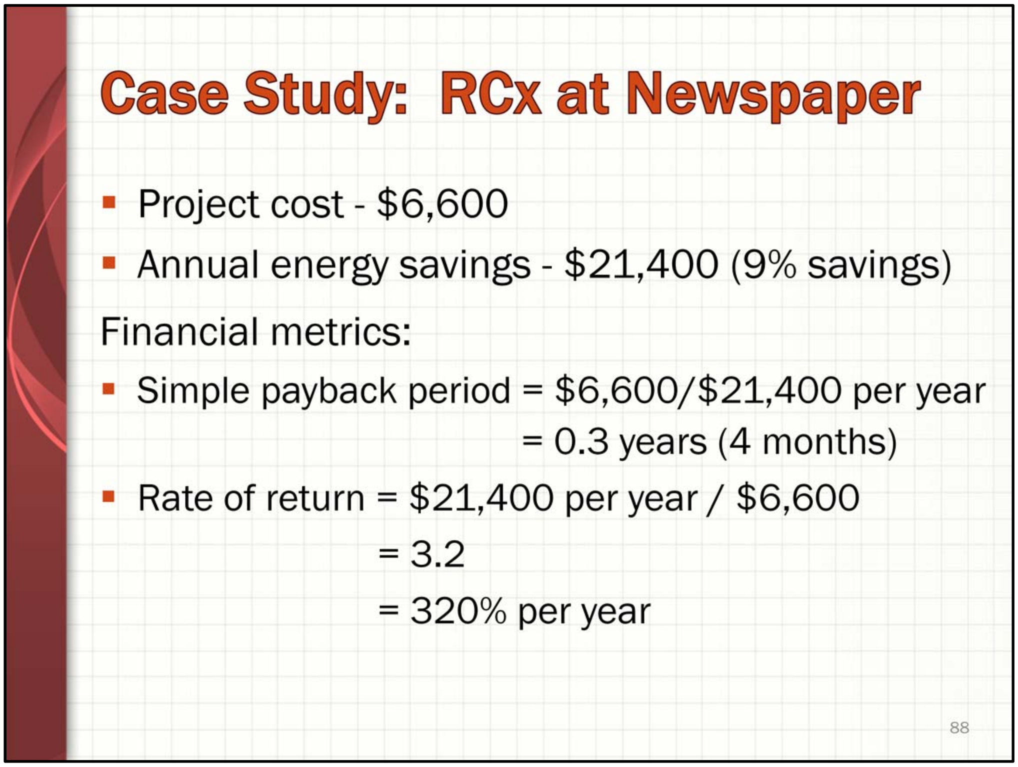
Retrocommissioning and Other Control Based Measures, CRN Summit, Jul 19, 2011, Katie Elliot, E Source



Note: this was a new building that had not been adequately checked. New buildings can not reliably be assumed to perform energy efficiently.

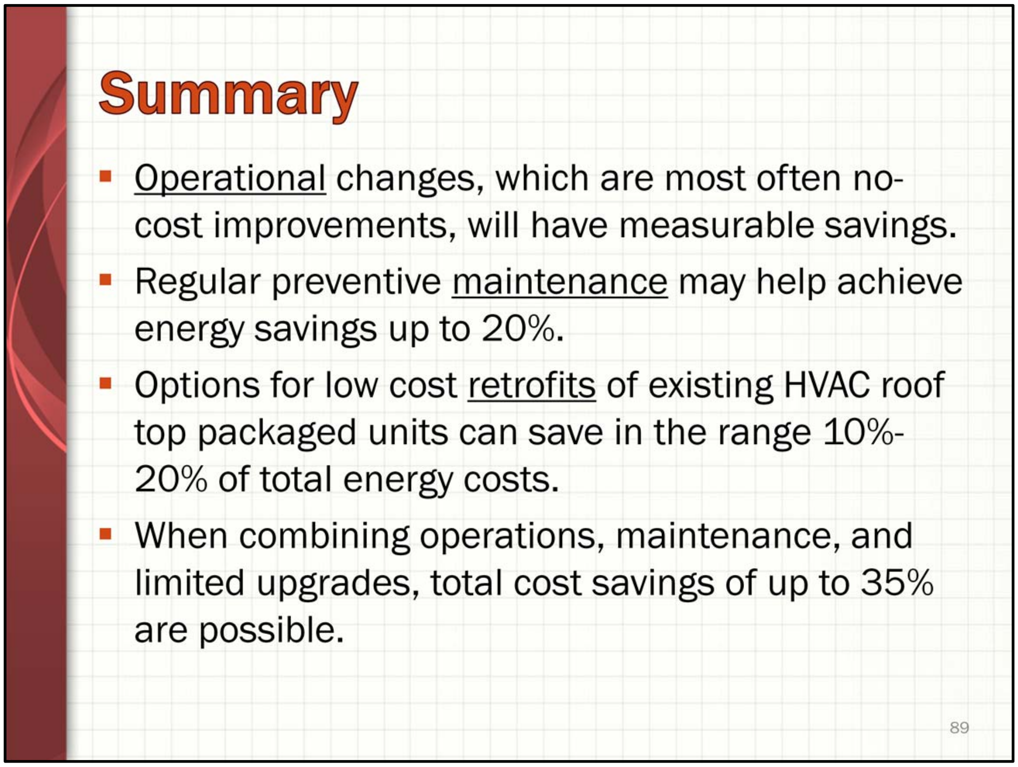
This newspaper building was larger than those we are generally considering, but the problems they experienced could occur in any building.

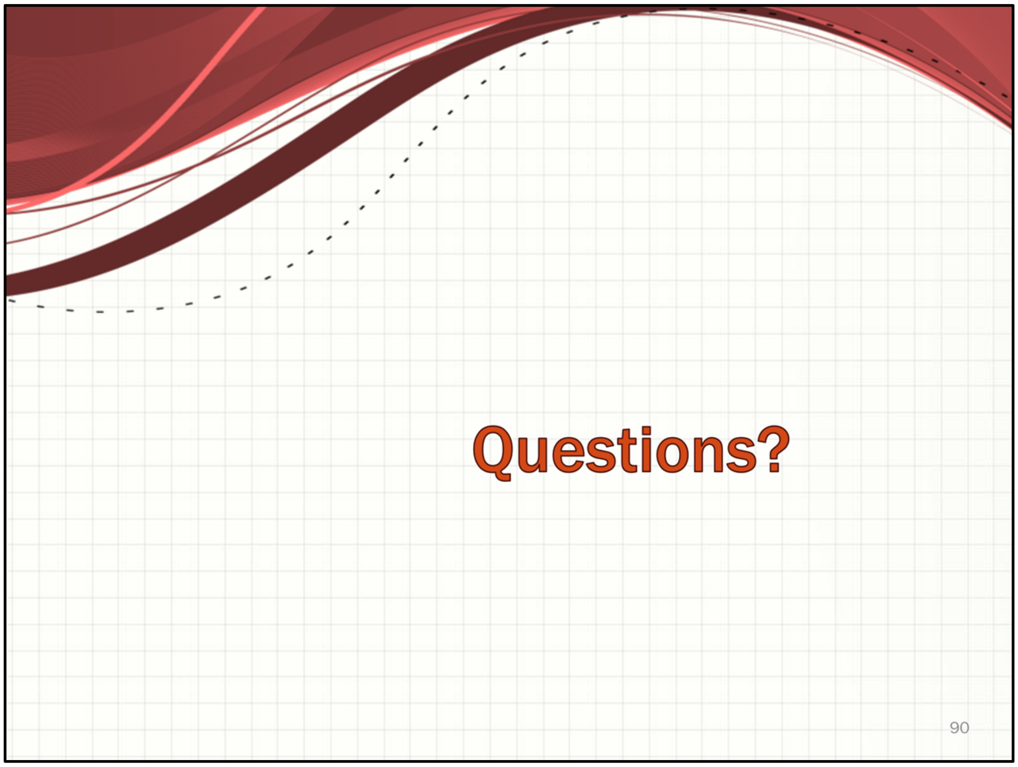
http://energytrust.org/library/case-studies/TheBulletin_CS_IND_1201.pdf



This company earned back the money spent on improvements in only 4 months.
This is equivalent to investing that amount and earning 320% interest on it!
We will go over the calculation of payback period and rate of return in Module 7.

http://energytrust.org/library/case-studies/TheBulletin_CS_IND_1201.pdf


Summary
Operational changes, which are most often no-cost improvements, will have measurable savings.
Regular preventive maintenance may help achieve energy savings up to 20%.
Options for low cost retrofits of existing HVAC roof top packaged units can save in the range 10%-20% of total energy costs.
When combining operations, maintenance, and limited upgrades, total cost savings of up to 35% are possible.
89


Questions?
90

Assessment

Questions

1. What are three examples of updating programmable thermostat settings that will reduce HVAC energy use?

    a. ______________________________

    b. ______________________________

    c. ______________________________

2. List two reasons why preventive maintenance is a key factor in minimizing HVAC energy use.

    a. ______________________________

    b. ______________________________

3. What are three typical maintenance issues found in small commercial HVAC systems?

    a. ______________________________

    b. ______________________________

    c. ______________________________

4. Improving air distribution may be warranted in many applications during retro-commissioning. What are two of the actions that may be needed?

    a. ______________________________

    b. ______________________________

5. Why does a variable speed HVAC supply fan motor, with appropriate drive and controls, reduce energy consumption?

    ____

    ____

    ____

6. Many small to medium commercial buildings are not ventilated according to code. Many other buildings that do have ventilation controls are not operating efficiently. List two options to help properly ventilate buildings in the most energy efficient manner that is practical.

    a. ____

    b. ____

Answers

1. What are three examples of updating programmable thermostat settings that will reduce HVAC energy use?

   Any three of the following:

   - **Ensure the normal schedule matches building occupancy**
   - **Ensure setback temperatures are used when the building is not in use**
   - **Account for low occupancy areas**
   - **Ensure settings are uniform in adjacent zones**
   - **Limit manual overrides**
   - **Ensure the building is not being ventilated when not in use**

2. List two reasons why preventive maintenance is a key factor in minimizing HVAC energy use.

   Any two of the following:

   - **Reduces repair expense**
   - **Ensures equipment is running close to design efficiency**
   - **Increases staff productivity**
   - **Improves client/customer satisfaction**

3. What are three typical maintenance issues found in small commercial HVAC systems?

   Any three of the following:

   - **Dirty filters**
   - **Air distribution problems**
   - **Poorly operating outside air damper or economizer**
   - **Incorrect refrigerant charge**
   - **Dirty evaporator coils**

4. Improving air distribution may be warranted in many applications during retro-commissioning. What are two of the actions that may be needed?

   Any two of the following:

   - **Duct sealing and flex duct repair**
   - **Test and balance**
   - **Modify duct configuration**
   - **Incorporate zone controls**

5. Why does a variable speed HVAC supply fan motor, with appropriate drive and controls, reduce energy consumption?

   For fans (and centrifugal pumps), a change in power consumption is proportional to the cube of the change in speed. This is known as the fan affinity law.

   $$p_1/p_2 = (s_1/s_2)^3$$

   where, s_1 and s_2 are the initial and changed fan speed, and p_1 and p_2 are the corresponding power usage.

   For example, a fan running at 80% of the full rated <u>speed</u> (a 20% reduction) results in using only 51% of the energy (a 49% reduction in <u>power</u> needed).

   $$\text{If } s_2/s_1 = 0.80, \quad p_2/p_1 = (0.80)^3$$
   $$\text{or} \quad p_2/p_1 = 0.512$$
   $$p_2 = \underline{\text{51\% of the original power}}$$

6. Many small to medium commercial buildings are not ventilated according to code. Many other buildings that do have ventilation controls are not operating efficiently. List two options to help properly ventilate buildings in the most energy efficient manner that is practical.

   Any two of the following:

   - **Ensure the fixed outdoor air damper is set properly**
   - **Reconfigure the ventilation controls**
   - **Evaluate fixed, mechanically controlled, and demand controlled ventilation for the particular application**
   - **Evaluate heat recovery ventilation**

Glossary

Module 1: Introduction

Action plan – a written report that details the findings from an energy audit. It includes the scope of work for whatever improvements are proposed, information on financing if appropriate, and recommendations for maintaining or building on efficiency gains in the future.

Benchmarking – comparing the performance of buildings with similar functions based on their energy intensity. Buildings performing worse than average are good targets for energy efficiency improvements. Portfolio Manager, developed by the US EPA, is the most common tool used to benchmark commercial buildings.

Client goals – an itemized list based on interviewing the client/building occupants on existing problems and desired outcomes. It should consider issues beyond energy costs, such as occupant health and comfort and potential for improving building value and occupant retention.

Energy audit – an assessment of energy use within a building and methods for reducing it. It examines the effectiveness of the building envelope and all energy uses with the building and recommends measures to reduce consumption.

Incentive – a cost reduction, rebate or other (usually financial) carrot to encourage customers to take desired action. Public recognition or designation of high-performing buildings may also be incentives.

Initial analysis – a first, rough analysis of a building's energy use and potential for improved efficiency based on a review of utility bills, benchmark data and an initial walk-through visit.

Retro-commissioning – commissioning of existing buildings to optimize energy efficiency, primarily through operation and maintenance changes and other low cost measures.

Module 2: Fundamentals of Commercial Energy Use

Baseload – the energy consumption of a building or business that does not vary with time of year.

Benchmarking – comparing energy consumption of a business or building with the average, median, and/or energy efficient use associated with a particular business classification such as office, retail, restaurant, etc., in a particular climate zone; energy intensity may be the sole measure of comparison, or the comparison may be statistical using a tool such as EPA's Portfolio Manager that accounts for additional factors such as hours of operation and staffing.

Energy Utilization Intensity (EUI) – the ratio of energy consumption to a unit of measurement (e.g. floorspace, number of staff, etc.); typically EUI is expressed in kBtu per square foot.

Portfolio Manager – a software tool developed by EPA for performing benchmarking of commercial buildings.

Module 3: Mechanical Systems Energy Codes and Standards

ASHRAE 90.1 – Standard from the American Society of Heating, Refrigerating and Air Conditioning Engineers for energy efficiency in buildings other than low-rise residential. New editions are issued every 3 years.

Codes – minimum safeguards for protecting health and safety, or specifying measures to achieve a minimum level of energy efficiency in buildings.

Complex mechanical systems – all HVAC systems that do not meet the definition of a simple mechanical system, as defined by the IECC in Section 503.3. It includes those with multiple zones, VAV systems, and hydronic heating and cooling.

Dehumidify – to remove a portion of the water vapor from the air.

Demand-controlled ventilation (DCV) – ventilation with outside air is controlled by carbon dioxide sensors to vary the amount of fresh air to match the occupancy of the building. (Since people exhale CO_2, the levels will increase as more people are present in the building.)

Energy recovery ventilation – the process of recovering heat from exhaust air and using it to pre-heat and humidify incoming fresh air (in winter). In summer, the same process, cools and dehumidifies incoming outdoor air with exhaust indoor air. It reduces the capacity needed for the HVAC system and saves energy.

Guidelines - improved, desired performance exceeding levels prescribed in Standards, or covering topics not addressed by other standards.

IECC – International Energy Conservation Code. A comprehensive code that sets minimum regulations for energy efficiency in buildings. It is compatible with all international codes published by the International Code Council (ICC). New editions are published every 3 years.

Performance path – also known as, "the simulated performance alternative", this method of complying with the IECC code uses modeling of the proposed design to show that it performs at least as well as a similar house designed with the prescriptive path.

Prescriptive path – one method of complying with IECC code where minimum design elements, such as R-values and efficiency levels are prescribed in the code.

Regulations – mandatory specifications adopted by law; they are often the same as standards but may be modified by state or local governments before adoption.

Semi-heated space – ASHRAE defines this as an enclosed space that is heated up to 15 Btu/hr/sq ft (for climate zone 5). Thermal requirements for the building envelope are lower than for fully heated areas.

Simple mechanical systems – an area served by unitary or packaged HVAC units, with each serving 1 zone, controlled by 1 thermostat. The IECC specifies separate requirements for simple vs. complex systems.

Standards – an extension of codes, they specify materials, design, testing or installation necessary to meet the minimum acceptable performance.

Module 4: Improvements in HVAC

Economizer – mechanism and controls that utilize outside air for cooling under a particular set of outside and inside environmental conditions.

Demand-controlled ventilation – using CO2 sensors to assist in control of ventilation rates based on load conditions rather than fixed or time or day settings; improves energy efficiency by improved matching of ventilation rates to occupant load.

Heat recovery ventilation – exchanging energy between incoming ventilation air with an exhaust air stream, thus improving energy efficiency.

Variable speed control – a means of controlling supply fan motors using variable frequency motors and drives to improve matching the load with the airflow required while also reducing energy consumption.

Module 5: Improvements in Refrigeration

Anti-sweat heaters – to prevent this condensation and "sweating," the refrigerated display case doors and frames are heated. (Hence the name, "anti-sweat heaters.") In essence, the heater dries up any warm, humid air that may have gotten trapped inside the display cases during customers' opening and closing of the doors. Anti-sweat heater controls, in turn, are used to ensure that the doors and frames are heated only when necessary.

Beverage merchandisers – merchandisers are self-contained, upright, refrigerated cabinets that are designed to hold and/or display refrigerated beverage items for purchase without an automatic vending feature. Typically they have glass doors and bright lighting. These cases are commonly used in convenience stores, aisle locations in supermarkets, and some retail stores and small foodservice establishments

Duty cycle – is a fixed repetitive load pattern over a given period of time which is expressed as the ratio of on-time to cycle period. When operating cycle is such that electric motors operate at idle or a reduced load for more than 25% of the time, duty cycle becomes a factor in sizing electric motors. Also, energy required to start electric motors (that is, accelerating the inertia of the electric motor as well as the driven load) is much higher than for steady-state operation, so frequent starting could overheat the electric motor.

Electronically Commutated Motor (ECM) – an ultra-high efficiency programmable brushless DC motor utilizing a permanent magnet rotor and a built-in inverter. EM motors maintain a high efficiency of 65–72% at all speeds

Latent Cooling Load – Cooling load that results when moisture in the air changes from a vapor to a liquid (condenses), releasing heat. The latent load puts additional demand on the cooling system.

Micron – a metric unit of length equal to one millionth of a meter

Power Consumption – refers to the electrical energy over time that must be supplied to an electrical device to maintain its operation. The power consumption is usually a result of power used to perform the intended function of the device plus additional "wasted" power that is dissipated as heat and/or light. Power consumption is usually measured in units of Watts.

Preventative Maintenance – the care and servicing for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects. Maintenance, including tests, measurements, adjustments, and parts replacement, performed specifically to prevent faults from occurring.

Refrigerants – a substance used in a heat cycle usually including, for enhanced efficiency, a reversible phase transition from a liquid to a gas. Traditionally, fluorocarbons, especially chlorofluorocarbons, were used as refrigerants, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane. Many refrigerants are important ozone depleting and global warming inducing compounds that are the focus of worldwide regulatory scrutiny.

Variable-speed drive (VSD) air compressor – is an air compressor that takes advantage of variable-speed drive technology. This type of compressor uses a special drive to control the speed (RPM) of the unit, which in turn saves energy compared to a fixed speed equivalent. The most common form of VSD technology in the air compressor industry is a variable-frequency drive, which converts the incoming AC power to DC and then back to a quasi-sinusoidal AC power using an inverter switching circuit. The variable-frequency drive article provides additional information on electronic speed controls used with various types of AC motors.

WICF – Walk-in coolers and walk-in freezers (walk-ins or WICF) are large, insulated refrigerated spaces with access door(s) large enough for people to enter, with a total chilled storage area of less than 3,000 square feet. Walk-ins are used to store temporarily refrigerated or frozen food or other perishable materials. The two major classes of walk-ins are coolers (above 32°F) and freezers (32°F and below). Although walk-ins can be used in a wide variety of applications, they are used primarily in food service and sales.

Module 6: Health and Safety

Acute – a sudden, sharp and short duration disease or ailment, as opposed to a long-term chronic problem.

Allergen – a substance that causes an allergy; common allergens include pollens and molds.

Asbestos – a fibrous mineral, formerly used for fireproofing, that can separate into tiny fragments and capable of causing lung disease if inhaled.

Asthma – a lung disease in which airways narrow, resulting in wheezing and difficulty breathing. Episodes are often brought about by allergies and inhaled irritants.

Bacteria – microscopic, single celled organisms, found everywhere in the environment. Some species can cause diseases.

Chronic (disease) – a long-term or frequently recurring problem that usually is not easily remedied.

Combustion appliance zone (CAZ) – the area around an appliance in which combustion occurs.

Carbon monoxide (CO) – an odorless, colorless gas produced by incomplete combustion of organic fuels. Breathing it can be fatal.

Draft – a current of air moving caused by temperature differences in an enclosed space.

Formaldehyde – a highly toxic, colorless gas used as a preservative and disinfectant as well as in the manufacture of many products.

Fungi – a biological kingdom of organisms, some single celled and some multi-celled, that take in food by absorption. Common examples are molds, yeasts, and mushrooms.

Humidity – the amount of water vapor present in the air; it varies with temperature and weather conditions.

Ozone – An especially reactive form of oxygen, O_3, formed naturally by lightning and by sunlight reacting with nitrogen oxides and volatile organic compounds. It is helpful in the upper atmosphere, but near ground level is harmful to breathe.

Radon – a colorless, odorless, radioactive gas formed by decay of radium. It is found in high concentrations in some soils and can cause health problems if allowed to accumulate inside buildings.

Viruses – sub-microscopic agents that are often capable of causing infections. They are considered non-living but are capable of replicating inside living cells.

Volatile organic compounds (VOC) – organic chemicals that give off gases at room temperatures. They can be irritating or toxic to humans.

Module 7: Financial Analysis and Incentives

Discount rate – an interest rate used to discount (reduce) the value of future amounts of money when comparing with costs today. It may represent the cost of borrowing money or the interest rate that could be earned by investing money at current rates.

First (initial) costs – the purchase price plus any delivery or installation cost of equipment.

Future value – the worth of money or property at some time in the future. Future values are greater than the present value of the same amount, assuming that inflation will occur or that the present value could earn interest between now and the future time.

Internal Rate of Return (IRR) – the interest rate that makes all present and future cash flow equal to 0 (a 'break-even' rate). It can be thought of as the interest rate money invested in a project would need to earn to be equivalent to the projected benefits of the project. If the IRR is greater than what the money could earn in an investment (or greater than the cost of borrowing money) it is a good choice. If IRR is less than either of these, the project costs money.

Life–cycle cost – the total cost of an item over its full life, from the raw materials through its disposal. Life-cycle costs ideally attempt to include environmental costs.

Life-time cost – the costs that occur to the user: purchase, installation, energy, maintenance and parts. It does not include environmental costs.

Payback period – the time necessary for the cumulative benefits of a project to equal the cost of the project. Usually interest rates are not considered and the simple payback period is calculated as the cost / annual benefits, giving the answer in years.

Present value – the value of some future amount or series of amounts discounted to the present with an assumed interest rate. It can be calculated as: $PV = FV / (1 + i)^n$ where FV is the future value, i is the interest rate and n is the number of years.

Rate of Return (ROR) – a percentage that represents the benefits of a project. It is determined by dividing the *annual savings* from a project by the *cost*. It is the inverse of the payback period.

Return on Investment (ROI) – another percentage used to express the benefits of a project. It may be calculated as (Benefits – Costs) / Costs. (Note, the same term is sometimes used for what we are defining as the ROR or the IRR.)

Module 8: Putting It All Together

Energy Utilization Intensity (EUI) – the ratio of energy consumption to a unit of measurement (e.g. floorspace, number of staff, etc.); typically EUI is expressed in kBtu per square foot.

Retro-commissioning – a process to improve performance and energy efficiency of electrical and mechanical systems in commercial buildings; the focus is on operational changes, maintenance, and limited upgrades of existing equipment rather than major equipment replacement.

Course Evaluation

Course title: Mechanical Systems Efficiency and Management for Light Commercial Buildings, Unit I

Date: ________________________ Location: ________________________________

Please circle your response:	**Strongly Disagree**	⟷			**Strongly Agree**
1. The course objectives were accomplished.	1	2	3	4	5
2. The course started and finished on time.	1	2	3	4	5
3. The instructor(s) was well-versed in their topic and well-prepared.	1	2	3	4	5
4. The materials presented were effective.	1	2	3	4	5

What did you like most about the course?

What did you like least about the course?

Please list other comments about this course, including ways to improve the course or suggestions for other courses (more room on the other side!) ⟶