
Introduction to Commercial Building Audits

Course No. ENRG 50

Outline

A. Introduction to concept of commercial building energy auditing

1. Why energy efficiency (EE) is important
2. Energy use and waste in commercial building operations
3. Prioritizing energy efficiency over renewable energy generation

B. Ordinances, policies and standards governing commercial building audits

1. San Francisco Existing Commercial Buildings Performance Ordinance
2. State of California energy goals
3. ASHRAE standards, including Building Energy Assessment Professional (BEAP)
4. Other audit standards

C. Three ASHRAE audit levels

1. Preliminary energy use analysis
2. Level 1, Walk-through analysis
3. Level 2, Intermediate, energy survey and energy analysis
4. Level 3, Detailed analysis of capital-intensive modifications

D. Developing the scope of work in a commercial building audit

1. Objectives of the audit, including needed data and

resources

2. Assessment management
3. Responsibilities of audit team members

E. Elements in preliminary analysis of building performance data

1. Engineering and architectural document review
2. Geographical and climatic review
3. Review and analysis of current energy use and costs
4. Benchmarking procedures

F. Factors in on-site building assessment

1. Common safety hazards and field safety techniques
2. Occupant interviews and assessment of building operations
3. Building envelope
4. Electrical systems
5. HVAC&R systems
6. Lighting systems and use
7. Miscellaneous other energy use systems
8. Domestic water systems and use
9. Indoor environmental quality

G. Analysis of data collected

1. Identify opportunities for efficiency improvement
2. Calculate value of efficiency improvements and return on investment
3. Prioritize options based on client criteria

H. Audit completion activities

1. Prepare and present written report
2. Assist with development of implementation plan

F. Factors in on-site building assessment

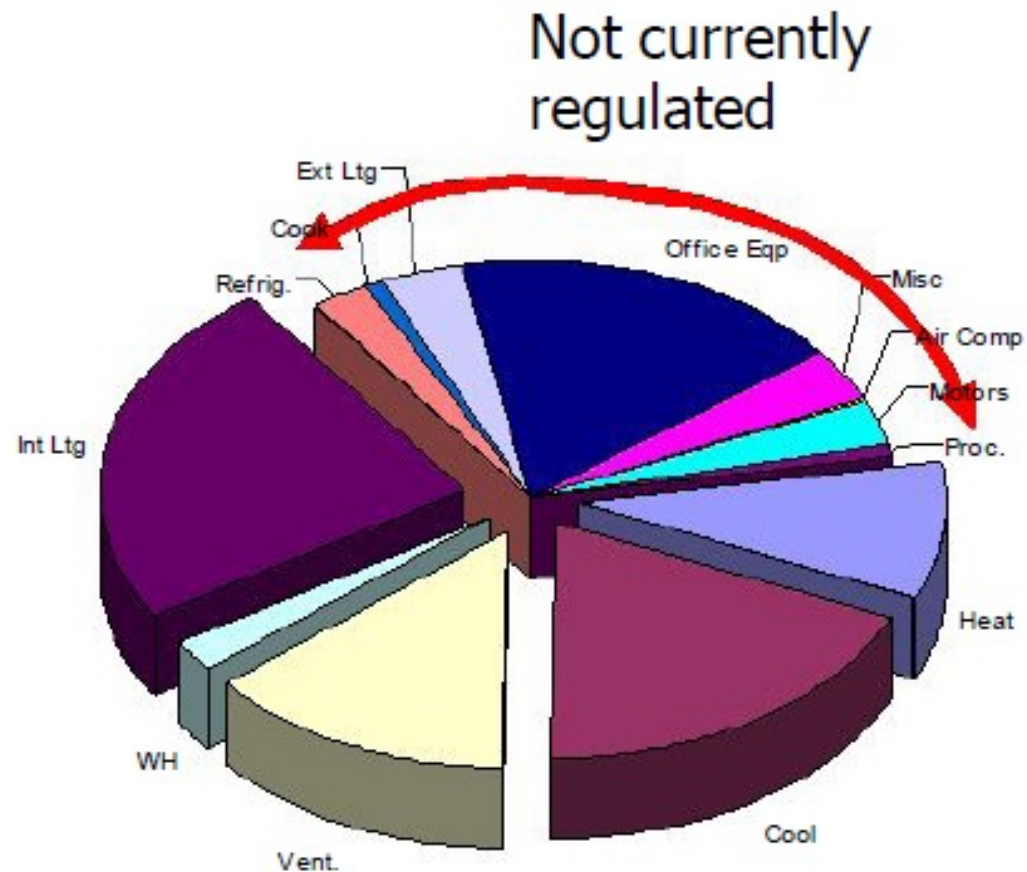
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Why are Miscellaneous/plug loads important?

- Represent 13% of commercial electric energy use
- The typical American owns 25 electronic products
- Leaking loads account for 5% of energy use in homes
- Plug-load equipment draws 1-15 watts in “off” mode
- Some facilities are dominated by these loads (IT, hospitals)
- National energy consumption by servers and data centers is 1.5% of US total & could double in another five years
- Most office equipment is left on for 24 hrs a day
- Many plug loads have minimal control strategies available
- These loads contribute heat to the space and cause the AC to run

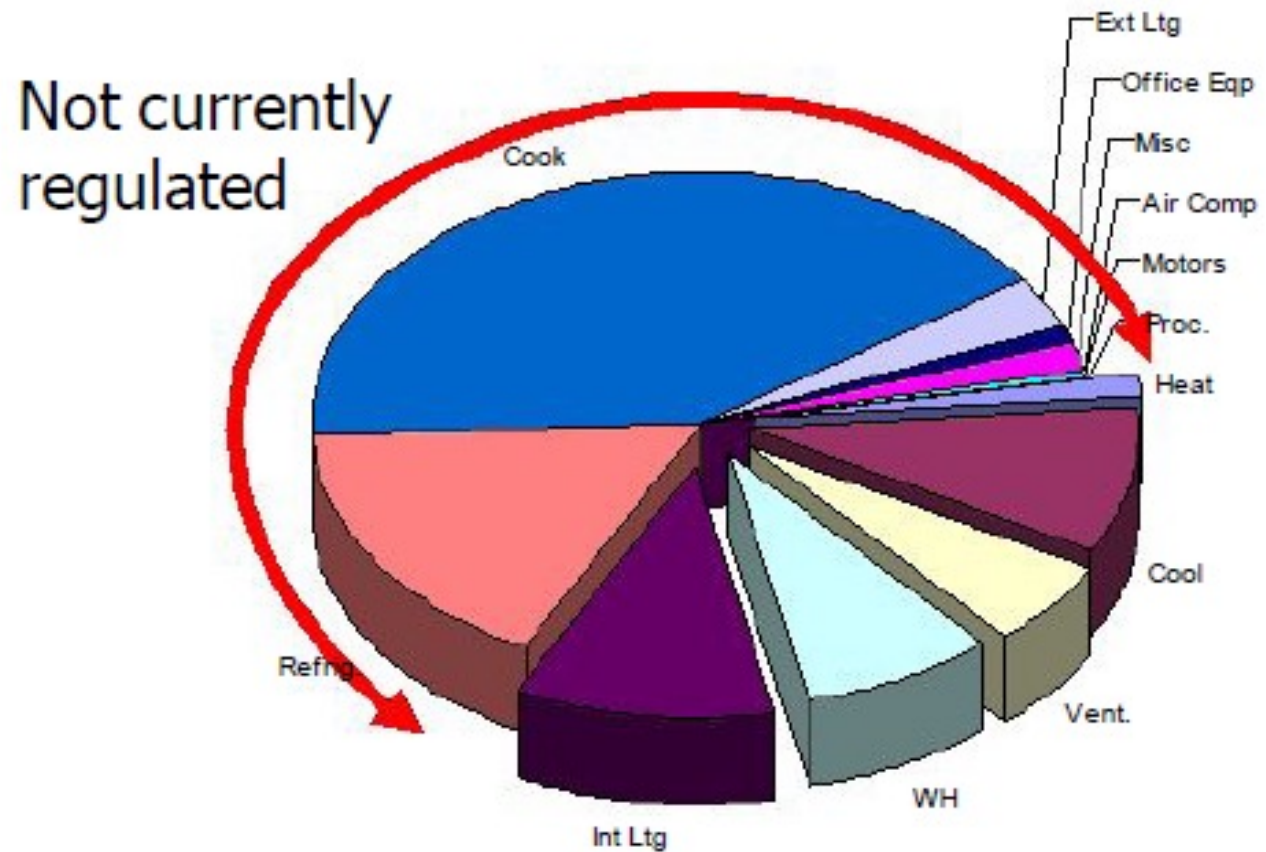
California Commercial End-use Survey

- Office



California Commercial End-use Survey

- Restaurant



Office plug loads

- Computers
- Monitors
- Printers
- Fax machines
- Copiers
- Multifunction devices
- Scanners
- Task lighting
- Heaters
- Gym equipment/showers
- Refrigerators
- Vendor machines
- Other

Power X Time → kWh → \$\$

Save energy and reduce cost:
By lowering watts
By reducing run-time

Miscellaneous other energy use systems

- Printers

- power draw: 20-100 watts
- sleep: 11-25 watts
- typical use:
 - active: 1.5hrs/day
 - off: 14.5hrs/day
- Should stay in stand-by mode



- Monitors

- power draw: 75-120 watts
- sleep: 0-10 watts
- typical use:
 - active: 4hrs/day
 - off: 14.5hrs/day
- Can control to OFF



Energy Star equipment

- Clothes dryers
- Clothes washers
- Computer monitors
- Copiers
- Dehumidifiers
- Dishwashers
- Fax machines
- Mailing machines
- Printers
- Room air cleaners
- Scanners
- Water coolers



Energy Star appliance list

The screenshot shows the Energy Star website's product finder interface. At the top, there's a banner with the Energy Star logo and a photo of a family. Below the banner is a navigation bar with links like 'About ENERGY STAR', 'News Room', 'FAQs', and social media icons. A search bar is on the right. Below the navigation bar are five tabs: 'PRODUCTS' (selected), 'HOME IMPROVEMENT', 'NEW HOMES', 'BUILDINGS & PLANTS', and 'PARTNER RESOURCES'. The main content area is titled 'Find ENERGY STAR Products' and features a grid of product categories. On the left, there's a sidebar with links like 'Product Finder', 'How a Product Earns the Label', 'Save Energy at Home', and 'Join Our Movement'. The product categories are organized into four columns: 'For Your Home', 'Business & Government', 'Products in Development', and 'Can't Find a Product?'. Each column lists various appliances and products with expandable options indicated by arrows.

U.S. ENVIRONMENTAL PROTECTION AGENCY

ENERGY STAR

About ENERGY STAR • News Room • FAQs •

SEARCH

PRODUCTS HOME IMPROVEMENT NEW HOMES BUILDINGS & PLANTS PARTNER RESOURCES

Products

Home > Products > Find ENERGY STAR Products

Find ENERGY STAR Products

All Products

For Your Home	Business & Government	Products in Development	Can't Find a Product?
Appliances <ul style="list-style-type: none">» Clothes Washers» Dehumidifiers» Dishwashers» Freezers» Refrigerators» Room Air Cleaners & Purifiers» Water Coolers Building Products <ul style="list-style-type: none">» Seal and Insulate» Roof Products» Windows, Doors and Skylights	Computers <ul style="list-style-type: none">» Computers» Displays » Imaging Equipment » Uninterruptible Power Supplies Electronics <ul style="list-style-type: none">» Audio/Video» Cordless Phones» Set-top Boxes & Cable Boxes» Televisions Battery Chargers <ul style="list-style-type: none">» Handheld Vacuums with	Heating & Cooling <ul style="list-style-type: none">» Air Conditioning, Central» Air Conditioning, Room» Boilers» Dehumidifiers» Ductless Heating & Cooling» Fans, Ventilating» Furnaces» Heat pumps, Air Source» Heat pumps, Geothermal» Home Sealing - Insulation & Air Sealing» Room Air Cleaners & Purifiers	Lighting and Fans <ul style="list-style-type: none">» Decorative Light Strings» Fans, Ceiling» Light Bulbs» Light Fixtures Plumbing <ul style="list-style-type: none">» Water Heater, Gas Condensing» Water Heater, Heat Pump» Water Heater, High Efficiency Gas Storage» Water Heater, Solar» Water Heater, Whole Home Gas Tankless

http://www.energystar.gov/index.cfm?c=products.pr_find_es_products

Miscellaneous other energy use systems

- PG&E offers Rebate for Business Computing:
 - Network desktop computer power management software
 - Plug load occupancy sensors

Business Computing Rebate Catalog
Saving energy for a brighter future.

http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/businesscomputing_final.pdf

Network Desktop Computer Power Management Software

Vendor List

The below vendors' energy-efficient software satisfies the requirements outlined for compliance with PG&E's Network Desktop Computer Power Management Software rebate.

If you offer power management software to business customers, please contact PG&E to determine if your software complies with PG&E's rebate requirements. Please email us at businesscustomerhelp@pge.com.

PG&E does not endorse specific products, services, or companies, only energy-efficient technologies.

As of March 10, 2012. To find the most up-to-date list, please visit:
www.pge.com/businessrebates

VENDOR NAME	PHONE NUMBER
1E (Night Watchman) US/Canada	1-866-592-4214
Absolute Software	1-800-220-0733
Altiris (eiPower Saver Solution)	1-617-947-4221
Autodesk Software	1-888-888-8888

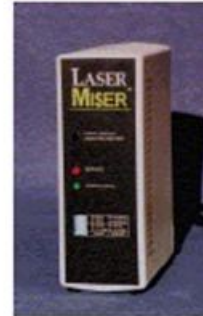
http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/rebatesincentives/vendorlist_computerpowermanagementsoftware.pdf

Miscellaneous other energy use systems

- Plug-load controllers

Applications:

- computers
- task lighting
- copiers
- Fax machines
- vending machines



- Timer controls

- isolate timer for individual devices
- demand savings (12-6pm)
- eliminate waste from loads with consistent usage patterns (coffee machines, irons)



Miscellaneous other energy use systems

- Vending machine controller
 - turns off light and compressor if no one is there
 - cycles compressor on if case exceeds a max temperature to insure product is cold



Miscellaneous other energy use systems

- Vending machine controller results

	Without VendingMiser	With VendingMiser Weekdays (261 days)	With VendingMiser Weekends (104 days)
Daily Wh	7,900	4,900	1,900
Daily Operational Cost (\$0.15 kWh)	\$1.19	\$0.73	\$0.29
Annual kWh	2,885	1,270	200
Separated Annual Operational Cost (\$0.15 kWh)	\$435	\$190	\$30
Combined Annual Operational Cost (\$0.15 kWh)	\$435	\$220	
Percent Savings with the VendingMiser		49%	

Miscellaneous tools and resources

- Clamp-on amp meters
- Split extension cords
- Plug load boxed
- Temperature loggers
- Occupancy sensors



Miscellaneous other energy use systems

2010–2012 Business Rebate List

Product offerings and rebate amount are subject to change.

Business Rebate Catalogs are available at www.pge.com/businessrebates.

Agriculture

Greenhouses

Rebate Code	Description	Rebate/Unit Measure
A10	Greenhouse Heat Curtain	\$0.20/sq. ft.
A102	Infrared Film for Greenhouses	\$0.05/sq. ft.

Irrigation

Rebate Code	Description	Rebate/Unit Measure
A272	Low Pressure Sprinkler Nozzles Hand Move	\$1.15/nozzle
A273	Low Pressure Sprinkler Nozzles	\$1.15/nozzle

http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/Business_Rebates_List.pdf

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Domestic water systems and use

Primary water use purposes in buildings:

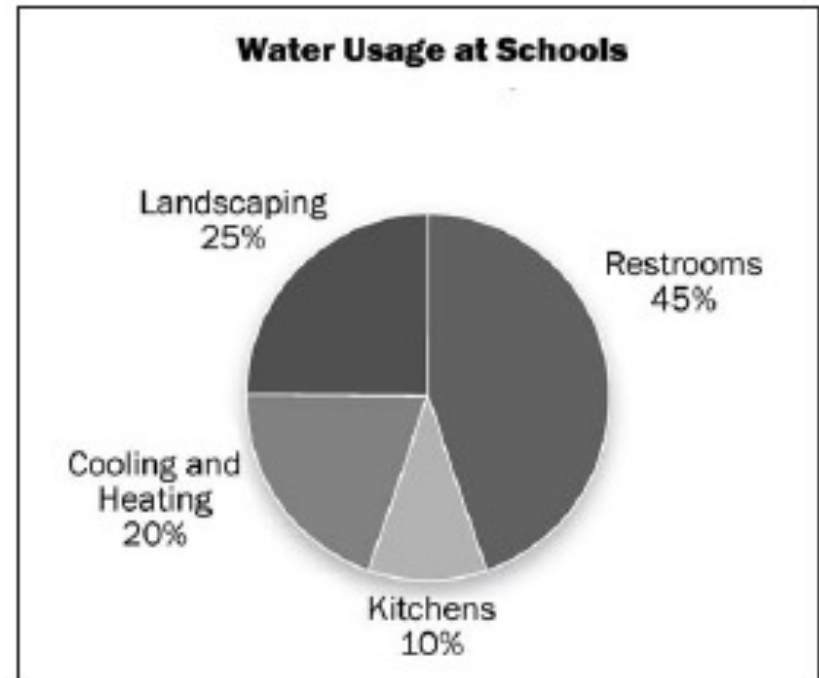
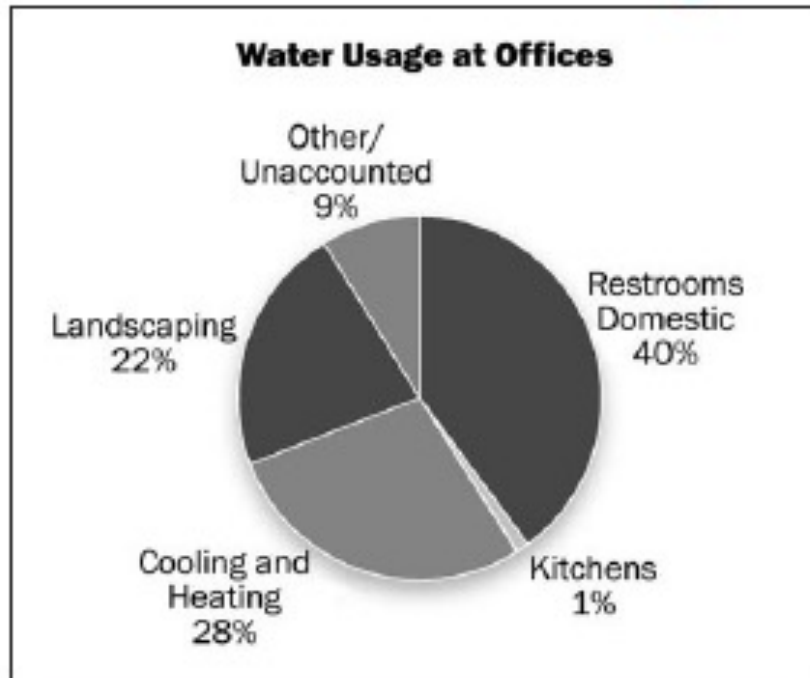
- Toilets
- Showers
- Wash basins
- Kitchens
- Laundry
- HVAC
- Landscaping



Domestic water systems and use

- Although water-consuming activities often remain similar, the sophistication of water infrastructure as well as the quantities and use patterns can vary significantly depending on the primary purpose of the building
- Showers and toilets are particularly important in residences, schools, hotels and office building
- HVAC system and landscaping can be major user of water for shopping center and other large commercial and institutional buildings.

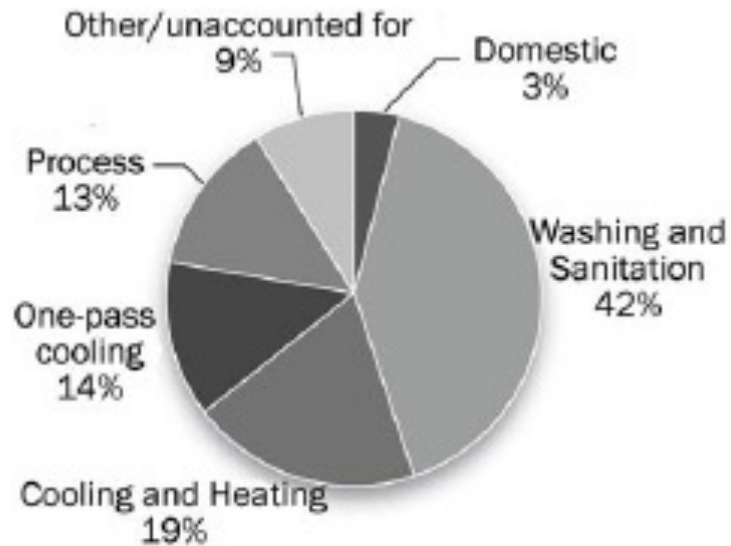
Domestic water systems and use



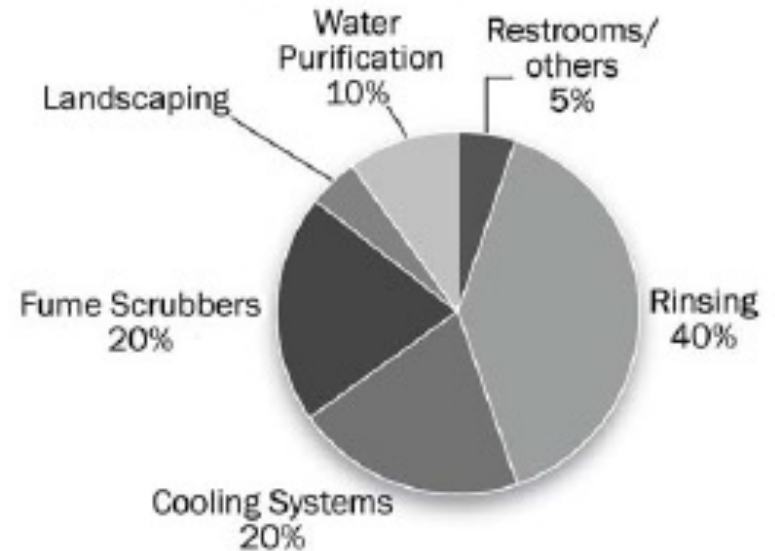
<http://infohouse.p2ric.org/ref/01/00692.pdf>

Domestic water systems and use

Water Usage at Food Processors



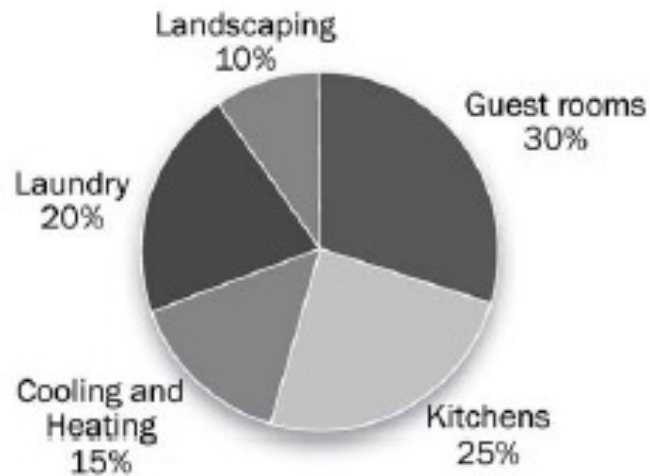
Water Usage at Computer and Electronic Manufacturers



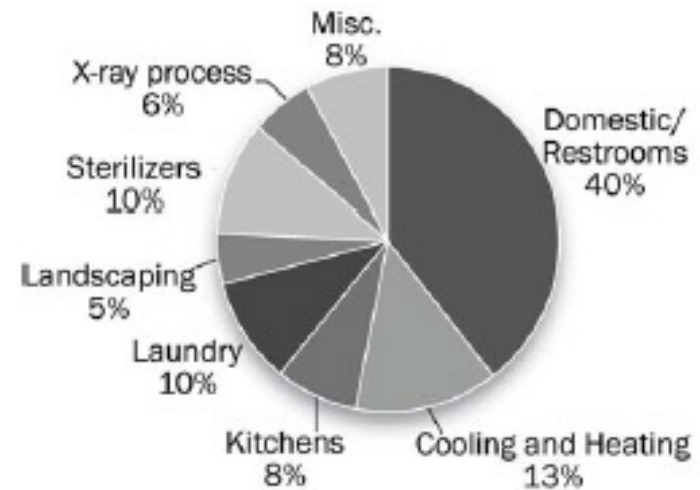
<http://infohouse.p2ric.org/ref/01/00692.pdf>

Domestic water systems and use

Water Usage at Hotels and Motels



Water Usage at Hospitals



<http://infohouse.p2ric.org/ref/01/00692.pdf>

Domestic water systems and use

Planning questions in a building site survey:

- How much water is consumed in different functions of the building?
- Which functions are the main consumers: HVAC, toilet facilities, technical areas, irrigation, others?
- What are the direct and indirect costs of water use in the building?
- What type of maintenance routines (such as leak inspections or equipment maintenance) are in place today?
- What water reuse and recycling systems are in use or have been considered?

Office building water savings opportunities

- Low-flow plumbing fixtures

Table 1: Fixture Water Usage Reduction Since 1992

Fixture type	Usage rate (gallons/flush (gpf) or gallons per minute (gpm))				
	Pre-1992	1st generation	2 nd generation	3 rd generation high-efficiency	% Reduction from pre-1992
Water closet	3.5 gpf	1.6 gpf	1.28 gpf ¹	Dual flush (1.6/0.8 gpf)	63.43% ²
Urinal	2.0 gpf	1.0 gpf	0.5 gpf ¹	0.125 gpf ³	93.75%
Shower	5.5 gpm	2.5 gpm	2.0 gpm ¹	1.75 gpm	68.18%
Faucet	3.0 gpm	2.2 gpm	1.5 gpm ¹	0.5 gpm	83.33%



Water efficiency strategies

Typical Water Consumption for Toilets

Years Manufactured	Gravity Tank Style	Flush Valve Style
Pre-1977	5.0-7.0 gpf	4.5-5.0 gpf
1977 to mid 1990s	3.5 (some 5.0 gpf)	3.5 gpf
Mid 1990s	1.6 gpf maximum	1.6 gpf maximum
2003+ best in class	1.3 gpf maximum	1.3 gpf maximum

Energy Policy Act of 1992

The Energy Policy Act established water efficiency plumbing standards for certain plumbing devices. Prior to 1992, many states and municipalities concerned about water conservation were setting unique standards, which created difficulty for manufacturers and distributors trying to meet these numerous standards. The Energy Policy Act created a set of unified national standards.

Effective Jan. 1, 1994, federal standards set for maximum water usage are:

Toilets	1.6 gpf
Urinals	1 gpf
Showerheads	2.5 gpm @ 80 psi or 2.2 gpm @ 60 psi
Lavatory Faucets	2.5 gpm @ 80 psi or 2.2 gpm @ 60 psi
Kitchen Faucets	2.5 gpm @ 80 psi or 2.2 gpm @ 60 psi

The water efficiency standard was established to:

- Preserve and protect water supply sources, both surface and groundwater.
- Ensure water availability for all beneficial uses.
- Reduce water and energy costs.
- Regulate and standardize plumbing fixture trade.
- Protect health and the environment.

The American Water Works Association estimates nationwide savings of 6.5 billion gallons per day will be achieved by the year 2025 through these standards.

As of the date of this publication, several trade associations and local jurisdictions have proposed further water conservation fixture standards. Revisions to these federal requirements are expected over the next five years.

Office building water savings opportunities

- Insulate piping and storage tanks:
 - avoid long water flow waiting for hot water coming
 - reduce heat losses
- Pressure reduction
 - applicable to high-rise and commercial settings
 - most plumbing codes required pressure-reduction valves on systems where pressures exceed 80 psi.

Office building water savings opportunities

- Fix all leaks!

Even a small drip adds up:

- 50,000 gallons/yr
- \$350 for water
- \$700 for water heating



Water efficiency strategies

Efficient landscape design:

- Use of recycled water for irrigation, where supplies are available
- Minimize turf grass
- Low water consuming plant species
- Weather based irrigation scheduling

Water efficiency strategies

Restaurant:

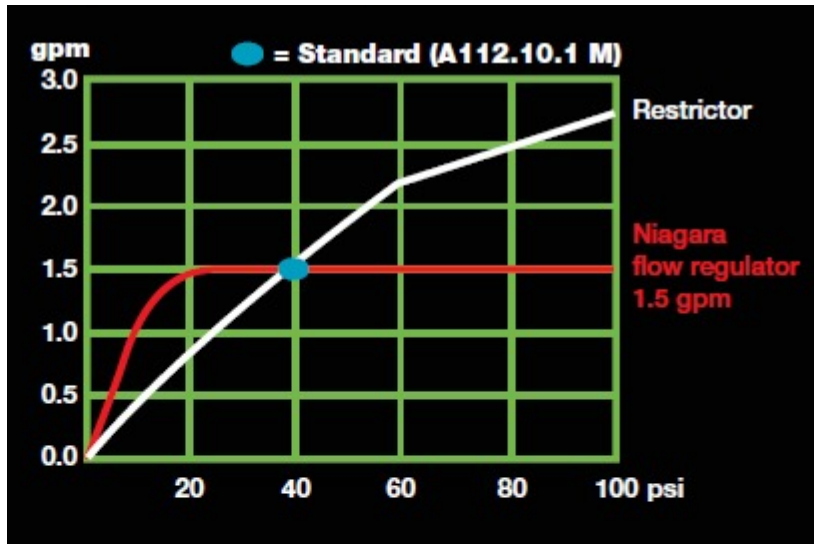
- Dishwashers: 2/3 of total water consumption in a restaurant.

Replace low efficiency dishwashers by high efficiency one:

- Yearly water savings: up to 1.5 acre-feet per machine
- Yearly energy savings: up to 66,000 kWh per machine
- Ice machines:
 - water-cooled ice machine typically use 10 times as much water as air-cooled ice machines.
- Pre-rinse nozzles
- Garbage disposers

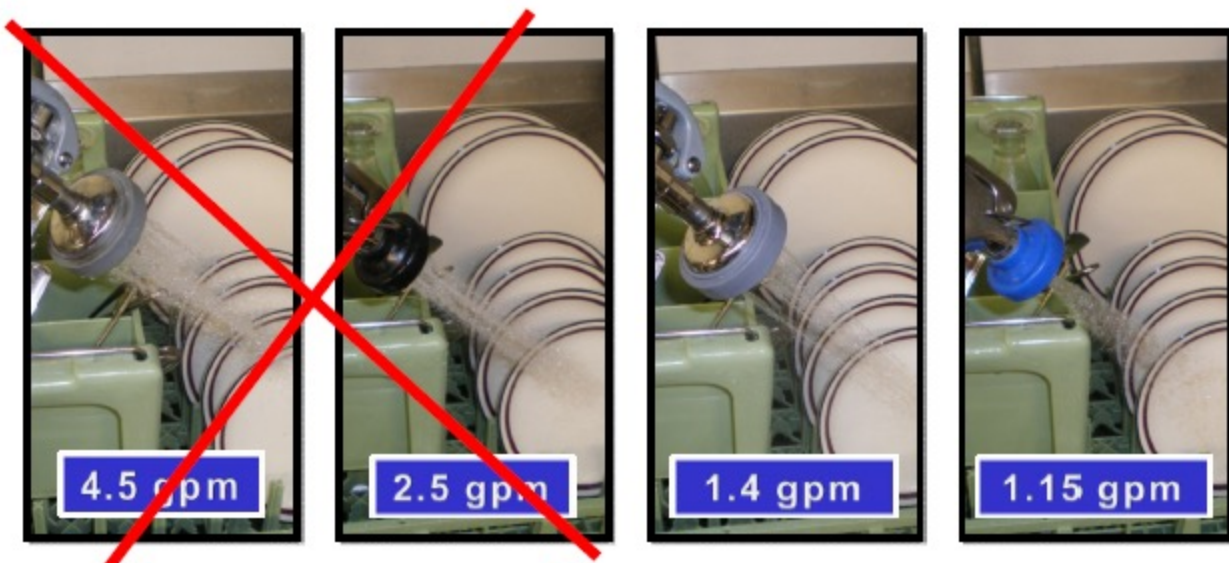
Kitchen

Water nuzzle <1.5 GPM at 40 psi
Standard A11.10.1M



Kitchen

INSTALL LOW FLOW PRE-RINSE SPRAY VALVES



The image displays four photographs of pre-rinse spray valves installed in a kitchen sink, each with a flow rate label at the bottom. The first two valves, labeled 4.5 gpm and 2.5 gpm, are crossed out with a large red 'X', indicating they are not compliant. The third valve, labeled 1.4 gpm, is also crossed out with a red 'X'. The fourth valve, labeled 1.15 gpm, is not crossed out, indicating it is compliant. The valves are shown spraying water onto a stack of white plates.

Valve Flow Rate (gpm)	Compliance Status
4.5	Not Compliant
2.5	Not Compliant
1.4	Not Compliant
1.15	Compliant

1.6 GALLONS PER MINUTE (GPM) OR LESS

64

Domestic water systems and use

- reading links:

<http://www.csemag.com/home/single-article/10-ways-to-save-water-in-commercial-buildings/8f74baabfc.html>

http://www.afedonline.org/water%20efficiency%20manual/PDF/5Chapter%204_Buildings.pdf

<http://www.ose.state.nm.us/water-info/conservation/pdf-manuals/cii-users-guide.pdf>

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Indoor environmental quality - IEQ

Why IEQ important?

- Staff costs far exceed other building costs
- Indoor environmental quality affects productivity



Reading link: http://wbdg.org/ccb/FEDGREEN/fgs_01571911.pdf

Indoor environmental quality - IEQ

- Americans spend about 90% of their time indoors, and indoor pollutant concentrations can be 2-5 times higher than outdoors (US EPA)
- Indoor pollutants can create significant health risks
- Indoor pollutants can affect learning

Do school facilities affect academic performance? By Mark Schneider

Reading link:

<http://www.ncef.org/pubs/outcomes.pdf>

A very thorough literature review showing the connection with:

- Indoor air quality, ventilation and thermal comfort
- Lighting
- Acoustics
- Building age, quality and aesthetics
- School size
- Class size

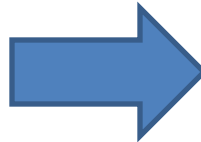
Health effects and symptoms

- **Health problems are typically classified as**
 - Sick Building Syndrome (SBS)
 - Building-Related Illness (BRI)
 - Multiple Chemical Sensitivity (MCS)
- **Symptoms range from:**
 - Mild discomfort and perception of bothersome odors
 - Severe illness and permanent injury
- **Health effects**
 - Increased rates of infectious diseases (influenza, common cold, etc)
 - Eye and respiratory irritation
 - Allergies and asthma
 - Chronic sinusitis
 - Headaches
 - Array of other diseases
- **Environmental factors such as light quality and acoustics may also effect occupant health**

Indoor pollutants

Sources

- Outside air
- Construction materials
- Furnishings
- Building envelope
- Equipment
- Site
- Ventilation systems
- Maintenance
- Occupants



Contents

- Gases and Vapors
 - VOCs: 300+ compounds
 - Inorganics: CO₂, CO, SO₂, NO_x, NH₃
 - Radon
- Fibers
 - Asbestos-Fibrous glass – Man-made fibers – Cotton - Textiles
- Dusts
 - Allergens – House mites – Pollens – Feathers
 - Danders – Smokes (Tobacco, Coal, Wood)
- Microbes
 - Bacterial – Protozoans – Fungi - Viruses

Indoor pollutants – Four Design Strategies

- 1) Source control
- 2) Ventilation control
- 3) Building commissioning
- 4) Building maintenance

Source control

- VOC emissions

Hazardous ingredients can degrade the natural environment during production and after disposal.
May be hazardous to installers and manufacturers.
May cause health problems for building occupants.



- Mold and mildew

design the ventilation system to control indoor humidity

minimize water vapor condensation

irrigation systems should not spray buildings

Keep water out of the building

during construction, remove finish materials exposed to moisture

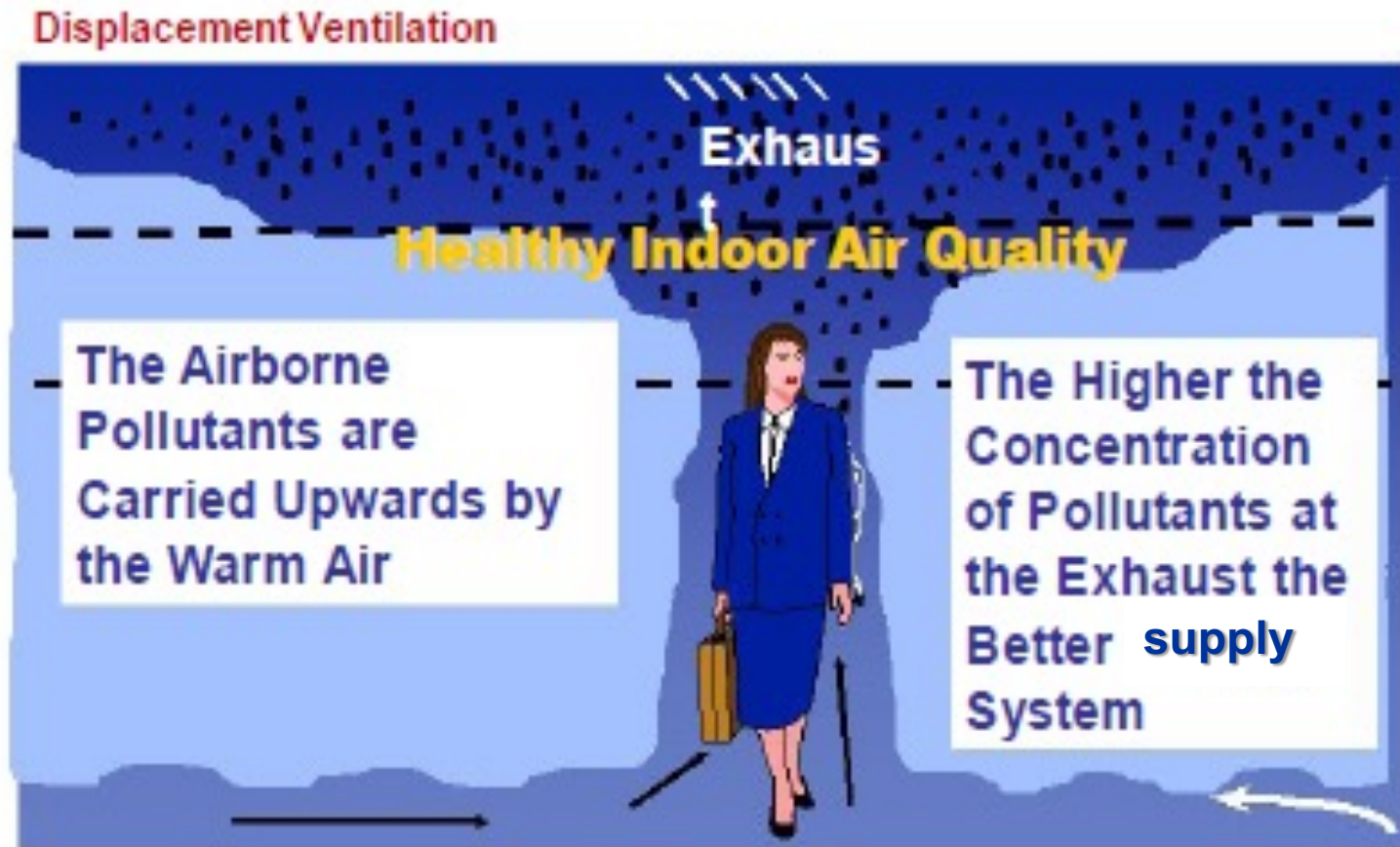


Source control

- During construction

- **Temporary construction ventilation:** Ventilate when installing materials emitting VOCs.
- **Dust protection:** during dust producing activities, turn ventilation system off, and protect HVAC supply and return openings.
- **Preconditioning:** allow products which have odors and significant VOC emissions to off-gas in dry, well-ventilated space prior to delivery to the construction site.
- **Mold protection:** immediately remove from site and properly dispose materials showing signs of mold and mildew.
- **Sequencing:** install odorous and/or high VOC emitting products before porous and fibrous materials, where this is not possible, protect porous materials with polyethylene drop cloths.
- **Filters:** replace all filtration media immediately prior to occupancy (Filtration media shall have a Minimum Efficiency Reporting Value (MERV) of 13 as determined by ASHRAE 52.2-1999)

Ventilation control



Why ventilate?

- Comfort → dilute odors
- Health → dilute CO₂ and other pollutants
- Codes say we must

ASHRAE 62.1 Ventilation Requirements:

- adopted in most codes
- outside air ventilation required per occupant
- outside air ventilation required per square foot
- total ventilation requirement is the sum of the per-occupant and per area requirements
- California requirements similar

Ventilation control

- How?

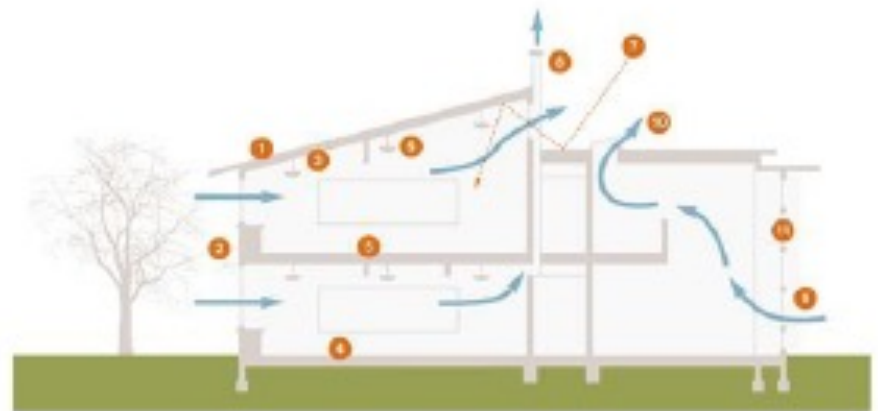
- Naturally
- Mechanically
- Mixed mode (i.e. both)

When is natural ventilation feasible?

- Appropriate climate
- Acceptable outdoor noise level
- Acceptable outdoor air quality (e.g. dust odors)
- Design meets code ventilation requirements

- Natural Ventilation

- Energy efficient ventilation potential
- Traditional in California
- Design for security



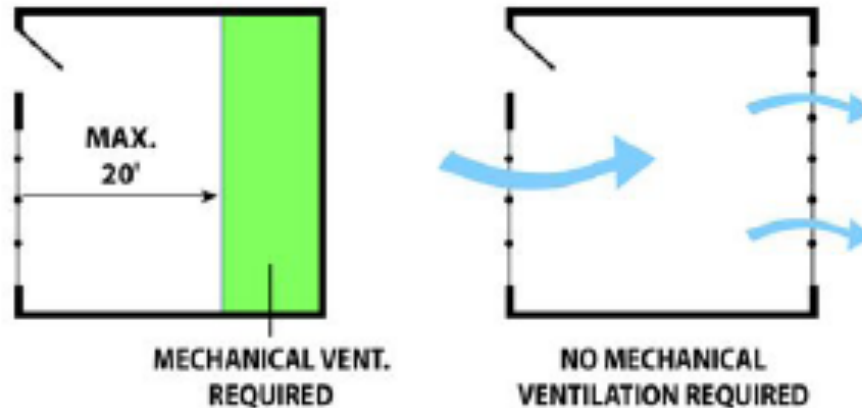
Codes and natural ventilation

- Title 24 Compliance using natural ventilation permitted if:

- All spaces within 20 ft of operable opening
- Total opening area $> 5\%$ of floor area

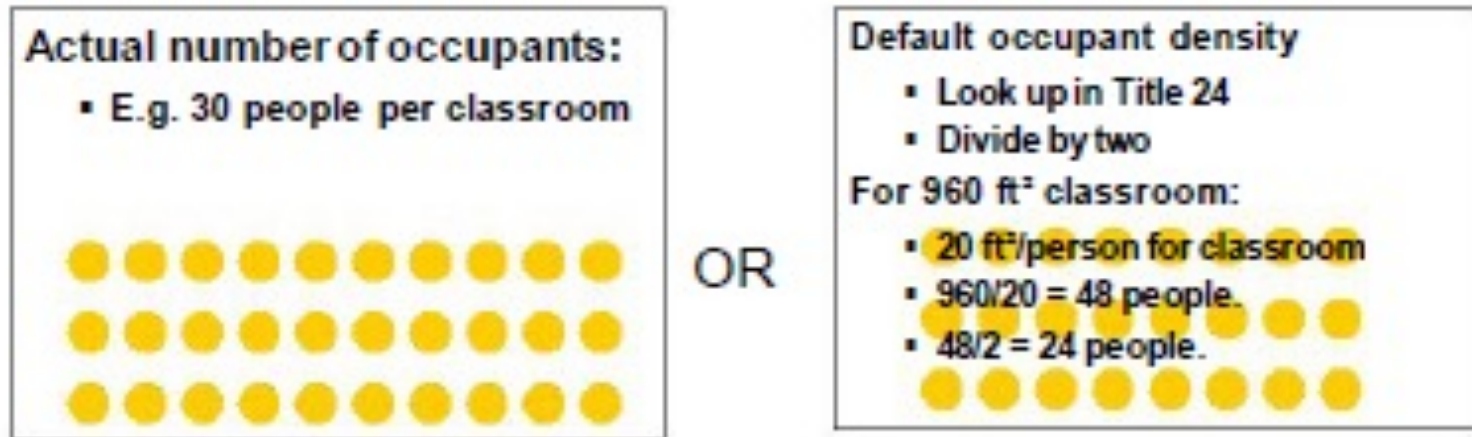
For a typical 960 ft² (30ft X 32 ft) classroom

- At least 48 ft² opening area
- Opening on two sides of the room



Mechanical ventilation for classroom

- Two options for calculating minimum ventilation rate



15 cfm per person minimum for classroom

$$15 \text{ cfm/person} \times 30 \text{ people} = 450 \text{ cfm}$$

$$15 \text{ cfm/person} \times 24 \text{ people} = 360 \text{ cfm}$$

Building commissioning and maintenance

- Four design strategies
 - source control
 - ventilation control
 - building commissioning
 - building maintenance



Visual comfort

- Classroom daylighting design principles
 - No direct sunlight penetration
 - provide gentle, uniform illumination
 - avoid glare
 - control the electric lights
 - plan the interior layout



Why acoustics is important in classrooms

- Speech communication is an important part of the learning process
 - students need good acoustics to understand and convey spoken messages
 - young students are still developing language skills
 - kids are more susceptible to noise and reverberation than adults
- As many as 1/3 of kids in typical classrooms have extra sensitivity to poor acoustics due to:
 - ESL, HOH, LD, ADD, etc. speech disabilities
- Speech intelligibility research shows that
 - HOH kids lag peers in educational achievement
- Many classrooms in the US have speech intelligibility ratings <75%

Resource documents on acoustics

- ANSI standard S12.60-2002 specifies:
 - Low background noise
 - 35 dBA maximum
 - 55 dBC maximum
 - Low reverberation time
 - 0.6 sec for normal classrooms
 - 0.7 sec for large classrooms
 - Sound isolation between classrooms and other spaces
- Classroom acoustics I from the Acoustic Society of America (ASA) is a primer on the basics of classroom acoustics
- Classroom acoustics II summarized studies that “connect” acoustics to learning and teacher performance

<http://www.wyle.com/PDFs/archive/NCAS.pdf>

Maximum A-weighted background noise levels

Unoccupied, furnished learning spaces

Learning space	Max one-hour-avg A-weighted steady background noise level, dB
Core learning space: volume < 20,000 ft ³	35
Core learning spaces: vol >20,000 ft ³ & all ancillary learning spaces	40
Corridors not used for formal learning	45

Maximum reverberation times in ANSI Standard

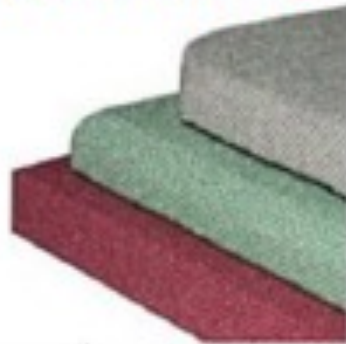
Volume & Type of Learning Space	Max Reverb time in 0.5, 1K, & 2KHz Octave bands
Core spaces Volume < 10,000 ft ³	0.6 sec
Core spaces volume between 10,000 ft ³ and 20,000 ft ³	0.7 sec.
Core spaces volume > 20,000 ft ³ & all ancillary learning spaces	Limits not specified, but RT control is discussed in Annex C

Indoor environmental quality

Sound absorbers reduce reverberation



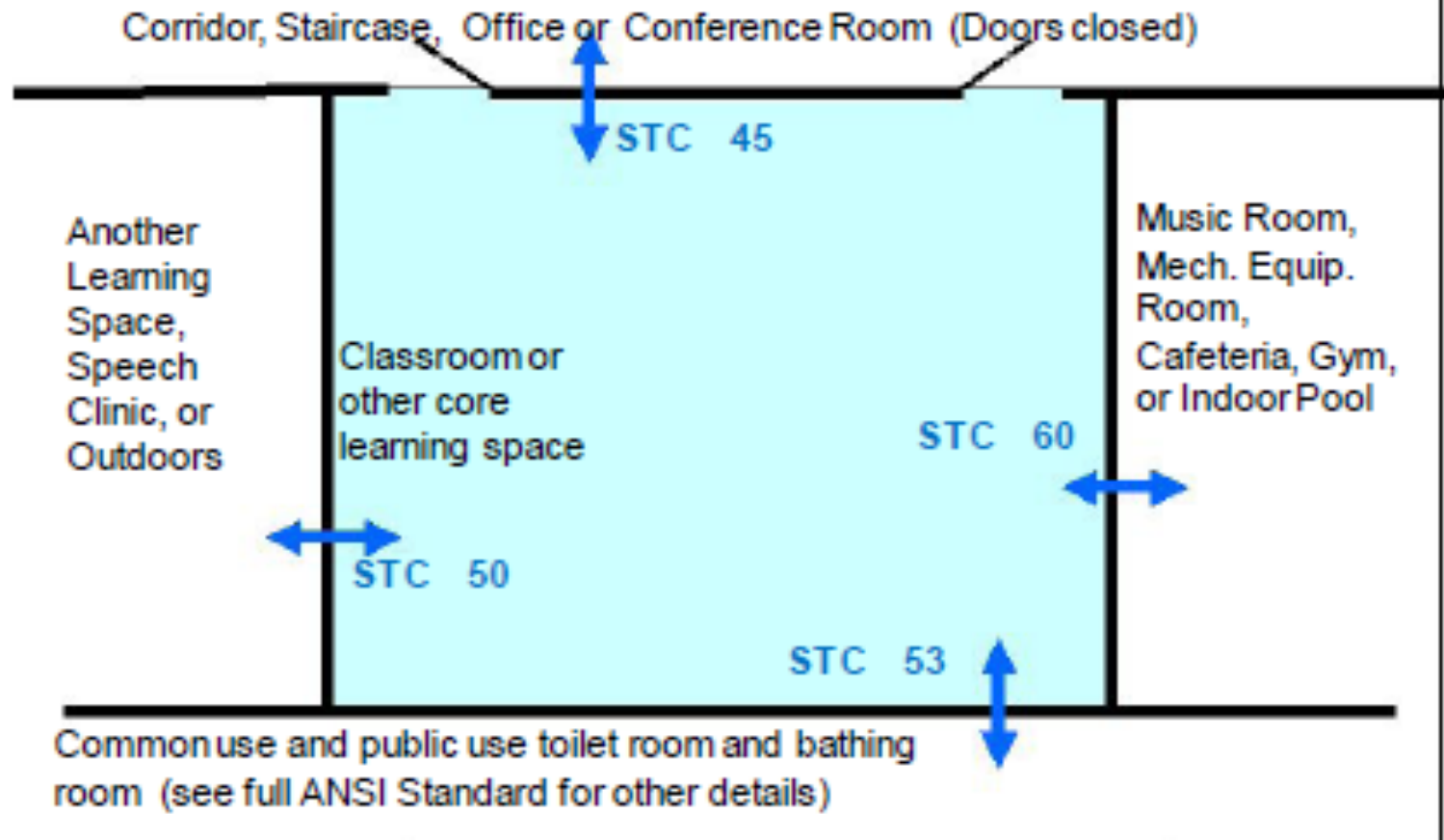
Suspended ceiling



Wall panels

Indoor environmental quality

Noise Isolation (STC) Requirements



Indoor environmental quality

- T

http://wbdg.org/ccb/FEDGREEN/fgs_01571911.pdf

http://www.wbdg.org/ccb/browse_doc.php?d=8020

BEST Center Curricula, Resources & Recordings

Academic Programs

Georgia Piedmont Technical College - Building Automation Systems

Milwaukee Area Technical College - Sustainable Facilities Operations

Laney College - Commercial HVAC Systems

City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos

National Institutes

Building Automation Systems Instructor Workshops

Webinars (e.g., BEST Talks)

Faculty Profile Videos

Reports & Case Studies

Marketing Resources

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