GPRO Building Operations & Maintenance Essentials

Welcome to Urban Green Council's GPRO *Operations and Maintenance Essentials* course.

[Introduce yourself.]

[Ask the students to introduce themselves, including:

- *What kind of building do they work in? Residential or commercial? Where is it?*
- *What is their role?*
- *What do they hope to learn today?]*

In this course you will learn about the core practices of sustainable building operations and maintenance.

We presume you are already knowledgeable about standard procedures in building operations and maintenance. This course addresses only the "green margin," or the new skills and techniques that make sustainable practices possible.

This course is an overview that will show you how to incorporate sustainable practices in your work, while encouraging you to pursue more in-depth training in those areas most valuable for your facility and for your career.

This course is an overview course to help you define the kinds of practices and technologies that make buildings green. We hope this course will inspire you to take more detailed classes that will help you to continue to increase your knowledge and improve your skills.

[Note: Notes in brackets are meant as comments for the instructor.]

COURSE OBJECTIVES

To understand:

A. How to measure the performance of your building

B. The role of the building envelope and how to improve its impact on the interior environment

C. Ways to improve and minimize water use

D. How heating and cooling systems work and how they can be improved

G|PRO Page 1

At the end of this course you will understand:

A. How to measure the performance of your building.

B. The role of the building envelope and how to improve its impact on the interior environment.

C. Ways to improve and minimize water use.

D. How heating and cooling systems work and how they can be improved.

A full list of the objectives covered in this course can be found on page 1 in your manual.

As you learned in the *Fundamentals of Building Green* course, the basic goal of sustainability is "a way of living and working that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Taking action to realize this goal is what this course is all about.

To become a GPRO certificate holder, you must pass the 50-question certificate exam which will include questions from both this course and the *Fundamentals of Building Green* course.

[All students should have taken a Fundamentals course prior to this course. If they didn't, please ask them to contact their delivery partner of GPRO (contact information is in the manual) before sitting for an exam.]

The short quizzes delivered throughout the manual will provide you with a sampling of the type of questions you will be expected to answer on the certificate exam.

Upon successfully passing the test, you will receive a GPRO Certificate, wallet card, and arm badge for *GPRO Operations and Maintenance Essentials*.

If you listed your email address on the roster, you should receive your exam results within 2 weeks. If not, written results, along with certificates, wallet cards, and arm badges will be mailed out within 6-8 weeks.

In the *Fundamentals* course, we explored sustainability in building operations and construction and how it benefits the environment, the economy, your job, and your health.

We now look at sustainability as it relates specifically to energy and water efficiency and environmental health in the buildings you manage.

We will look closely at the responsibilities of the building operator as you balance increased building operations efficiency with the health and safety of occupants and workers.

[Ask students:] "Do green buildings require special O&M, or does good O&M make a building green?" The answer is "both" and you'll soon see what we mean.

A Green Building

A **green building** is designed, constructed and maintained to minimize adverse environmental impacts and to reduce energy consumption, while contributing to the health and productivity of its occupants.

A key component is consideration of the building's impacts and performance over its entire lifespan.

LEED Gold Building, NY

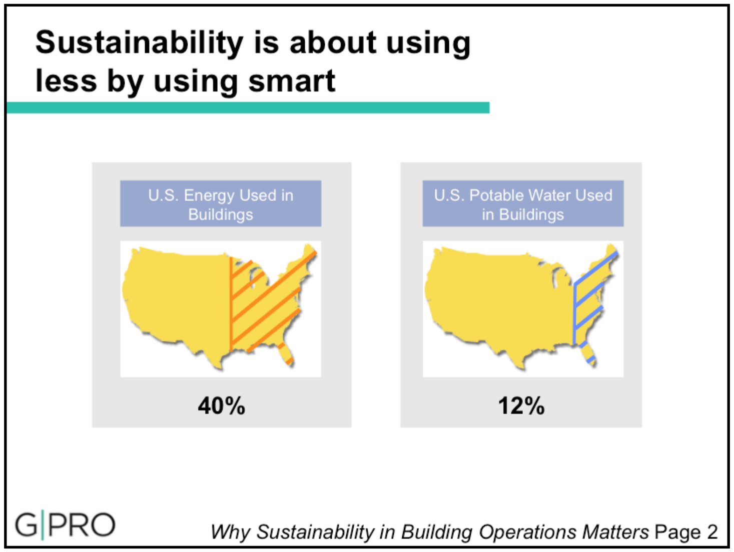
G|PRO

Let's review our definition of green building:

A **green building** is designed and constructed to minimize adverse environmental impacts, reduce energy consumption, and contribute to the health and productivity of both workers during construction and occupants after completion.

A key component is consideration of the building's durability and performance over its entire life.

However, these green building characteristics can create new constraints and requirements for the construction and operations team.



Most buildings in the U.S. that will still be standing in 30 years have already been constructed. This is even more drastic in U.S. cities – 95% of the buildings that will exist in NYC in 2030 are already here – so building operators have a critical role to play in ensuring a more sustainable future.

Most buildings are not operating as efficiently as possible, which leads to water and energy waste.

Sustainability is about using less by using smart and we have a lot to work with!

40% of all U.S. energy and 12% of all potable water is used in buildings.

However, different buildings use these resources differently. The energy use breakdown of a commercial building is about 1/3 heating fuel and 2/3 electricity due to the large amount of lighting, computers, and cooling.

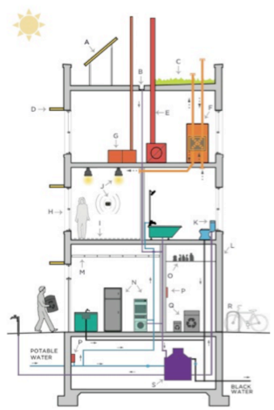
Residential buildings use 2/3 of their energy in heat and hot water with the remaining 1/3 going to cooling, appliances, lighting, and everything else.

Understanding the conditions that result in these differences is essential for a building operator who is looking for the most appropriate energy-efficiency measures to apply to the building.

Therefore, lowering energy and water use in buildings can have a major nationwide impact!

The Whole-Building Approach

All these complex systems work together, whether they are working well or not.



G|PRO *Why Sustainability in Building Operations Matters* Page 3-4

As we work toward greater sustainability in our facility operations, it is important that we think about buildings as integrated systems. This is known as the "whole-building" approach.

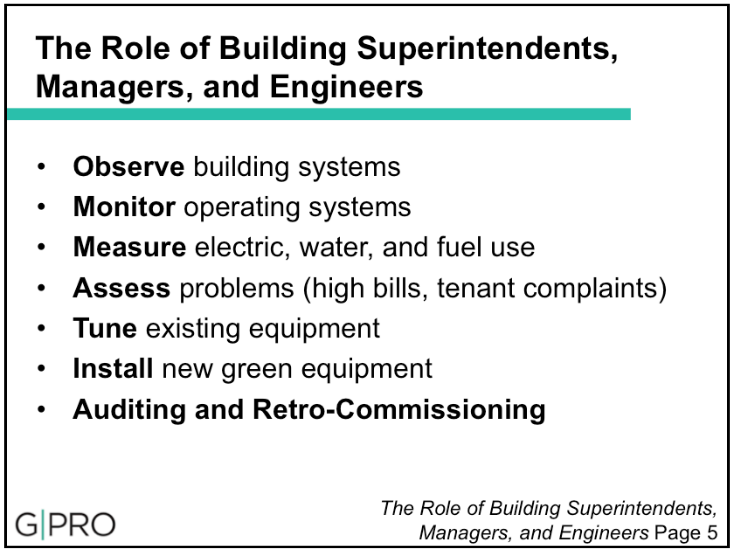
The "whole-building approach" recognizes that a building is a complex collection of interacting systems that must be looked at in an integrated way because achieving efficiency in one system might have a substantial effect on another.

Examples of this interdependence:

- If you change out all your lighting from incandescent bulbs to fluorescents you will save money on your electric bill, but you will also see the heating bill go up slightly, and the air conditioning bill go down. Why? Because the wasted energy from the incandescent lights no longer heats up the space.
- More outside air in the ventilation system means healthier air, but larger heating & cooling bills.
- Tightening up the building envelope will increase energy efficiency but may lead to poor indoor air quality or even health issues if ventilation is not adequate.

Before making changes, it is important to understand how the building systems work together and find the right balance.

Not all building are designed to be green but all buildings have the potential to perform more efficiently than they currently do. Building operators must have thorough awareness about building systems, how they work, and how they interact with each other.



Building superintendents and staff are critical to the proper operation of buildings.

- **Observe**: You are the eyes and ears of the building!
- **Monitor** operating systems and log results. (Are the fans noisy? Is the ventilation system drawing air properly? Are smoke or odors detectable?)
- **Measure** electric, water, and fuel use.
- **Assess** problems (high bills, tenant complaints) and opportunities to repair and improve building systems and elements.
- **Tune**: Make existing equipment function as well as possible with available resources.
- **Install** new green equipment such as more efficient HVAC, low flow fixtures, and variable fan drives.
- **Auditing and Retro-commissioning**: Provide support for outside engineers (we'll talk more about this later in the course).

TEST YOURSELF:

1. Why does sustainability in building operations and maintenance matter?
2. Why use a "whole-building" approach when thinking about operation of a building's facilities?
3. Give an example of how the operation of one facility system in a building affects another of the building's systems.

G|PRO

Page 5

[OPTIONAL]

1. Since buildings consume more than 40% of energy and 12% of water, achieving more sustainable building operations can contribute toward significant environmental improvements. When properly operated for efficiency, well-maintained buildings can have 20-50% lower operating costs while drastically reducing environmental impact. In addition to energy savings, indoor air quality (IAQ) is a primary sustainability concern for building occupants, operators, and engineers - given the profound impact it can have on human health.

2. Buildings are interdependent systems, and changing one system can have an impact on other systems. This "integrated systems" approach is used to explore energy and water usage in buildings and to determine how to make our buildings operate more efficiently.

3. Consider the fact that if you change out all your lighting from incandescent to fluorescent you will save money on your electric bill, but you will also see the heating bill go up slightly, and the air-conditioning bill go down. The power going to the lights, which is released as heat to the space the lights are in, will have been reduced dramatically. This increases the heating load and decreases the cooling load.

Excessive consumption of energy and water leads to environmental damage through greenhouse gas emissions, increased sewage requiring treatment, and the impacts of electricity production.

Most of a building's environmental impact is revealed in its utility and fuel bills.

Keeping track of water and energy consumption is an important component of achieving sustainability in your building operations, as it allows you to identify areas for improvement and benchmark progress.

In this chapter, we discuss understanding water and energy data found on your facility's utility bills, how to use benchmarking to manage energy use, and standards that can be applied for saving energy.

How Water Usage is Measured

- Gallon (gal): volume
- Gallon per minute (gpm): fluid flow
- Cubic feet (cf) and Hundred cubic feet (HCF or CCF): large volumes

Water Meter

G|PRO *How Water and Energy Usage is Measured* Page 6

A *gallon* (gal) is a general measurement of volume. A toilet will use some number of gallons per flush.

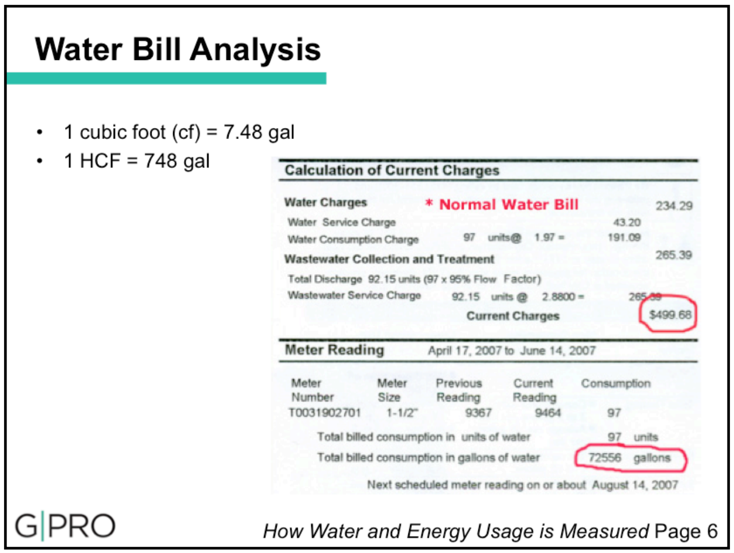
The term *gallons per minute* (GPM) is used when measuring fluid flow or pump capacity. It is often associated with faucets, showerheads, and pumps.

The term *cubic feet* (cf) is used when measuring larger amounts of water.

1 cubic foot of water = 7.48 gallons of water, and weighs 62.4 lbs.

100 cubic feet of water is written "1 CCF" or "1 HCF" on water bills and is equivalent to 748 gallons.

Water meters for larger buildings may have two dials: one for high flow, measured in HCF, and one for low flow, measured in CF. Add them together to find total water consumption.



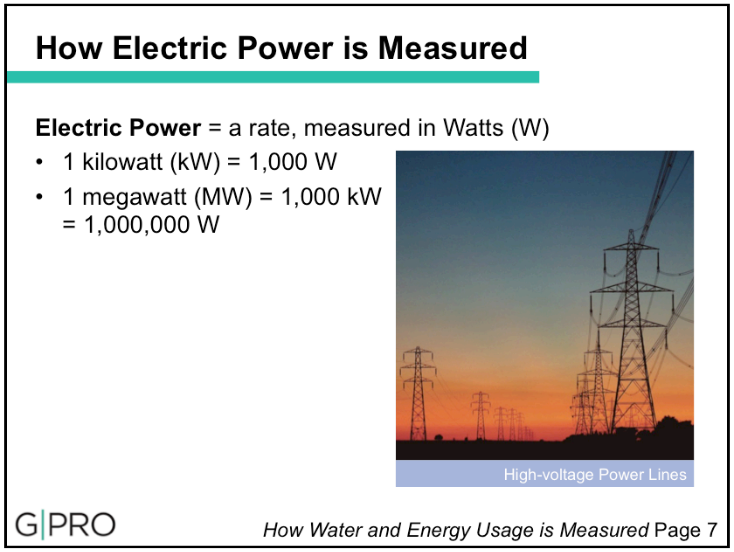
Your building's water bill contains valuable information. The most important item on the bill is water usage, which identifies the amount of water that flows through your water meter (measured in CCF or HCF).

The read dates (date on which the meter was read) are also an important factor when analyzing the bill because they reflect the number of days in the billing period.

One way to analyze your building's water usage is by dividing total number of gallons per day by the total number of occupants in the building.

The average American uses about 100 gallons of water per day. This includes domestic water (bathing, toilets, cooking) and landscape uses (sprinklers, irrigation).

Large buildings may have digital water meter readers which can help identify leaks by immediately detecting a spike in water use.



Power is the rate at which work is being done, and is measured in *watts (W*).

1 kilowatt (kW) = 1,000 Watts

1 megawatt (MW) = 1,000 kW = 1,000,000 W

Watts are used for measuring the power of small appliances (such as a 35 W lamp). Kilowatts are used for large appliances or total usage in a small apartment (a 2 kW electric room heater), and megawatts are used for sizing electric delivery systems or power plants.

Watts and kilowatts are analogous to gallons per minute of water, in that they measure a flow.

How Electric Consumption is Measured

Electric energy = an amount, measured in kilowatt-hours (kWh)

- 1 kilowatt (1,000 W) x 1 hour = 1 kWh
- 100 watts (100 W) x 10 hours = 1,000 watt-hours (Wh) or 1 kWh

Electric Meter

G|PRO *How Water and Energy Usage is Measured* Page 7

Electric energy consumption is the amount of work actually done by electricity over time, and is measured in kilowatt-hours (kWh), as shown on your electric bill.

If 1 kilowatt (1,000 W) of electric power is used for 1 hour, then 1 kilowatt-hour of electric energy has been consumed.

Similarly, if 100 watts (100 W) of electric power are used for 10 hours, then 1,000 watt-hours or 1 kWh will have been consumed.

A kilowatt-hour is an **amount**, like a gallon of water, and a kilowatt is a **rate**, like gallons per minute.

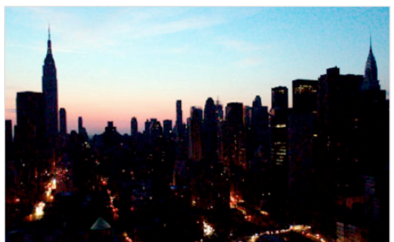
All electric meters record electric energy consumption, almost always in kWh. If you don't have access to your electrical bills, you can track your electric consumption by leaving a clipboard near the meter and recording the values at regular intervals.

Expressed in terms of watt-hours, 1.0 kWh = 1,000 Watt-hours (Wh), and 1 MWh = 1,000 kWh = 1,000,000 Wh.

In the 1970s, refrigerators used more than 2,000 kWh/year. Today's ENERGY STAR refrigerators use less than 500 kWh per year.

Peak Demand

- Maximum power drawn during some time period, usually a month.
- Measured in kilowatts (kW)
- Demand charges can be a substantial part of your utility bill.



Blackout, Eastern U.S. August 17, 2003

G|PRO *How Water and Energy Usage is Measured* Page 7

Peak demand (also called peak load) is the maximum power, measured in kilowatts (kW, not kWh), drawn during some time period, usually 1 month.

For billing purposes in many utility districts, peak monthly demand is the highest value of power drawn through the meter during the month.

The total power demand on an electric utility is the sum of the demands from all the equipment in all the buildings in its territory. In order to provide sufficient power to all its customers, the utility needs to pull out all the stops which may require using its least efficient and dirtiest power plants.

Since peak load is when the electric grid is under the greatest strain and most likely to overload and produce a blackout, great effort is put into finding ways to reduce peak loads. Peak demand is generally on a hot day in summer, due to excessive use of air conditioning systems.

Larger electric customers pay a "demand charge" to the electric utility based on their peak demand each month.

The demand charges can be substantial depending on whether your building's demand coincides with the utility's peak demand.

You can't measure demand charges at the meter – you need the bill to see how much of your electric bill goes to consumption and how much goes to demand.

We will review strategies to reduce electrical demand charges.

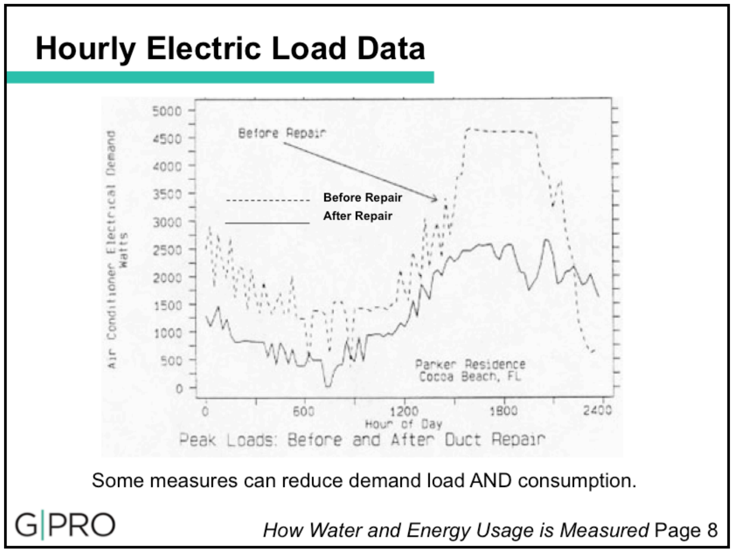


Photo source:
Source: The Florida Solar Energy Center

Standard electric meters record how much energy (kWh) was used in a month, and (sometimes) the peak load in kW.

But meters are also available that record the power in watts or kW every hour or even more often. This can provide useful data.

Electricity costs quite a bit more to produce and deliver at times of high load (midday, for example) than at off peak hours (such as 2 am).

[Discuss the demand patterns in commercial buildings versus residential buildings (residential loads morning and evening, commercial loads mid-day).]

When you analyze your electrical costs, you should take note if your high costs are due to high consumption and/or high demand. Different situations call for different strategies for energy conservation and for demand reduction.

Strategies to reduce consumption cost: lighting occupancy sensors, increase machine efficiencies, VFD fans.

Strategies to reduce demand: cycle A/C equipment mid-day, get an interval meter for more accurate information.

Some measures reduce consumption AND demand. The dotted line on the graph shows an HVAC system in Florida with leaky ducts. The system couldn't deliver enough air so the equipment just kept maxing out. The high power draw created a high demand load. The solid line shows the energy profile after the ducts were sealed. The equipment worked much more efficiently, reducing consumption AND demand.

How Fuel Consumption is Measured

- Electricity in *kWh*
- Gas in *therms*
- Steam in *Mlb*
- Oil in *gallons*

Meters

G|PRO

How Water and Energy Usage is Measured Page 8

- Therms: 1 therm is equal to 100,000 Btu and is the energy unit used in natural gas bills.
    - If you are charting your gas consumption by watching your meter, you might see the dials read hundreds of cubic feet, or "CCF."
    - You can easily convert CCF to therms to Btu (conversion table is in the manual).
- Pounds: used to measure steam delivered through a meter, often from a large distributed generation facility such as Con Edison in New York City.
- Mlb: 1,000 pounds of steam (again, the "M" is U.S. terminology for thousand, not 1 million).
- Gallons: refers to heating fuel (propane or oil). Propane is shipped and stored under pressure as a liquid (gallons), but vaporized to a gas (cubic feet, below), before it is burned.

How to Compare Different Heating Fuels

Fuel Type	Energy Content
Natural Gas	1,030 Btu / cf
Propane (liquid)	92,500 Btu / gal
Propane (gas)	2,500 Btu / cf
#2 Oil	138,500 Btu / gal
#4 Oil	145,000 Btu / gal
#6 Oil	150,000 Btu / gal
Steam (@ 212°F)	970 Btu / lb
Electric Heat	3,413 Btu / kWh

1 therm = 100,000 Btu, or the energy equivalent of burning 97 cf of natural gas.

G|PRO *How Water and Energy Usage is Measured* Page 8

Fuel, which includes heating oil, steam, and natural gas, is measured in terms of the heat produced, as well as the amount shipped and stored. It is measured using the following units:

- British Thermal Unit (Btu): the amount of heat required to raise 1 pound of water 1°F. It is used in the power, steam generation, and HVAC industries to describe energy content of fuel. 1 Btu is approximately equal to the heat from one wooden match stick.
- Btu per hour (Btu/h): the rate at which thermal energy is delivered. It can be used to describe the power of heating and cooling systems.

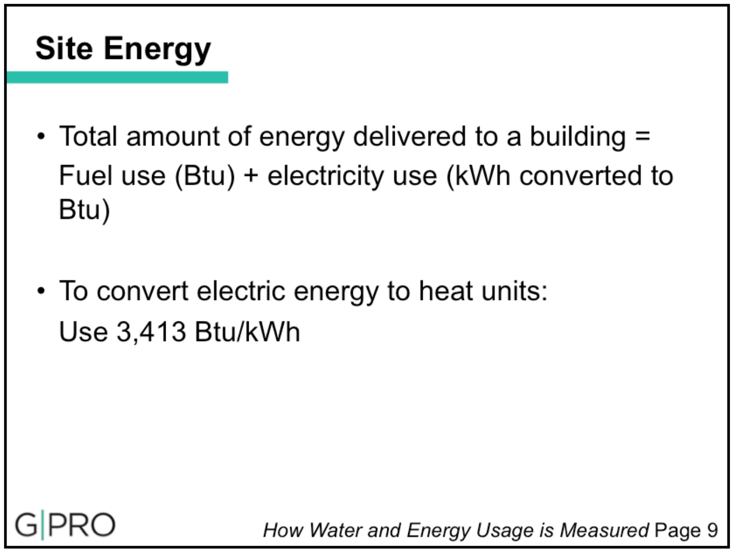
Not all equipment produces heat at the same level of efficiency, so this must be factored in when figuring out the actual heating values attained by any given device.

For example, to find the heat energy that will be provided by a boiler, the heating value must be multiplied by the efficiency of the boiler. A boiler fired by #2 oil with an efficiency of 80% would only produce 0.80 x 138,500 = 110,800 Btu for each gallon of oil.

When Btu describes the energy content of fuels (as in this table), they give the absolute maximum energy that can be obtained with perfect combustion and no losses to the stack or anywhere else.

Since we pay for the fuel going in, it makes sense to choose equipment with the highest possible efficiency.

[ASK WHICH HEATING FUELS THE STUDENTS' BUILDINGS USE.]

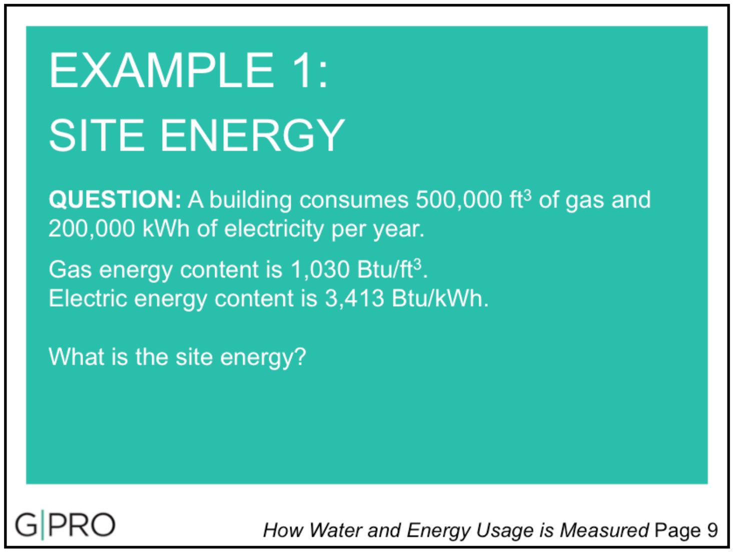


The amount of energy delivered to a building is the site energy (SiteE) and includes all fuel used directly in the building plus electricity delivered to the building measured in Btus.

Site energy is the total amount of the fuel used directly in the building (natural gas or fuel oil) plus the amount of electricity delivered to the building.

To add these amounts together we need to use the same units. The fuel is usually measured in heat units: British thermal units (Btus). Electricity use is measured in kilowatt-hours and must be converted to Btus at a rate of 3,413 Btu/kWh.

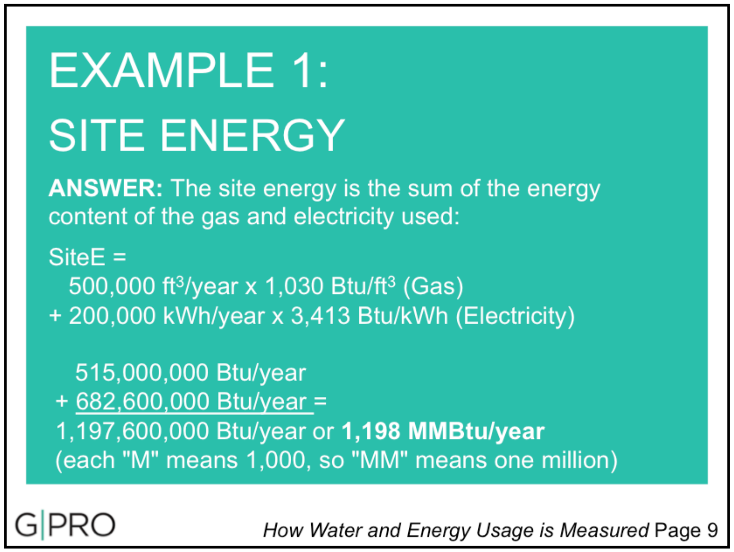
Let's look at a sample building and calculate the site energy.



[This example is the same as in the manual. It is less important to get the math correct than to understand that different fuels need to be converted differently in order to add them together.]

QUESTION: A building consumes 500,000 ft^3 of gas and 200,000 kWh of electricity per year.

Gas energy content is 1,030 Btu/ft^3.
Electric energy content is 3,413 Btu/kWh.
What is the site energy?



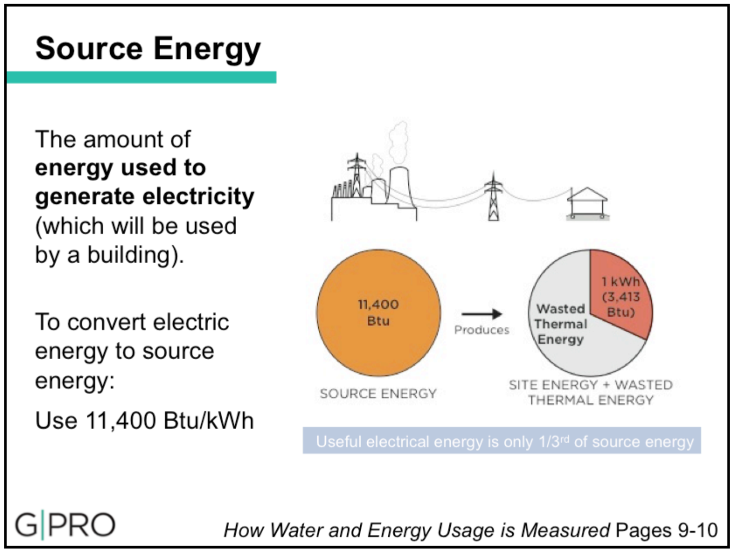
ANSWER: The site energy is the sum of the energy content of the gas and electricity used:

SiteE = fuel use + electricity use (in building)

(500,000 ft^3/year x 1,030 Btu/ft^3)
+ (200,000 kWh/year x 3,413 Btu/kWh) =

515,000,000 Btu/year + 682,600,000 Btu/year =

1,197,600,000 Btu/year *or* 1,198 MMBtu/year
(For Btus, each "M" means 1,000, so "MM" means one million)



Source energy is the amount of energy used to generate the electricity. Source energy gives us a better indication of a building's overall environmental impact than site energy by measuring the amount of fossil fuels burned to produce the energy used at the building. In the U.S. it takes approximately 3x the energy to produce the electricity that is actually delivered to the building.

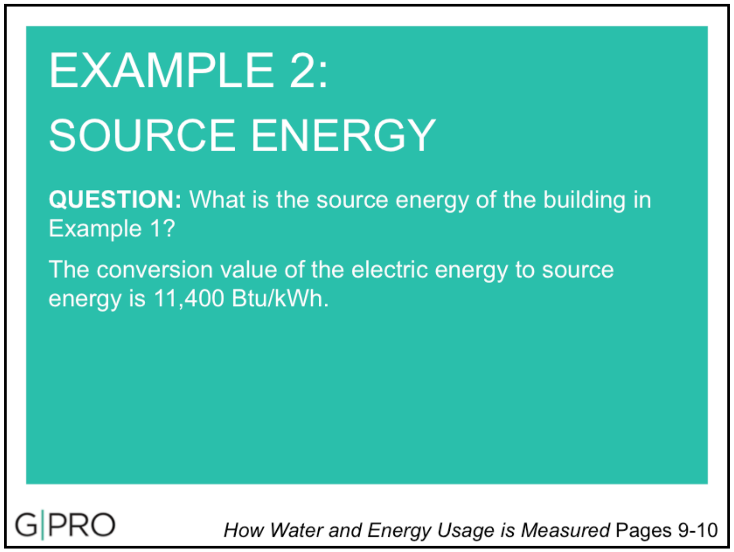
The amount of useful electrical energy actually delivered to a building is typically only about *one-third* of the amount of energy used to generate it!

The other two-thirds are lost mainly in wasted heat at the generating plant and in transmission.

To account for this large amount of lost energy when we compare energy use between buildings that use both fuel and electricity, we use a concept called **source energy** (SourceE).

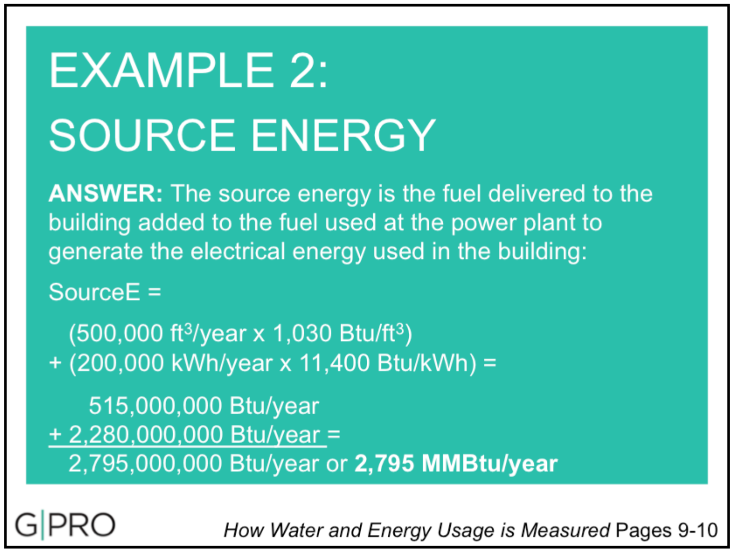
Source energy is the amount of energy in the fuel used to generate the electricity.

The U.S. EPA's national average value for the conversion of electric energy to source energy is 11,400 Btu/kWh. That's a little over three times the 3,413 Btu/kWh of energy calculated for site energy use.



QUESTION: What is the source energy of the building in Example 1?

The conversion value of the electric energy to source energy is 11,400 Btu/kWh.



ANSWER: The source energy is the fuel used at the building added to the fuel used at the power plant to generate the electrical energy used in the building:

SourceE = fuel use in building + fuel use in power plant

SourceE =

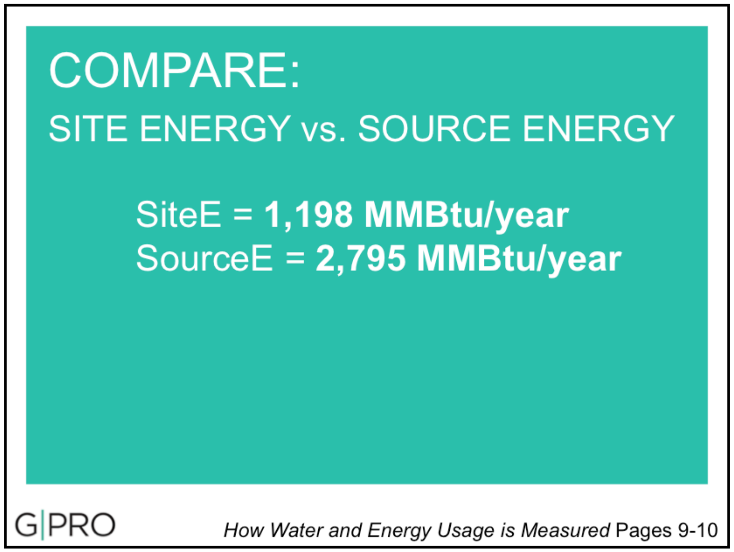
(500,000 ft^3/year x 1,030 Btu/ft^3)

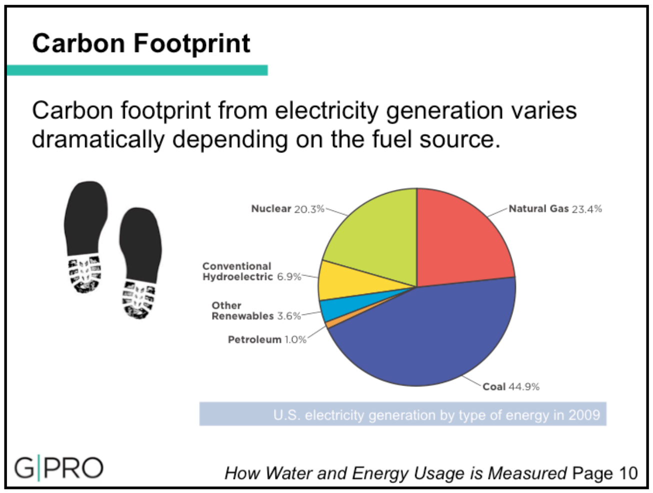
+ (200,000 kWh/year x 11,400 Btu/kWh) =

515,000,000 Btu/year + 2,280,000,000 Btu/year =

2,795,000,000 Btu/year or 2,795 MMBtu/year

You can see the big difference in SiteE and SourceE and why we care about calculating the energy used to generate the energy we consume. We are actually using much more energy than our building meters directly measure!





Climate change is a key priority in sustainability. As we discussed in *Fundamentals,* it is driven by emissions of carbon dioxide and other greenhouse gasses such as methane created from burning fossil fuels to generate energy.

[Ask the class to tell you the definition of carbon footprint]: the amount of greenhouse gases released through the life cycle of a product or service.

The carbon footprint from electricity production varies dramatically depending on the fuel source, which will vary from one region of the country to another.

44.9% of U.S. electrical generation comes from coal, therefore a large quantity of carbon is released into the air from coal-powered electrical generation. Also, coal contains mercury and burning coal accounts for half of all mercury emissions in the U.S. In early 2012 the U.S. EPA issued regulations to reduce mercury emissions from power plants by 90% by 2017.

POP QUIZ:

What is the most expensive fuel?

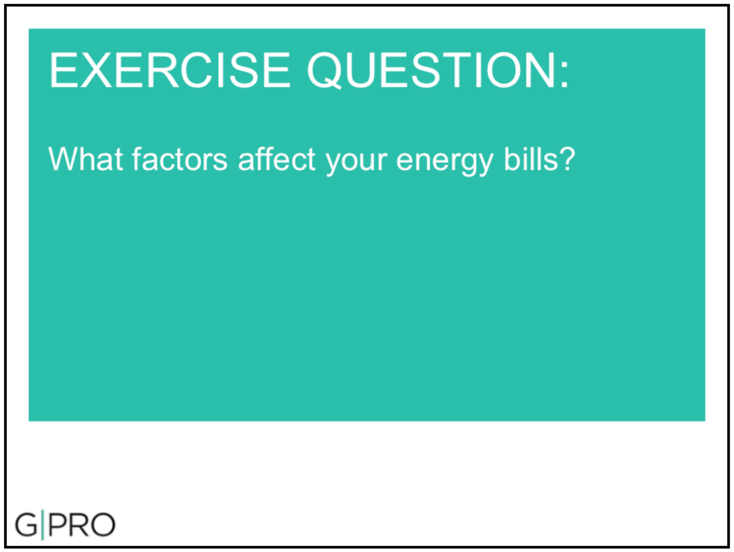
G|PRO

POP QUIZ:

Fuel Type (unit)	Cost / unit	Btu / unit	Cost / million Btu
Natural Gas (mcf)	$11.34	1,030,000	$11.01
Propane (gallons)	$1.86	92,500	$20.10
#2 oil (gallons)	$2.69	138,500	$19.40
#6 oil (gallons)	$2.30	150,000	$15.30
Steam (lb)	$.024	970	$24.70
Electricity (kWh)	$0.110	3,413	$32.20

Data for Dec 2010-Jan 2011 updated April 2011

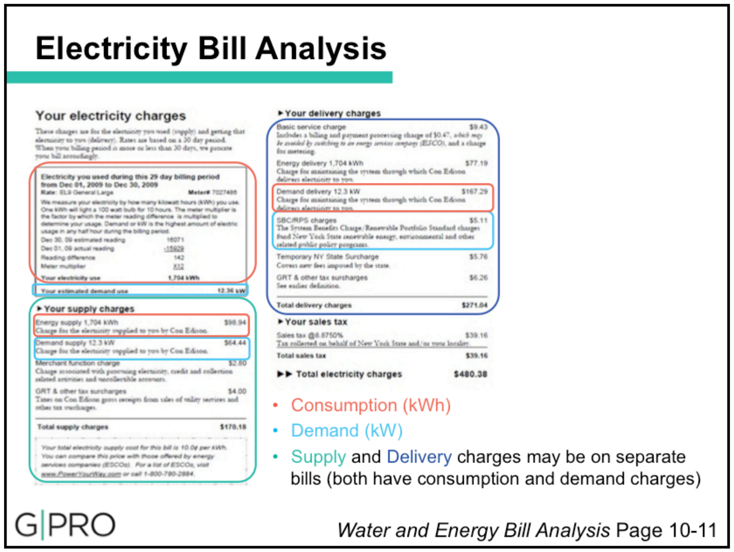
G|PRO



What factors affect your energy bills?

*[Write the students' suggestions on the board. Then review the list to see which items the operators have control over. * indicates items operators may be able to control.]*

- Weather
- Tenant behavior
- Energy prices
- Building Occupancy (people gone for the summer or holidays)
- *Staff behavior
- *Equipment efficiency
- *Equipment failure
- *Building improvements
- Size of building
- Size of unit
- Age of equipment

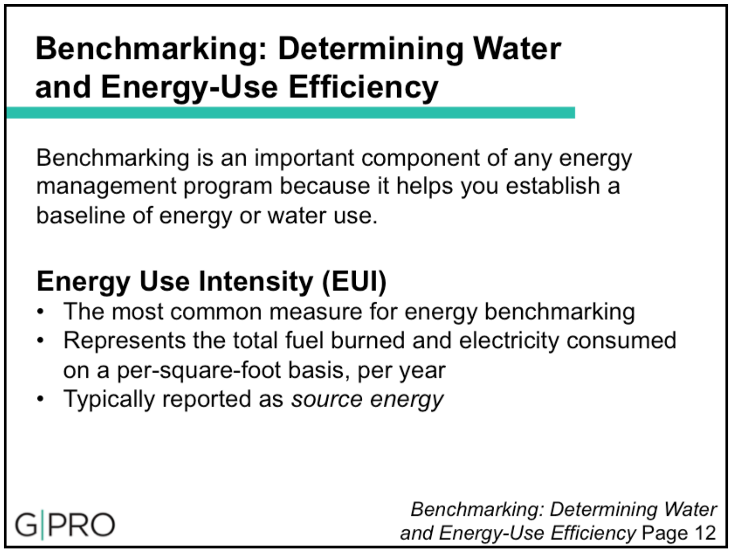


Being familiar with the different parts of your facility's utility bill will help you understand how energy is being used in your facility and how you are being charged. Regularly reviewing your bills gives you the opportunity to monitor energy use patterns of the building.

When reading an electricity bill, you should be aware of three major charges: customer, demand, and energy charges.

These are defined as:

- **Customer charge** is the monthly account fee and stays roughly the same each month until there is a tariff increase.
- **Demand charge** is based on the monthly peak load (discussed earlier), measured in kW. Normally, larger customers such as commercial and multi- family buildings have demand meters and pay demand charges. In some utility districts, demand charges can comprise a major portion of the bill
- **Energy consumption charge** is based on the monthly electric energy consumed, as measured in kWh.

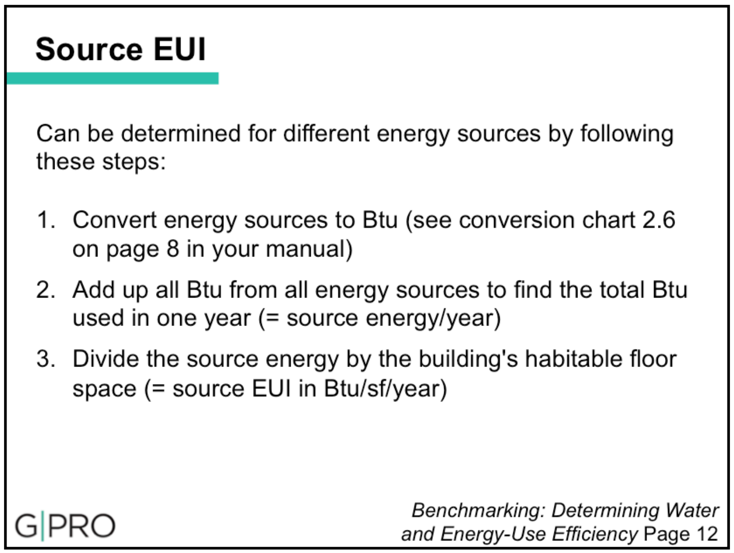


Benchmarking is the foundation of any energy management program.

When benchmarking, you establish a baseline of energy or water use over at least a full-year period for comparison with future annual patterns of use and average behavior for similar buildings.

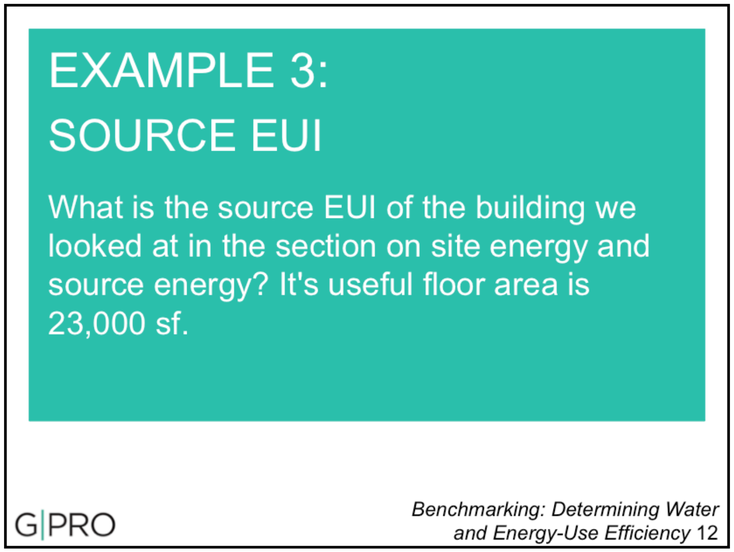
The process of benchmarking identifies potential savings and prioritizes necessary improvements.

Energy Use Intensity represents the total of fuel burned and electricity consumed on a per-square-foot basis, per year. This can be done using either site energy or source energy. Source EUI is a more meaningful number and the one that is used in most benchmarking programs.



Source EUI can be determined for different energy sources by following these steps:

1. Convert energy sources to Btu (see conversion chart 2.6 on page 8 in your manual)
2. Add up all Btu components to find the total Btu used in one year (= source energy/year)
3. Divide the source energy by the building's habitable floor space (= source EUI in Btu/sf/year)



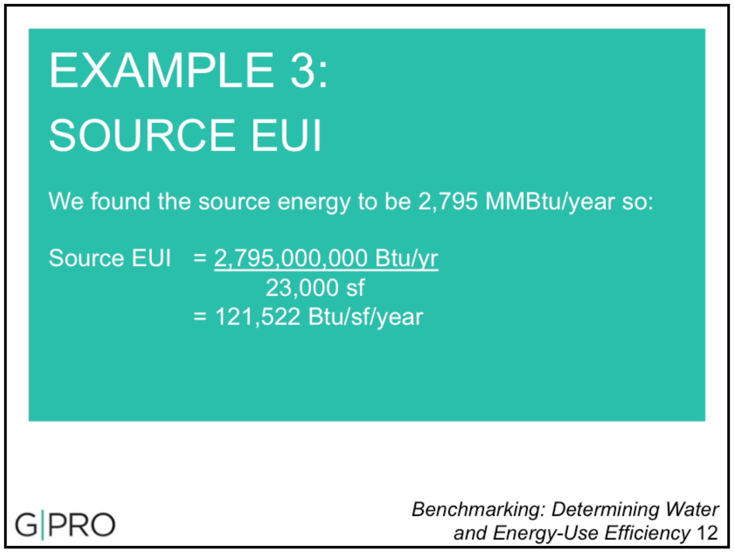
- Source EUI can be used to measure the progress of energy saving strategies internally within a building.
- Portfolio Manager uses Source EUI to calculate a building's overall environmental impact.

Example 3:

QUESTION:

What is the source EUI of the building from Examples 1 and 2?

The useful floor area is 23,000 sf.



ANSWER:

We found the site energy to be 2,795 MMBtu/year, so:

Source EUI =

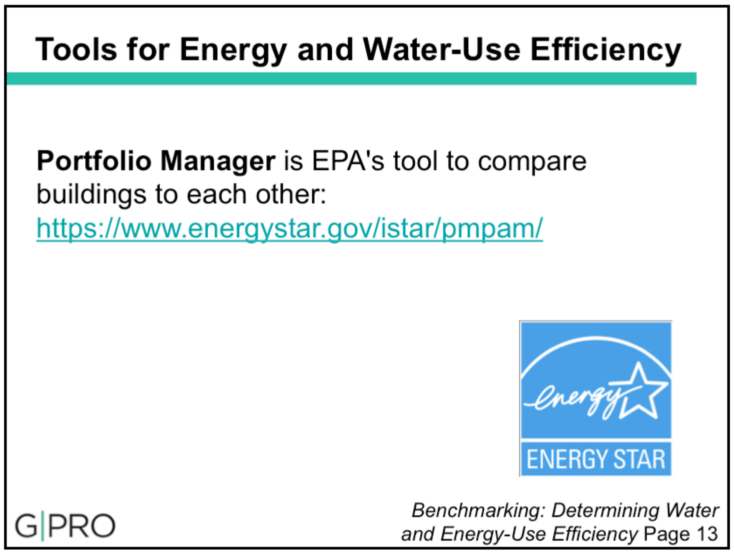
$$\frac{2{,}795{,}000{,}000 \text{ Btu/year}}{23{,}000 \text{ sf}} =$$

121,522 Btu/sf/year

This is an average value for a multi-family residential building.

Source EUI is used in Portfolio Manager, and is a good indicator of environmental impact.

[Note: Example 3 in the manual uses a different number for source energy, but the calculation is correct.]



[All links will be on gpro.org.]

There are many standards, tools, and rating systems available that can assist in achieving meaningful results when it comes to sustainability.

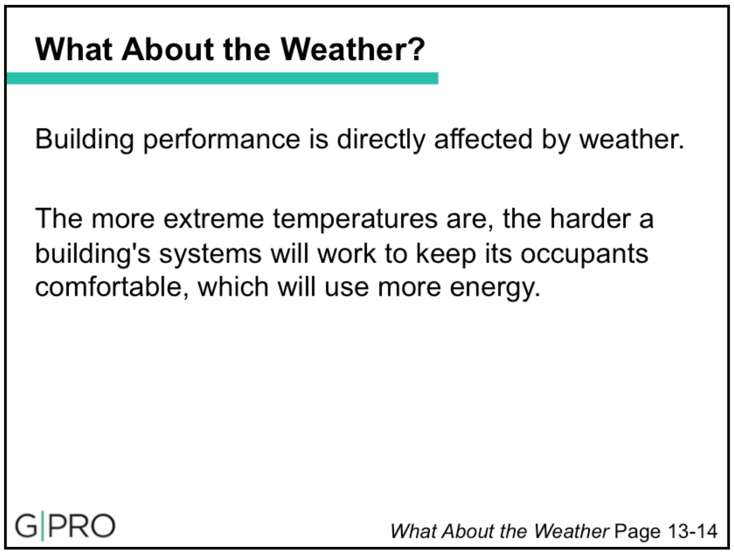
Portfolio Manager calculates EUI including all electricity, fuel for heat and hot water, and water use.

It calculates this information based on the *source energy use intensity, or "Source EUI"*

Portfolio Manager, a software tool created and administered by ENERGY STAR (a program of the U.S. EPA and the U.S. DOE) is used by commercial building owners to make decisions about how best to save energy — which buildings need the most improvement, and how inefficient a building really is compared to buildings of similar size and type around the country or region.

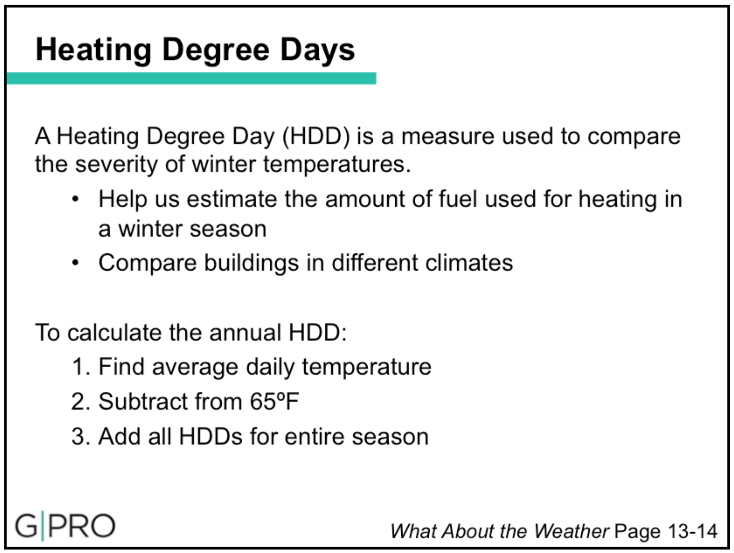
Portfolio Manager allows building owners, operators, and engineers to track and measure energy and water consumption, as well as to rate a building's energy performance. Portfolio Manager provides an automated way to calculate and use the energy use intensity developed in the previous section, and for commercial buildings, it will provide useful comparisons of the subject building's energy use to that of other, similar buildings. Data for any building can be entered, but Portfolio Manager will only provide useful comparisons for commercial buildings.

A commercial building that scores in the top 25% for its type will receive an ENERGY STAR rating and can display the ENERGY STAR plaque.



One of the most important things to remember about building performance is that it is directly affected by weather.

The more extreme temperatures are, the harder a building's systems will need to work to keep its occupants comfortable. Consequently, more energy will be used.



A Heating Degree Day (HDD) is a measure used to compare the severity of the winter temperatures.

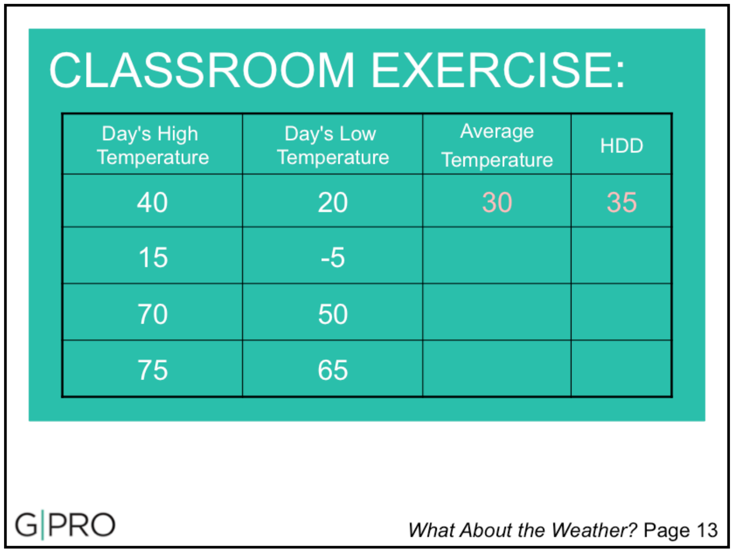
HDDs also help us estimate the amount of fuel used for heating in a winter season, which corresponds directly to the daily temperatures. It also allows us to compare efficiencies for buildings in different climates.

If you make improvements to your building, and the following winter, heating bills are higher, it may be because of a colder winter rather than ineffective improvements – we need a way to remove the effect of weather, and HDD is the way to do it.

The National Weather Service keeps track of HDD, and many newspapers publish the data every day as they accumulate.

You should see your fuel use increase if the values are high (indicating a cold winter).

Similarly, air conditioning loads are driven by high temperatures, and "cooling degree days" (CDD) provide a measure of how hard cooling systems must work.



CLASSROOM EXERCISE:

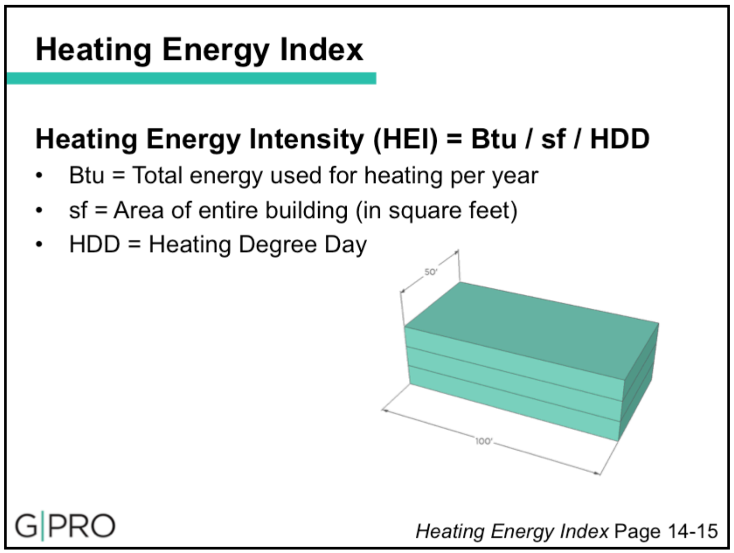
Day's High Temperature	Day's Low Temperature	Average Temperature	HDD
40	20	30	35
15	-5		
70	50		
75	65		

Use this chart to practice calculating Heating Degree Days by subtracting the daily average temperature from 65°F.

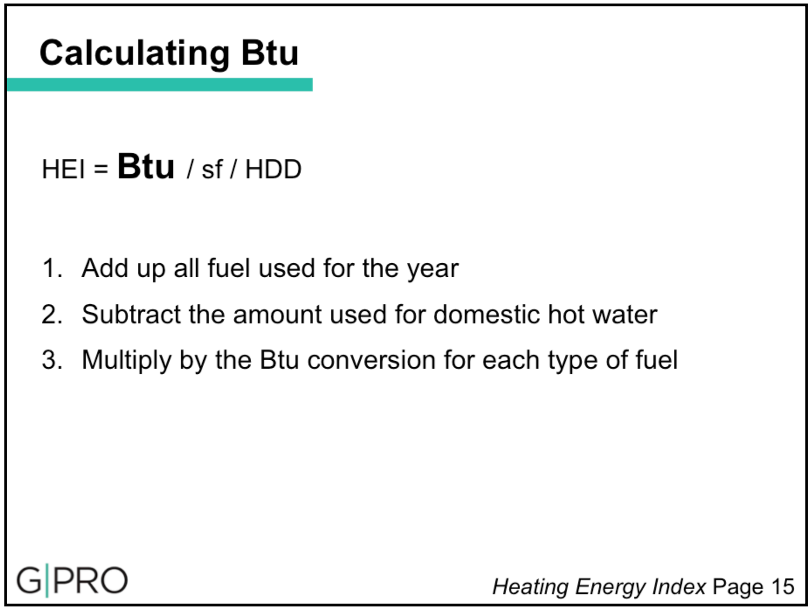
ANSWER:

High	Low	Avg	HDD
40	20	30	35
15	-5	5	60
70	50	60	5
75	65	70	5 CDD

[Note the last line is a trick question. You can't have negative HDD but a similar calculation on warm days gives you CDD.]



Since many building operators don't have access to utility bills or to a Portfolio Manager account for the building, we have provided a classroom exercise that will allow students to figure out how much energy is being used to heat a building while removing the effect of the weather. Also, if you operate or manage more than one building, it is useful to report energy use on a square foot basis so that you can compare efficiencies of the heating systems in the buildings.



Assume this is a multi-family building. First we calculate the energy in Btus.

1. Add up all fuel used for the year.
2. Subtract the amount used for domestic hot water by calculating the lowest fuel use which is the average of the 3 months with the lowest usage (typically in the middle of summer). We call that the baseload. Then subtract a year's worth of baseload. (Multiply monthly baseload by 12 and subtract from total.)
3. Convert energy content of all fuels to Btu by multiplying by the Btu conversion for each type of fuel.

You'll probably have a number in the billions.

Calculating Area

HEI = Btu / **sf** / HDD

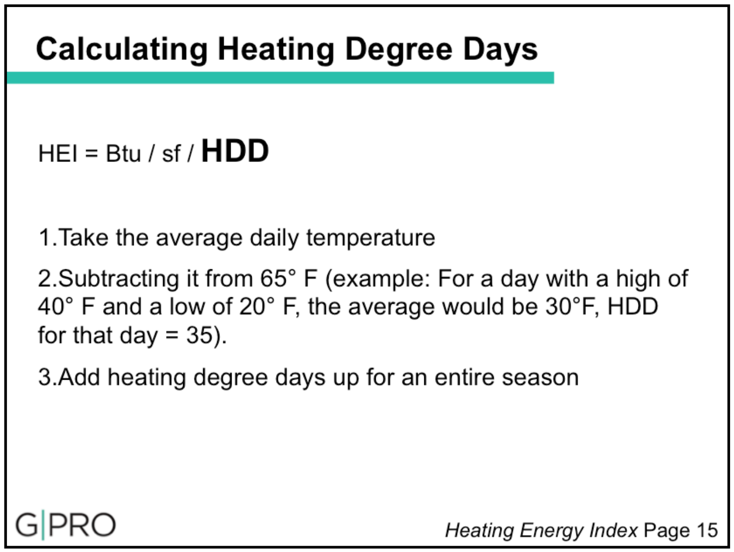
1. Measure the floor space of the entire building in square feet
2. Include the basement spaces if they are conditioned

G|PRO *What About the Weather?* Page 15

Sf

1. Measure the floor space of the entire building.
2. Include the basement spaces if they are conditioned

While the easiest way to do this is to measure the roof and multiply by the number of floors, a more complex building may require analysis of the blueprints



1. Take the average daily temperature
2. Subtracting it from 65° F (example: For a day with a high of 40° F and a low of 20° F, the average would be 30°F, HDD for that day = 35).
3. Add heating degree days up for an entire season

You don't have to do this. You can look current values up in the daily papers or online (Google "heating degree days").

GROUP EXERCISE:

See Classroom Exercise #1 on page 89 of your manual:

Calculate the heating energy index (HEI) for the sample building.

CLASSROOM EXERCISE #1:
BUILDING PERFORMANCE METRICS -
HEATING ENERGY INTENSITY (HEI)
PAGE 2/3: CALCULATION SHEET

Use the 1-year gas history to calculate the energy used by the sample building.

ENERGY (Btu)
Average of three months
with lowest fuel use (monthly baseload) ______ therms
Multiply by 12 to get annual baseload ______ therms
Total quantity of fuel used ______ therms
Total quantity of fuel used minus annual baseload = Total quantity of fuel used for heating only ______ therms
Multiply by conversion factor ______ Btu/therm
Btu = Total quantity of fuel used for heating only Multiply by conversion factor (see Information Sheet) ______ Btu

Use the building area calculated on the previous page.

AREA (Sq Ft)
Floor area ______ Sq Ft
# stories ______ stories
Area = Floor Area x # Stories ______

Use the Heating Degree Days for New York City included on the Information Sheet.

HEATING DEGREE DAYS (HDD)
Total heating degree days for time period ______ Heating Degree Days

HEATING ENERGY INTENSITY (HEI)
Energy (Btu) ______ Btu
Area (Sq Ft) ______ Sq Ft
Heating Degree Days (HDD) ______ HDD
HEI = Energy / Area / Heating Degree Days ______ Btu / Sq Ft / HDD

HEI RANGE

0-10
Extremely Efficient: low air infiltration, well-insulated, high heating efficiency, ERV (energy recovery ventilator, small window area, efficient windows.

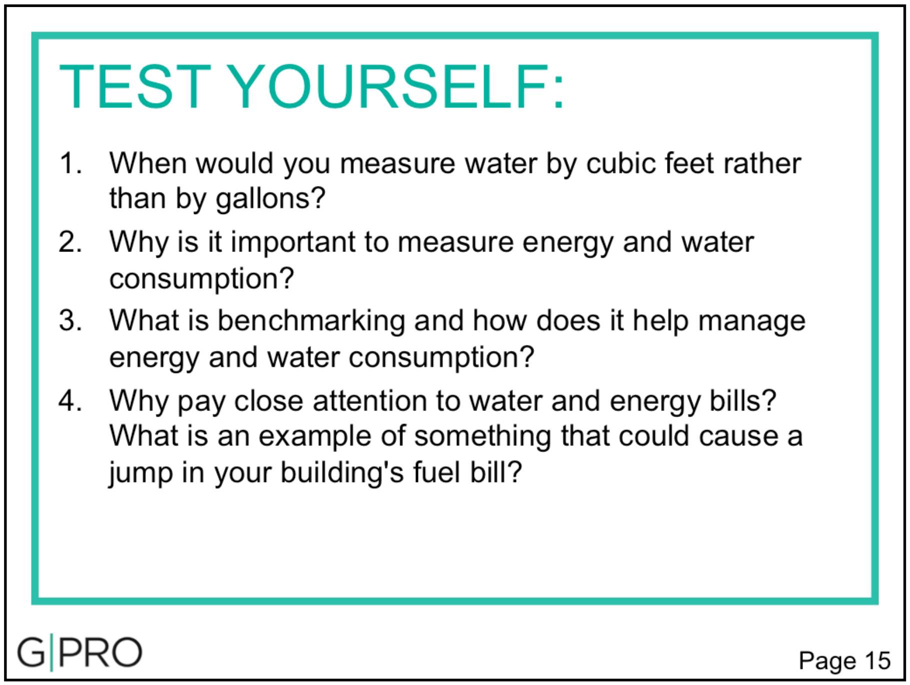
11-24
Moderately Efficient.

25+
Very Inefficient: Poor insulation, high volume of air leakage, inefficient heating systems.

GPRO: OPERATIONS AND MAINTENANCE ESSENTIALS HANDOUTS URBAN GREEN

G|PRO

Page 82



[OPTIONAL]

1. The term cubic feet (cf) or hundred cubic feet (ccf or HCF) is used when measuring larger amounts of water.

2. Keeping track of water and energy consumption is an important component in achieving sustainability in your building operations, as it allows you to identify areas for improvement and benchmark progress.

3. Benchmarking helps manage energy and water consumption by using metrics to track, monitor, and assess energy and water use, the process of benchmarking identifies potential savings and prioritizes necessary improvements.

4. Paying careful attention to water and energy bills and learning how to make sense of the data helps you to identify problems that need immediate attention and improvements. An example of something that could cause a jump in your building's fuel bill is equipment or control failure, since a pump can be running full time when it is only needed a few hours per day.

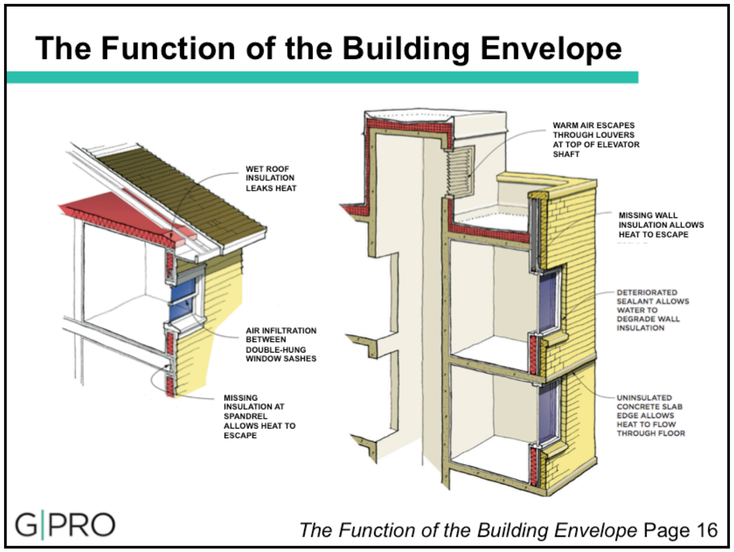
The *building envelope* is a term used to describe the outside shell, or skin, of the building.

The primary components are walls, roofs, doors, and windows. A properly functioning envelope is essential to thermal comfort and the efficient operation of building systems. If the envelope does not limit heat flow, control air infiltration, and manage moisture sufficiently, the building can have serious problems that can affect the health of building occupants, require other building systems to work harder, increase energy consumption, and even reduce the life of the building.

Building envelopes must perform under significant extremes between inside and outside conditions. Most of the layers of the envelope are not visible, and failure through faulty construction, freezing/thawing, leaks, and pests may not be readily apparent. Initially, the only symptom of a compromised envelope may be that more heat is required in a portion of the building or that a damp spot appears periodically.

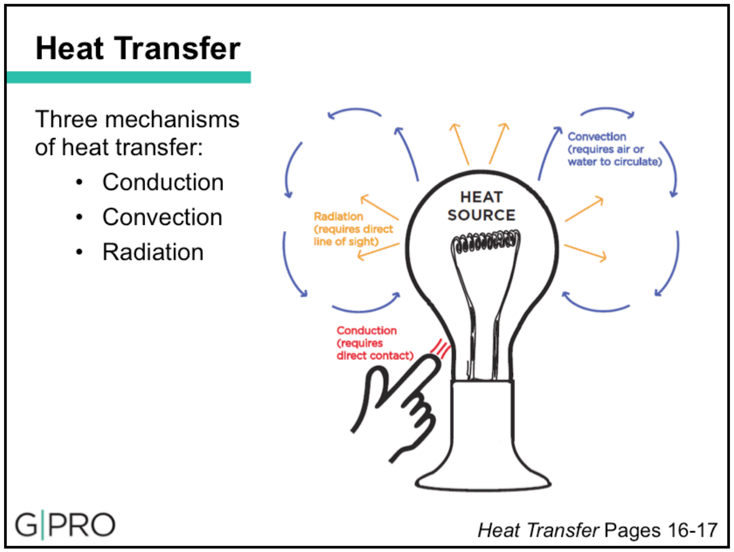
A whole-building approach to building operations, which includes the monitoring of performance across all systems, can help ensure envelope performance and properly balanced building systems.

This chapter covers core building dynamics and operational issues that the building operator must understand to manage system performance. These are **heat transfer, air integrity, and moisture control.**



[Review diagram and talk about the importance of a well insulated and air-sealed building envelope.

Also note that when we show small buildings, we don't necessarily refer to single family homes, it is just easier to show walls, floors, windows, and roofs as one system]

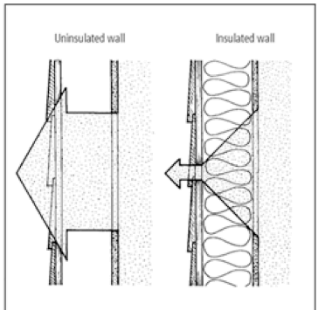


Heat transfer occurs by three different mechanisms:

- **Conduction:** Heat is transferred through direct material contact. Building insulation increases the thermal resistance of the envelope and reduces *conductive* losses. Example: feel a cold window sash in the winter.
- **Convection:** Heat is transferred through the movement of air (or water). Tight building construction, weather seals, and vapor barriers work to reduce air infiltration and *convective* heat losses. Example: In an uninsulated closed cavity; changes in temperature create a convective loop which creates air currents that move around dirt and contaminants. *Convectors* heat air which then rises into the room.
- **Radiation**: Heat is transferred through direct line-of-sight electromagnetic waves (light or infra-red). Glass and roof coatings or shade on the building can influence the reflection and/or absorption of solar heat *radiation*. Example: If you are near a steam or hot water *radiator* you can feel the heat radiating off it onto your skin.

Managing Conductive Heat Transfer

- Air is a poor conductor of heat, especially if it can't move. This makes it a good insulator.
- Insulation is effective because it contains tiny pockets of air, which slow heat flow.
- Minimizing heat flow reduces the energy demands on equipment, operating costs, and environmental impact.



Insulation works by trapping small pockets of air.

G|PRO

Heat Transfer Pages 17-18

[Ask students to define conduction…heat transfer through direct physical contact.]

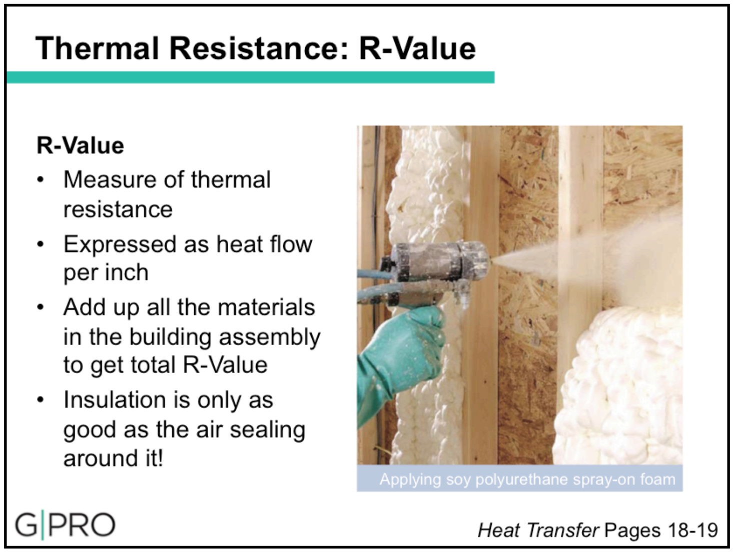
Warm air flows naturally from a warmer to a cooler space, and all materials offer some resistance to heat flow.

Insulation is material specifically designed to slow the flow of heat as much as possible. In winter, the heat moves directly from interior heated spaces to the outdoors — wherever there is a difference in temperature.

During the summer, as the sun beats down on the roof and exposed walls, heat moves from outdoors into the building interior.

Insulation works by slowing the flow of heat through a material through tiny pockets of air.

The better the building envelope controls and minimizes the flow of heat, the lower the energy demands, operating costs, and environmental impacts will be.



Thermal resistance refers to the ability of a material to resist the transfer of heat.

R-value is a measure of thermal resistance and is typically used to describe the insulation value of building materials.

Everything that makes up a building's envelope can technically help in resisting the transfer of heat, and therefore has an "R-value." The greater the R-value, the greater the resistance a material has to heat transfer.

R-values are expressed as heat flow per inch, so 6" thick material with an R-value of 2 will have a total R-value of 12. Heat flows first through one component, and then through another, such as first through gypsum wall board, then insulation, then sheathing and siding, we can add the R-values from each building component together for a total R-value of the building assembly.

But if the insulating material is not continuous, heat can flow around the material and substantially reduce the R-value.

Insulation is only as good as the air sealing around it.

Sometimes heat flows through two parallel paths, such as through insulation batts and simultaneously through the joists between the batts. This is called thermal bridging or a thermal short circuit.

Heat travels the path of least resistance. For instance, in a stud wall, heat will be lost through the less insulative wood or steel studs even if the cavity is well insulated. Many design and construction teams use continuous insulation at the interior or exterior of the building to reduce this thermal short circuiting.

Which Insulation is Right for You?

- Batts
- Boards / Rigid
- Blown-in
- Spray-on foam
- Pipe

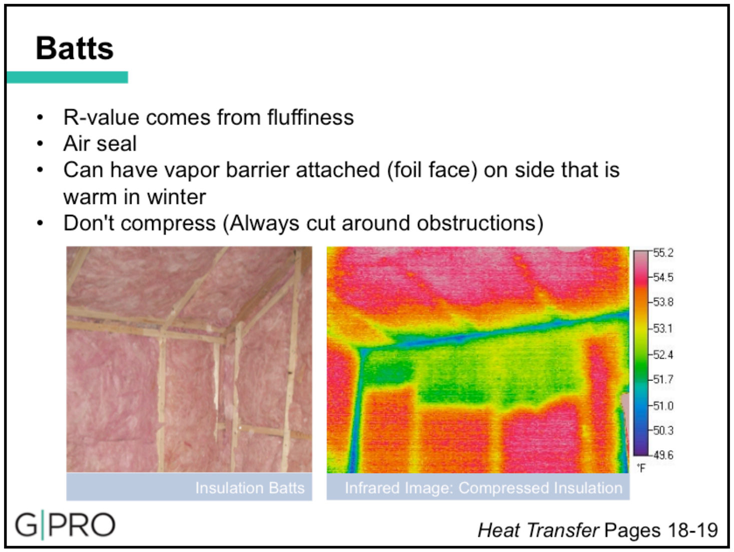
G|PRO

Heat Transfer Pages 18-20

Different types of insulation are right for different applications. There are cost and installation issues to be aware of. Some different insulation types are:

- Batts
- Boards
- Blown-in
- Spray-on foam
- Pipe

Let's take a look at all of these in detail.



Fluffy blankets traditionally made from mineral fibers, including fiberglass or rock wool, are available in widths suited to the standard spacings of wall studs and attic or floor joists.

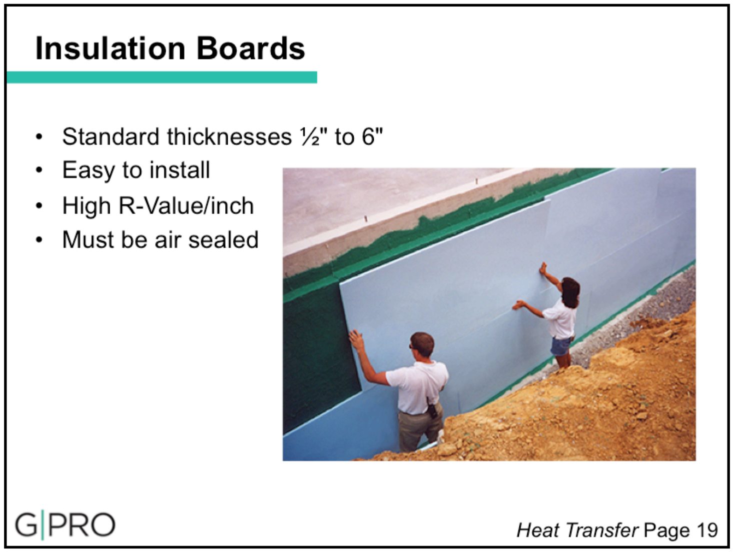
New products made of cotton or recycled blue jeans are also now available as a greener alternative – they are more sustainably produced and easier and safer to install.

All of these products must be hand-cut and trimmed to fit wherever the spacing is nonstandard (such as near windows, doors, or corners), or where there are obstructions in the walls (such as wires, electrical outlet boxes, or pipes).

If there are gaps around the edges of the batts, it significantly reduces the R-value of the material.

As is the case with any insulating material, joists, studs, and intrusions into the insulating cavity can reduce the wall's R-value significantly. To achieve the highest thermal resistance from a particular insulation, appropriate air and vapor barriers must also be installed.

[RIGHT IMAGE: This is a picture of batt insulation that has compressed in the cavity – the green is where there is no longer any insulation and the blue line is an opening in the eave beyond.]



Made from fibrous materials or plastic foams and produced in board-like forms and molded pipe coverings. These products come is standard thicknesses of ½" up to 6" and are easy to install.

If properly air sealed, rigid insulating panels provide a high R-value where space is limited.

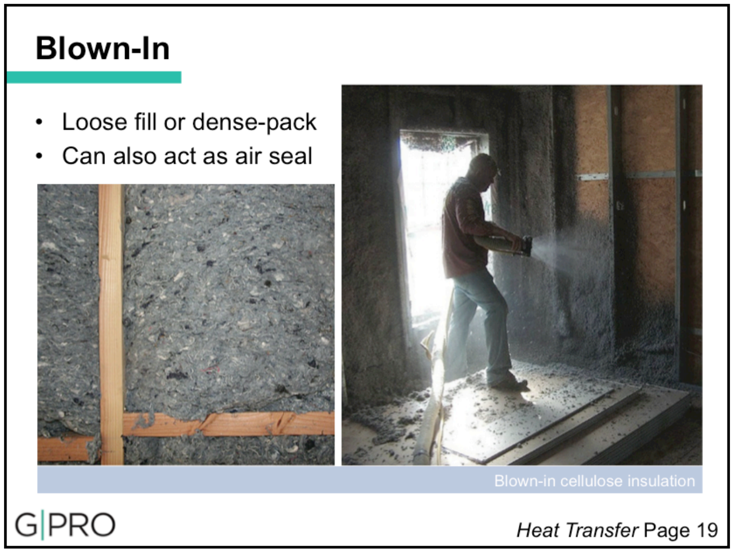
Rigid insulation can be waterproof and is often used at foundation walls, below roof membranes, and as an insulating wall sheathing.

If installed on the outside of a building, just under the siding, rigid insulation can provide a continuous thermal barrier, overcoming the "short circuits" that joists give rise to, and providing a superior thermal envelope.

Many rigid insulation boards are also water resistant

Different types of insulation boards:

- Polystyrene (Styrofoam):
- Polyisocyanurate (polyiso) can be tapered for roof insulation
- Polyurethane



Cellulose, fiberglass, rock wool, or even blue jeans in the form of loose fibers or fiber pellets are blown in using pneumatic equipment.

This insulation is usually performed by professional installers and can be used in wall cavities and attic floors, because it fills in irregularly shaped areas and fits around obstructions.

Blown-in insulating material must achieve its specified density to provide its rated R-value. If installed properly, blown-in insulating material will also provide an air-sealing barrier.

Example: Dense pack cellulose (which is ground-up, treated newspaper) should be installed at a density of 3.5 pounds per cubic foot. If you are verifying an installer's work, make sure they use the right volume of materials to fill the cavity, at the right density.

Spray Foam

- Soy based
- Acts as an air seal
- Needs to be professionally installed
- High R-Value/inch


Applying spray-on foam

G|PRO

Heat Transfer Page 19

Innovative soy-based, spray-on foam insulation products have excellent thermal and sound-insulating properties.

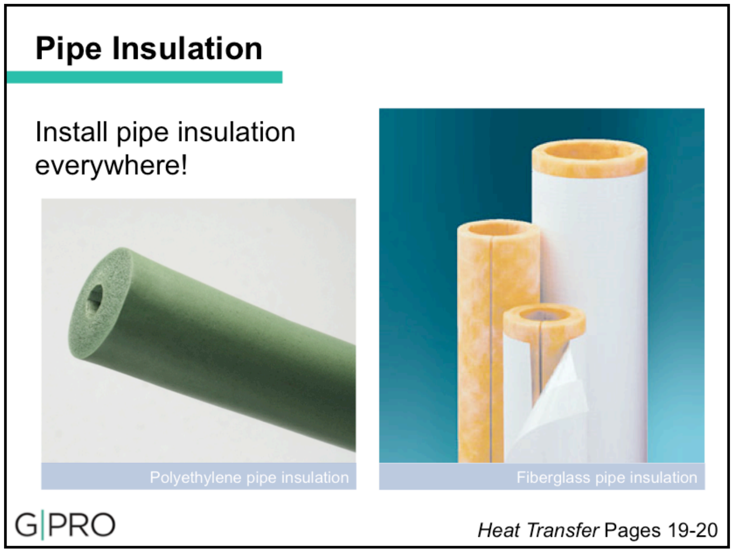
They use a two-part polyurethane that expands up to 100 times its original size upon application. IF USING SPRAY FOAM ON OR AROUND A DOOR OR WINDOW, USE THE NON-EXPANDING KIND!

This green insulation uses renewable resources in place of some of the petroleum-based ingredients found in other types of insulation products.

Used in both residential and commercial buildings, this material adheres directly to surfaces between wall studs, floor and ceiling joists, and on foundation walls inside crawl spaces.

Spray foam can be installed at the exterior of a building.

Professionals using specialized equipment are needed to install it.



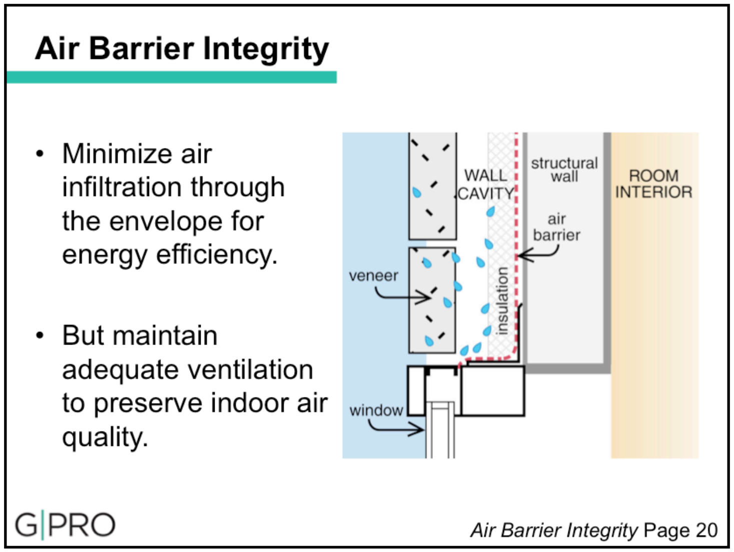
Pipe insulation for both hot and cold pipes will provide a very quick return on your investment.

[Ask students to tell you why….Hot will reduce heat loss, Cold will prevent condensation.]

Not only exterior pipes need to be insulated. Even if a steam or hot water heating pipe is inside a building, it will pay to insulate it, since the heat lost to the interior of the building cannot be controlled by valves at the radiators, resulting in overheating and opened windows.

Many different configurations of pipe insulation are available to be slid over or wrapped around the pipe; they are made of polyethylene foam, or for higher temperatures, pre-formed fiberglass half-rounds.

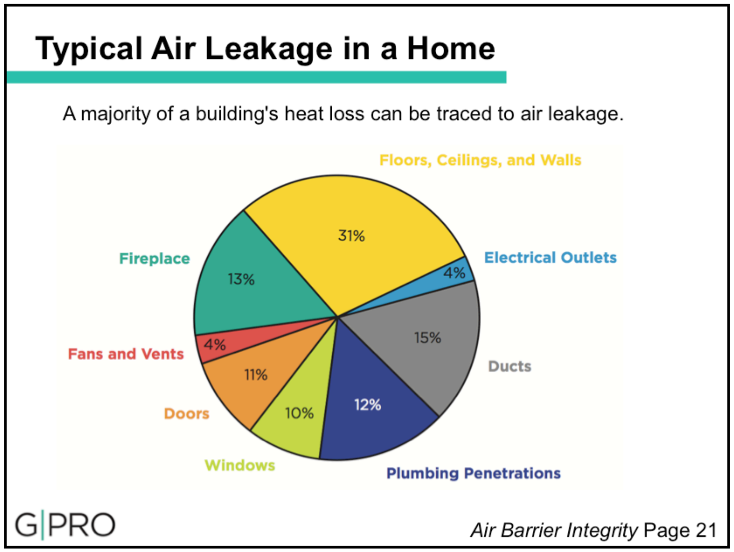
When insulating pipe, make sure you also insulate the joints, elbows, and connections and have the right materials for the temperature of the pipe. Make sure the insulation fits snugly around the pipe.



Air barrier integrity is the degree to which air entering and leaving a building is controlled and a proper balance is maintained.

Managing the flow of air through a building requires balancing two contradictory concerns of energy efficiency and good indoor air quality. On the one hand, every bit of conditioned air that escapes a building is replaced by outside air, which increases the heating and cooling loads. On the other hand, fresh air is absolutely necessary for good health and a pleasant indoor environment.

Conventional buildings have long relied on a building's intrinsic leakiness to provide fresh air. We now understand that this is unsatisfactory from the perspective of both ventilation and energy. Today, the most efficient practice for healthy indoor quality is to minimize air infiltration from the envelope and rely on operable windows and controlled mechanical ventilation systems.



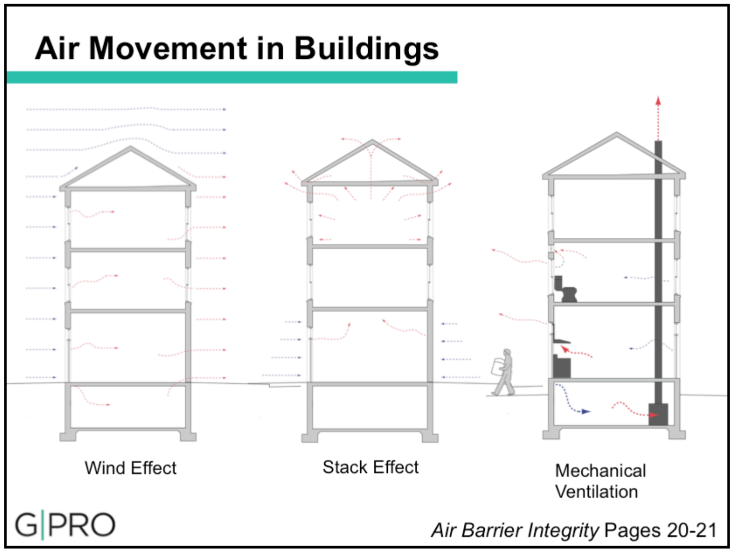
In a small building such as a single family home, a majority of the building's heat loss can be traced to air leakage.

As shown in this figure, there can be significant leaks from ducts, plumbing penetrations, and fireplace flues in addition to the more predictable openings around doors and windows, as well as through floors, ceilings and walls. In these buildings, cumulative air leaks can account for up to 30% of heating and cooling costs.

In buildings with large floor plates, losses from the envelope are less severe.

However, air leaks can be responsible for significant health and safety concerns when pollutants such as carbon monoxide (CO) infiltrate occupied spaces from a boiler room or attached garage.

In modern buildings, the entire shell is wrapped in a vapor-permeable film that prevents air flow, called an "air barrier." This prevents air infiltration, but allows water vapor to escape over time. The air barrier should be tightly caulked at the perimeter of all window and door openings.



Buildings are affected by many kinds of air movement.

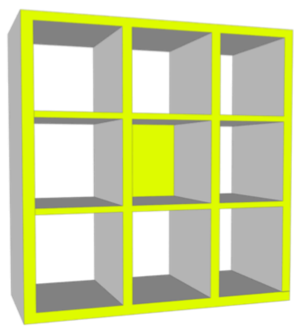
Wind Effect: Wind causes both positive pressure on the windward side of a building, pushing air in, and negative pressure on the leeward side, pulling it out. This makes it difficult to calculate ventilation rates using natural ventilation.

Stack Effect: The stack effect occurs when the hot air within a building rises to the top and escapes through openings at the roof, pulling in new, cooler air from openings at the bottom. This cycle also happens in reverse when it is warmer outside, pulling warm moist air in from the top of the structure, although it is normally much less pronounced. This is why, in some tall buildings, occupants are hot on the top floors, but cold closer to the ground. Sealing openings at the roof, basement and ground floor can significantly reduce the stack effect.

Mechanical Effect: Mechanical devices such as exhaust fans, dryers, and combustion appliances move air into and out of buildings. Engineers account for the inflows and exhausts when they calculate the proper amount of ventilation that is required for the building. If new air intakes or exhausts have been added to the building, it may affect the IAQ. An engineer may need to be called in to recalculate the ventilation rates or it may be able to be corrected during retro-commissioning.

Compartmentalization

Isolate spaces to prevent tobacco, cooking odors or air contaminants (from labs and parking garages) from entering occupied spaces.



G|PRO

Air Barrier Integrity Page 21

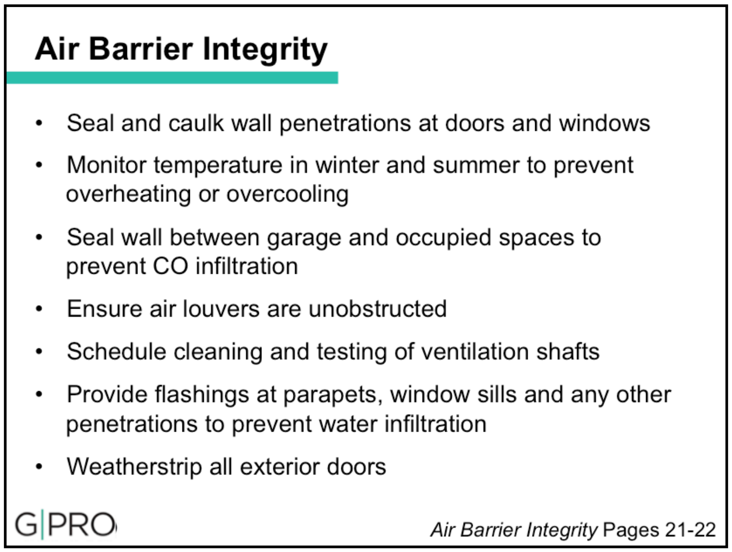
One air quality issue you may be familiar with is the transfer of smells from one apartment to another.

In residential buildings, if someone cooking opens a window on the windward side of the building, it can increase the air pressure beyond the kitchen exhaust fan's capacity and push odors into the corridor and throughout the building.

Newer buildings pressurize the corridors to reduce this transfer of odors. This also reduces the possibility of smoke traveling from apartment to apartment during a fire.

In commercial buildings and schools, parking garages and science labs may need to be compartmentalized and kept at positive pressure (meaning that air can't flow out from the lab to the classroom next door) and directly exhausted to the exterior.

A blower door test could be used to confirm how well a compartmentalized space is sealed.



Some of the important actions that the building manager or engineer can take to control air integrity are:

- Ensure careful sealing at the wall penetration and at the entire perimeter of the window opening during any window replacement or other façade repair and caulk around windows and doors
- Request that tenants notify the building manager if the temperature is too hot in the winter, rather than opening windows, in an attempt to prevent overheating of apartments.
- If the building has underground parking facilities, make sure there is adequate air sealing to eliminate possible carbon monoxide exhaust infiltration into the living spaces.
- Ensure all exterior louvers are unobstructed
- Schedule regular cleaning and testing of the building's ventilation shafts.
- Provide and repair flashings at roof parapets, roof penetrations, window sills, and anywhere else where water can enter.
- Weatherstrip all exterior doors, especially at the roof.

How Water Enters Buildings

- Bulk Water (leaks)
- Condensation
- Vapor

Leak at Exterior Wall

G|PRO *Condensation Control* Page 22

Just like heat flows from hot to cold, water will always go from wet to dry.

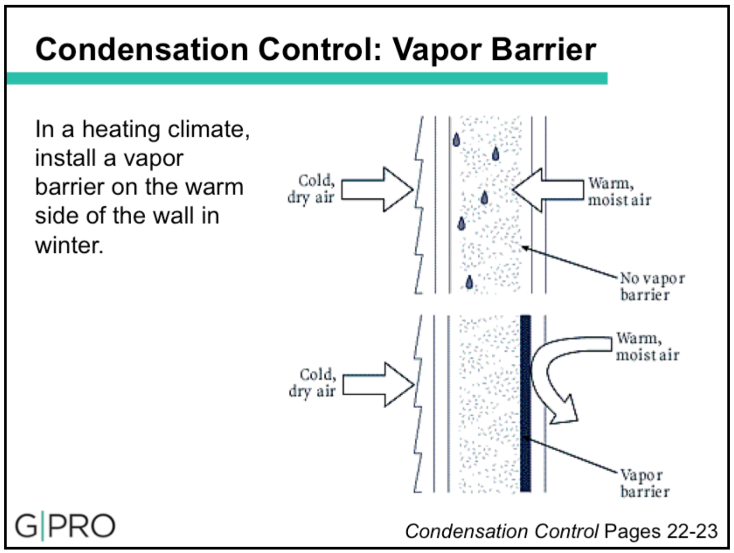
Moisture will enter a building wherever it is given the chance.

Bulk Water: The easiest moisture infiltration to see and control are leaks. Water can enter through foundation walls, cracks or holes in walls, deteriorated caulk, or masonry joints. These leaks must be traced and corrected immediately. Water will cause quick deterioration of building materials. Make sure all damp areas are completely dry before closing up walls.

Condensation: *[Ask class to remember what condensation is… when humid air comes into contact with a cold surface, moisture collects on that surface]* Condensation occurs in walls and on windows when relatively warm, humid air meets a cold surface. In many, climates, condensation occurs in both winter and summer, as either heating systems in the winter or air conditioning in the summer can create a relative difference with outdoor temperature and humidity conditions.

Uninsulated cold water pipes or ducts can drip water onto floors or into wall cavities. Moisture can also collect on uninsulated window frames and drip into the wall cavity below. Prevention of condensation is your best strategy. Make sure all pipes and ducts are properly insulated. If windows "sweat" make sure all seams at perimeter are sealed until the window can be replaced with a more efficient model.

Vapor: Vapor enters buildings when humid air infiltrates the envelope from the outside. It can also originate inside the building from steam showers or broken radiator steam vent air valves. Excess water vapor can cause mold [*see Chapter 7 for more information]* The best remedy for ongoing problems with excess water vapor is to improve the ventilation in those areas.



If correctly installed, a vapor barrier prevents moisture from entering the wall cavity and reaching the, reducing the amount of condensation that can occur there.

The vapor barrier needs to protect the insulation from condensation because wet insulation is rendered useless.

In mixed heating and cooling climates, the moisture and heat flows are reversed from winter to summer, making control more difficult.

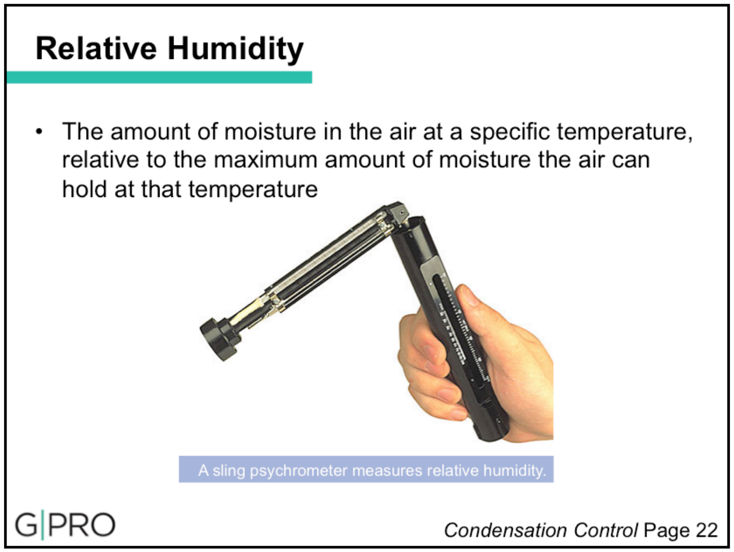
Improperly installed vapor barriers can actually trap moisture that has entered the wall cavity and contribute to mold growth and deterioration of insulation and a building's wall structure.

The most important step is to ensure that there is only one vapor barrier in a wall, and it should face the side that is warm in winter, so that moisture on either side of it can dry out.

In all heating-dominated climates, the vapor barrier should be on the interior of the wall, inside the insulation and beneath all paint and plaster. In cooling-dominated climates, the vapor barrier should be outside the insulation.

Sometimes a sheet of polyethylene will be used as vapor barrier. At other times the gypsum wall board or foil faced insulation will provide this function.

For new wall sections, you may need to consult a building engineer or architect.



At any given temperature, there is a *maximum absolute humidity*, a maximum amount of water vapor that can remain in the air at that temperature

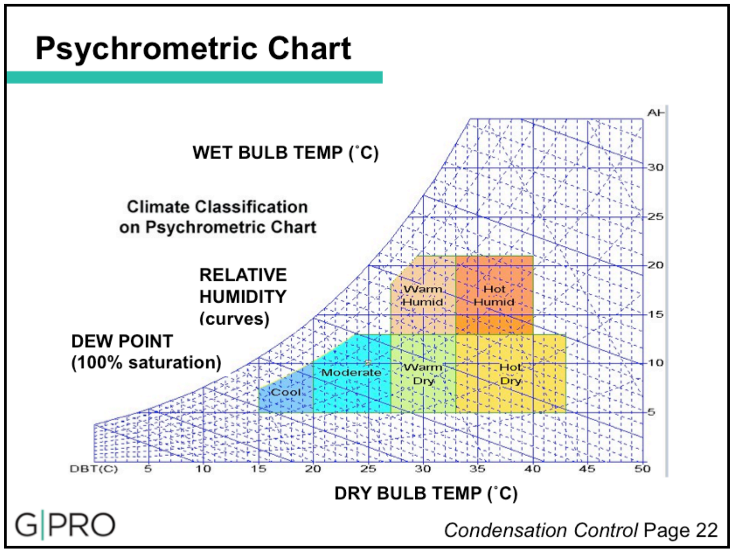
The warmer the air, the more moisture can remain vaporized (i.e. "hot humid days of summer").

Relative humidity is the amount of moisture suspended in the air at a specific temperature relative to the maximum amount of moisture that can remain vaporized at that temperature.

Since more water can remain vaporized at warm temperatures than at cold ones, an air sample with a given moisture content has lower relative humidity at warmer temperatures.

This is why a leaky building has such dry air in the winter: Cold air enters the building; as it warms up, the relative humidity becomes lower, since the amount of water vapor that could remain vaporized is increasing, while the amount of water vapor actually present is not changing.

Human comfort zone is around 50% RH with an acceptable range of 40% to 60%. As buildings have become more controlled, occupants have a smaller comfort zone and dryer or moister air is noticeably uncomfortable and may lead to complaints.



DRY BULB TEMPERATURE - vertical lines on the chart (**°C**).

WET BULB TEMPERATURE - lines that slant diagonally from the upper left of the chart (along the line of saturation) down to the lower right of the chart. (**°C**).

RELATIVE HUMIDITY - lines that curve from the lower left hand side up and to the right. The unit of measure used for relative humidity is **%**.

DEW POINT = 100% saturation

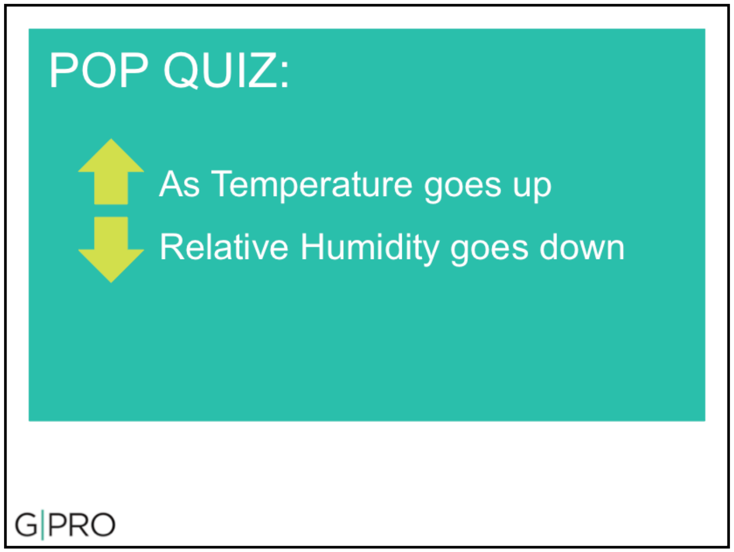
Also: ENTHALPY, **MOISTURE CONTENT / HUMIDITY RATIO**

POP QUIZ:

If the relative humidity in this room is 60%, and we raise the temperature, what happens to the relative humidity?

G|PRO

[Explain that the reverse is true and why.]



Addressing Envelope Problems

- Routine visual inspections
- Monitor renovation work
- Log tenant complaints
- Watch for increased heating or cooling demand
- Identify water leaks and repair

Efflorescence on a brick wall

G|PRO

Addressing Envelope Problems: Options for Building Managers Page 23

Conduct **routine visual inspections** of exterior walls, roofs, and foundation walls to identify damage that may lead to air or water infiltration.

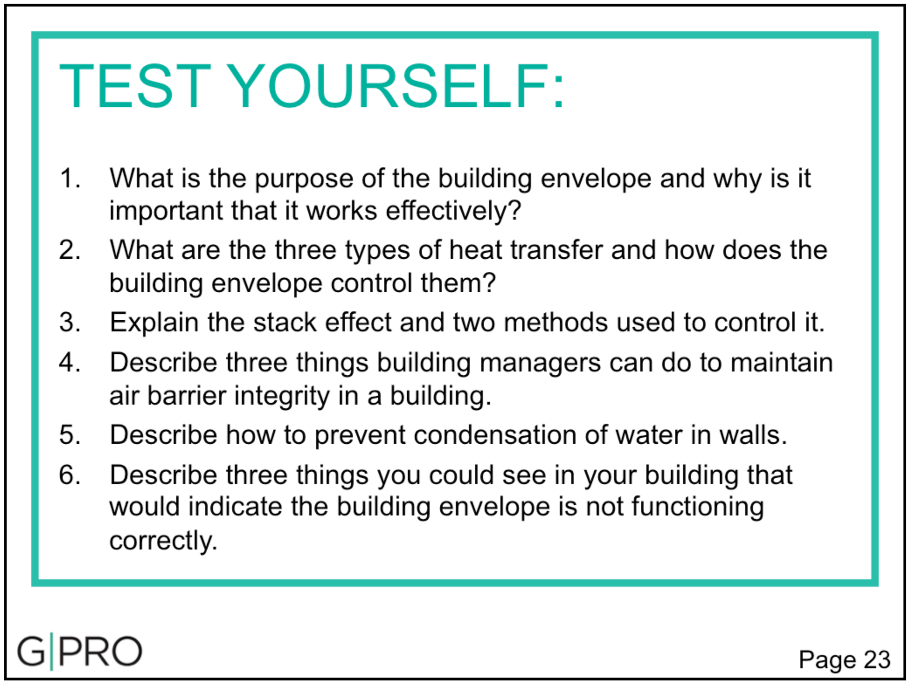
- Pest infiltration
- Spider webs (spiders love air currents and will help you find areas of infiltration)
- Efflorescence is when salts and minerals leach out of masonry and leave a white residue on the wall. This indicates that the wall cavity is not draining properly. Efflorescence is not dangerous for occupants, but it can reduce the life of the wall.

Closely monitor renovation and repair work that includes the envelope to ensure that individual components are not compromised in any way and that they are rebuilt to the original design specifications, unless a design professional has directed changes.

Keep a detailed log of complaints concerning thermal discomfort or periodic moisture to establish patterns that may identify a hidden problem.

Watch out for increased demand on heating or cooling systems that may point to problems in the envelope.

Identify water leaks and make repairs immediately to prevent damage or mold buildup.



[OPTIONAL]

1. A properly functioning envelope keeps moisture out and limits the amount of air than can infiltrate. It is essential to the thermal comfort and the efficient operation of building systems.

2. **Conduction:** Heat is transferred through direct material contact. (Building insulation) **Convection:** Heat is transferred through air (or water) movement. (Tight building construction) **Radiation:** Heat is transferred through direct line-of-sight electromagnetic waves. (Glass, and roof coatings).

3. The stack effect occurs when the warm air within a building rises to the top and escapes through openings at the roof, pulling in new, cooler air from openings at the bottom. (Sealing openings at roofs and basements, and compartmentalizing interior spaces)

4. Ensure careful sealing at wall penetrations. Request that tenants notify the building manager or engineer if the temperature is too hot in the winter, rather than opening windows. This could be a symptom of either an unbalanced heating system or stack effect. Make sure there is adequate air sealing to eliminate the possibility of CO infiltration, especially at spaces adjacent to parking facilities.

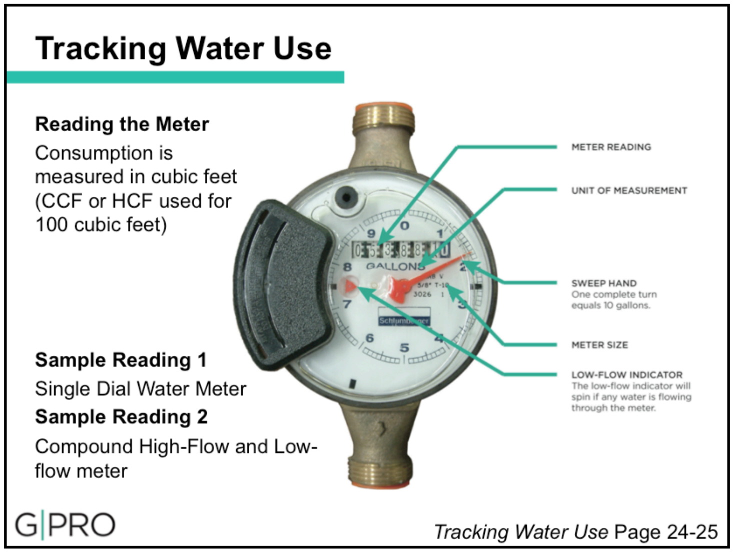
5. Condensation is best controlled through proper wall and pipe insulation, well-sealed insulated windows, and vapor barriers.

6. Increased demand on heating or cooling systems, water leaks or mold buildup, patterns of complaints concerning discomfort

4 WATER USE

G|PRO

Page 24



For the building manager or engineer who wants to find ways to improve water usage, the first step is to understand how to read the building's water meter.

There are a variety of different types of water meters you may encounter. Some of the differences are:

- On simple meters: One revolving dial equals 1 cf.
- Compound meters for larger buildings may have 2 dials: The high flow dial may show 10 cf or 100 cf with each revolution. These will have fixed or painted zeros at the right-hand end of the meter. The low flow dial will show 1 cf per revolution.
- The flow indicator rotates whenever water flows through the meter. If the triangle turns when you think all water is turned off, you may have a leak.
- For either type of meter, you get a reading in cf by using all of the numbers, including fixed or painted zeros.
- If you have access to utility bills, make sure utility charges are correct. The meter must be the right size and calibrated correctly.

SAMPLE READING 1:

A 6-unit apartment building has 12 people living in it. The building has a single-dial water meter. The water rate is $4.27 per HCF.

Meter Reading January 1: 001123 cf

Meter Reading March 31: 011623 cf

Amount of water used in 3 months:

$$\begin{array}{r} 011623 \\ \underline{-\ 001123} \\ 10{,}500\ \text{cf} \end{array} \qquad \frac{10{,}500\ \text{cf}}{100} = 105\ \text{HCF}$$

Cost of water used:

105 HCF @ $4.27/HCF = $448.35

G|PRO

Tracking Water Use Page 25

SAMPLE READING 1:

Cost per apartment per quarter:

$$\frac{\$448.35}{6 \text{ apts.}} = \$74.73/\text{apt.}$$

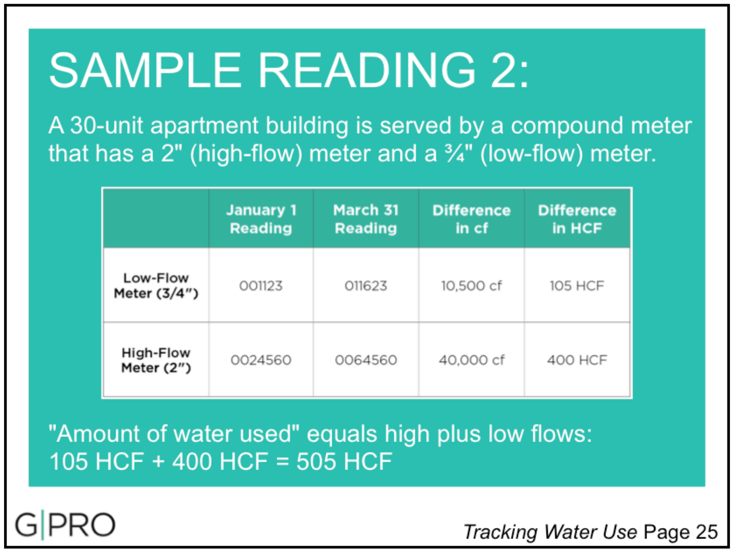
Cost per apartment per year (at this rate):
$74.73 x 4 = $298.92/apt./year

Water used (in gallons): (Remember: 1 HCF = 748 gallons)
105 HCF x 748 gal/HCF = 78,540 gal

Gallons per person per day:
78,540 gal / 90 / 12 people = 73 gal/person/day

G|PRO

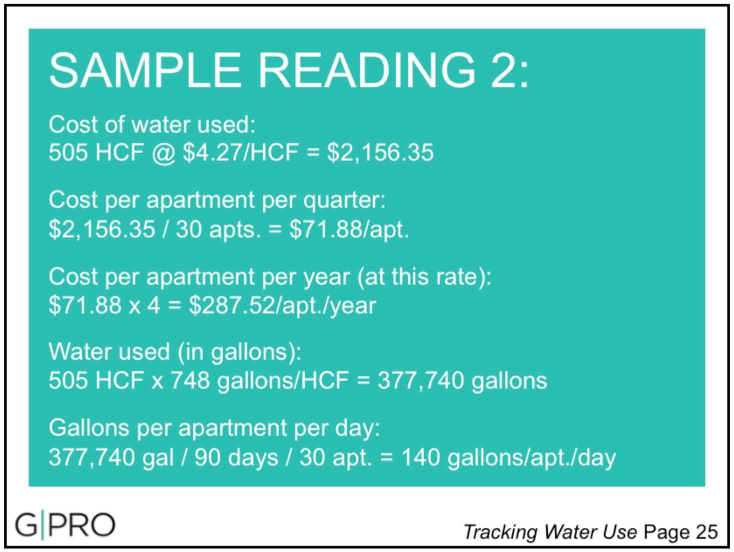
Tracking Water Use Page 25



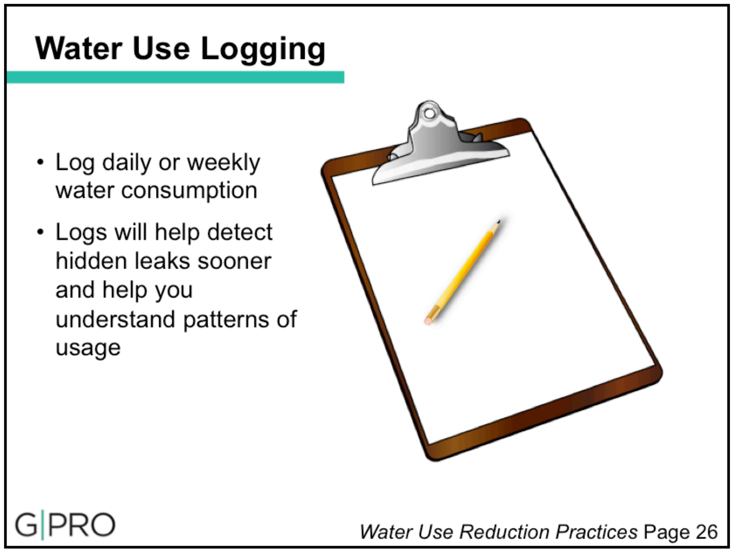
Many municipalities use compound water meters, or high- and low-flow meters. The low-flow meter measures lower or small flows, that is, 1 cubic foot per minute (cfm), while the high-flow meter measures the higher flows (e.g., 100 cfm).

In Figure 4.2, on page 25 in your manual, the 2" (high-flow) meter has 7 digits in its reading, while the ¾" (low-side) meter has 6. The 0 at the far right of the 2" meter's dial is a fixed 0. The 2" (high-side) meter registers a change every time 10 cf of water flows through, while the ¾" (low-side) meter registers a change every time 1 cf of water flows through.

You must use both sides of the meter when calculating water consumption.



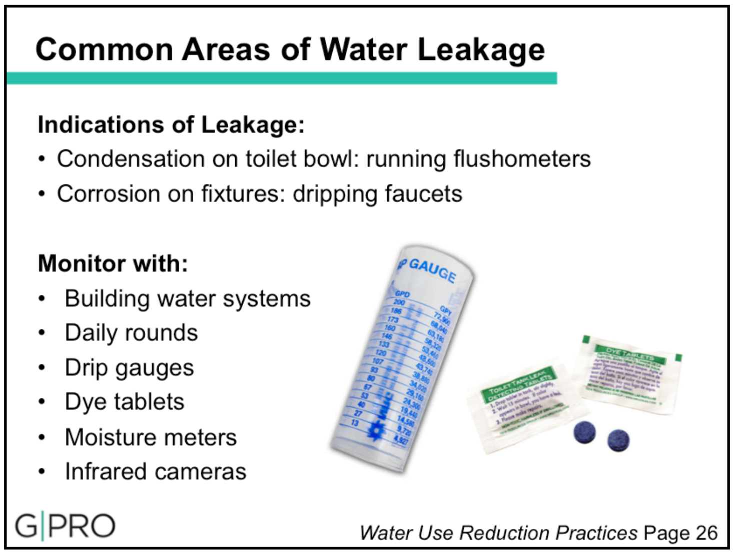
Some meters read like a car odometer. Some older meters have several dials with pointers. These are considered obsolete and should be replaced. Many newer meters permit electronic reading by the water utility, and in some cities, meters can be read remotely from a drive-by vehicle.



Keeping a water usage log combined with a monthly review of your water bill is a helpful troubleshooting strategy that will alert you to any spikes in water usage.

Over time, as you read the water meter and track usage, you can create a long-term monitoring log, or daily-use log, measuring water consumption in whatever units your meter measures. Any number of variables, including leaks, outdated or malfunctioning equipment and appliances, occupant usage, etc. can cause a spike in water consumption.

Keeping a log allows you to catch these changes so you can address them as soon as possible, saving water, money, and time.



Sometimes the most difficult part of repairing leaks is finding them. Some common areas of water leakage are:

- Condensation on the underside of toilet tanks or bowls; this may indicate that the tank float valve is malfunctioning and allowing water to flow constantly
- Corrosion on fixtures; indicating a leaky faucet valve

Performance should be checked daily and during each shift. In Mechanical Equipment Rooms (MERs), examine floor drains and note any unexplained water on the floor or dripping from valves and fittings.

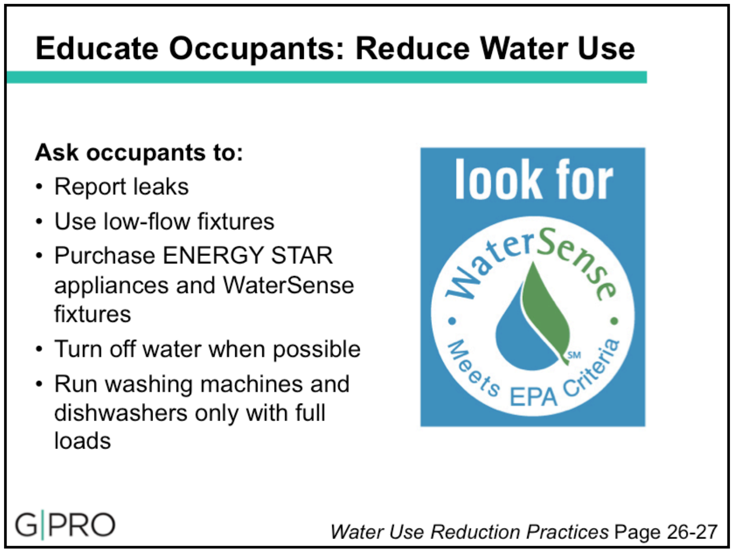
Leaks from faucets, toilets, and pipes can waste vast amounts of water over time (e.g., a leaky toilet might waste 52,800 gallons of water/year).

Use a *drip gauge,* an inexpensive device placed under a leaky faucet, to measure how many gallons of water are wasted per day and per year in a shower, sink, or toilet. This will help you estimate the expected savings after leaks are repaired.

Dye tablets are used to detect silent leaks in a toilet. When a tablet is dropped into the toilet tank, it colors the water. If color shows up in the bowl, you know there is a leak.

A moisture meter can help identify areas of leaks behind walls; a section of wall may appear dry, but a moisture meter can indicate the pressure of water at the interior of the wall. A moisture meter is especially useful to confirm the area is dry after repairs are completed.

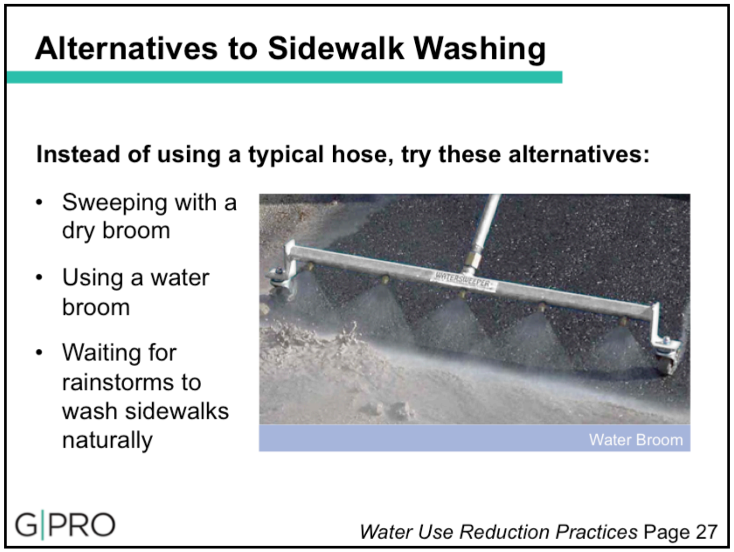
An infrared camera or service can identify leaks below floor slabs or in walls. The wet areas will appear "colder" than surrounding areas.



Educating occupants and residents about ways to reduce water consumption and **responding promptly to problems** will encourage cooperation while saving water.

Some of the actions building occupants can take include:

- Reporting leaks and corrosion
- Using low-flow fixtures (a low-flow shower head may save 750 gallons or more per month)
- Purchasing newer ENERGY STAR and Water Sense appliances that use less water — such as toilets that use 1.28 gallons of water per flush or have dual-flush capability; washing machines that can save up to $175/year; hot water heaters; dishwashers, etc.
- Turning off water when brushing teeth or while scrubbing pots in the sink
- Washing clothes and dishes only when there is a full load



Find alternatives to washing sidewalks with potable water. This can include simple steps, such as:

- Sweeping with a dry broom
- Using a water broom rather than a hose
- Letting rainstorms naturally wash the sidewalks

Detecting Hidden Leaks in Mechanical Systems

Make sure to check mechanical system components for leaks:

- Excessive use of make-up water in **boilers**?
- Malfunctions in **cooling towers**?
- Wasted water in **condensate tanks**?
- Lost water in **closed loop water systems**?

G|PRO *Detecting Hidden Leaks in Mechanical Systems* Page 27

Boilers: When the water level in a boiler dips below a set amount, the controller adds make-up water to allow for continued operation.

If you have a leak in the make-up water system, you will see higher-than-expected water use. To check this, attach a water meter to the low water cutoff and automatic feeder combination, and track usage through your logging process.

Another way to determine a leak here is by turning off the water feed valve, then marking the gauge glass with a grease pencil and checking the level over several hours. If the water level has dropped a large amount, there is most likely a leak.

Cooling Towers: An inexpensive water meter to monitor water use will reveal malfunctions and waste that can otherwise go undetected for years. Check that floats/level sensors are set correctly. If the level is set too high, the water might be going down the overflow pipe on a regular basis. Also check the blowdown is working correctly. It may also make the cooling tower eligible for sewer bill credits in some areas.

Condensate Tanks: Overcooling of condensate before it enters the drain will waste excessive amounts of water. Also, failed steam traps will not just waste steam, but require more water for cooling down to the right temperature.

Closed Loop Water Systems (Chilled, Secondary, etc.): Systems should not lose water. You can use a sight glass test stated above. Also check floor drains at system reliefs/system drain down piping.

Read water treatment reports! Usually they will indicate excessive water loss or increased use of chemicals.

Fixtures and Appliances

- Look for WaterSense and ENERGY STAR labels on fixtures and machines
- Install low-consumption (LC) or high efficiency toilets (HET)
- Install low-flow showerheads
- Choose front-load washers, which are more efficient

G|PRO *Fixtures and Appliances* Page 28

The primary standard for water efficiency is the WaterSense program, which is a partnership program sponsored by the EPA to help people conserve water by choosing products and practices that result in more efficient use of one of our most precious resources.

Fixtures:

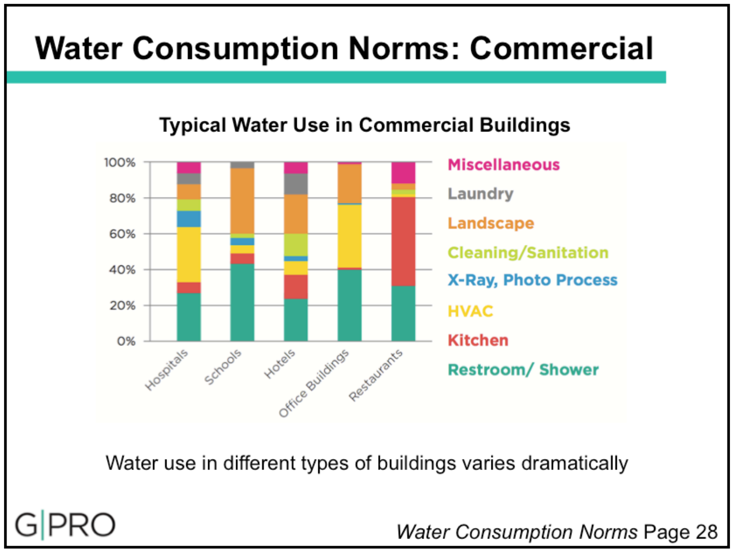
Based on the current code requirements, low-consumption toilets must meet the maximum 1.6 gallons per flush (gpf) standard, but high efficiency toilets (HET) are available at 1.28 gpf; which comply with WaterSense standards and use 20% less water than code compliant toilets. A third party tests toilets to rate the ones that flush well; look for a "MaP score" of 1000. You can find the ratings at http://www.map-testing.com/.

Replace conventional showerheads with low-flow models, which will pay for themselves almost immediately in reduced energy and water costs.

Appliances:

When looking for appliances such as washing machines and dishwashers (which use both water and electricity), choose products that meet the ENERGY STAR standard for both energy and water efficiency.

For residential building laundry rooms, choose Energy Star front loading machines, which are rated at a maximum of 28 gal/load (note that the building pays for the electricity, water and hot water, but the laundry company gets the revenue – so, the building should require high efficiency equipment).



As you can see, there are some differences in water usage for different commercial buildings.

Commercial water consumption norms depend largely on the type of building.

In most cases though, one of the largest areas of water consumption is bathrooms.

Reducing Water Use for Irrigation

- Replace conventional plantings with native, climate-adapted plants
- Manage irrigation schedules
- Use a drip irrigation system instead of a hose
- Invest in a sensor and timer that will activate the irrigation system only when needed
- Maintain your irrigation system to prevent leaks
- Irrigate with greywater or harvested rainwater instead of potable water

G|PRO *Reducing Water Use for Irrigation* Page 29

The American Water Works Association Research Foundation (AWWARF) reports that in dry places, such as Phoenix and Scottsdale, outdoor water use accounts for 59%–67% of total residential water use, while in wetter places, such as Seattle and Tampa, outdoor use accounts for 22%–38%.

No matter where your building is located, there are many steps that can be taken to reduce the use of potable water for outdoor irrigation:

- Replace conventional plantings with native climate-adapted or drought resistant plants, which require little or no irrigation
- Manage your irrigation schedule to water plants in the morning when it is cooler and before the heat of the day can evaporate the moisture
- Use a drip irrigation system instead of a hose
- Invest in a sensor and timer that will confirm moisture levels of the soil and activate the irrigation system only when needed
- Maintain your irrigation system to prevent leaks
- Use greywater or harvested rainwater instead of potable water for outdoor irrigation

BRAINSTORM:

What are ways you are already reducing your water consumption?

What are ways to get management to spend money on water efficiency upgrades?

G|PRO

TEST YOURSELF:

1. How is using a single-dial water meter different from using a compound water meter?
2. What are two ways to check for water leaks in boilers?
3. Name two or three causes of water use spikes.
4. Describe three or four ways tenants can reduce water consumption.

Page 29

[OPTIONAL]

1. On a single dial water meter, the consumption is read on one gauge. On a compound meter, both need to be added together.

2. If you have a leak in the mechanical water system, you will see higher-than-expected water use. To check this, attach a water meter to the low water cutoff and automatic feeder combination, and track usage through your logging process. Another way to determine a leak here is by turning off the water feed valve, then marking the gauge glass with a grease pencil and checking the level 12 hours later. If the water level has dropped by a large amount, there is most likely a leak.

3. Leaks, outdated or malfunctioning equipment or appliances, occupant usage.

4. Reporting leaks and signs of corrosion, using low-flow fixtures, purchasing newer ENERGY STAR and WaterSense appliances that use less water, turning off water when brushing teeth, scrubbing pots in the sink, and washing clothes and dishes only when there is a full load.

LET'S TAKE A BREAK!

G|PRO

Green Professional Building Skills Training