Introduction to Energy and Building Science Fundamentals

Course No. ENRG 52

Outline

A. Introduction to fundamentals of lighting

- Lighting terminology
- Physics and principles of lighting
- Units of measurement
- Vision and colors
- Ambient, directional and task lighting
- Over- and under-illuminance

B. Lighting systems

- Components
- Types of lamps
- Ballasts
- Lamp comparison matrix
- Types of lighting luminaires and intensities
- Energy efficiency measures (EEMs)

C. Lighting controls

- Basic concepts of effectiveness of lighting control
- Types and appropriate applications of lighting controls
- Lighting control equations
- Energy efficiency measures (EEMs)

D. Additional EEMs

- De-lamping
- Scotopic lighting
- Task and ambient light levels
- Circadian rhythms

E. Lighting measurements

- Tools
- Data loggers and applications

F. Lighting calculations

- Equation and method of calculating lumens (zonal cavity formula)
- Equation and method of calculating energy savings
- Method of calculating skylight energy savings

G. Lighting standards, codes and regulations

- Underwriters' Laboratory (UL)
- Uniform Building Code (UBC)
- Americans with Disabilities Act (ADA)
- Title 24 applications

H. O&M measures to assure optimal performance

A. Introduction

1. Why do energy auditors need to understand the concepts of energy and building science
2. Critical terms for understanding and measuring environmental conditions and building energy use
3. Tools used for measuring heat and light

A. Introduction

1. Why do energy auditors need to understand the concepts of energy and building science
2. Critical terms for understanding and measuring environmental conditions and building energy use
3. Tools used for measuring heat and light

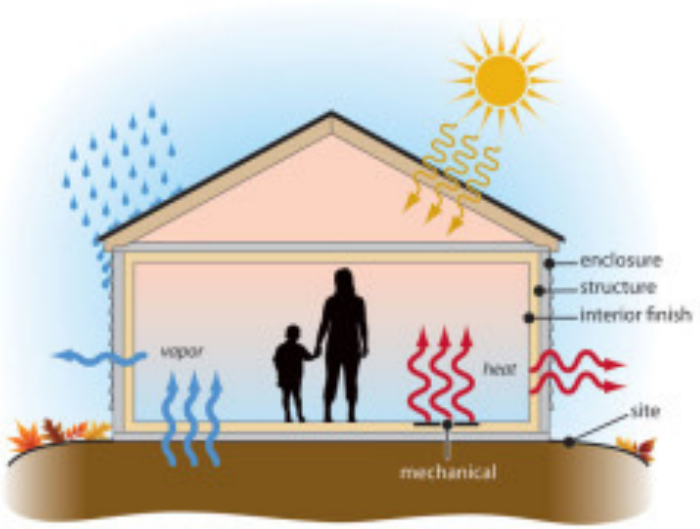
1. Why energy auditors need to understand the concepts of energy and building science
   - Variability of indoor environment characteristics such as light, temperature and humidity are variable
   - Energy consumption by the systems that control indoor environmental conditions
   - Slight changes in indoor environments can change energy consumption without affecting occupant comfort or productivity

What is Building Science?

- Building science is the study of how buildings *resist* environmental forces, such as rain, solar gain, wind, earthquakes
- It's about how the building is built to protect the occupants from the elements; what materials were used, how the building is situated
- It's the study of how a building's systems create interior comfort
- It's the study of how can the building be made to operate efficiently

Building Science

When you take the fundamentals of what a building is (foundations, walls, roofs, etc.) **and combine** that knowledge with an understanding of building systems, materials, and climate, you are engaging in **building science.**



Building science studies **how** heat, air, and vapor flows interact with building enclosure layers.

The Take Away

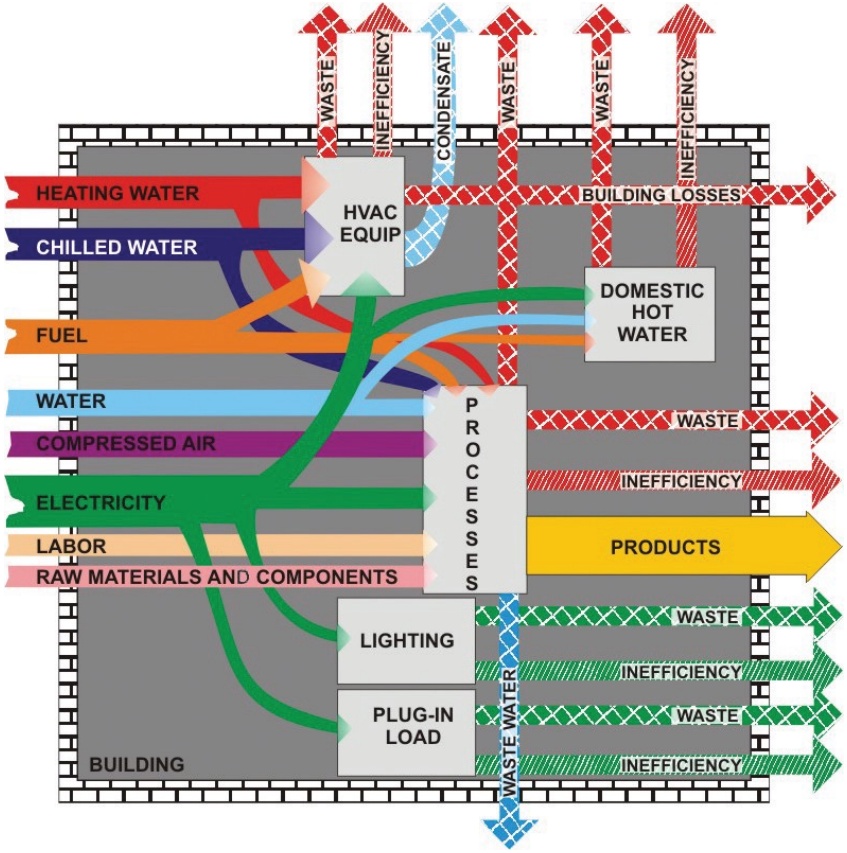
- Building Science matters because it is directly linked to the work energy auditors do, and that is:
  - Inspect, survey and analyze energy flows for the purposes of identifying energy conservation opportunities in a building
  - The audit is a **standard process** to reduce the amount of energy input into the system without negatively affecting the output(s)
- We cannot make recommendations for improvements without understanding the Building Science: how the elements, like heat, air, and water vapor interact with the building itself

For example:

- During an audit you learn from the building superintendent that:
  - Occupants complain a lot when it's too cold or too hot outside
  - Managers complain of reduced productivity of workers due to uncomfortable temperature conditions
  - Some have complained of indoor air quality issues because of the presence of mold and mildew
  - Business owner complains of high utility bills
- Next steps: Conduct the energy audit with a view to reduce energy usage costs and to improve occupant comfort.
- Based on what you know about the building, its location, and the area's climate, you begin to formulate reasons for why the complaints are happening. Possible reasons include:
  - Little or no insulation in the roof or walls
  - Cracks in the exterior walls of the building and around the frames of window allow drafts. The unconditioned air and moisture get in and condensation cause mold and mildew
  - Too much sun on a wall that has a lot of windows increases the temperature in the building and the HVAC can't cool the building
  - Wasted energy flows out of the building and the owner pays for it

Understanding Wasted Energy

- Waste is defined as the use of excess energy due to a piece of equipment or system that is not performing to its capabilities
- Instead of heat reaching its destination, it is given off or lost at the equipment, or
- The temperature of hot water, or heat, is lost along the way after it leaves the Water Heater or the HVAC unit through un-insulated pipes, leaks in the ducts, etc.



Energy Audits

- The purpose of the energy audit is to reduce energy consumption while maintaining or improving human comfort
- Beyond simply identifying the sources of energy use, an energy audit seeks to **prioritize** the energy savings opportunities in the order of highest to the lowest energy savings potentials

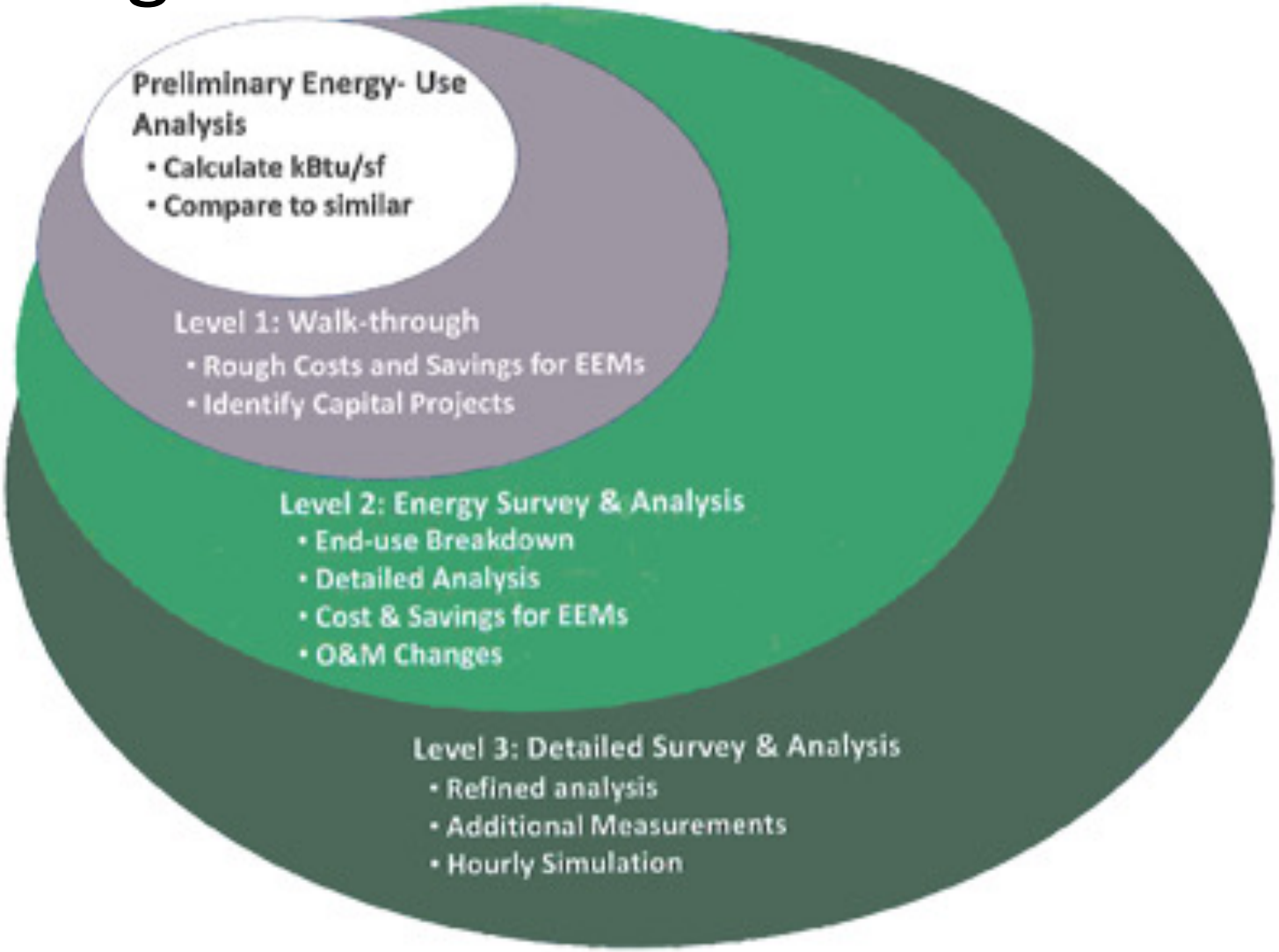
Energy Audits by Building Type

- Residential
  - Single occupancy detached house, 2/4 plex, multi-family
- Non-residential
  - Small and Medium Commercial (7-11's, strip malls, schools)
  - Large commercial (hospitals, high-rise buildings, hotels)
  - Industrial (cement plants, manufacturing plants, waste-water treatment plants)

Residential Energy Audits

- Home energy audit
  - Often referred to as “Residential” audits; these are broken into two categories
    - Single family (4 units or less)
    - Multi family (5 or more units in a building)
  - The focus of the residential energy audit is to improve the energy efficiency of heating, cooling, water heating, refrigeration, lighting and “plug loads,” in the house
  - There are many “on-line” audit tools available for these types of audits

4 Degrees of Non-Residential Audits



Main Points of the Energy Audit Process

- The analysis of building and utility data
  - Identification of customer concerns and needs
  - Understanding of building interaction with weather, occupancy, and operating schedule
  - Survey of existing equipment and analysis of energy bills
  - Survey of existing operating conditions
  - Selection and evaluation of energy conservation measures
  - Estimates of energy savings

A. Introduction

1. Why do energy auditors need to understand the concepts of energy and building science
2. Critical terms for understanding and measuring environmental conditions and building energy use
3. Tools used for measuring heat and light

Basic Units in Electricity

- The three most basic units in electricity are:
    1. Voltage (**V**): is measured in volts
    2. Current (**I**, an uppercase "i"): is measured in amps
    3. Resistance (**r**): is measured in ohms
- An good analogy to help understand these terms is a system of plumbing pipes.
    1. The voltage is equivalent to the water pressure
    2. The current is equivalent to the flow rate,
    3. The resistance is like the pipe size

Voltage

- The difference in charge between two points.
- It is a way of using numbers (volts) to describe an electric field.
- Without voltage there can be no electrical current.
- Voltage creates the potential for current to flow
- It is the medium used to transmit energy in the world

You will need to be able to use a voltmeter to record voltages in order to use the data in analysis.

You may not be an electrical engineering, but you will probably need to understand enough about basic electrical measurements to be able to use modern sensors and instruments

Using a Voltmeter

- For our introduction to the voltmeter, we need to be aware of three items on the voltmeter.
  1. The display. This is where the result of the measurement is displayed. You meter might be either analog or digital. If it's analog you need to read a reading off a scale. If it's digital, it will usually have an LED or LCD display panel where you can see what the voltage measurement is.
  2. The positive input terminal, and it's almost always red.
  3. The negative input terminal, and it's almost always black.
- Next, you need to be aware of what the voltmeter measures: A voltmeter measures the voltage difference between the positive input terminal of the voltmeter and the negative input terminal.
- That's it. That's what it measures. Nothing more, nothing less - just that voltage difference. That means you can measure voltage differences in a circuit by connecting the positive input terminal and the negative input terminal to locations in a circuit.

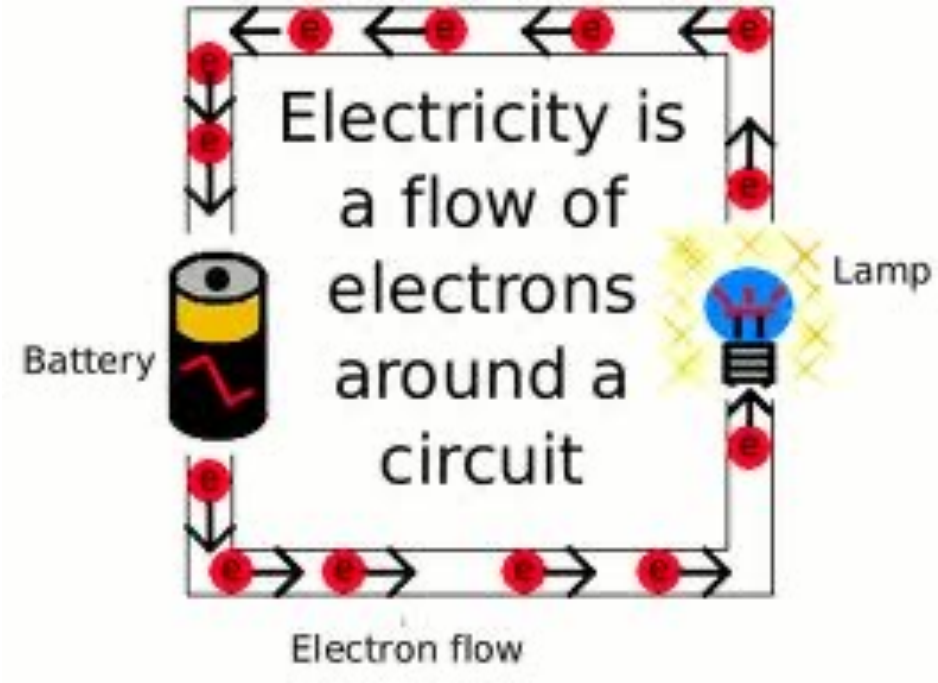
Amperage

- Amperage is the amount of electric current running through an electrical component, like a wire
- Specifically, amperage measures the number of electrons passing any given point time over a given time
- Measuring amperage is important to make sure that electrical components, or wires, are not handling more current than they are rated for
- You measure amperage with a special tool called a multimeter

Using a Multimeter

- Looks a lot like a voltmeter
- It has a knob

A Simple Circuit



- This picture illustrates a single lamp. The Voltage from the battery cell is pushing the electrons through the bulb and the wire.
- Without this push, the electrons would be happy to remain stationary.
- In this case, chemical action within the battery causes the push. When the battery gets old, its chemical reaction slows down and its internal push gets weaker and weaker.
- That's why the bulb gets dim.

Resistance

- Resistance is the friction in an electrical circuit that controls the flow of current; it is measured in Ohms (Ω)
- Conceptually: Think of your kitchen faucet. Water flow is directly related to how far you turn the faucet. In electrical terms, the faucet is an adjustable resistor – it slows or speeds up the rate of water flow or the current.
- Why do we need resistance? We need resistance to control the flow of electrons through a circuit in order to avoid catastrophic failure (over loaded fuses, excessive heat, fire, etc.)

Safety or Service Factor

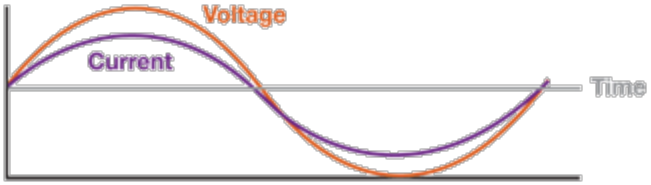
- The service factor – SF – is a measure of periodically overload capacity at which a motor can operate without overload or damage
- The NEMA (National Electrical Manufacturers Association) standard service factor for enclosed motors is 1.0
- A motor operating continuously at a service factor greater than 1 will have a reduced life expectancy compared to operating at its rated nameplate horsepower

True Power

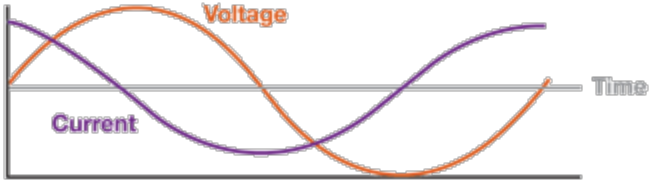
- Power that is dissipated (consumed) by a load is referred to as **true power** (sometimes called active or real)
- True power is symbolized by the letter **P** and is measured in the unit of Watts (W).
- To determine energy consumption, we have to measure the portion of energy consumed by a load, and disregard the amount of energy stored and returned to the source.
- The ratio of the “True Power” which is the power actually consumed, to “Apparent Power” is called the “Power Factor”.

Power Factor

- In an AC circuit, power is used most efficiently when the current is aligned with the voltage.



- However, most equipment tend to draw current with a delay, misaligning it with the voltage. What this means is more current is being drawn to deliver the necessary amount of power to run the equipment. And the more an equipment draws current with a delay, the less efficient the equipment is.



- **Power factor** is a way of measuring how efficiently electrical power is being used within an electrical system, by taking a look at the relationship of the components of electric power in an AC circuit. These components are referred to as **True Power**, **Apparent Power,** and **Reactive Power.**

Power Factor

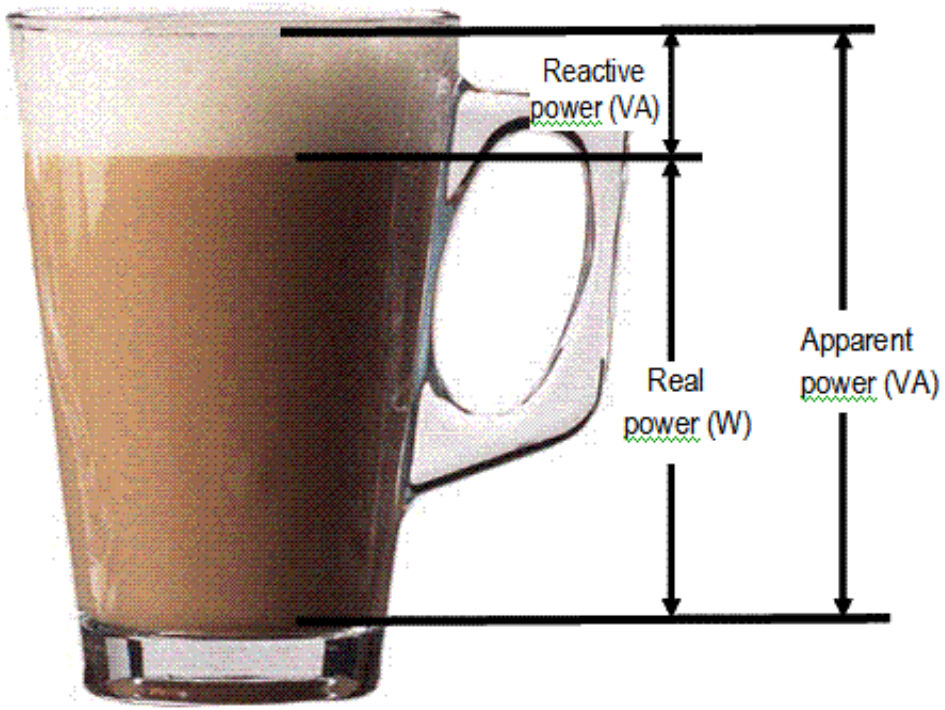
- Power factor is defined as the ratio of the **True (real) power** to the **apparent power,** where
  - **True Power** is measured in watts (k*W*) and is the power drawn by the electrical resistance of a system doing useful work. This is the energy that runs the equipment.
  - **Apparent Power** is measured in kVA (amps x volts). This is what the power company must deliver.
  - **Reactive Power** is measured in volt-amperes reactive (*kVAr*). Reactive Power is power stored in and discharged by inductive motors, transformers and solenoids.

Power Factor (Continued)

- The maximum power factor is 1, expressed as 100%. This is possible when equipment turns all of its supplied energy into output.
- Good power factor is 95% or better. Lower power factors require additional energy generation and transmission
- Low power factors are often associated with equipment that contain an electromagnets, such as electric motors, transformers, and chargers. With equipment like these, energy is used to maintain the magnetic field even though the equipment isn't actually doing work.
- Low power factors indicate that electricity suppliers need to provide more generating capacity that what is actually required
- You can increase power factor through the use of power factor correcting equipment, such as capacitors.

The Power Factor Latte Analogy

Latte Analogy



Power Factor is the ratio of coffee (W) to coffee + foam (VA). As the foam increases and coffee decreases, the PF is reduced. This latte looks like it has a Power Factor of .8.

Units of Energy

- British Thermal Unit (BTu):
  - 1 Btu is approximately the amount of heat required to raise the temperature of 1 lb of water by 1°F.
  - It can be described as the heat produced by burning a single wooden match
- Therm:
  - A unit of heat equivalent to 100,000 Btu
  - It is the measurement natural gas companies use to determine your natural gas usage

Units of Energy

- Kilowatt-hour (kWh):
  - A unit of energy equal to 1,000 watts operating for one hour:

$$kWh = kW * h$$

Where:

kWh is the energy

kW is the power

h is the time in hours

Temperature

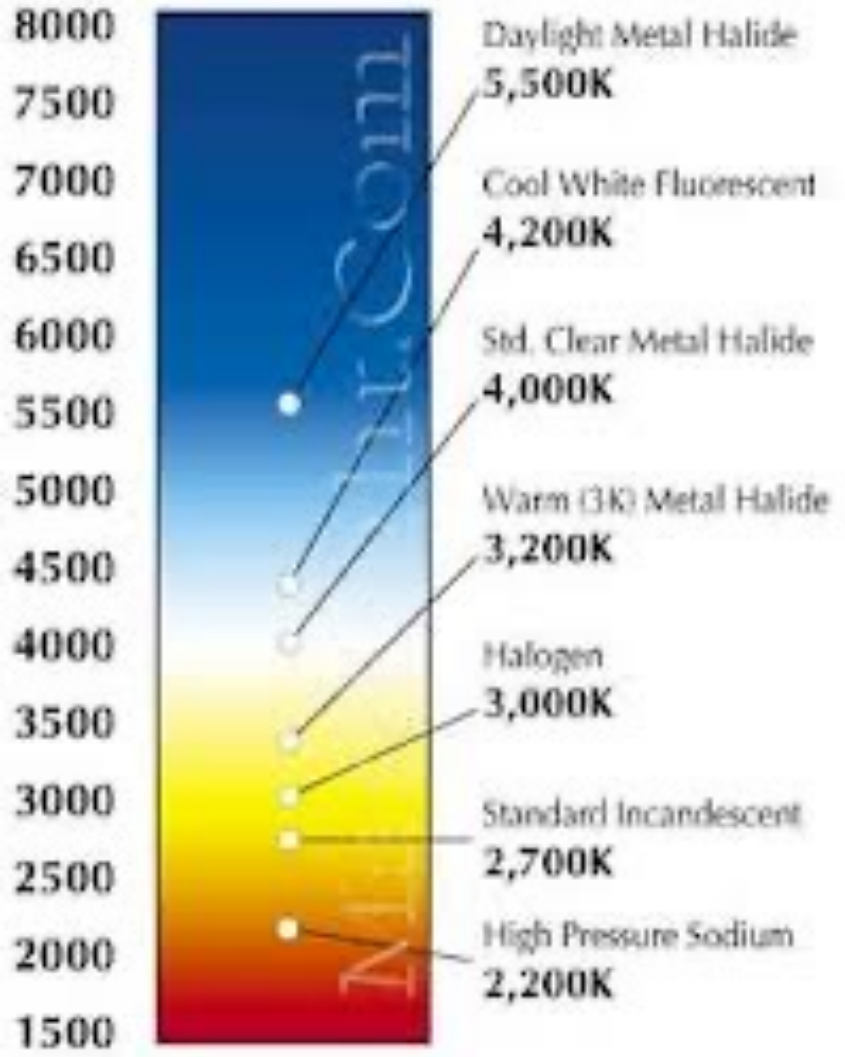
- Temperature is the measure of how hot or cold something is
- It is based on how fast or slow molecules are moving
- Two scales for measuring temperature are
  - Celsius (C)
  - Fahrenheit (F)
- It can be measured by a thermometer

Basic Lighting Terms

- Lumen
  - A measure of the total “amount” of light emitted by a source
- Luminance
  - Think of it as “brightness;” it is the measure of how intense or bright a source of light is
- Foot-Candle
  - A unit of measure of the intensity of light falling on a surface
  - It is equivalent to the illumination produced by a source of one candle at a distance of one foot

Basic Lighting Terms (continued)

- **Kelvin** is a unit of measurement often used in the measure of the color temperature of light sources.
- Correlated Color temperature (CCT) defines a color as the temperature degrees Kelvin that a “black body” source must reach in order to produce that same color.



A. Introduction

1. Why do energy auditors need to understand the concepts of energy and building science
2. Critical terms for understanding and measuring environmental conditions and building energy use
3. Tools used for measuring heat and light

Tools for Measuring

- Heat
  - Thermometers (use heat sensitive liquid)
  - Temperature sensors (electronic, wireless)
- Light
  - Light meters: handheld device that provides light level readings
  - Optometer: a light meter with added sophistication able to measure single and multiple pulse or strobe light activity
  - Photometer/Radiometer: handheld instrument that does what the light meter and optometer do, that is also able to operate and display four different levels of light at the same time including radiation

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

BEST
Building Efficiency for a Sustainable Tomorrow

NSF National Science Foundation