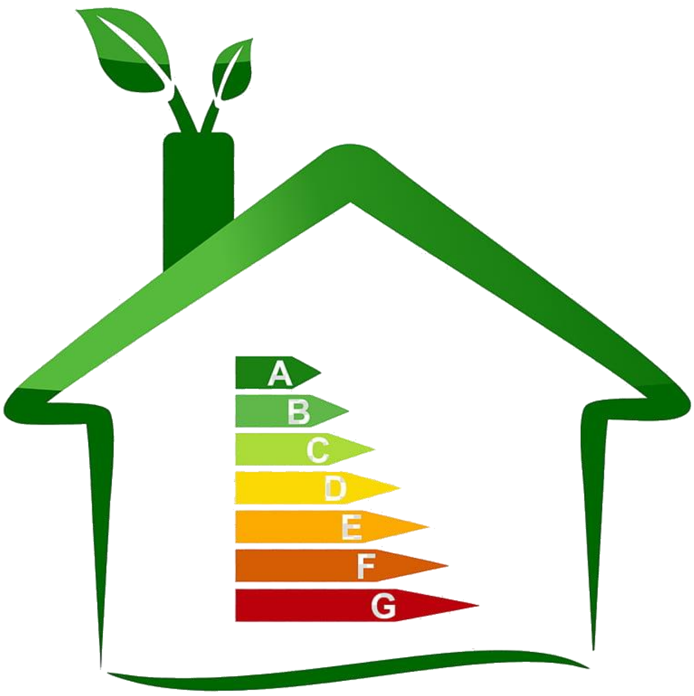
**Al-Karkh University of Science**

**College of Energy and Environmental Sciences**

# Design for Energy Efficiency

Level - 4

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2022

## Lecture One

1. **Efficient energy use**, sometimes simply called **energy efficiency**, is the goal to reduce the amount of energy required to provide products and services and can also reduce effects of air pollution. For example, insulating a building allows it to use less heating and cooling energy to achieve and maintain a thermal comfort. Installing light-emitting diode bulbs, fluorescent lighting, or natural skylight windows reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses.
2. **Motivations to improve energy efficiency**

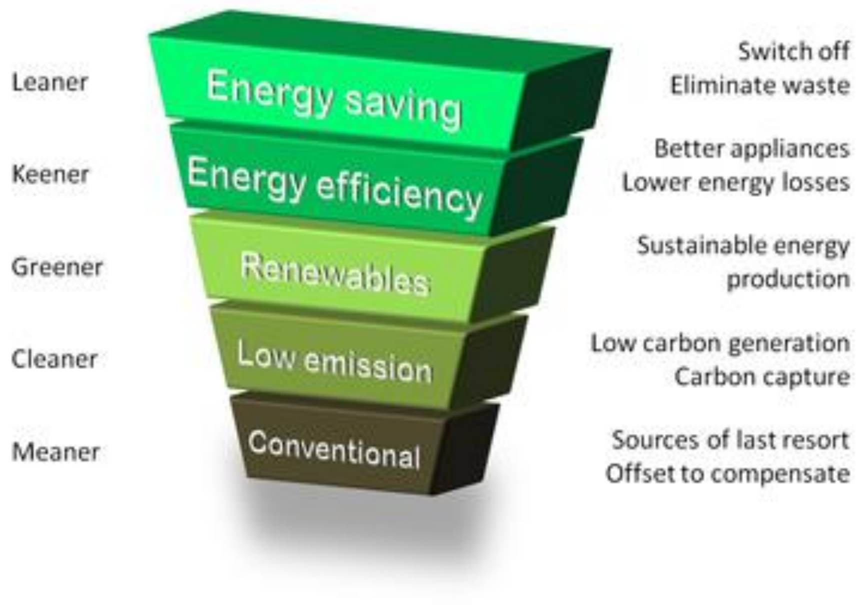
There are many motivations to improve energy efficiency:

1. Decreasing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy-efficient technology.
2. Reducing energy use is also seen as a solution to the problem of minimizing greenhouse gas emissions. According to the International Energy Agency (IEA), improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.
3. Another important solution is to remove government led energy subsidies that promote high energy consumption and inefficient energy use in more than half of the countries in the world.

Energy efficiency and renewable energy are said to be the **twin pillars** of sustainable energy policy and are high priorities in the sustainable **energy hierarchy**. In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.

### 3. Energy Hierarchy

The **Energy Hierarchy** is a classification of energy options, prioritised to assist progress towards a more sustainable energy system. It is a similar approach to the waste hierarchy for minimising resource depletion, and adopts a parallel sequence. The Energy Hierarchy was proposed by the Institution of Mechanical Engineers as a new approach to energy policy. It ranks options as an inverted pyramid of priorities, with the most sustainable at the top, and the least sustainable at the bottom:




The Energy Hierarchy with the most favoured options at the top

The highest priorities cover the prevention of unnecessary energy usage both through eliminating waste and improving energy efficiency. The sustainable production of energy resources is the next priority. Depletive and waste-producing energy generation options are the lowest priority.

For an energy system to be sustainable: the resources applied to producing the energy must be capable of lasting indefinitely; energy conversion should produce no harmful by-products, including net emissions, nor wastes which cannot be fully recycled; and it must be capable of meeting reasonable energy demands.

### 3.1 Energy saving (Leaner)

The top priority under the Energy Hierarchy is energy conservation or the prevention of unnecessary use of energy. This category includes eliminating waste by turning off unneeded lights and appliances and by avoiding unnecessary journeys. Heat loss from buildings is a major source of energy wastage,[1] so improvements to building insulation and air-tightness can make a significant contribution to energy conservation.[2]

### 3.2 Energy efficiency (Keener)

This is about making better use of our energy, through better design or changes in technology. For example, switching to more energy-efficient models, such as newer appliances, or LED lighting, can help to reduce energy use. This is a longer-term project than energy saving, but can be—and is—an important part of reducing energy consumption.

### 3.3 Using Sustainable/Renewable Energy Sources (Greener)

Renewable sources of energy are those that are not depleted by use, such as solar, tidal or wind power. Governments and energy generation companies have invested heavily in these in recent years. These sources do, however, have significant drawbacks, and particularly that the energy sources may not be available when demand is highest: for example, most people want to use lights at night when solar power is not available.

To a certain extent, biofuels are also included in renewable sources. However, these must be replaced, rather that automatically regenerating. They may also have an environmental cost in themselves: for example, if corn is used to make biodiesel, it cannot be eaten, and nor is the land available to grow food crops. Growing these crops may also demand use of water, another natural resource that is increasingly under pressure.

### 3.4 Low-Impact or Low-Emission Energy Production (Cleaner)

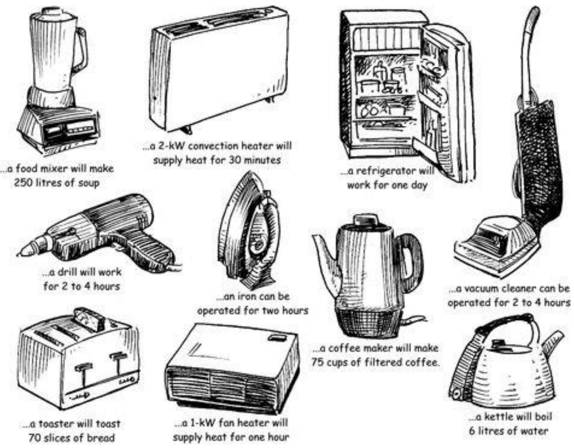
It is possible to reduce the impact of producing energy from conventional sources. For example, the technology that allows carbon capture and storage can reduce the impact of using fossil fuels. The reduction of nuclear waste can also reduce the long-term impact of nuclear power generation. Overall efficiency and sustainability can also be improved by capacity- or fuel-switching from less efficient, less sustainable resources to better ones; but this is mainly covered under the fourth level of the hierarchy.

Investment in these technologies tend to be made at governmental level, or by big corporations encouraged by government incentives such as tax breaks.

### 3.5 Conventional or High-impact Energy Production (Meaner)

This final option, at the bottom of the pyramid, describes the exploitation of non-renewable natural resources (oil, gas and coal) to provide cheap and reliable power. There is really no nice way to put this: this technology, which is pretty much the current default globally, is a problem. It is resource-intensive, and also polluting.

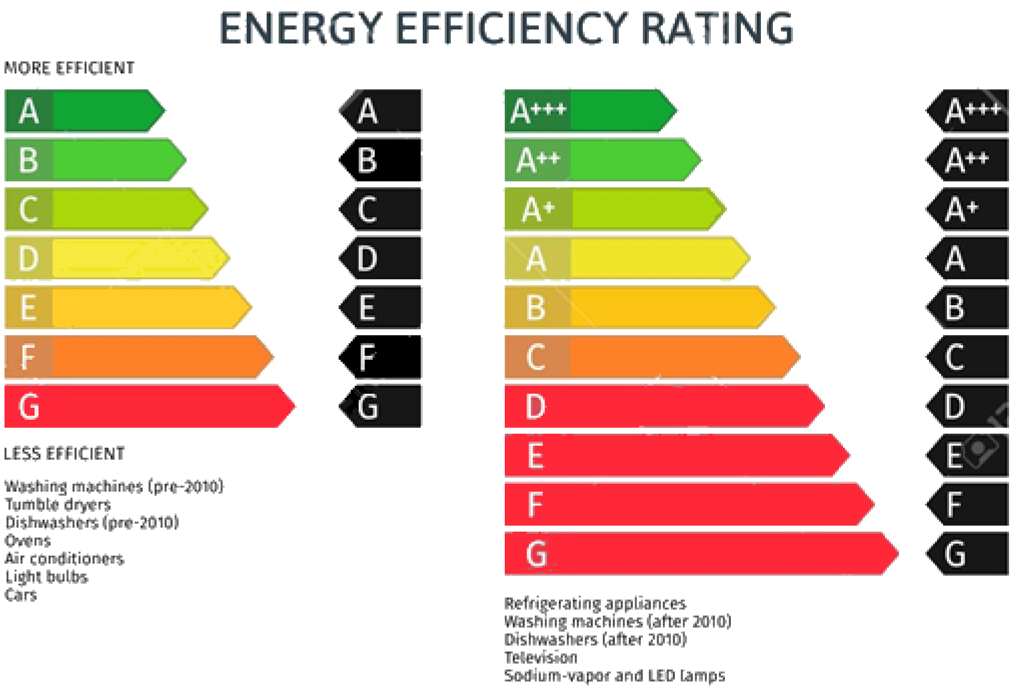
## 4. Appliances




Modern appliances, such as, freezers, ovens, stoves, dishwashers, clothes washers and dryers, use significantly less energy than older appliances. Installing a clothesline will significantly reduce one's energy consumption as their dryer will be used less. Current energy-efficient refrigerators for example, use 40 percent less energy than conventional models did in 2001. Following this, if all households in Europe changed their more than ten-year-old appliances into new ones, 20 billion kWh of electricity would be saved annually, hence reducing CO2 emissions by almost 18 billion kg. In the US, the corresponding figures would be 17 billion kWh of electricity and 27,000,000,000 lb ($1.2 \times 10^{10}$ kg) CO2. According to a 2009 study from McKinsey & Company the replacement of old appliances is one of the most efficient global measures to reduce emissions of greenhouse gases. Modern power management systems also reduce energy usage by idle appliances by turning them off or putting them into a low-energy mode after a certain time. Many countries identify energy-efficient appliances using energy input labelling.

### 4.1 Energy input labelling

Energy efficiency labels indicate the energy efficiency of the appliance in question. Appliances that are energy efficient use less electricity to achieve the same level of performance to similar models with the same size or capacity. ... This means the ratings can only be compared between one type of appliance.




The impact of energy efficiency on peak demand depends on when the appliance is used. For example, an air conditioner uses more energy during the afternoon when it is hot. Therefore, an energy-efficient air conditioner will have a larger impact on peak demand than off-peak demand.

An energy-efficient dishwasher, on the other hand, uses more energy during the late evening when people do their dishes. This appliance may have little to no impact on peak demand.

### 4.2 2021 Energy Efficiency Labelling Improvements

Since the original A to G scale was introduced in 1992, there have been some astonishing improvements in energy, water and detergent use for household appliances. So much that in 2011 A+, A++ and A+++ were added to the scale because almost all appliances were falling into the A-rated category. More improvements followed, leaving A+++ covering a wide range, with no way of telling which are the most efficient appliances. Technology is advancing faster than the old EU energy labelling can keep up with.

So, on 1 March 2021, the EU energy scale was adjusted to reintroduce the A to G ratings, taking away the + categories, and making it easier for customers to compare the energy efficiency of their purchases. The new rating will make it easier to identify the most efficient among products. For example, a fridge that currently has the A+++ label could be reclassified as C, even though it is just as energy efficient as before, or a dishwasher rated A++ could become an E on the new label. Many products which previously scored A+++ will now be rated as D or E on the new scale.

The classification system has been designed so that the A category is virtually empty at first, and B and C categories contain only those products with top efficiency. This allows room in the scale to introduce more energy efficient products as they are designed and new technology is developed.

**When will the labelling change?**

From 1 November 2020 manufacturers will supply both labels in the box.

From 1 January 2021, the label will start to introduce the Union Flag to replace the EU flag.

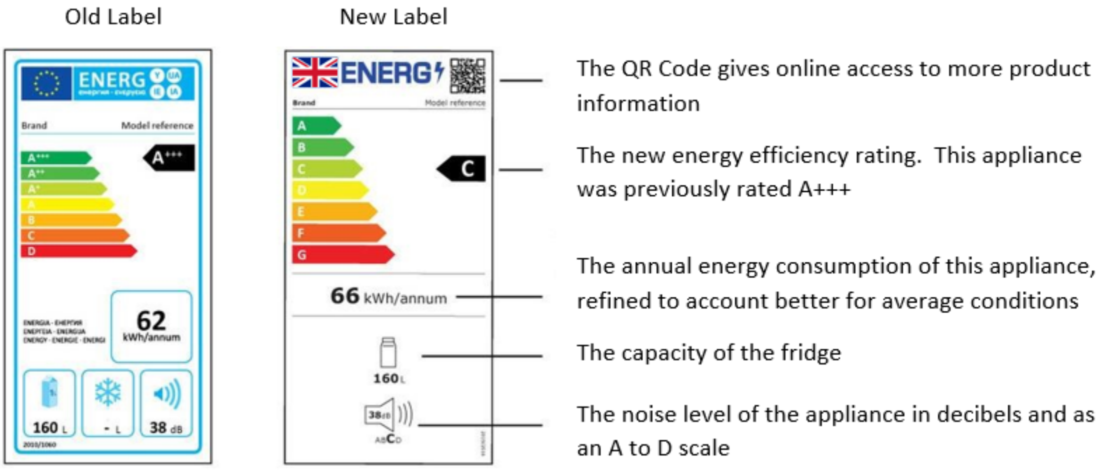
From 1 March 2021 dishwashers, washing machines, refrigeration appliances and electronic display products will use the new label instore and online.

From 1 September 2021 lamps will be relabelled.

New labels for ovens, cooker hoods, water heaters and air conditioning units are expected in 2022.  Products which have been discontinued prior to 1 March 2021 can still use the old label until 1 December 2021.

**How to recognise the new energy efficiency labelling**

On March 30 and 31, 2009, the European Commission presented their proposal to change the scale used to rate products of the categories televisions, fridges, freezers and washing machines by introducing a scale based on the current A-G scale with extra levels for products considered to be beyond A (A-20%, A-40%, A-60% etc.) (ECEEE, 2009). The rationale behind this label is that no reclassification of products would be needed and that this system could easily be harmonized throughout all EU countries




The Council reached an agreement in March to add these extra levels for top-rated products, and while the European Parliament adopted the proposed scheme for fridges and freezers, the decision was blocked for the product category of televisions. Now, the European Parliament has called on the Commission to withdraw the draft directive and to submit a new proposal for the product category of televisions to the committee by the end of September 2009. At the time of writing, the Commission was launching a big consumer survey in order to test the effectiveness of both labels; they have also decided not to suggest new labels for other product categories (e.g. computers, monitors, imaging equipment, etc.)

until the new label for TVs has been adopted (ECEEE, 2009).


Figure illustrates the energy efficiency classes of both label options and the next paragraph will shortly review the pros and cons of both discussed label schemes

## Lecture Two

### Calculating Annual Electricity Consumption and Costs

follow these steps for finding the annual energy consumption of a product, as well as the cost to operate it.

1. **Estimate the number of hours per day an appliance runs.** There are two ways to do this:

   **- Rough Estimate**

   If you know about how much you use an appliance every day, you can roughly estimate the number of hours it runs. For example, if you know you normally watch about 4 hours of television every day, you can use that number. If you know you run your whole house fan 4 hours every night before shutting it off, you can use that number. Refrigerators, although turned "on" all the time, actually cycle on and off as needed to maintain interior temperatures.

   **- Keep a log**

   It may be practical for you to keep a usage log for some appliances. For example, you could record the cooking time each time you use your microwave, work on your computer, watch your television, or leave a light on in a room or outdoors.

## 2. Find the wattage of the product.

There are three ways to find the wattage an appliance uses:

**- Stamped on the appliance**

The wattage of most appliances is usually stamped on the bottom or back of the appliance, or on its nameplate. The wattage listed is the maximum power drawn by the appliance.


Many appliances have a range of settings, so the actual amount of power an appliance may consume depends on the setting being used. For example, a radio set at high volume uses more power than one set at low volume. A fan set at a higher speed uses more power than one set at a lower speed.

**- Multiply the appliance ampere usage by the appliance voltage usage**

If the wattage is not listed on the appliance, you can still estimate it by finding the electrical current draw (in amperes) and multiplying that by the voltage used by the appliance. Most appliances use 220 volts. The amperes might be stamped on the unit in place of the wattage, or listed in the owner's manual or specification sheet.

**- Use online sources to find typical wattages or the wattage of specific products you are considering purchasing**. Such as Home Energy Saver , ENERGY STAR .

Home Energy Saver & Score: Engineering Documentation

Search this site

Welcome
What's New
Sitemap

HES Single Family
Home Energy Saver
Defaults
HES Pro/Consumer API
User Interface
Known Issues & Release Notes
The Home Energy Scoring Tool
User Interface
Defaults
Dependencies on Occupancy and House Size
Scoring Methodology
Interpreting the Label
Scoring Tool API
Scoring Tool workarounds

Calculation Methodology > Calculation of Energy Consumption > Appliances > Miscellaneous Equipment Energy Consumption >

Default Energy Consumption of MELs

The table below gives the default energy consumption estimates for the miscellaneous end-uses available in the Home Energy Saver. This does not apply to the Home Energy Scoring Tool which calculates miscellaneous end-use electrical consumption from the building floor area.

| Appliance | Number in Default House | Active Power (Watts) | Usage Increment | Usage Period | Season Increment (months) | Active Usage (hours) | Active Energy (kWh) | Standby Power (Watts) | Standby Usage (hours) | Standby Energy (kWh) | Total Energy (kWh) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Home Entertainment | | | | | | | | | | | |
| Boom Box | 1 | 8 | 30 | minutes / week | | 26 | 0.2 | 5.2 | 8734 | 45 | 46 |
| Cable Boxes (standby losses) | 1 | 140 | 90 | minutes / day | | 548 | 77 | 11.6 | 8213 | 95 | 172 |
| CD Player | 1 | 7 | 30 | minutes / week | | 26 | 0.2 | 3.7 | 8734 | 19 | 19 |

3. **Find the daily energy consumption using the following formula:**

   (Wattage × Hours Used Per Day) ÷ 1000 = Daily Kilowatt-hour (kWh) consumption

**Example: A bulb of 60 watt runs for 30 hours. How much electrical energy is consumed?**

The bulb has consumed 1800 Watt-hours or 1.9 kWh. 60W x 30h =1500 wh.1 kWh = 1 unit of electrical energy (measurement used for billing, by your electricity provider).

## Energy Use of Home Appliances

How much electricity do our appliances use? You can usually find the wattage of most appliances on the nameplate on the back or bottom of the appliance. The wattage listed is the maximum power drawn by the appliance. Wattage = current X voltage. Often you will see the letters UL on the nameplate, which means the product has been tested to safety standards. Adjusting volume or changing settings can affect the actual amount of power consumed. Many appliances draw small amounts of power even when they are turned off.

**Now let's calculate the annual cost to run an appliance for a year.**

Annual Appliance Operating Cost

$$\frac{\text{Watts} \times \text{Hours used per day} \times \text{Days used per year}}{1000} = \text{Kilowatt-hour (kWh) Consumption}$$

**Multiply this number by your local utility's rate per kWh consumed**

**Example**

If John uses a window fan (200 watts) 4 hours a day for 120 days per year, how much does it cost him to run his fan per year?

( 200 X 4 X 120)/ 1000 = 96 kWh

96 kWh X 8.9 Cents/kWh = $8.16 per year

**3.1 How to Convert kVA to Amps?**

**Current in Amperes = Apparent Power in kVA x 1000 ÷ (Voltage in Volts)**

**I = (kVA x 1000) ÷ V**

**Example:**

Find the current in amps if the RMS voltage of a 3kVA transformer is 120V.

**Solution:**

I = (3kVA x 1000A) ÷ 120V **= 25 A**

**Example:**

Calculate the current in ampere of a 100kVA rated transformer having the line-to-line voltage of 240V.

**Solution:**

I = (100kVA x 1000 ÷ (1.732 x 240V)

**I = 240.5 A**

**Calculation with Line to Neutral Voltage**

**Current in Amperes = Apparent Power in kVA x 1000 ÷ ((3 x Voltage in Volts)**

$$\mathbf{I = kVA \times 1000 \div (3 \times V_{L\text{-}N})}$$

**Example:**

A three phase 180kVA rated transformer having the line to neutral voltage of 480V. Calculate the rating of current in amperes.

**Solution:**

$$I = (180kVA \times 1000) \div (3 \times 480V) \mathbf{= 125A}$$

4. **Find the annual energy consumption using the following formula:**

   Daily kWh consumption × number of days used per year = annual energy consumption

5. **Find the annual cost to run the appliance using the following formula:**

   Annual energy consumption × utility rate per kWh = annual cost to run appliance

# Lecture Three

# Embodied Energy

## 1. Building design

Buildings are an important field for energy efficiency improvements around the world because of their role as a major energy consumer. However, the question of energy use in buildings is not straightforward as the indoor conditions that can be achieved with energy use vary a lot. The measures that keep buildings comfortable, lighting, heating, cooling and ventilation, all consume energy. Typically, the level of energy efficiency in a building is measured by dividing energy consumed with the floor area of the building which is referred to as specific energy consumption
or energy use intensity:

$$\frac{\text{Energy consumed}}{\text{Built area}}$$

However, the issue is more complex as building materials have embodied energy **(is the total non-renewable energy that goes into the manufacture of a material and plays a large role in the choice of building materials).**

## 2. What Is Embodied Energy?

The International Journal of Sustainable Built Environment considers embodied energy to be the total amount of energy consumed during the production of a residential or commercial building.

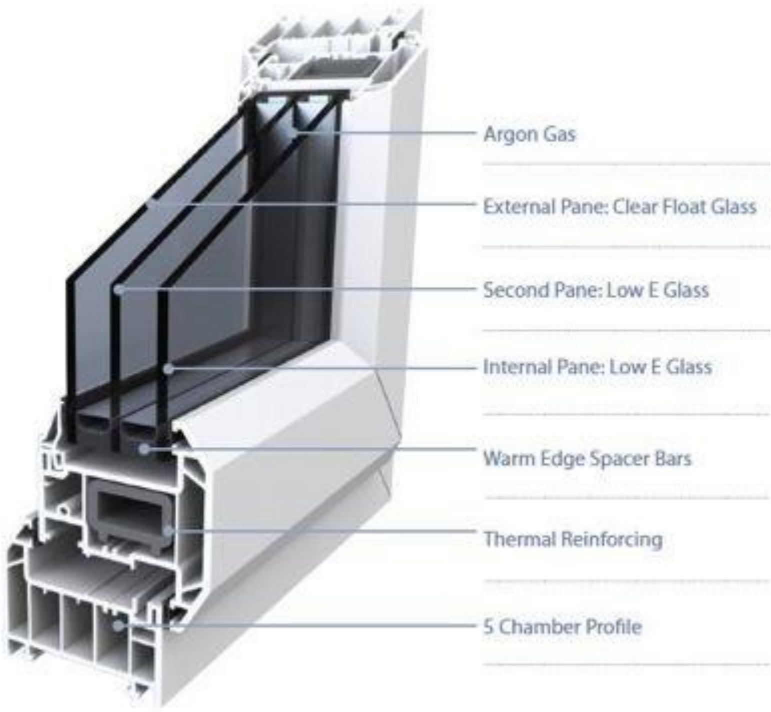
Think about the embodied energy in your home. Look around and review all of the different materials and products used to make the finished product. The granite in your kitchen countertop required an enormous amount of energy to be mined from a stone quarry. The power used to cut down the trees and mill the lumber for the 2x4s and flooring in your living room similarly came with substantial energy requirements. The foam insulation that improves the energy efficiency of your basement and home foundation also required an enormous amount of energy to produce.

The embodied energy footprint of a home is calculated by considering the energy used during:

- Mining and acquisition of natural resources
- Manufacturing and other industrial processes of transforming raw resources into usable building components
- Transportation of building materials from their source of origin to your home
- Energy used during the building process itself
- Energy used to operate the home during its lifetime

## 3. Important of Embodied Energy?

In many ways, the embodied energy in the homes we live in might seem like an aspect of home sustainability that is simply out of the scope of our responsibility. To reduce energy usage, every homeowner can choose to complete upgrades like installing a more energy-efficient refrigerator, installing triple-pane windows, or maybe even installing solar panels.

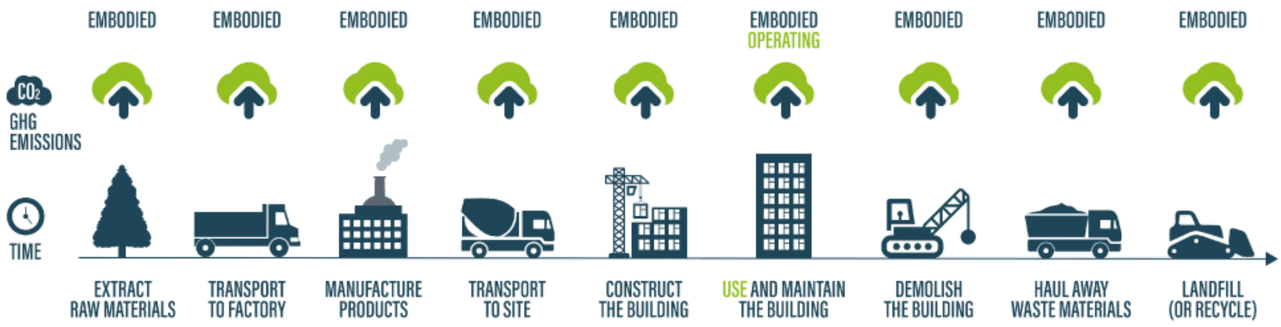



Behavioural change (such as turning off the lights and adjusting the thermostat accordingly) is also a tangible way to increase our homes' operational efficiency. But, can we be accountable for the amount of energy used to mine and manufacture the cement used in the foundations of our home?

Unlike operational efficiency (i.e., the amount of energy and electricity our homes use to keep us comfortable), the embodied energy is not occupant dependent. Still, every homeowner should be concerned about the energy that went into the materials in our homes. Why? Because this "upstream" component of the lifecycle impact of our homes might be equivalent to *decades* of the operational energy use of our homes.

The World Green Building Council published an important report in 2019. They stated that 11 percent of global carbon emissions stem from the materials and construction processes that occur during the building's lifecycle.

To date, most strategies to "green" the building and construction sector have focused almost exclusively on improving operational efficiency. Today, however, the World Green Building Council and other leaders in the industry are dedicated to incorporating strategies to eliminate embodied carbon emissions.




### 3.1 Renovate Instead of Rebuild to Reduce Embodied Energy

Building a new home will require enormous materials, all of which have large amounts of embodied energy. Even replacing an older, less energy-efficient home with a modern, net-zero home will generally take several decades to offset. Carl Elefante, a leading architect who considers the embodied energy footprint of a building, once said that "the greenest building is the one already standing."

### 3.2Opt for Durable Building Materials to Reduce Embodied Energy

Unfortunately, many buildings today are constructed with inferior and substandard materials that have relatively short expected lifespans. Every time you have to replace your carpet, insulation, or drywall, the embodied energy footprint of your home will increase. Thus, investing more upfront for materials that are durable and long-lasting should be a priority.

### 3.3 Prioritize Local Products to Reduce Embodied Energy

Wooden flooring made from exotic hardwood species will most likely have a higher embodied energy footprint than a product made by a local manufacturer from locally harvested timber. The energy cost of transporting building materials long distances adds to the embodied energy of every building material, especially if they are heavy or bulky. When purchasing building materials for a home renovation, check the origin of the product and prioritize relatively close materials to your building site.

### 3.4 Natural Materials over Synthetics to Reduce Embodied Energy

Synthetic and human-made materials almost always have a higher embodied energy footprint than natural products. For example, consider the embodied energy footprints of the following types of insulation according to the chart we referenced above:

- Cellulose insulation (cotton): 3.3
- Recycled sheep's wool: 14.6
- Fiberglass: 30.3
- Polyester: 53.7

### 3.5 Incorporate Recycled or Reclaimed Materials into Your Home Renovations to Reduce Embodied Energy

Homeowners should also attempt to incorporate recycled materials into their home renovation plans as often as possible. Many of these, like salvaged hardwood flooring, recycled paper countertops, are becoming much more accessible to source from mainstream manufacturers. These and other products containing recycled materials reduce the mining or acquisition of raw materials, a considerable component of embodied energy in building materials.

Considering the embodied energy footprint of your home might seem impossible at first. However, the suggestions mentioned above are simple ways that every homeowner can reduce the embodied energy of the homes we inhabit.

In mathematical terms, embodied energy is measured by the quantity of non-renewable energy per unit of building material. The embodied energy of each material used in your home is conveyed in megajoules (MJ) or gigajoules (GJ) per unit weight (kg or ton) or area (m2). To try and make this a bit clearer, the Australian government has calculated synthetic rubber to have an embodied energy rating of 110 (measured in MJ per KG). At the same time, air-dried sawn hardwood has a rating of just 0.5 MJ/kg.

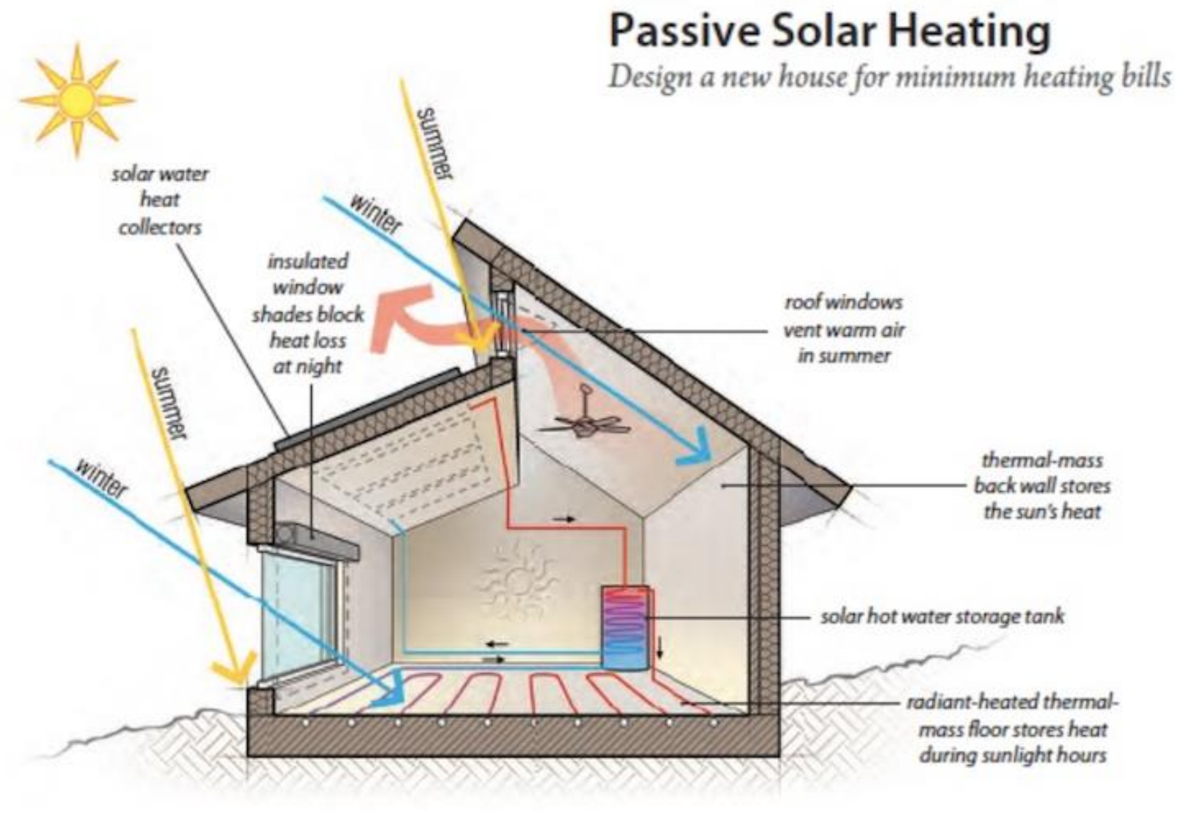
**What Can You Do to Lower the Embodied Energy of Your Home?**

It is an important factor to consider when assessing the life cycle of a building and it relates directly to the sustainability of the built environment. in them. On the other hand, energy can be recovered from the materials when the building is dismantled by reusing materials or burning them for energy. Moreover, when the building is used, the indoor conditions can vary resulting in higher and lower quality indoor environments. Finally, overall efficiency is affected by the use of the building: is the building occupied most of the time and are spaces efficiently used — or is the building largely empty? It has even been suggested that for a more complete accounting of energy efficiency, specific energy consumption should be amended to include these factors:

$$\frac{\text{Embodied energy} + \text{Energy consumed} - \text{Energy recovered}}{\text{Built area} \times \text{Utilization rate} \times \text{Quality factor}}$$

Thus, a balanced approach to energy efficiency in buildings should be more comprehensive than simply trying to minimize energy consumed. Issues such as quality of indoor environment and efficiency of space use should be factored in. Thus, the measures used to improve energy efficiency can take many different forms. Often, they include passive measures that inherently reduce the need to use energy, such as better insulation. Many serve various functions improving the indoor conditions as well as reducing energy use, such as increased use of natural light.

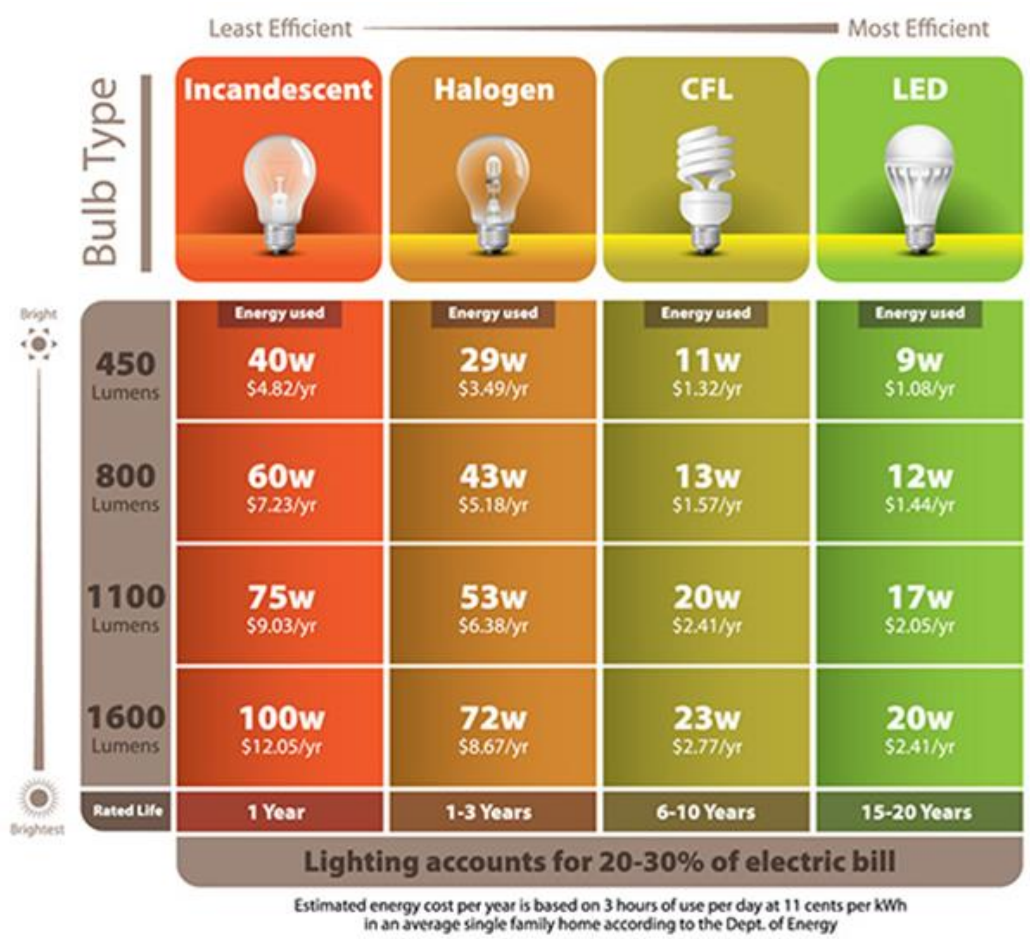
A building's location and surroundings play a key role in regulating its temperature and illumination. For example, trees, landscaping, and hills can provide shade and block wind. In cooler climates, designing northern hemisphere buildings with south facing windows and southern hemisphere buildings with north facing windows increases the amount of sun (ultimately heat energy) entering the building, minimizing energy use, by maximizing passive solar heating.



Tight building design, including energy-efficient windows, well-sealed doors, and additional thermal insulation of walls, basement slabs, and foundations can reduce heat loss by 25 to 50 percent.

Dark roofs may become up to 39 °C (70 °F) hotter than the most reflective white surfaces. They transmit some of this additional heat inside the building. US Studies have shown that lightly colored roofs use 40 percent less energy for cooling than buildings with darker roofs. White roof systems save more energy in sunnier climates. Advanced electronic heating and cooling systems can moderate energy consumption and improve the comfort of people in the building. Proper placement of windows and skylights as well as the use of architectural features that reflect light into a building can reduce the need for artificial lighting. Increased use of natural and task lighting has been shown by one study to increase productivity in schools and offices.

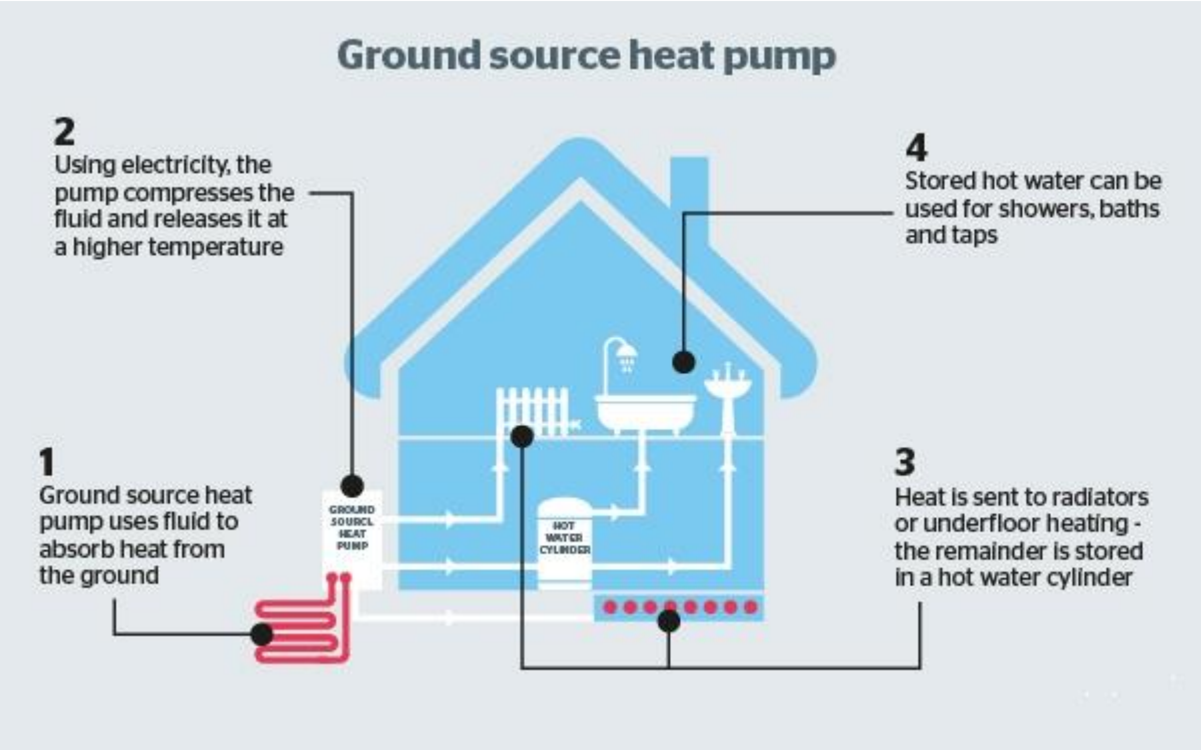
Compact fluorescent lamps use two-thirds less energy and may last 6 to 10 times longer than incandescent light bulbs. Newer fluorescent lights produce a natural light, and in most applications they are cost effective, despite their higher initial cost, with payback periods as low as a few months. LED lamps use only about 10% of the energy an incandescent lamp requires.




Effective energy-efficient building design can include the use of low-cost passive infra reds to switch-off lighting when areas are unoccupied such as toilets, corridors or even office areas out of-hours. In addition, lux levels can be monitored using daylight sensors linked to the building's lighting scheme to switch on/off or dim the lighting to pre-defined levels to take into account the natural light and thus reduce consumption. Building management systems link all of this together in one centralised computer to control the whole building's lighting and power requirements.

In an analysis that integrates a residential bottom-up simulation with an economic multi-sector model, it has been shown that variable heat gains caused by insulation and air-conditioning efficiency can have load-shifting effects that are not uniform on the electricity load. The study also highlighted the impact of higher household efficiency on the power generation capacity choices that are made by the power sector.

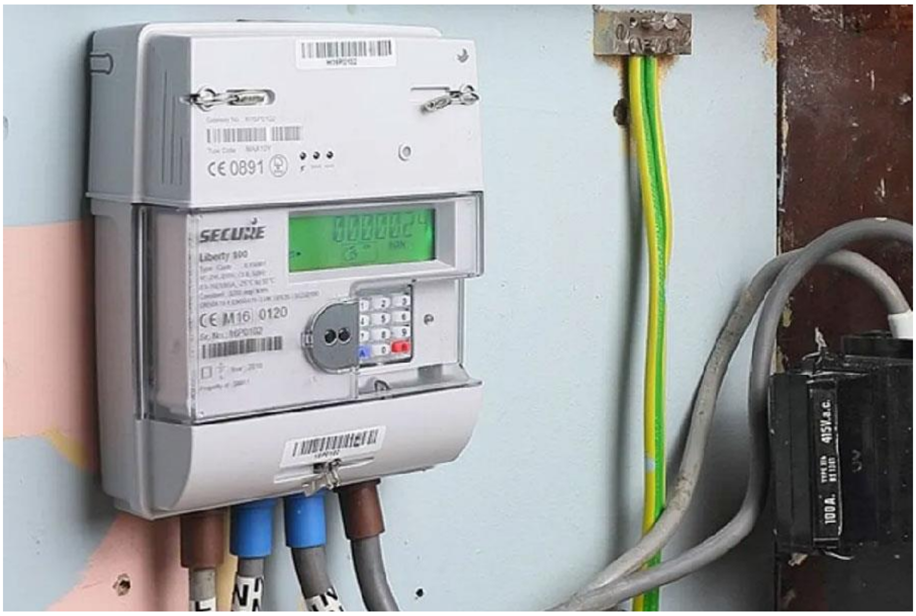
The choice of which space heating or cooling technology to use in buildings can have a significant impact on energy use and efficiency. For example, replacing an older 50% efficient natural gas furnace with a new 95% efficient one will dramatically reduce energy use, carbon emissions, and winter natural gas bills. Ground source heat pumps can be even more energy efficient and cost-effective.




These systems use pumps and compressors to move refrigerant fluid around a thermodynamic cycle in order to "pump" heat against its natural flow from hot to cold, for the purpose of transferring heat into a building from the large thermal reservoir contained within the nearby ground. The end result is that heat pumps typically use four times less electrical energy to deliver an equivalent amount of heat than a direct electrical heater does.

Another advantage of a ground source heat pump is that it can be reversed in summertime and operate to cool the air by transferring heat from the building to the ground. The disadvantage of ground source heat pumps is their high initial capital cost, but this is typically recouped within five to ten years as a result of lower energy use.

Smart meters are slowly being adopted by the commercial sector to highlight to staff and for internal monitoring purposes the building's energy usage in a dynamic presentable format. The use of power quality analysers can be introduced into an existing building to assess usage, harmonic distortion, peaks, swells and interruptions amongst others to ultimately make the building more energy-efficient. Often such meters communicate by using wireless sensor networks.



## 4. How is Embodied Energy Calculated?

One of the biggest challenges that come with understanding the embodied energy footprint of our homes is that embodied energy is calculated in a very sophisticated way. To discover the operational efficiency of your home, homeowners can quickly find a **carbon footprint** (A carbon footprint is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions.) calculator on the internet and devise a plan to reduce overall energy demand. However, an embodied energy analysis for the steel beam in your ceiling needs to consider the amount of energy used to mine steel, manufacture it into a usable product, transport it to your home site, and any energy used in raising it and welding it into place.


The average carbon footprint for a person in the United States is 16 tons, one of the highest rates in the world. Globally, the average carbon footprint is closer to 4 tons. To have the best chance of avoiding a 2℃ rise in global temperatures, the average global carbon footprint per year needs to drop to under 2 tons by 2050.

## 4.1 Electricity Consumption and Calculating a Carbon Footprint

There is no uniform formula to calculate a carbon footprint from electricity.

The typical carbon footprint Calculator includes some variation of combining the amount of electricity consumed, the average emissions released based on the regional power generation profile, and the average emissions released by the industry equivalent sites.

This methodology does not take into account the quality of the electricity being consumed. If the efficiency of generation, distribution and consumption of electricity is low, there is an increase in energy consumed by electrical energy loss rather than energy consumed by loads. In other words, large amounts of the electricity is generated and subsequently lost as heat or vibration contributing only to the carbon footprint and added costs.

## Lecture Four

**Green Building XML** is an emerging scheme, a subset of the Building Information Modelling efforts, focused on green building design and operation. It is used as input in several energy simulation engines. But with the development of modern computer technology, a large number of building performance simulation tools are available on the market. When choosing which simulation tool to use in a project, the user must consider the tool's accuracy and reliability, considering the building information they have at hand, which will serve as input for the tool.

**Leadership in Energy and Environmental Design (LEED)** is a rating system organized by the US Green Building Council (USGBC) to promote environmental responsibility in building design.

They currently offer four levels of certification for existing buildings (LEED-EBOM) and new construction (LEED-NC) based on a building's compliance with the following criteria: **Sustainable sites, water efficiency, energy and atmosphere**, **materials and resources, indoor environmental quality, and innovation in design.** In 2013, USGBC developed the LEED Dynamic Plaque, a tool to track building performance against LEED metrics and a potential path to recertification. The following year, the council collaborated with Honeywell to pull data on energy and water use, as well as indoor air quality from a BAS to automatically update the plaque, providing a near-Realtime view of performance. The USGBC office in Washington, D.C. is one of the first buildings to feature the live-updating LEED Dynamic Plaque.

A **deep energy retrofit** is a whole-building analysis and construction process that uses to achieve much larger energy savings than conventional energy retrofits. Deep energy retrofits can be applied to both residential and non-residential ("commercial") buildings. A deep energy retrofit typically results in energy savings of 30 percent or more, perhaps spread over several years, and

may significantly improve the building value. The Empire State Building has undergone a deep energy retrofit process that was completed in 2013. The project team, consisting of representatives from Johnson Controls, Rocky Mountain Institute, Clinton Climate Initiative, and Jones Lang LaSalle will have achieved an annual energy use reduction of 38% and $4.4 million.

For example, the 6,500 windows were remanufactured onsite into super windows which block heat but pass light. Air conditioning operating costs on hot days were reduced and this saved $17 million of the project's capital cost immediately, partly funding other retrofitting.

Receiving a gold Leadership in Energy and Environmental Design (LEED) rating in September 2011, the Empire State Building is the tallest LEED certified building in the United States.

The Indianapolis City-County Building recently underwent a deep energy retrofit process, which has achieved an annual energy reduction of 46% and $750,000 annual energy saving.

Energy retrofits, including deep, and other types undertaken in residential, commercial or industrial locations are generally supported through various forms of financing or incentives.

Incentives include pre-packaged rebates where the buyer/user may not even be aware that the item being used has been rebated or "bought down". "Upstream" or "Midstream" buy downs are common for efficient lighting products. Other rebates are more explicit and transparent to the end user through the use of formal applications. In addition to rebates, which may be offered through government or utility programs, governments sometimes offer tax incentives for energy efficiency projects. Some entities offer rebate and payment guidance and facilitation services that enable energy end use customers tap into rebate and incentive programs.

To evaluate the economic soundness of energy efficiency investments in buildings, cost effectiveness analysis or CEA can be used. A CEA calculation will produce the value of energy saved, sometimes called megawatts, in $/kWh. The energy in such a calculation is virtual in the sense that it was never consumed but rather saved due to some energy efficiency investment being made. Thus, CEA allows comparing the price of megawatts with price of energy such as electricity from the grid or the cheapest renewable alternative. The benefit of the CEA approach in energy systems is that it avoids the need to guess future energy prices for the purposes of the calculation, thus removing the major source of uncertainty in the appraisal of energy efficiency investments.

## Lecture Five

### Energy Audit

An energy audit is **an inspection survey and an analysis of energy flows for energy conservation in a building**. It may include a process or system to reduce the amount of energy input into the system without negatively affecting the output.

### Types of Energy Assessments

- Heating & Air Conditioning.
- Air Sealing.
- Insulation.
- Appliances.
- Lighting.
- Water Heating.

During an energy audit, a trained energy expert collects and analyses data on how your home uses energy. Many utilities offer energy audits to their customers at a reduced cost as a way to help customers learn about their home and find ways to use less energy.

### Types of Energy Audit

The type of industrial energy audit conducted depends on the function, size, and type of the industry, the depth to which the energy audit is needed, and the potential and magnitude of energy savings and cost reduction desired. Based on these criteria, an industrial energy audit and its types can be classified into two types: Preliminary Energy Audit (Walk-through Energy Audit) and a Detailed Energy Audit (Diagnostic Energy Audit).

1. **Preliminary Energy Audit (Walk-through audit)**. In a preliminary energy audit, readily-available data are mostly used for a simple analysis of energy use and performance of the plant. This type of audit does not require a lot of measurement and data collection. These audits take a relatively short time and the results are more general, providing common opportunities for energy efficiency. The economic analysis is typically limited to calculation of the simple payback period, or the time required paying back the initial capital investment through realized energy savings.

2. **Detailed Energy Audit (Diagnostic Energy Audit)**. For detailed (or diagnostic) energy audits, more detailed data and information are required. Measurements and a data inventory are usually conducted and different energy systems (pump, fan, compressed air, steam, process heating, etc.) are assessed in detail. Hence, the time required for this type of audit is longer than that of preliminary audits. The results of these audits are more comprehensive and useful since they give a more accurate picture of the energy performance of the plant and more specific recommendation for improvements. The economic analysis conducted for the efficiency measures recommended typically go beyond the simple payback period and usually include the calculation of an Internal Rate of Return (IRR), Net Present Value (NPV), and often also Life Cycle Cost (LCC).

# Energy Audit Instrument

## ENERGY AUDIT INSTRUMENT

| S.No. | Name of the Instrument | Intended Use |
|---|---|---|
| 1. | Flue Gas Analysers | Used for optimizing the combustion efficiency by measuring/monitoring the oxygen and CO levels in flue gas of boilers, furnaces etc. and calculation of CO2 percentage in excess air level and efficiency. |
| 2. | Temperature Indicators | Used for measuring temperatures of gases/air, liquids, slurries, semi solids, powders etc. Using different types of probes. |
| 3. | Infrared Thermometers | Used for measuring temperatures from a distance using infrared technology. |
| 4. | Thermal Insulation scanner | Used for measuring loss of energy in Kcal per unit area from hot/cold insulated surfaces. The total loss can be obtained by multiplying the total surface under study. |
| 5. | Steam Trap Monitor | Used for performance evaluation of steam Traps. |
| 6. | Conductivity Meter | Used for on the spot water analysis of the amount of dissolved solids in water. |
| 7. | pH meter | Used for on the spot analysis of effective acidity or alkalinity of a solution/water. Acidity /alkalinity water. |
| 8. | Thermo-hygrometer | Used for measurement of air velocity & humidification, ventilation, Air-conditioning and refrigeration systems etc. |
| 9. | Thermo-hygrometer | Used for measurement of humidity and temperature and the calculation of dew point to find out the heat being carried away by out going gases in industries. Where product drying requires hot air. |

| | | |
|---|---|---|
| 10. | Ultrasonic Flow Meter | Used for measurement of flow of liquids through pipelines of various sizes through ultrasonic sensors mounted on the pipelines. |
| 11. | U-Tube Manometer | Used for measurement of differential pressure. |
| 12. | Digital Manometer | Used for measurement of differential pressure. |
| 13. | Visguage | Used for measurement of differential viscosity. |
| 14. | Used Lube Oil Test Kit | Used for testing lube oil. |
| 15. | Non-Contact Tachometer | Used for measurement of speed of rotation equipment. |
| 16. | Demand Analyser | Used for measurement and analysis of electrical load and demand control. |
| 17. | Power Analyser | Used for measurement and analysis of electrical Power. |
| 18. | Harmonic Analyser | Used for analysis of harmonics in power System. |
| 19. | Luxmeter | Used for measurement of illumination level. |
| 20. | Clip on Dig. Watt Meter | Used for measurement of power without interrupting the connections. |
| 21. | Clip on Dig. PF Meter | Used for measurement of power factor without interrupting the connection. |
| 22. | Clamp on amp. Meter | Used for measurement of current without Interrupting the connections. |
| 23. | Digital Multimeter | Used for measurement of voltage. Current and resistance. |
| 24. | Frequency Meter | Used for measurement of power supply frequency. |

## Definition & Objectives of Energy Management

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.

The term energy management means many things to many people. One definition of energy management is:

*"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"*
(Cape Hart, Turner and Kennedy, Guide to Energy Management Fairmont press inc. 1997)

Another comprehensive definition is:

"The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

The objective of Energy Management is to achieve and maintain optimum energy procurement and utilisation, throughout the organization and:

• To minimise energy costs / waste without affecting production & quality

• To minimise environmental effects.

**Energy Audit: Types and Methodology**

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions.

Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management programme.

As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

**Need for Energy Audit**

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction.

Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists.

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities.

Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

**Type of Energy Audit**

The type of Energy Audit to be performed depends on:

- Function and type of industry

- Depth to which final audit is needed, and

- Potential and magnitude of cost reduction desired

Thus, Energy Audit can be classified into the following two types.

I) Preliminary Audit

ii) Detailed Audit

**Preliminary Energy Audit Methodology**

Preliminary energy audit is a relatively quick exercise to:

• Establish energy consumption in the organization

• Estimate the scope for saving

• Identify the most likely (and the easiest areas for attention

• Identify immediate (especially no-/low-cost) improvements/ savings

• Set a 'reference point'

• Identify areas for more detailed study/measurement

• Preliminary energy audit uses existing, or easily obtained data

## Detailed Energy Audit Methodology

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre-Audit Phase

Phase II - Audit Phase

Phase III - Post Audit Phase

## A Guide for Conducting Energy Audit at a Glance

Industry-to-industry, the methodology of Energy Audits needs to be flexible.

A comprehensive ten-step methodology for conduct of Energy Audit at field level is presented below. Energy Manager and Energy Auditor may follow these steps to start with and add/change as per their needs and industry types.

## Ten Steps Methodology for Detailed Energy Audit

| Step No | PLAN OF ACTION | PURPOSE / RESULTS |
| --- | --- | --- |
| | Phase I –Pre Audit Phase | |
| Step 1 | • Plan and organise<br>• Walk through Audit<br>• Informal Interview with Energy Manager, Production / Plant Manager | • Resource planning, Establish/organize a Energy audit team<br>• Organize Instruments & time frame<br>• Macro Data collection (suitable to type of industry.)<br>• Familiarization of process/plant activities<br>• First hand observation & Assessment of current level operation and practices |
| Step 2 | • Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.) | • Building up cooperation<br>• Issue questionnaire for each department<br>• Orientation, awareness creation |
| | Phase II –Audit Phase | |
| Step 3 | • Primary data gathering, Process Flow Diagram, & Energy Utility Diagram | • Historic data analysis, Baseline data collection<br>• Prepare process flow charts<br>• All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution.<br>• Design, operating data and schedule of operation<br>• Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview) |
| Step 4 | • Conduct survey and monitoring | • Measurements :<br>Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data. |
| Step 5 | • Conduct of detailed trials /experiments for selected energy guzzlers | • Trials/Experiments:<br>- 24 hours power monitoring (MD, PF, kWh etc.).<br>- Load variations trends in pumps, fan compressors etc. |

| | | |
|---|---|---|
| | | - Boiler/Efficiency trials for (4 – 8 hours)<br>- Furnace Efficiency trials Equipments Performance experiments etc |
| Step6 | • Analysis of energy use | • Energy and Material balance & energy loss/waste analysis |
| Step 7 | • Identification and development of Energy Conservation (ENCON) opportunities | • Identification & Consolidation ENCON measures<br>• Conceive, develop, and refine ideas<br>• Review the previous ideas suggested by unit personal<br>• Review the previous ideas suggested by energy audit if any<br>• Use brainstorming and value analysis techniques<br>• Contact vendors for new/efficient technology |
| Step 8 | • Cost benefit analysis | • Assess technical feasibility, economic viability and prioritization of ENCON options for implementation<br>• Select the most promising projects<br>• Prioritise by low, medium, long term measures |
| Step9 | • Reporting & Presentation to the Top Management | • Documentation, Report Presentation to the top Management. |
| | Phase III –Post Audit phase | |
| Step10 | • Implementation and Follow-up | Assist and Implement ENCON recommendation measures and Monitor the performance<br>• Action plan, Schedule for implementation<br>• Follow-up and periodic review |

**Phase I -Pre-Audit Phase Activities**

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

**Initial Site Visit and Preparation Required for Detailed Auditing**

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

• Discuss with the site's senior management the aims of the energy audit.

• Discuss economic guidelines associated with the recommendations of the audit.

• Analyse the major energy consumption data with the relevant personnel.

• Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.

• Tour the site accompanied by engineering/production

**The main aims of this visit are: -**

• To finalise Energy Audit team

• To identify the main energy consuming areas/plant items to be surveyed during the audit.

• To identify any existing instrumentation/ additional metering required.

• To decide whether any meters will have to be installed prior to the audit e.g. kWh, steam, oil or gas meters.

• To identify the instrumentation required for carrying out the audit.

• To plan with time frame

• To collect macro data on plant energy resources, major energy consuming centres.

• To create awareness through meetings/ programme.

**Phase II- Detailed Energy Audit Activities**

Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

**The information to be collected during the detailed audit includes: -**

1. Energy consumption by type of energy, by department, by major items of process equipment, by end-use.
2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
3. Energy cost and tariff data
4. Process and material flow diagrams
5. Generation and distribution of site services (e.g., compressed air, steam).
6. Sources of energy supply (e.g., electricity from the grid or self-generation)

7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).

8. Energy Management procedures and energy awareness training programs within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baseline data:

- Technology, processes used and equipment details
- Capacity utilisation
- Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated
- Percentage rejection / reprocessing
- Efficiencies / yield

**Identification of Energy Conservation Opportunities**

**Fuel substitution:** Identifying the appropriate fuel for efficient energy conversion

**Energy generation:** Identifying Efficiency opportunities in energy conversion equipment/utility such as captive power generation, steam generation in boilers, thermic fluid heating, optimal loading of DG sets, minimum excess air combustion with boilers/thermic fluid heating, optimising existing efficiencies, efficient energy conversion equipment, biomass gasifiers, Cogeneration, high efficiency DG sets, etc.

**Energy distribution:** Identifying Efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, Etc.

**Energy usage by processes:** This is where the major opportunity for improvement and many of them are hidden. Process analysis is useful tool for process integration measures.

**Technical and Economic feasibility**

The technical feasibility should address the following issues

• Technology availability, space, skilled manpower, reliability, service etc

• The impact of energy efficiency measure on safety, quality, production or process.

• The maintenance requirements and spares availability

The Economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using a variety of methods. Example: Pay back method, Internal Rate of Return method, Net Present Value method etc. For low investment short duration measures, which have attractive economic viability, simplest of the methods, payback is usually sufficient. A sample worksheet for assessing economic feasibility is provided below:

**Sample Worksheet for Economic Feasibility**

**Name of Energy Efficiency Measure**

| i. Investment | 2. Annual operating costs | 3. Annual savings |
|---|---|---|
| a. Equipments<br>b. Civil works<br>c. Instrumentation<br>d. Auxiliaries | • Cost of capital<br>• Maintenance<br>• Manpower<br>• Energy<br>• Depreciation | • Thermal Energy<br>• Electrical Energy<br>• Raw material<br>• Waste disposal |

| Net Savings /Year (Rs./year) | Payback period in months |
|---|---|
| = (Annual savings-annual operating costs) | = (Investment/net savings/year) x 12 |

**Classification of Energy Conservation Measures**

Based on energy audit and analyses of the plant, a number of potential energy saving projects may be identified. These may be classified into three categories:

1. Low cost - high return;
2. Medium cost - medium return;
3. High cost - high return

Normally the low cost - high return projects receive priority. Other projects have to be analysed, engineered and budgeted for implementation in a phased manner. Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns, and may require careful scrutiny before funds can be committed. These projects are generally complex and may require long lead times before they can be implemented. Refer Table for project priority guidelines.

| PROJECT PRIORITY GUIDELINE | | | |
|---|---|---|---|
| **Priority** | **Economical Feasibility** | **Technical Feasibility** | **Risk / Feasibility** |
| **A - Good** | Well defined and attractive | Existing technology adequate | No Risk/ Highly feasible |
| **B -May be** | Well defined and only marginally acceptable | Existing technology may be updated, lack of confirmation | Minor operating risk/May be feasible |
| **C -Held** | Poorly defined and marginally unacceptable | Existing technology is inadequate | Doubtful |
| **D -No** | Clearly not attractive | Need major breakthrough | Not feasible |