green awareness

Electrical

Energy Efficiency

Plumbing

Protecting Our Future

Comfort Conditioning

Building Science

Second Edition

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ENERGY EFFICIENCY

COMFORT CONDITIONING

Green Awareness

2nd Edition

PLUMBING

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ELECTRICAL

BUILDING SCIENCE

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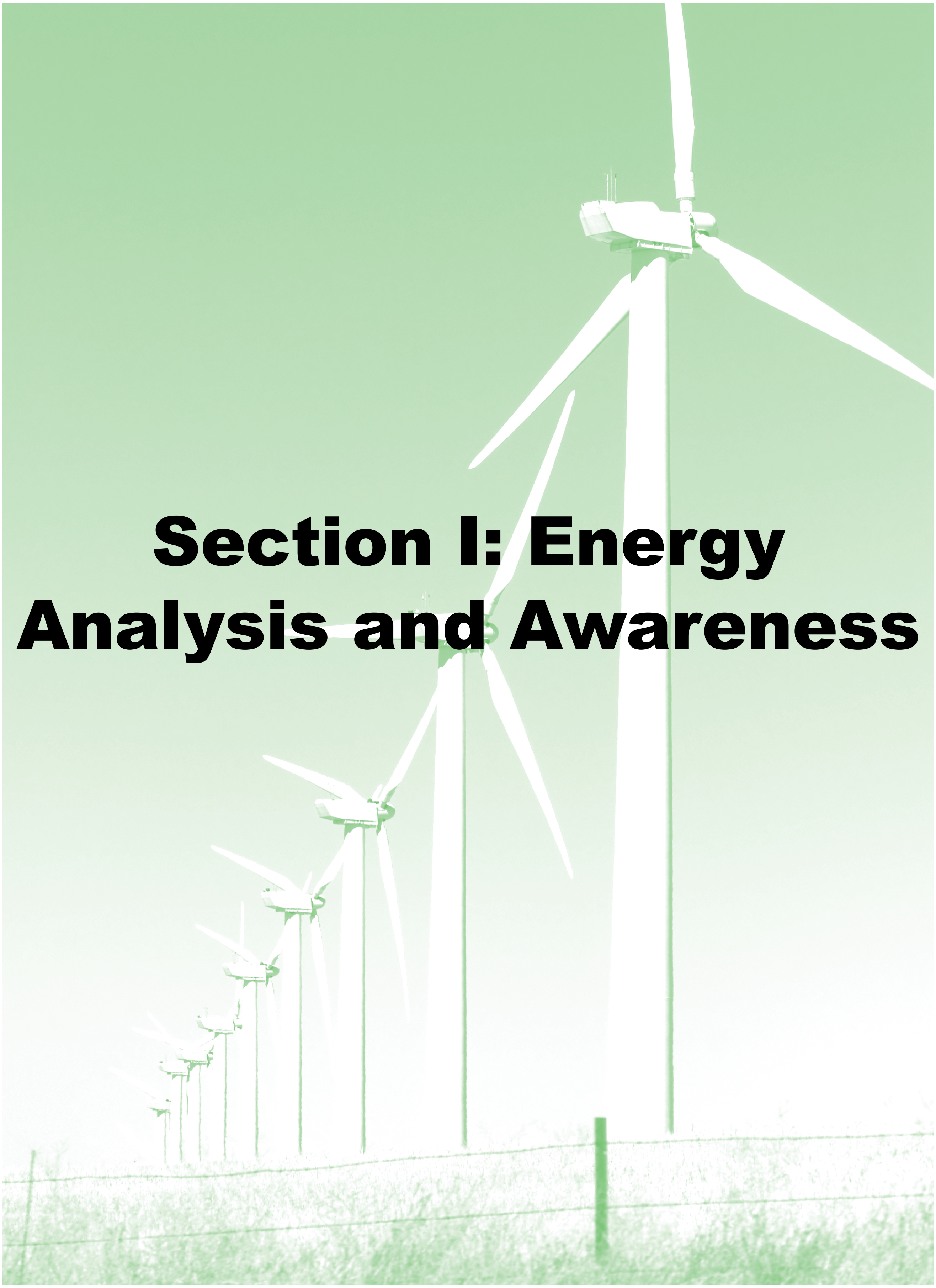
Table of Contents

Table of Contents

Table of Contents

Table of Contents



Section I: Energy Analysis and Awareness

Bioenergy

Bioenergy is renewable energy obtainable from organic materials derived from biological sources and stored sunlight. It is often a by-product, residue or waste product of agricultural processes and the processing of consumer waste.

Biomass is considered to be any material obtained from anything living or recently living (Figure 1-2). Living things that produce biomass can be as small as bacteria and as large as a tree. Bacteria and microorganisms produce gasses and reduce material to other usable products. Trees and other growing things produce products as a result of photosynthesis or the chemical process of growing.

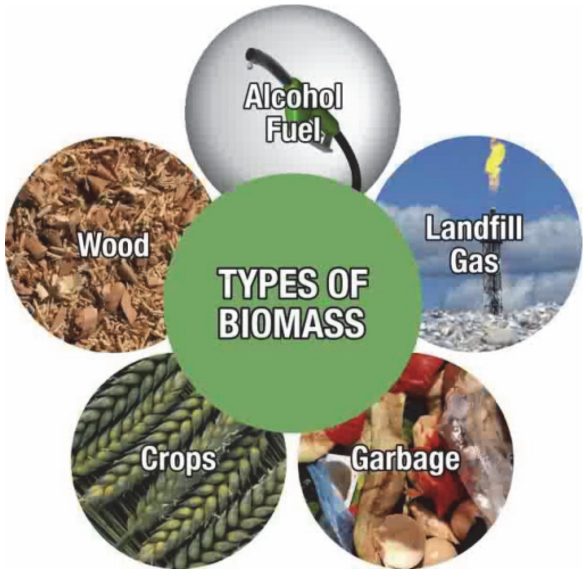


Figure 1-2: Types of Biomass

Nearly all organic materials degrade depending on factors found in nature, for example; microorganisms, water and sunlight. The question is how long do we want to wait for products to break down or degrade? The term "biodegrade" is an overused term that needs some additional explanation. The definition of the term biodegradable comes from a European organization that has developed several standards regarding products and their ability to biodegrade. The Organization for Economic Co-operation and Development (OEDC) has defined Biodegrade (or Biodegradation) as "the process by which organic substances are decomposed by microorganisms mainly **aerobic bacteria** into simpler substances such as carbon dioxide, water and ammonia."

Nearly everything ends up in waste systems. The types of energy which can be reclaimed from the waste materials depend on the degradation process. Post consumer waste is described as waste products that are produced after a product is purchased and used. Recycling can reduce the amount of waste going into a landfill. Some materials are acceptable; others tolerated; and some are not compatible with waste systems. It is important to understand that new materials are coming to the market. These new materials will have labels indicating their ability to biodegrade. Decisions concerning the compatibility of these materials in waste systems will need to be made at some point in the future once their behaviors are monitored and more data has been collected and evaluated.

NREL's 4R philosophy consists of reducing, reusing, recycling, and re-buying as many materials as possible. The total resources are shown in Figure 1 -3.

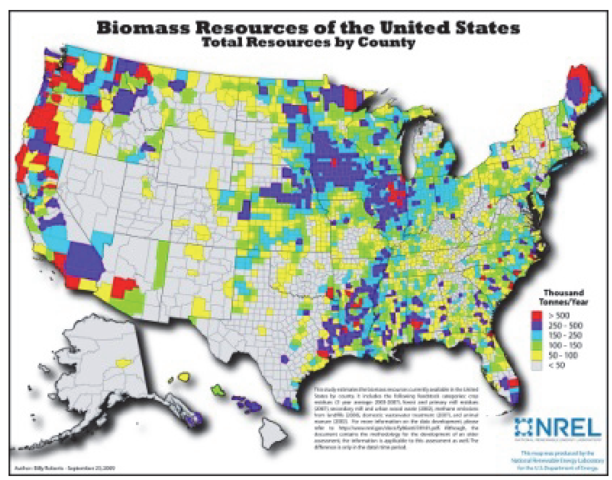


Figure 1-3: U.S. Biomass Resources

REDUCE. Reduction of post-consumer waste can be done at any time products are being used, installed, upgraded, or replaced. Reuse the backside of paper in the office for printing drafts. Print using fast draft printing to save ink. Reducing post-consumer waste has the effect of reducing the amount of refuse in landfills. In addition, the amount of energy and other resources used as a result can also be reduced.

consuming devices based on energy rates and *peak demand* times or periods.

Environmental Impact

Consciously planning when and how much energy is consumed during different rate times can have a significant impact on utility bills and reduce strain on the electrical grid during peak times.

Commercial and industrial customers, either after a power outage or before a planned start-up, can reduce energy cost by avoiding the simultaneous restart of all the equipment.

Energy consumption and demand analysis evaluates the present energy usage and energy demands of a building, industry or complex, especially the peak demand times or periods. Many or most electrical utilities charge the commercial and industrial consumers according to the peak demand of electrical energy used. These peak demand periods can be re-scheduled or the energy can be spot purchased from various sources in time slots. The Energy Consumption and Demand Analysis Report provides this information to management for consideration and implementation. The report should include an equipment efficiency review of how the electrical energy is being purchased and consumed (Figure 1-15).

Evaluation of Energy Consumption: All energy consuming equipment within a structure should be analyzed. The data collected from equipment nameplates, manufacturer's specifications, etc. is the baseline information on how a piece of equipment should utilize energy. The next step is to determine the typical operating conditions of the equipment. Operating conditions can have a major impact on the energy efficiency of equipment. The actual operational efficiency should be compared to the baseline data. This comparison may rationalize replacement or upgrade of equipment.

The cost of electrical energy for commercial use is determined by peak demand and kilowatt hours. If all major energy-consuming devices are allowed to start up simultaneously, the demand of the starting load will very likely increase the rate per kilowatt hour for the entire billing cycle.

More information can be found at: www.eia.doe.gov

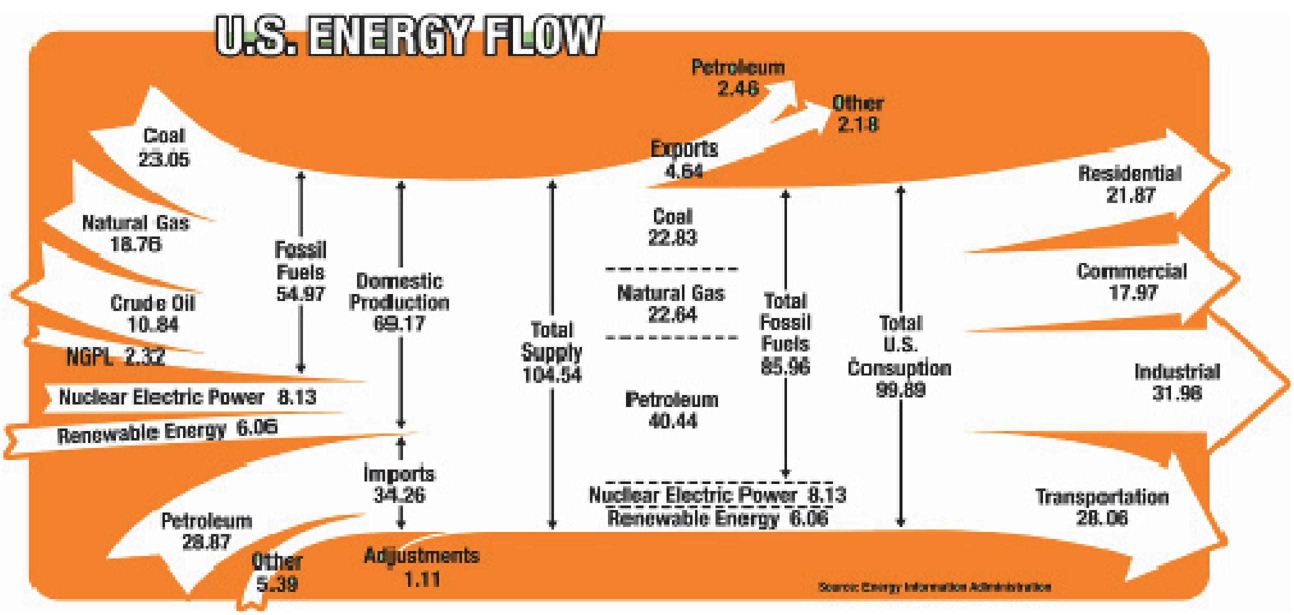


Figure 1-15, U.S. Energy Flow

Section II: Building Science

comfortable temperature. and also be able to maintain this temperature.

Insulation is made of many different materials each having its own thermal resistance properties. The thermal resistance of a substance is referred to as its R-value and is based on a material thickness of 1 inch. The R-value of a particular insulation material varies with thickness and density. Compressing a piece of insulation to make it fit into a wall cavity, for example, will result in the lowering of the effective R-value of the insulation. R-values are cumulative, so adding additional layers of insulation on top of other insulation will result in higher effective R-values. Consider a wall that has an R-value of 15 and the homeowner decides to add additional sheathing with an R-value of 4 to the shell of the structure. The effective R-value for the wall will now be 19.

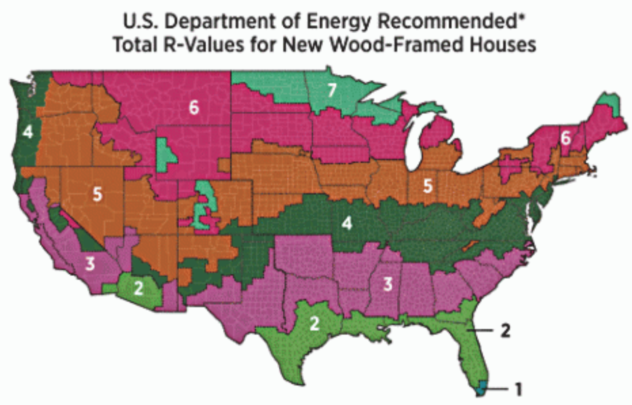
Although adding more insulation sounds like a great idea in all instances, a point will be reached where the cost of making walls thicker and continuing to add more insulation outweighs the benefit and is no longer cost effective in an effort to reduce heat transfer.

Fenestration (Windows and Doors)

According to ASHRAE, a fenestration is any area which allows light to pass through an external wall of a building. Fenestration is commonly referred to as any opening, usually glazed, in a building envelope such as windows, skylights, and doors. Fenestration affects building energy usage through four basic mechanisms: thermal heat transfer, solar heat gain, air leakage, and daylighting.

Fenestration will gain or lose heat by:

- Direct conduction through the glass or glazing, frame, and/or door.
- The radiation of heat into a house (typically from the sun) and out of a house from room-temperature objects, such as people, furniture, and interior walls.
- Air leakage through and around them.



Zone	Attic	Cathedral Ceiling	Cavity	Insulation Sheathing	Floor
1	R-30 to R-49	R-22 to R-38	R-13 to R-15	None	R-13
2	R-30 to R-60	R-22 to R-38	R-13 to R-15	None	R-13
3	R-30 to R-60	R-22 to R-38	R-13 to R-15	None	R-25
4	R-38 to R-60	R-30 to R-38	R-13 to R-15	R-2.5 to R-6	R-25 to R-30
5	R-38 to R-60	R-30 to R-38	R-13 to R-15	R-2.5 to R-6	R-25 to R-30
6	R-49 to R-60	R-30 to R-60	R-13 to R-21	R-5 to R-6	R-25 to R-30
7	R-49 to R-60	R-30 to R-60	R-13 to R-21	R-5 to R-6	R-25 to R-30
8	R-49 to R-60	R-30 to R-60	R-13 to R-21	R-5 to R-6	R-25 to R-30

Figure 2-9: Recommended R-Values.

Windows are a critical component of a heat load calculation, particularly in retrofit or replacement applications. The use of glazing and shading strategies to control solar heat gain to supplement heating through **passive solar gain** and minimize cooling requirements are potential energy effects of fenestration. There is the added benefit of using day lighting to help reduce electrical lighting requirements as well.

New installations of comfort conditioning systems should be subjected to all of the performance tests applicable to the specific type of appliance as a standard start-up and commissioning protocol for new equipment. This testing will verify that the new equipment is operating as designed by the manufacturer. Existing installations should undergo continued performance verification testing to ensure that the appliances continue to operate as designed. When testing documents show an existing installation is no longer operating as designed, a tune-up should be conducted to restore the appliance to its designed operational status.

Life Cycle Cost Analysis

The **Life Cycle Assessment** or **Life Cycle Cost Analysis** (LCCA) should be understood before you specify or install products and systems.

The initial cost of a product or system, coupled with the expense of installation is frequently 10% or less of the total Life Cycle Cost. The remaining 90% of the cost includes the estimated lifetime power / fuel consumption and maintenance costs. Using LCCA to evaluate the cost of projects aids the builder or owner in making decisions that affect the total future cost. Cost may include an entire site complex or just a specific building system component.

Note: It is important to understand that if mechanical equipment is not maintained properly, the operating and repair costs will increase to more than the Life Cycle Cost Analysis prediction.

Life cycle assessment is an evaluation of the materials and resources used in building manufacturing processes utilizing a cradle-to-grave methodology. The cradle-to-grave process estimates and evaluates life cycle cost over the life expectancy of raw materials from the point at which they are compiled until they are returned back to the earth. Conversely, **cradle-to-cradle** is the continued use and reuse of a product and has little or no environmental impact. (Figure 2-14)

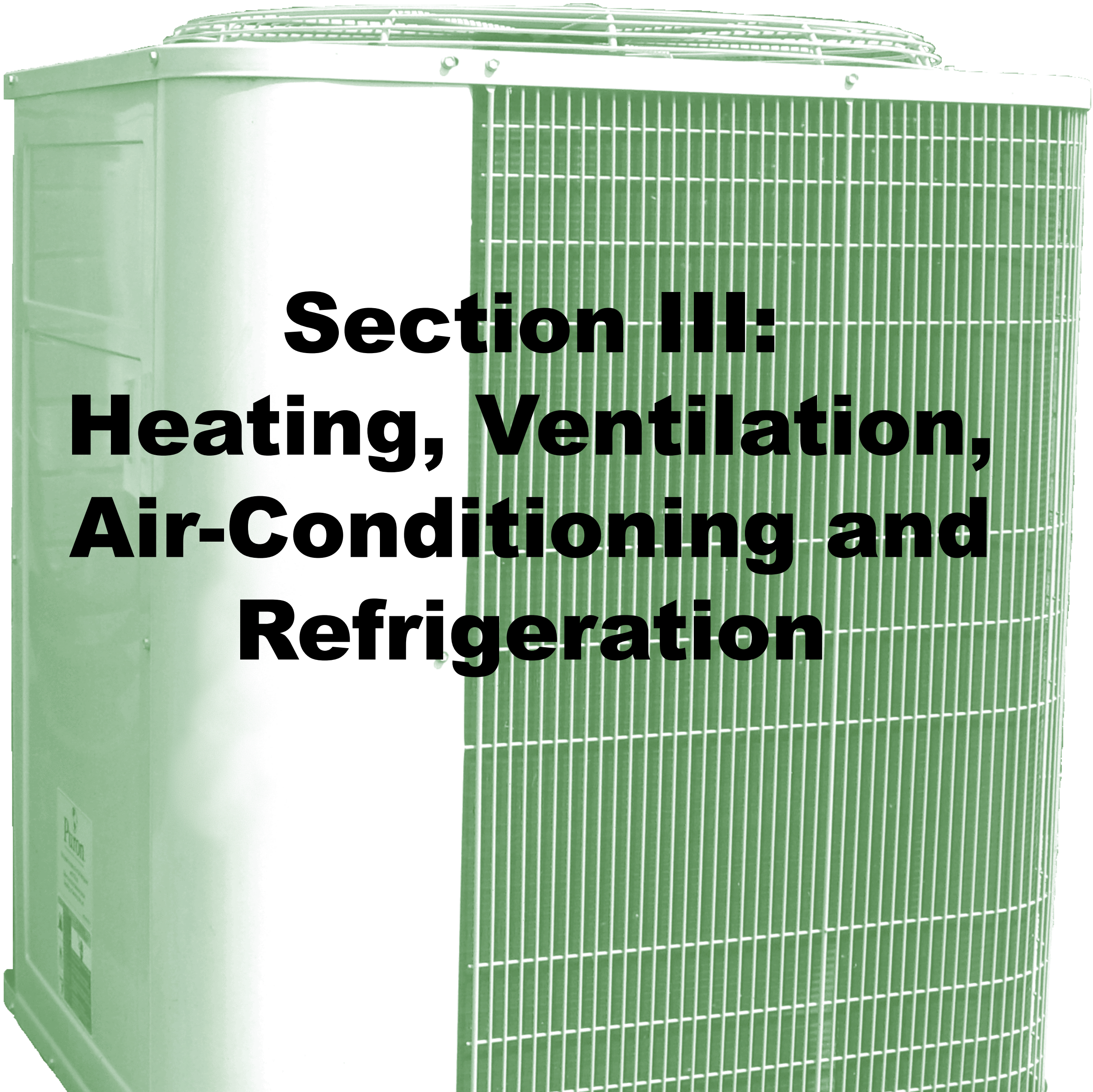
Environmental Impact

Cradle-to-grave and cradle-to-cradle evaluations provide insight into total cost expenditures over the lifetime of a product or mechanical system. Utilizing this information to improve the efficiency and longevity of products and mechanicals is of great benefit to the environment through improved product design, efficiency and recyclability.

	Performance test					
Appliance type	Temperature Rise	Fuel Pressure	Combustion Analysis	Air flow	Gas Meter Clocking	Electrical Tests
Gas Furnace	*	*	*	*	*	*
Oil Furnace	*	*	*	*		*
Electric Furnace	*			*		*
Gas Boiler	*	*	*		*	*
Oil Boiler	*	*	*			*
Electric Boiler	*					*
Gas Water Heater	*	*	*		*	*
Oil Water Heater	*	*	*			*
Electric Water Heater	*					*

Figure 2-13: Equipment Testing.

Section III: Heating, Ventilation, Air-Conditioning and Refrigeration



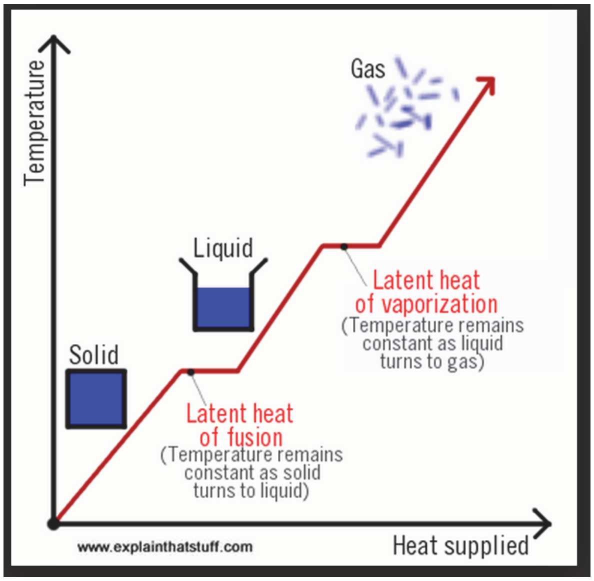


Figure 3-6: Water Properties.

Evaporative Cooling

When water changes state it "evaporates" from a liquid to a vapor. 970 Btus of latent heat energy is absorbed for every pound of water that is evaporated (Figure 3-6). The source of this heat is the water that remains behind and, as a result, the temperature of the water drops. The amount of temperature drop depends on the amount of moisture in the air. The lower the relative humidity of the air, the more moisture will be evaporated, and the greater the cooling effect. Evaporative cooling systems work best in climates with low humidity such as the American Southwest.

In operation, water is pumped over a pad through which the dry outdoor air passes. As the warm air passes through this pad, some of the water evaporates and cools the airstream. This airstream is then introduced to the space to be cooled (Figure 3-7). Since water is constantly evaporating from the evaporative cooler, there must be provisions for providing make-up water to the unit.

Two-Stage, or Cascade, Evaporative Cooling

To adapt evaporative coolers to geographic areas with higher humidity levels, there was a need to

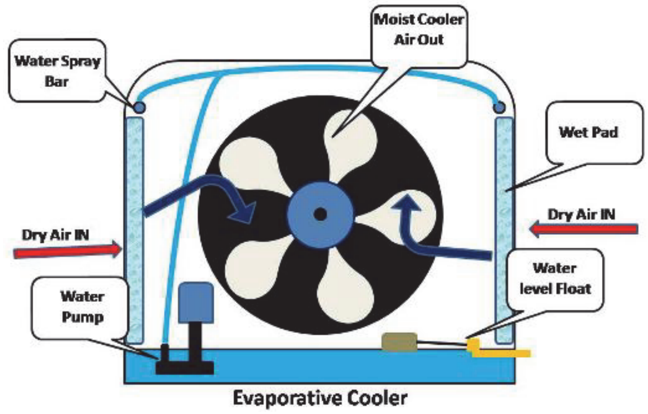


Figure 3-7: Evaporative Cooler Parts.

redesign the basic, single-stage, evaporative cooling system.

Two-stage, evaporative coolers produce less humidity compared to traditional single-stage evaporative coolers. The two-stage systems have two heat exchangers, one dry and one wet (Figure 3-8.). The warm outdoor air passes first through the dry heat exchanger, which is often described as an indirect evaporative cooling (IEC) heat exchanger. The air passing through the heat exchanger is separated from the wet pad, so no moisture is added to the airstream in the first stage. So, during the first stage of cooling, the temperature of the air is reduced and, as a result, the relative humidity of the air increases without actually adding moisture to the air.

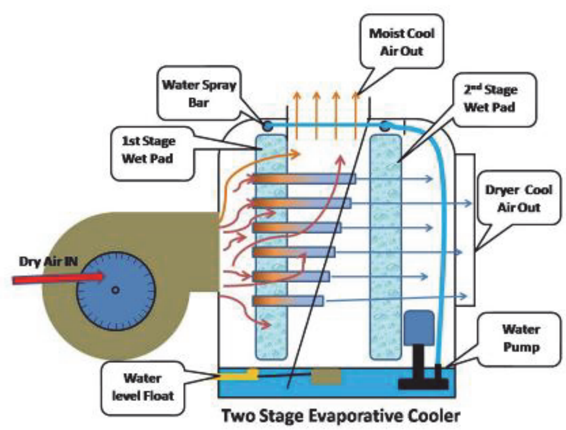


Figure 3-8: Two Stage Evaporative Cooler Parts.

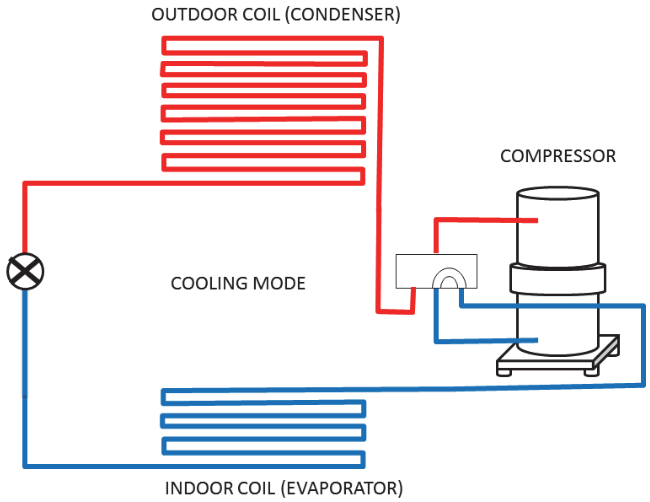


Figure 3-37. Geothermal Heat Pump in Cooling Mode

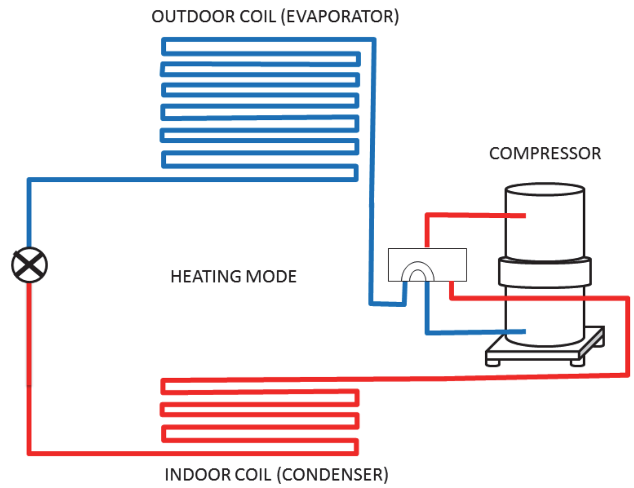


Figure 3-38. Geothermal Heat Pump in Heating Mode.

evaporator. In order to effectively transfer heat, refrigerants are used. Refrigerants have the ability to readily change between the liquid and vapor states and, in doing so, absorb and reject large amounts of heat. The system's evaporator absorbs heat into the refrigerant making the surrounding area colder. The system's condenser transfers the heat to the surrounding area making it warmer.

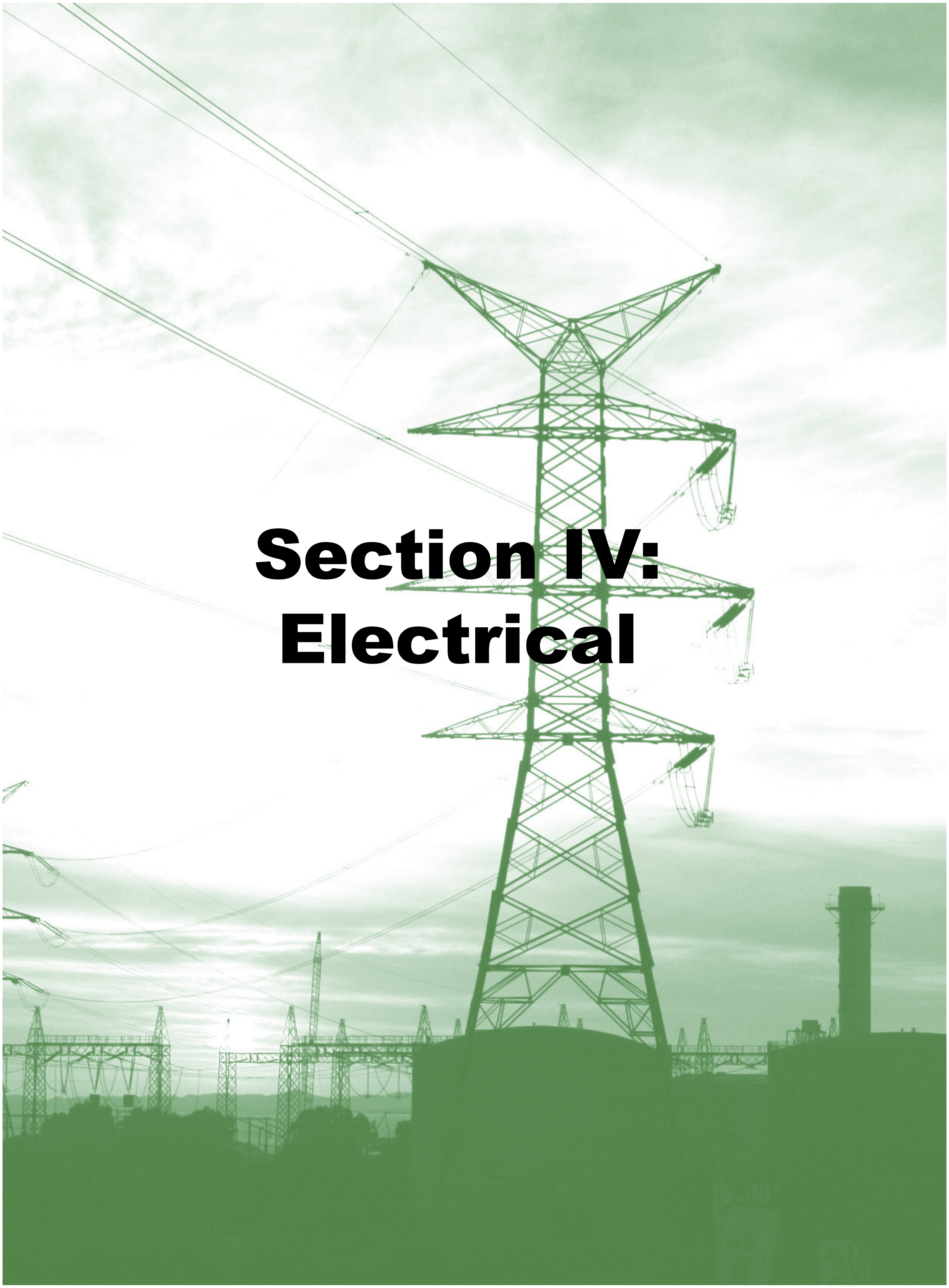
Heat pump systems use these same basic components, but also use a reversing valve to control the flow of refrigerant, switching the operation of the heat exchangers. In the cooling mode, the outdoor coil operates as the condenser, while the indoor coil operates as the evaporator (Figure 3-37). In the heating mode, the outdoor coil operates as the evaporator, while the indoor coil operates as the condenser (Figure 3-38).

A geothermal system is a special type of heat pump system that utilizes the earth as both a heat sink and a heat source. The ground is a very large thermal mass and can be used to absorb unwanted heat from the space for comfort cooling. When used in this manner, the ground acts as a heat sink.

The ground can also be used as a heat source to transfer heat into homes and other structures during colder weather. Water in wells, lakes, ponds, etc. may also be used as heat sources and heat sinks in geothermal systems.

There are many varying designs of geothermal heat pumps. Geothermal units are among the most efficient heating and cooling systems currently available with the direct expansion being the most efficient. This is because the ground temperature is relatively constant year-round and these systems do not, generally speaking, require defrost. Compared to a comparable fossil fuel-fired heating system, the cost of operation is reduced by 66%. One major concern is the initial cost of installing a geothermal system. The installation cost can be 5 times the cost of a traditional heating and cooling system. These systems require qualified installation and set-up personnel. These systems may be coupled with solar panels to provide the required electrical energy source.

Section IV: Electrical



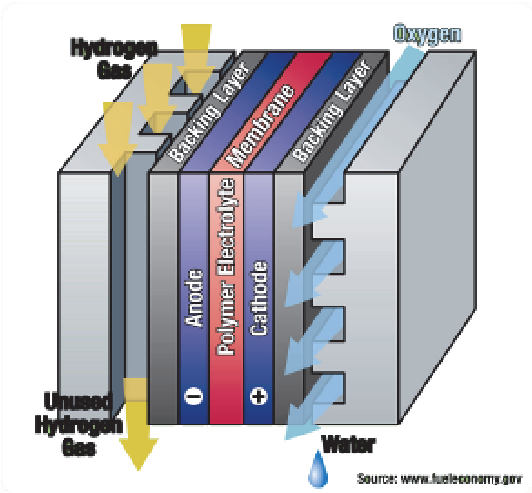


Figure 4-3: Fuel Cell Construction.

Comparison of Fuel Cell Technologies

Fuel cells can be arranged or stacked to produce the required voltage and current for larger applications, including automotive and commercial equipment. Fuel cells can be used as back-up power during natural disasters to power warehouses, critical communications centers, water supply systems, healthcare and hospital facilities. With support from the **U.S. Department of Energy (DOE)**, fuel cells for back-up power have been proving to be a very cost-effective use of the technology. As a result, the speed of market adoption has increased greatly. Fuel cell technologies have been advancing for centuries and will continue to do so until the "ultimate" energy source is found.

Regenerative fuel cells produce electricity from hydrogen and oxygen, while producing heat and water as by-products, just like all other fuel cells. However, regenerative fuel cell systems can use electricity from solar power or other sources to divide the excess water into oxygen and hydrogen gas. This process is called "electrolysis." This means the fuel cell continues to regenerate itself. This is a comparatively young fuel cell technology being developed by NASA and other organizations.

The major challenges in commercializing fuel cells are cost and durability. In transportation applications, these technologies face even higher price tags and durability difficulties.

Environmental Impact

A fuel cell will leave a much smaller carbon footprint than a fossil fuel combustion process. This is because it uses a chemical process to operate that does not contribute to global warming. This makes fuel cells environmentally friendly.

Photovoltaic (PV) Technology

The word "photovoltaic" combines two terms, photo and voltaic. Photo comes from "phos" meaning light and "volt" meaning voltage. A photovoltaic system uses photovoltaic cells to directly convert sunlight into electricity.

Photovoltaic cells , also referred to as solar cells, produce direct current (DC) electricity. To power most common household items, a power inverter must be used to convert the DC voltage to 60 cycle AC voltage.

Photovoltaic technology is used to power street lighting, NASA satellite equipment, calculators, watches, roadside signs, and even provide power to the electrical grid. The uses for photovoltaic energy are limitless, in addition to being environmentally friendly, clean, quiet and, for the most part, an energy source that does not deplete natural resources. Solar or photovoltaic cells , when connected together electrically, form the solar panels or modules that are commonly seen on rooftops, ground level or mounted on tracking frames.

In today's PV technology there are two types of materials used to make solar cells: crystalline and amorphous silicon. Crystalline silicon cells are the oldest technology, developed 40 years ago. Some crystalline silicone solar panels are still in operation today, exhibiting outstanding longevity. Single crystal and polycrystalline are two sub-categories of crystalline cells.

Amorphous silicon technology for solar cells is economical to manufacture and offers greater flexibility, but will degrade with use and the efficiency is half that of crystalline cells. This type sufficient electrolyte for the lifetime of the cell. AGM batteries are approximately twice the price of flooded lead acid batteries. AGM batteries are lighter in weight and have a higher power output than lead acid batteries as they can be discharged and recharged faster.

Gel batteries use silica to thicken the electrolyte solution into a gel. Gel batteries must be charged at a slower rate than flooded or AGM batteries. Gel batteries require less maintenance in that the electrolyte does not boil off as easily as flooded batteries, eliminating the need to top off the battery.

Nickel Cadmium batteries are fast-charging even after long storage periods, and can be charged thousands of times with correct maintenance. These batteries are economically priced and are available in a wide range of sizes. Nickel cadmium batteries should not be disposed of in landfills due to the toxicity of the cadmium.

Lithium-Ion batteries have electrodes made of lithium and carbon. These batteries have no memory, which means complete discharging is unnecessary before recharging. Lithium-ion batteries can be discharged and charged a few thousand times before failure.

Wind Turbines

Wind turbines are different from windmills. A windmill coverts kinetic energy produced from the wind into usable mechanical energy that can be used for a number of purposes that include pumping water or grinding grain. The terms "wind energy" or "wind power" describe the process by which the wind is used to generate electricity. The wind acts on the blades causing them to turn. The blades are connected to a low-speed shaft that is connected to a gear box, which connects to a high-speed shaft. This high-speed shaft turns a generator, producing electricity. (Figure 4-6)

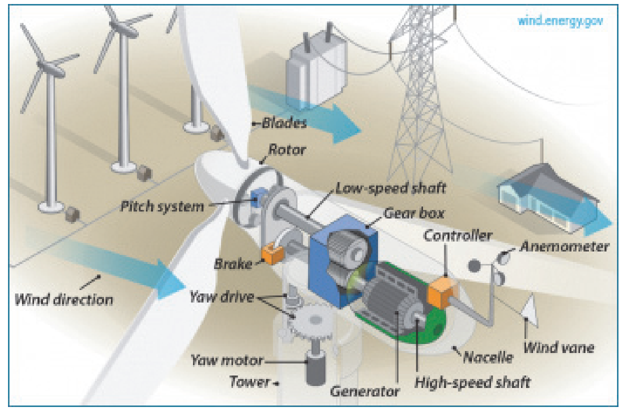


Figure 4-6: Anatomy of Wind Turbine

Environmental Impact

*Wind energy does not generate pollution or greenhouse gases. Wind turbines convert **kinetic energy** from the wind into mechanical power, which is then converted into electrical power. The electricity generated is used to power electrical devices in homes, businesses, schools, etc.*

Wind energy is available in all parts of the world; it is a free, renewable resource that will always be available from nature.

Wind speed is a critical feature of wind resources. This is because the energy in wind is proportional to the cube of the wind speed. Stronger winds equate to more power. In order for a wind turbine to work effectively, wind speeds need to be above 7-1/2 miles per hour. Increasing the wind speed one mile per hour increases the amount of power derived from a wind turbine by a factor of three. Wind speed can exceed a turbines capacity. Controlling speed using brakes and/or changes in the pitch of the blades prevent wind turbines from turning too fast.

Wind turbines can produce both alternating current (AC) and direct current (DC). DC wind turbines are generally used to produce electricity for storage in batteries, whereas AC wind turbines are used for immediate use or sold to the grid.

The use of a wind turbine for a specific application requires a match between the amount of electrical

Section V: Plumbing

energy consumption. Copper piping is a great choice for use since it is totally recyclable. However, increased copper costs has led to the use of other materials such as polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC) and cross-linked polyethylene (PEX) piping. PEX piping can be a simpler material to use and is readily available in the smaller sizes allowable in the manifold system. Plumbing codes and manufacturer's installation requirements should be adhered to.

One common installation practice to be avoided concerning PEX tubing is the bundling of hot and cold tubing together. Doing so can lead to heat transfer between the cold-water and hot-water tubing defeating the purpose of using the manifold system altogether.

Protection of the Water Distribution System

An efficient and sound water distribution system installation requires protection from damage due to cross-connections or possible backflow. Damage to the water distribution system can occur from water hammer or thermal expansion, causing system leaks and possible premature water heating equipment failure. This will lead to losses of potable water and increased energy costs. Cross-connections can lead to the contamination and loss of potable water and possible health hazards.

Water hammer most commonly occurs when the flow of moving water is suddenly stopped by a rapidly closing valve. Flushometer and other electronically actuated valves often cause water hammer. The sudden stop of water flow results in a tremendous pressure spike behind the valve, which acts like a tiny explosion inside the pipe. This pressure spike can reverberate throughout the water distribution system, rattling and shaking pipes, until the pressure dissipates. A sufficient pocket of air will be able to absorb such a pressure spike, however, if no pocket of air is present, faucets, fixtures and appliances can be damaged when left to absorb this pressure spike. The damage will usually be in the form of leaking faucets, appliances, and water closets. The water heating equipment may develop faulty temperature and pressure relief valves.

The most effective means of controlling water hammer is to provide a measured, compressible cushion of air, which is separated from the water system . These devices are called water hammer arresters (Figure 5-34). One model of arrester shown employs a pressurized cushion of air and a two-O-ring piston. When the valve closes and the water flow is suddenly stopped, the pressure spike pushes the piston up in the arrester chamber against the pressurized air pocket. The air pocket in the arrester reacts instantly, absorbing the pressure spike that causes water hammer. Many styles of water hammer arresters

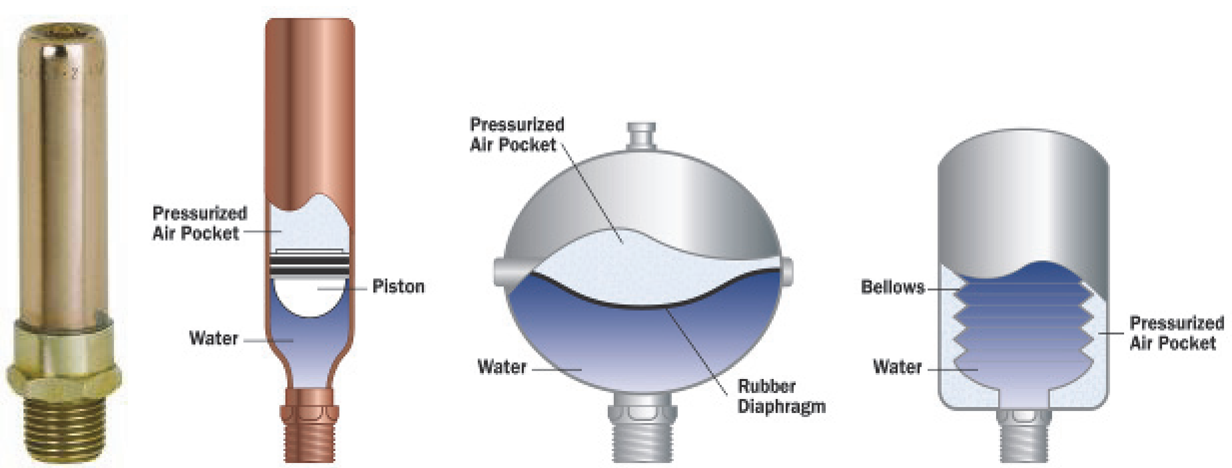


Figure 5-34: Types of Water Hammer Arresters.

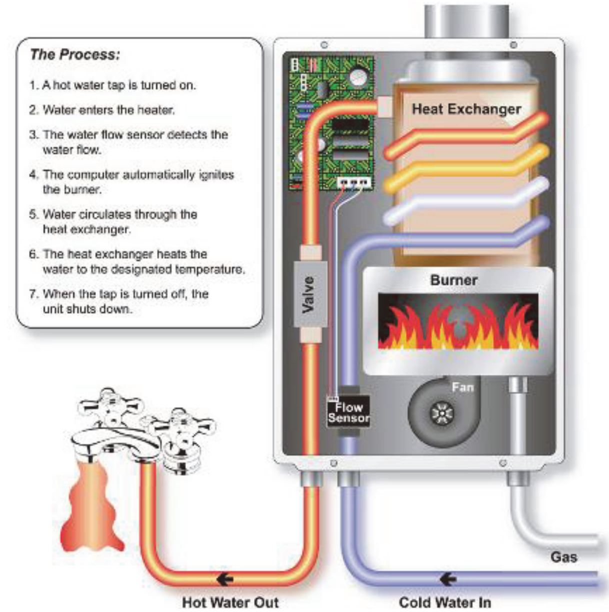


Figure 5-38: How a Tankless Water Heater Works.

losses. Large tankless water heaters are normally natural gas systems requiring venting of the products of combustion (Figure 5-38). They can provide hot water for large installations by being installed in series creating the ability to provide a large volume of hot water. Electric tankless systems are smaller and are normally for individual fixtures (Figure 5-39 & 5-40).

Figure 5-39: Electric Tankless Water Heater.

Heating water on demand requires less energy over time when compared to the energy required by tank type heaters over the same period of time with stand-by losses. During times when there is low or no hot water demand, tank-type heaters experience heat loss through the insulating jacket of the tank. Most residential water heaters expend energy to heat and maintain water temperature when the house is empty. At times

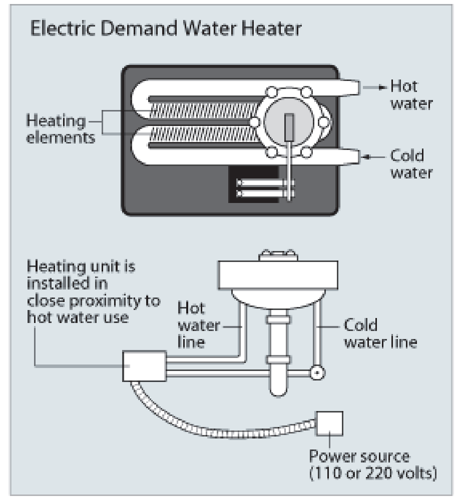


Figure 5-40: Electric Tankless Water Heater Connections.

when there is a large demand, tank-type systems may not keep up with the demand. Tankless water heaters solve these problems.

Heat Pump Water Heaters

Heat pump water heaters (Figure 5-41) are rarely installed in the U.S. Although heat pumps are normally associated with heating and cooling systems, a heat pump also can be used to heat water – either as a stand-alone water heating system, or as combination water-heating and space-conditioning system. A heat pump water heater can be two to three times more energy efficient than conventional electric resistance water heaters.

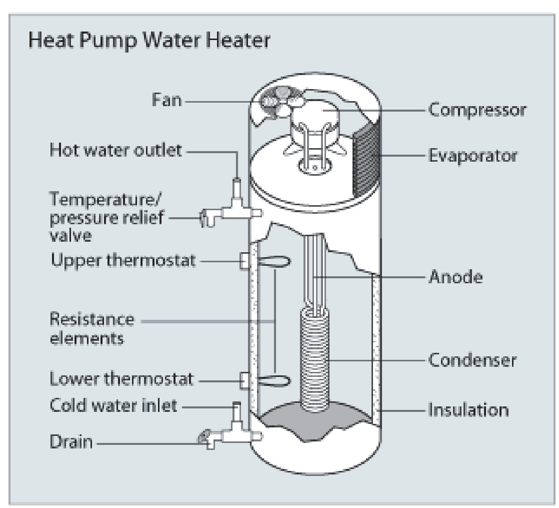


Figure 5-41: Heat Pump Water Heater.

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