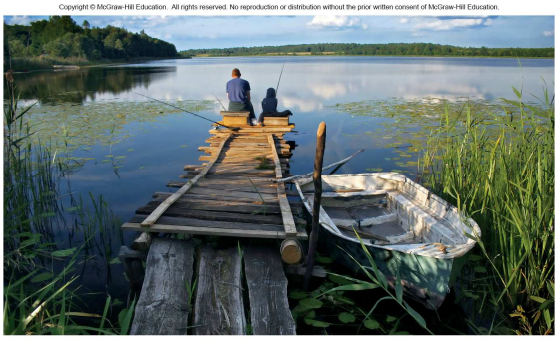
Chapter 4

Matter and Energy Resources: Types & Concepts

DISCLAIMER: Principles and concepts on atomic structure, the Periodic Table, atoms, ions, ionic and covalent compounds, metals, and nonmetals will not be covered in this course. You are expected to know this information from your previous Chemistry coursework.

Matter, Energy, and Life



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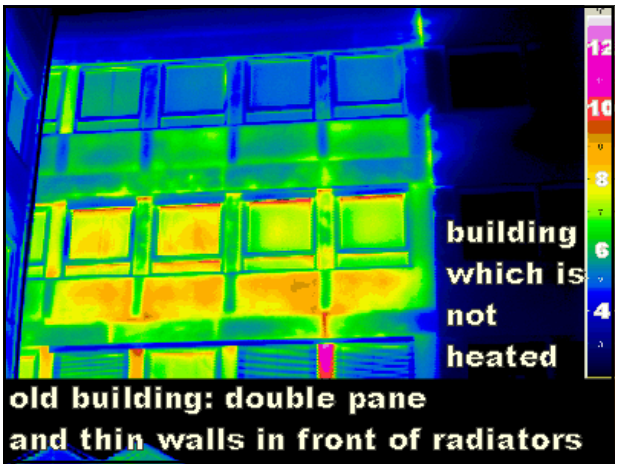
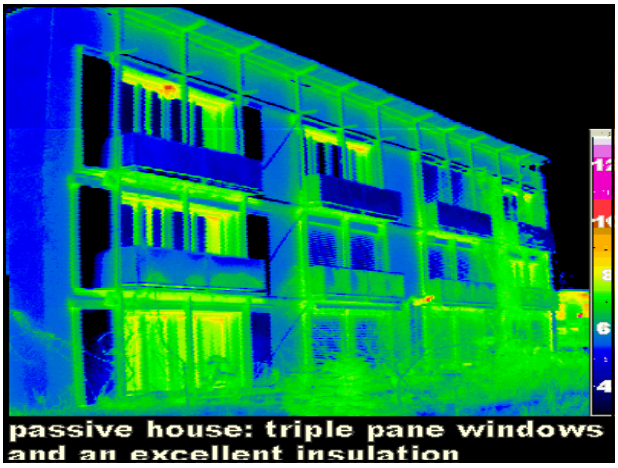
Outline

- Elements of Life
- Energy
  - Laws of Thermodynamics
- Energy for Life
  - Photosynthesis/Respiration
- From Species to Ecosystems
  - Food Webs
  - Ecological Pyramids
- Material Cycles
  - Hydrologic, Carbon, Nitrogen, Phsophorous





Introduction

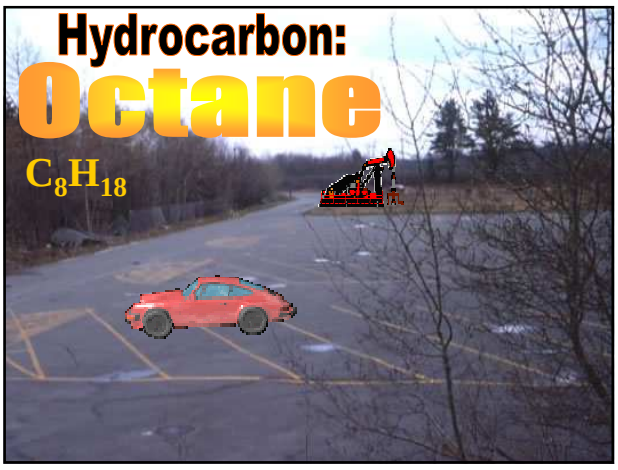
- Ecology is the scientific study of the relationship between organisms and their environment.
- At the core of the study of Ecology is a question about how matter and energy are exchanged between organisms and their surroundings. This chapter looks at matter and energy.

Elements of Life

- Matter - everything that has mass and takes up space
  - Solid - Liquid - Gas – Plasma = 4 states of matter
- Matter is neither created nor destroyed but rather recycled over and over. The atoms in your body may have been in a dinosaur.
- The idea that matter cannot be destroyed but is simply transformed from one form to another is the principle of Conservation of Matter.

Elements

- Matter consists of elements.
- Elements - substances that cannot be broken down into simpler forms by ordinary chemical reactions
  - 122 elements, just four (oxygen, carbon, hydrogen and nitrogen) make up 96% of the mass of living organisms.

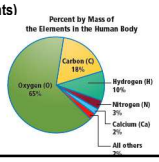


Elements of Life

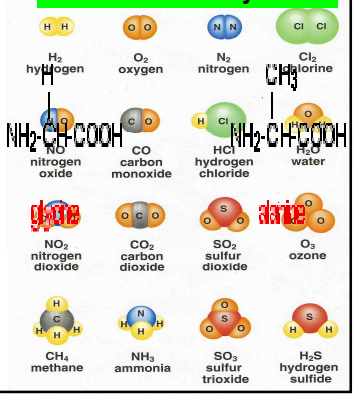
- All elements are composed of atoms.
- Atoms - smallest particles exhibiting characteristics of the element
- Atoms are composed of:
  - Protons (+) - Neutrons - Electrons (-)
  - Protons and neutrons are in the nucleus; electrons orbit the nucleus.
  - Atomic Number- Number of protons
  - Isotope - forms of an element differing in atomic mass due to the fact that the isotopes have different numbers of neutrons

Elements in Humans

- Oxygen (65%)
- Carbon (18%)
- Hydrogen (10%)
- Nitrogen (3%)
- Calcium (1.5%)
- Phosphorus (1.0%)
- Potassium (0.35%)
- Sulfur (0.25%)
- Sodium (0.15%)
- Magnesium (0.05%)
- Copper, Zinc, Selenium, Molybdenum, Fluorine, Chlorine, Iodine, Manganese, Cobalt, Iron (0.70%)
- Lithium, Strontium, Aluminum, Silicon, Lead, Vanadium, Arsenic, Bromine (trace amounts)



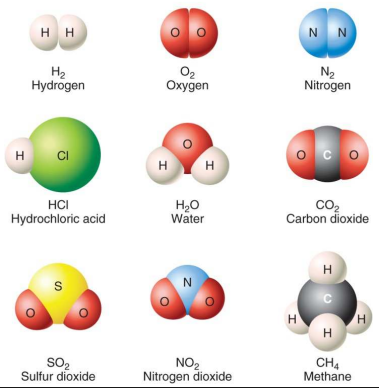
Common Compounds we'll talk about this year



Chemical Bonds

- Compound - substance composed of different kinds of atoms
  - Molecule - two or more atoms joined together
  - Chemical Bond - forces (chemical energy) holding atoms together in molecules
    - Ionic - Atoms with opposite charges (ions) form a bond, e.g., Na+ and Cl^- .
    - Covalent - atoms share electrons (but not always equally). For example, in water the oxygen attracts the electrons more strongly than the hydrogens do, so the hydrogens have a slight positive charge and the oxygen a slight negative charge.

Common Molecules



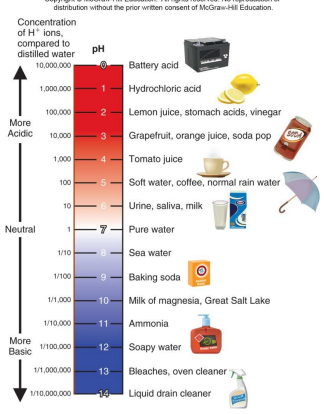
Oxidation and Reduction

- When an atom gives up one or more electrons, it is oxidized.
- When an atom gains electrons, it is reduced.
- Oxidation and reduction are an important part of how organisms gain energy from food.
- Forming bonds uses energy; breaking bonds releases energy.
- Activation energy is often needed to begin a reaction (e.g., match needed to start a fire).

Ions, Acids, and Bases

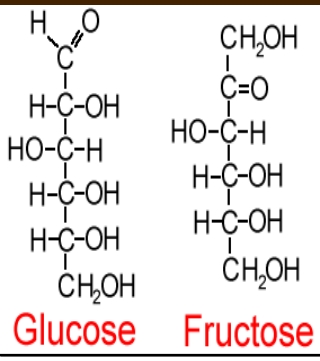
- Ions - atoms that have a positive or negative charge because they have more/less electrons than protons.
  - Anions have a negative charge.
  - Cations have a positive charge.
- Acids - substances that release hydrogen ions in water
- Bases - substances that readily bond with hydrogen ions
  - pH scale: 0 to 7 is acidic / 7 is neutral / 8 to 14 is basic

pH Scale



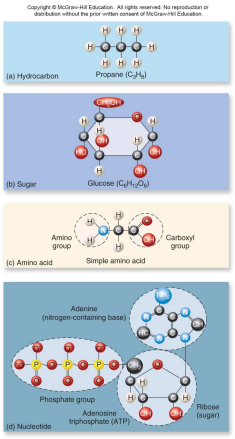
Organic Compounds

- ***organic compounds*** **– compounds of living things that contain carbon**
- **Four categories: carbohydrates, lipids, proteins, and nucleic acids.**



Organic Compounds

- Organic Compounds - Material making up biomolecules, which in turn make up living things.
  - All organic compounds contain carbon.
- Four major categories of organic compounds:
  - Lipids
  - Carbohydrates
  - Proteins
  - Nucleic Acids



High quality Matter
Organized, Concentrated, Found near Earth's Surface, Great Potential for use.

Low quality Matter
Disorganized, dilute, dispersed, little potential for use as a matter resource.

solid

gas

High quality Matter
Organized, Concentrated, Found near Earth's Surface, Great Potential for use.

Low quality Matter
Disorganized, dilute, dispersed, little potential for use as a matter resource.

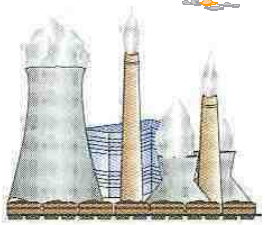
salt

solution of salt in water

High quality Matter
Organized, Concentrated, Found near Earth's Surface, Great Potential for use.

coal

Low quality Matter
Disorganized, dilute, dispersed, little potential for use as a matter resource.



coal-fired power plant emissions

High quality Matter
Organized, Concentrated, Found near Earth's Surface, Great Potential for use.

gasoline

Low quality Matter
Disorganized, dilute, dispersed, little potential for use as a matter resource.

automobile emissions

High quality Matter
Organized, Concentrated, Found near Earth's Surface, Great Potential for use.

aluminum can

Low quality Matter
Disorganized, dilute, dispersed, little potential for use as a matter resource.

aluminum ore

High quality Matter
Organized, Concentrated, Found near Earth's Surface, Great Potential for use.

Low quality Matter
Disorganized, dilute, dispersed, little potential for use as a matter resource.

Entropy – measure of the disorder or randomness of a system

Low Entropy
More Ordered

aluminum can

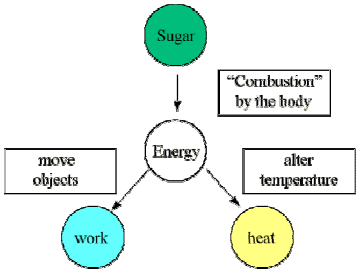
High Entropy
More disorder

aluminum ore

Entropy typically increases – it takes energy to reduce entropy.

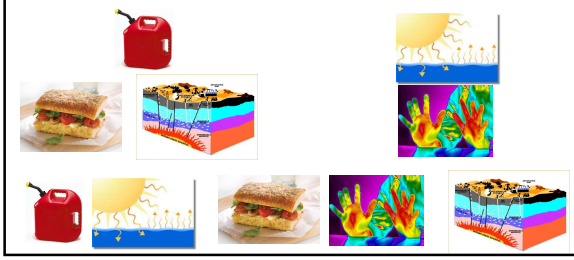
WHAT IS ENERGY?

ENERGY IS THE CAPACITY TO DO WORK AND TRANSFER HEAT.

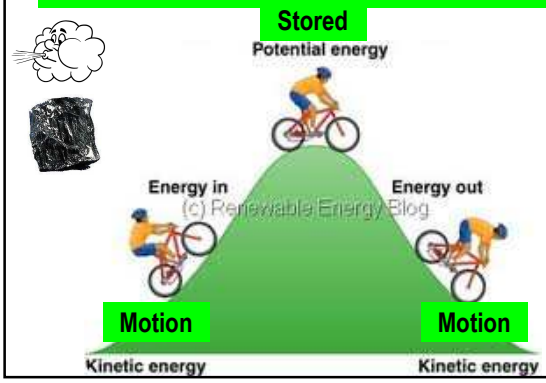


HIGH VS LOW QUALITY ENERGY

HIGH QUALITY	LOW QUALITY
ORGANIZED, CONCENTRATED, CAN BE USED TO DO WORK.	NOT CONCENTRATED, CAN BE USED FOR RADIANT HEATING



KINETIC AND POTENTIAL ENERGY



Energy

- Energy - ability to do work
  - Kinetic - energy in moving objects
  - Potential - stored energy
  - Chemical - stored in food or fossil fuels
- Heat - Energy that can be transferred between objects of different temperature. When a substance absorbs heat, the motion of its molecules increases and it may change state (e.g., a liquid may become a gas). Evaporation and condensation distribute heat around the globe.

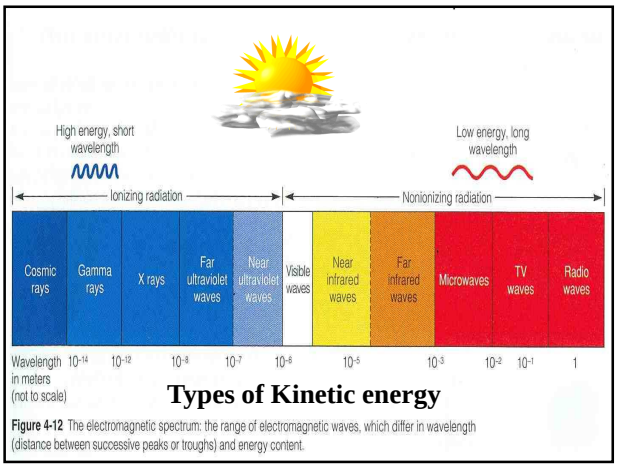


Figure 4-12 The electromagnetic spectrum: the range of electromagnetic waves, which differ in wavelength (distance between successive peaks or troughs) and energy content.

Thermodynamics

- Energy must be supplied (from the sun) to keep biological processes running, because as it flows through the various biological processes, it becomes dissipated.
- First Law of Thermodynamics - Energy is neither created nor destroyed (it is *conserved*).
- Second Law of Thermodynamics - With each successive energy transfer, less usable energy is available to perform work.
  - Entropy (disorder) increases.

Law of Conservation of Matter = matter is neither created or destroyed it is just rearranged into a different physical or chemical form.

Is this a violation of the law of conservation of matter?

Growth of a tree from seed

Energy for Life

- Ultimately, most organisms depend on the sun for the energy needed to carry out life processes.
- A few very ancient organisms called archaea are able to get their energy from inorganic compounds that bubble up from vents in the sea floor or from hot springs (chemosynthesis).
  - These organisms represent one-third of all the biomass on the planet.
  - The methane generated by these undersea communities could be a source of natural gas

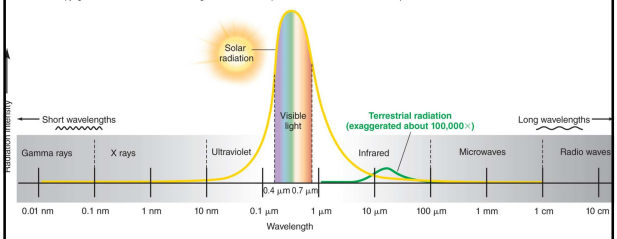
Energy from the Sun

- Solar energy is essential for two reasons:
  - Warmth - Most organisms can exist only in a relatively narrow temperature range.
  - Photosynthesis in plants
    - Radiant energy is transformed into useful, high-quality chemical energy in the bonds of organic molecules. Most life on Earth depends on photosynthesis.

Energy For Life

- Of all solar radiation reaching the earth's surface, about 10% is ultraviolet, 45% is visible, and 45% is infrared.
  - Most of this energy is absorbed by land or water, or reflected back into space.
  - Only about 1-2% of the sunlight falling on plants is captured for photosynthesis.

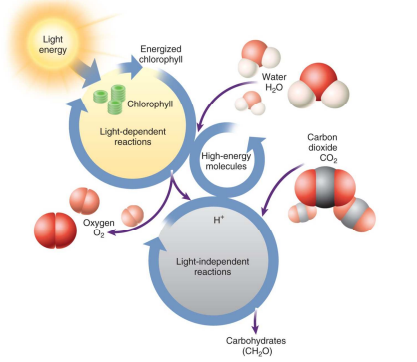
Electromagnetic Spectrum



Photosynthesis

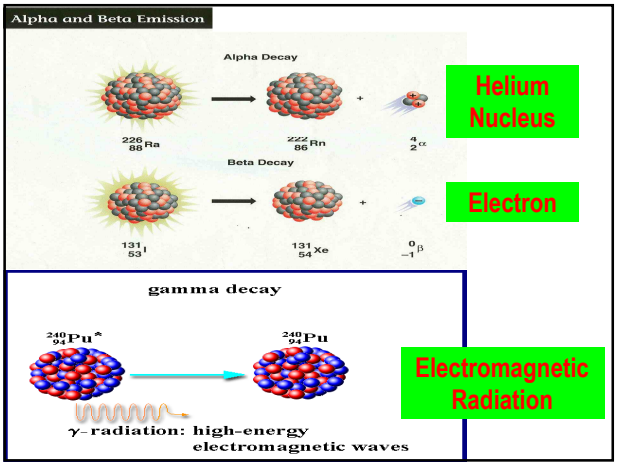
- Occurs in organelles called chloroplasts within plant cells ⇨
- $6\ H_20 + 6\ CO_2$ + solar energy $C_6H_{12}O_6 + 6O_2$
- Water and carbon dioxide in the presence of sunlight and chlorophyll (the green pigment in chloroplasts) yield glucose (sugar) and oxygen.
- Glucose serves as primary fuel for all metabolic processes. Energy in its chemical bonds can be used to make other molecules such as proteins, fuel cellular movement, or transport of ions across membranes.

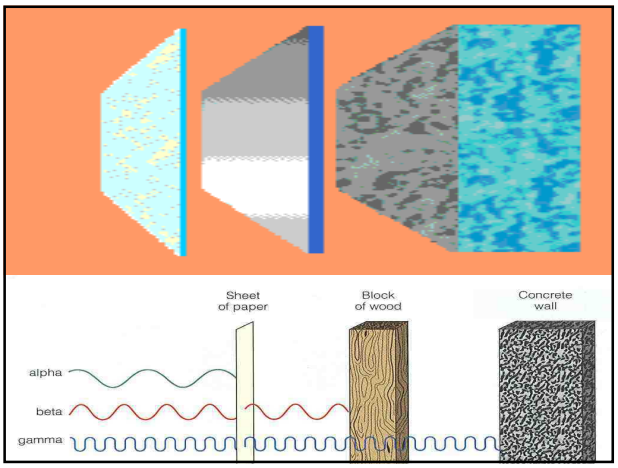
Photosynthesis



Cellular Respiration

- Photosynthesis captures energy, while cellular respiration releases energy.
- Cellular respiration splits carbon and hydrogen atoms from sugar and recombines them with oxygen to produce carbon dioxide and water (opposite of photosynthesis).
- This is how animals get all their energy. The reason that you need to breathe is to supply this pathway with oxygen.
  - $C_6H_{12}O_6 + 6\ O_2 \Rightarrow 6\ H_2O + 6\ CO_2 + \text{energy}$





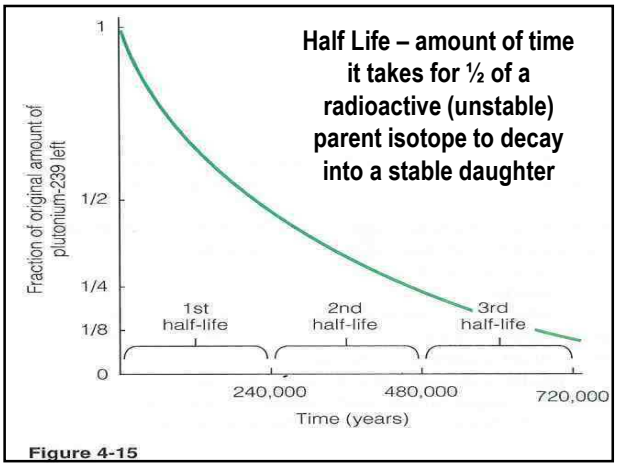


Figure 4-15

Table 4-1 Half-Lives of Selected Radioisotopes

Isotope	Half-Life	Radiation Emitted
Potassium-42		
Iodine-131		
Cobalt-60		
Hydrogen-3 (tritium)		
Strontium-90	28 years	Beta
Carbon-14		
Plutonium-239	240,000 years	Alpha, gamma
Uranium-235		
Uranium-238	4.5 billion years	Alpha, gamma

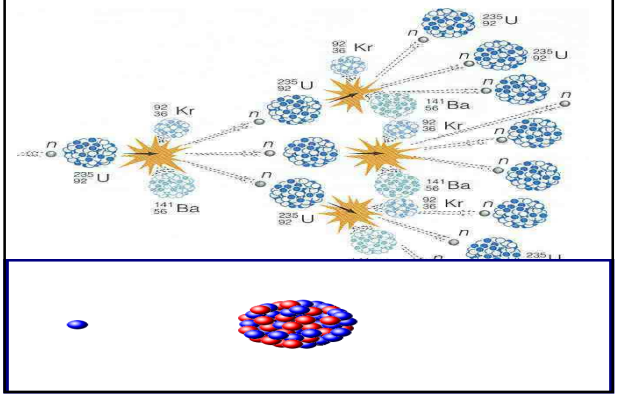
Used in Medicine as a Tracer

Used to sterilize spices and certain foods – kills bacteria and other pathogens.

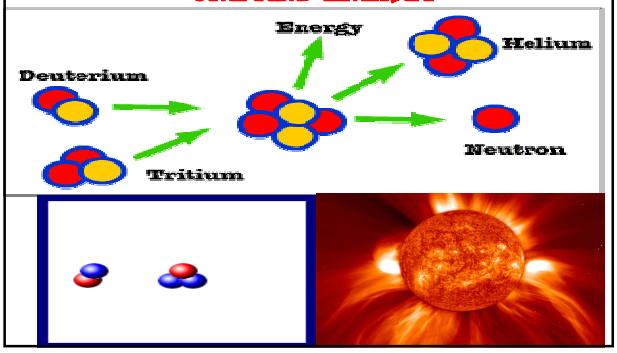
Used to date fossilized bones

Used for nuclear power generation

FISSION = SPLITTING OF AN ATOM



FUSION= SLAMMING TOGETHER TWO SMALLER ATOMS TO MAKE A LARGER ONE AND ENERGY



The Two Laws of Energy

First Law of Thermodynamics – during ordinary chemical reactions energy is conserved and only changes form

$$6\,CO_{2(g)} + 6\,H_2O_{(g)} \xrightarrow{\text{sun}} C_6H_{12}O_{6(s)} + 6\,O_{2(g)}$$

Second Law of Thermodynamics – as energy changes form, it becomes lower quality.

Heated wood releases gases

$$6C_{10}H_{15}O_7 + \text{Heat} \rightarrow C_{50}H_{10}O + 10CH_2O$$

(wood) (charred wood) (gas)

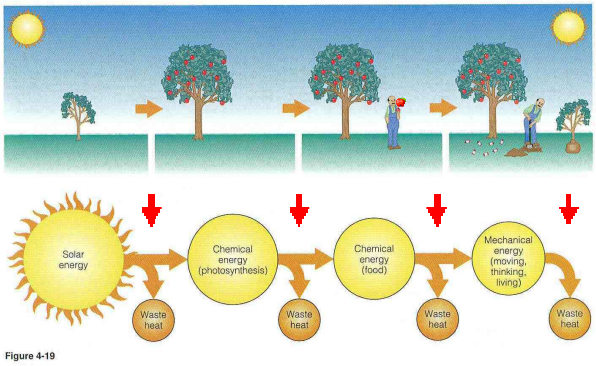
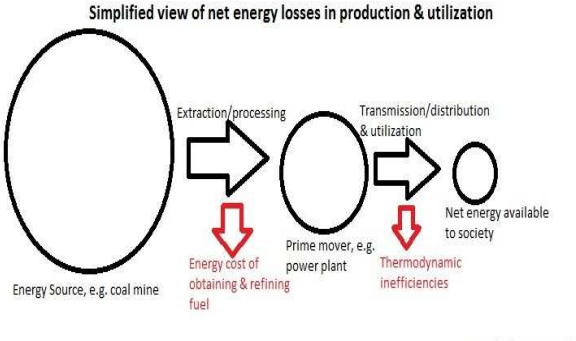


Figure 4-19

Second Law: Each time energy changes forms the energy is degraded to a lower quality; usually to waste heat.



High Waste Societies	***Matter Recycling Societies***	***Low Waste Societies***
High throughput of matter and energy for economic growth Problems – needs lots of matter, lots of energy, and produces lots of pollution.	Allow economic growth without depleting resources or producing excessive pollution. Problems – still takes energy to recycle, creates waste heat, materials can be recycled a limited number of times.	Shift from a society based on high throughput to a sustainable system. Goal – low matter use, low energy use, and low waste production for long term stability.