ANKARA UNIVERSITY
Department of Energy Engineering

Introduction to Basic Energy Concepts

INSTRUCTOR
Dr. Özgür SELİMOĞLU

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What is Energy ?

- The word ‘ENERGY’ itself is derived from the Greek word ‘en-ergon’, which means ‘in-work’ or ‘work content’.
- Energy is “the capacity to do work”. It is the power to create, shape, transform and animate. “work” is the action of moving something against a force. The work output depends on the energy input.
- In physics, energy is the quantitative property that must be transferred to an object in order to perform work on, or to heat, the object.
- Energy is always conserved (or converted into mass) so is incredibly useful in working out the results of any kind of physical or chemical process.
- It’s essential to modern life. We depend on energy.

- $\frac{1}{2} mv^2$
- mgh
- $P_{ext} \Delta V$
- $C_v \Delta T$
- I^2R
- $h\nu$
- mc^2

What is Energy ?

- We use energy to walk and bicycle, to move cars, move boats through water, to cook food on stoves, to make ice in freezers, to light our homes and offices, to manufacture products, and to send astronauts into space.
- There are many different forms of energy, including
  - Heat
  - Light
  - Motion
  - Electrical
  - Chemical
  - Gravitational
- These forms of energy can be grouped into two general types of energy for doing work:
  - Potential or stored energy
  - Kinetic or working energy

- $\frac{1}{2} mv^2$
- mgh
- $P_{ext} \Delta V$
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Table 1.1: Energy Form and Common Units

Energy Form	Energy Type: Transitional	Energy Type: Stored	Conversion
Electrical power: W, kW energy: kWh	electrical current	electrostatic field inductive field	• easy & efficient conversion to mechanical and thermal energy • easy, less efficient conversion to electromagnetic and chemical energy
Electromagnetic energy: eV	electromagnetic radiation	–	• easy, but inefficient conversion • photosynthesis is most common conversion process • there is no known stored form
Chemical energy/mass: kJ/kg energy/mol: kJ/kmol	–	chemical potential (+) exothermic (−) endothermic	• easily converted to thermal, electrical and mechanical energy • there is no known transitional form
Nuclear energy: MeV	–	atomic mass	• easily converted to mechanical energy, then into thermal energy • no known transitional form

Mechanical energy: ft·lbf, J power: hp, kW, Btu/hr	**work**	gravitational kinetic (inertia) elastic-strain flow potential magnetic	• easily converted to other forms of energy
Thermal energy: Btu, kJ, cal power: Btu/hr, W	**heat**	internal energy sensible heat latent heat	• inefficient conversion to mechanical and electrical energy • conversion limited by 2nd law of thermodynamics • all other forms are easily converted into thermal energy • thermal energy can be stored in everything

1) **Zeroth law of thermodynamics-** When two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
2) **First law of thermodynamics-** Heat and mechanical work are mutually convertible. **or** Energy can neither be created nor destroyed,it can transfer from one form to another.
3) **Second law of thermodynamics-** There is a definite limit to the amount of mechanical energy, which can be obtained from a given quantity of heat energy.

History of Energy

The history of energy consumption shows how important energy is to the quality of life for each of us.

- Before Industrial Revolution:
- For heat: sun and burned wood, straw, and dried dung were used
- For transportation: horses and the power of the wind in our sails were used.
- For work: animals were used to do jobs that we couldn't do with our own labor. Water and wind drove the simple machines that ground our grain and pumped our water.

Before Industrial Revolution

six different periods of societal development from oldest to most recent

Table 1-1
Historical Energy Consumption [Cook, 1971]

Period	Era	Daily per capita Consumption (1000 kcal)				
		Food	H & C*	I & A**	Trans.***	Total
Primitive	1 million B.C.	2				2
Hunting	100,000 B.C	3	2			5
Primitive Agricultural	5000 B.C.	4	4	4		12
Advanced Agricultural	1400	6	12	7	1	26
Industrial	1875	7	32	24	14	77
Technological	1970	10	66	91	63	230

* H & C = Home and Commerce
** I & A = Industry and Agriculture
*** Trans. = Transportation

personal energy consumption was relatively constant until the Advanced Agricultural period when it increased substantially.

Industrial Revolution (1750-1850)

- Machines replaced human/animal labor in manufacture and transportation

- Steam engines: heat energy into forward motion

- A single steam engine, powered by coal, could do the work of dozens of horses.

- Changes in agriculture, manufacturing, mining, transportation and technology ultimately affected social and economic conditions.

After Industrial Evolution

- Steam engines were soon powering locomotives, factories, and farm implements.
- Coal was also used for heating buildings and smelting iron into steel.
- In 1880, coal powered a steam engine attached to the world's first electric generator.
- Thomas Edison's plant in New York City provided the first electric light to Wall Street financiers and the New York Times.
- By the late 1800s, a new form of fuel was catching on: petroleum. By the turn of the century, oil, processed into gasoline, was firing internal combustion engines.
- Energy use grew quickly, doubling every 10 years.

Nowadays……

- The invention of the automobile
  - increased the demand for oil products

Within 200 years, energy consumption of industrialized nations increased eightfold.

- More cars
  - Job growth in automobile-related industries.
  - Major role in development of industrialized nations.
- Cars altered people's lifestyles:
  - Vacationers --greater distances.
  - People could live farther from work
    - Led to cities and suburbs.
    - labor-saving, energy-consuming devices became essential
    - Energy dependent

Energy Consumption and Standard of Living

- The energy consumption of a nation can be broadly divided into the following areas or sectors depending on energy-related activities:
-
  • Domestic sector (houses and offices including commercial buildings)
  • Transportation sector
  • Agriculture sector
- • Industry sector
- Consumption of a large amount of energy in a country indicates increased activities in these sectors. This may imply better comforts at home due to use of various appliances, better transport facilities and more agricultural and industrial production. All of this amount to a better quality of life. Therefore, the per capita energy consumption of a country is an index of the standard of living or prosperity (i.e. income) of the people of the country.

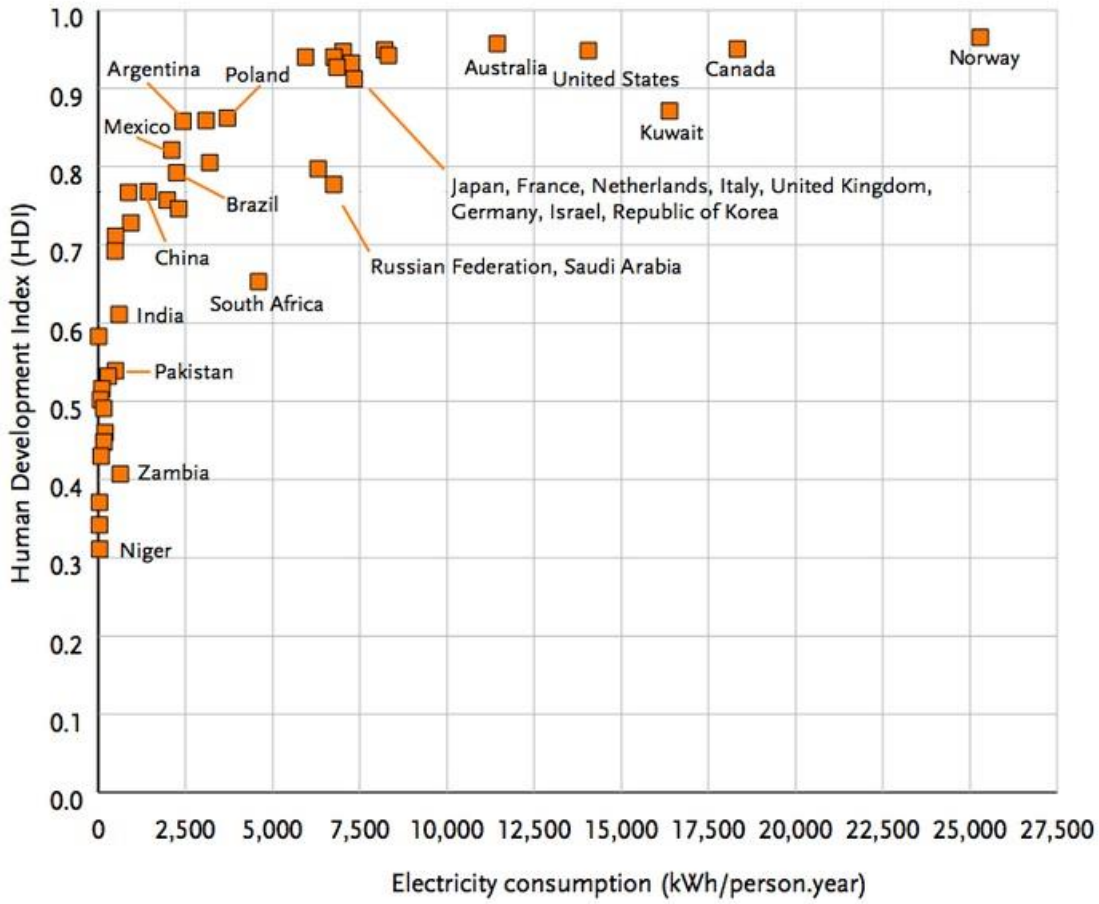
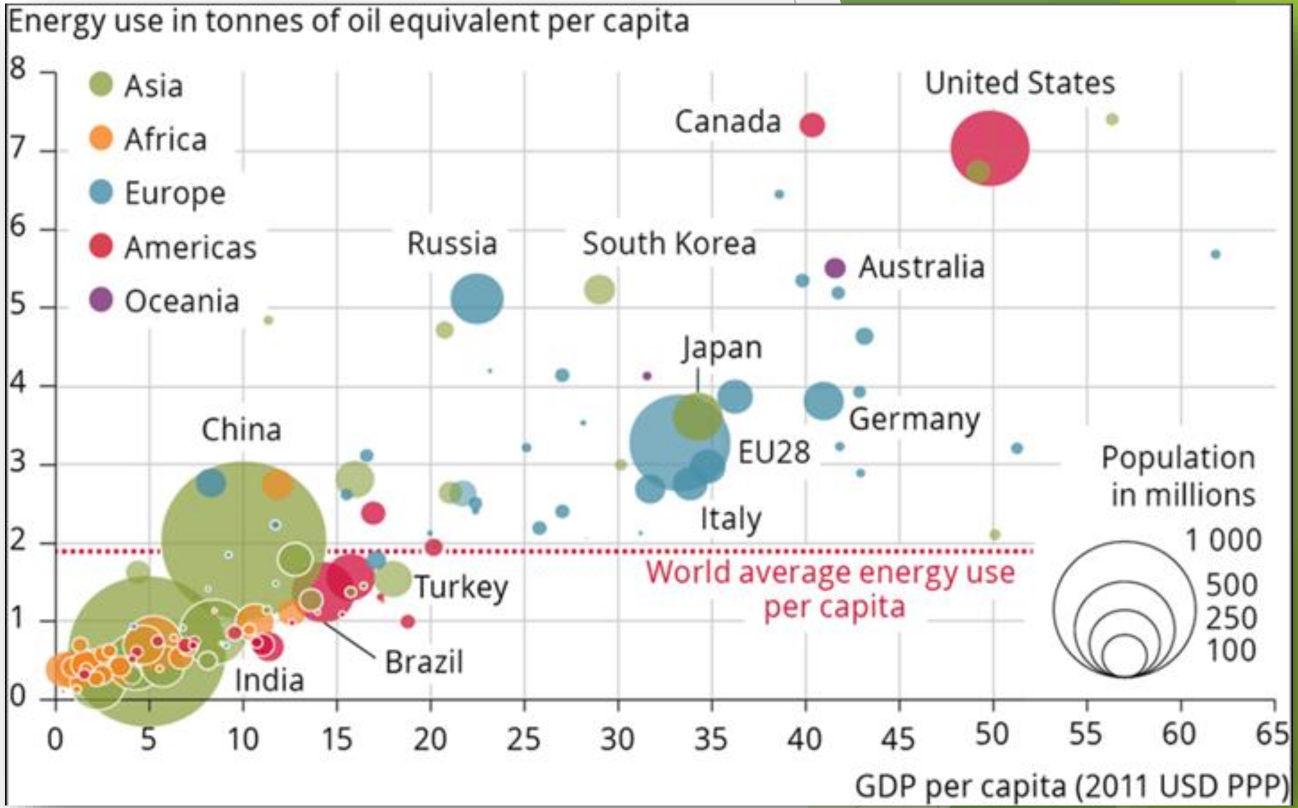


Figure 1.6 Relationship between human development index (HDI) and per capita electricity consumption, 2003 – 2004

Note: World average HDI equals 0.741. World average per capita annual electricity consumption, at 2,490 kWh per person.year, translates to approximately 9 gigajoules (GJ)/person.year [10,000 kilowatts (kWh) = 36 GJ]

Source: UNDP, 2006.



Energy Balance

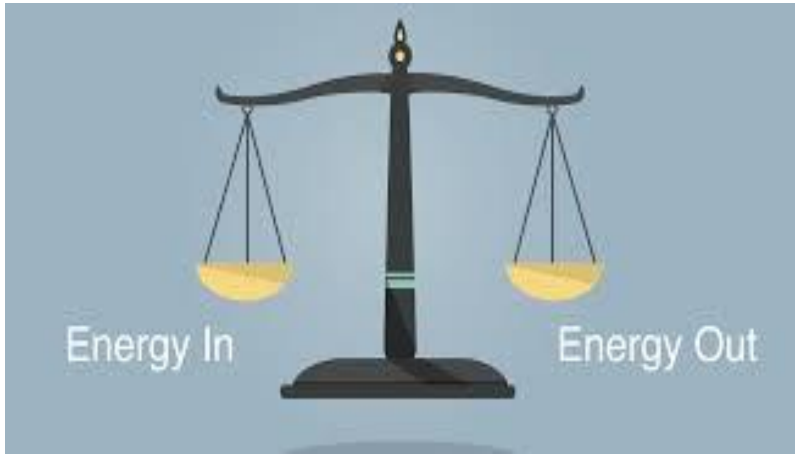
- An energy balance is a set of relationships accounting for all energy which is produced, transformed and consumed in a certain period. It can be set up for a village, a household, a farm, or an agricultural unit, region or a country.

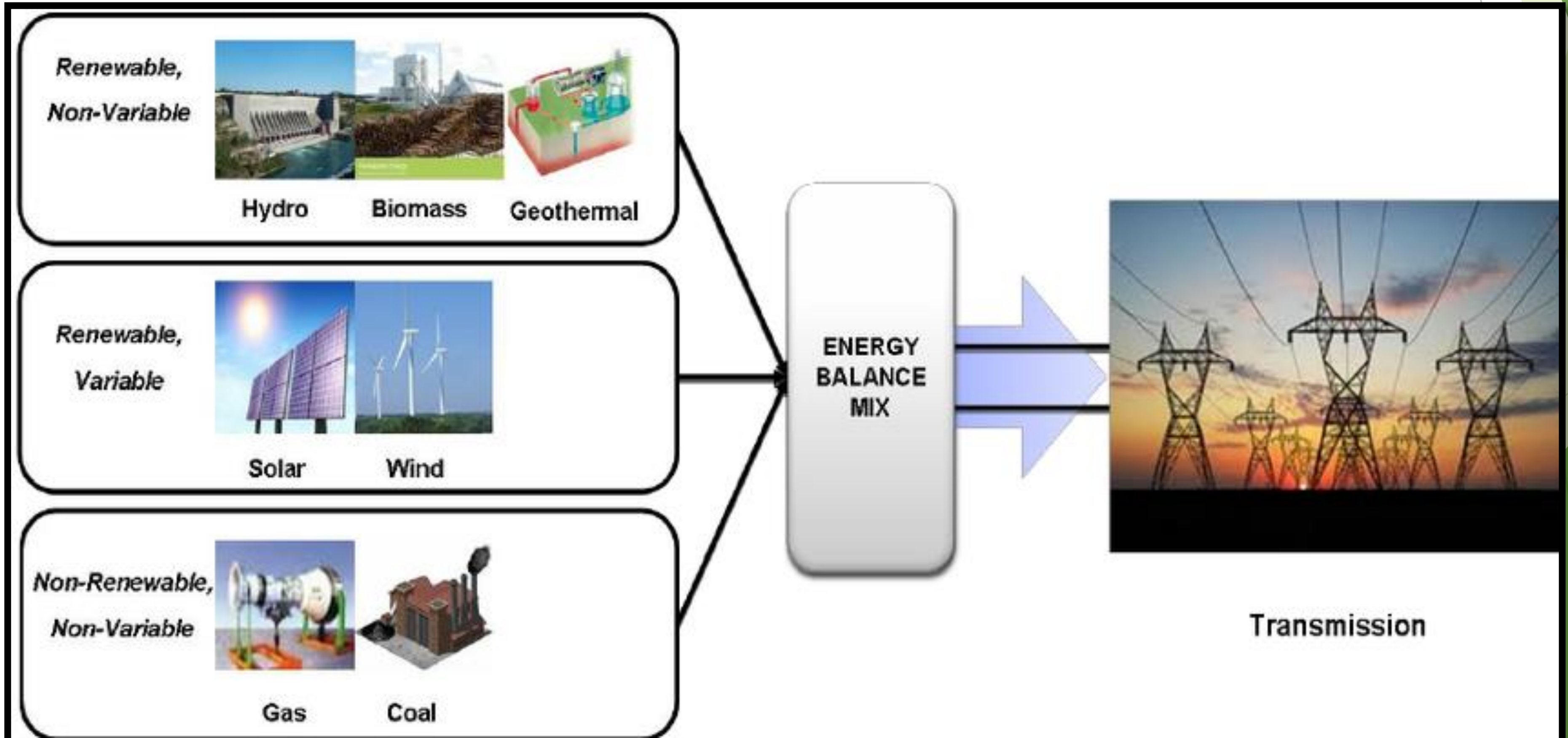
source + import = export + variation of stock + use + loss

Sources are the local (or national) primary energy sources, like coal, hydro, biomass, animate, etc.
Imports are energy sources which come from outside the region (or country).
Exports go to other regions (or countries).
Variations of stock are reductions of stocks (like of forests, coal, etc.), and storage.

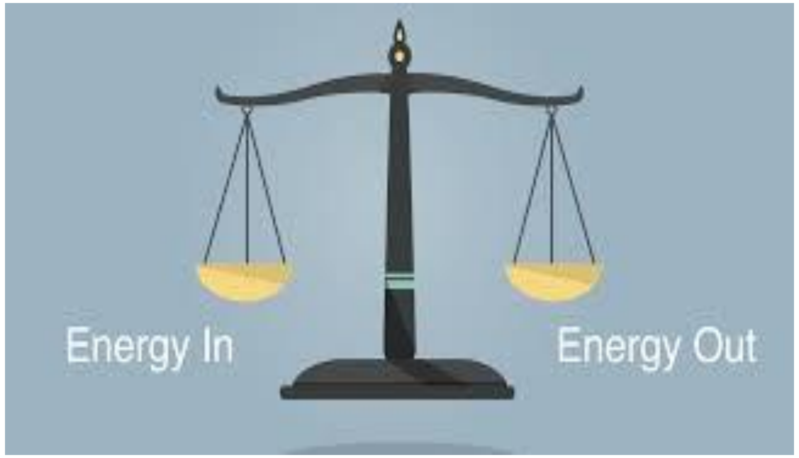
Use can be specified sectoral, or by energy form, or by end-use, etc., as required.
Losses:
*technical losses are due to conversions and transport or transmission
*administrative losses are due to non-registered consumptions.

Energy Balance





Energy Balance



- Energy balances provide overviews, which serve as tools for analyzing current and projected energy positions.
- Energy data are to be translated into economic terms, for a further analysis of options for action.
- It is useful for purposes of resource management, or for indicating options in energy saving, or for policies of energy redistribution, etc.

Basic Units and Dimensions

Quantity	SI-unit	Alternative units
Time	s (second)	h (hour)
Length	m (meter)	in (inch)
		ft (foot)
Mass	kg (kilogram)	lb (pound)
Temperature	K (Kelvin)	°C (Celsius)
		°F (Fahrenheit)
Force	N (Newton)	kp (kilopond)
Pressure	Pa (Pascal) = N/m^2	bar
		atm (atmosphere)
		mm Hg (millimeter mercury column)
		psi (pound per square inch)
Energy	J (Joule) = Nm	kWh (kilowatt hour)
		cal (calorie)
		Btu (British thermal unit)
Power	W (Watt) = J/s	calorie/h, Btu/h

Basic Units and Dimensions

- British thermal unit [Btu]: energy required to raise the temperature of 1 lbm of water at 68 Fahrenheit(F) by 1 F.
  - **1 Btu = 1055 J = 252 cal**
- Joule [J]: equivalent of 1 N of force exerted over a distance of 1 m.
  - **1 J = 0.2388 cal**
- calorie [cal]: energy required to raise the temperature of 1 g of water by 1 Celcius.
  - **1 cal =4.1868 J**
- horsepower [hp]: power of a typical horse in England during Watt's period to raise 33 000 lbm by 1 ft in 1 minute.
  - **1 hp = 746 W ; 1 hp.hr = 2.68 ×10^6 J = 0.746 kWh**

Basic Units and Dimensions

Table 2. Derived SI units

dimension	unit	symbol
area	square meter	m^2
volume	cubic meter	m^3
speed	meter per second	m/s
acceleration	meter per second	m/s^2
pressure	pascal	Pa (=N/m)
volume flow	cubic meter per second	m^3/s
mass flow	kilogram per second	kg/s
density	kilogram per cubic meter	kg/m^3
force	newton (*)	$N(=kg.m/s^2)$
energy	joule (**)	J(=N.m)
power	watt	W (=J/s)
energy flux	watt per square meter	W/m^2
calorific value	joule per kilogram	J/kg
specific heat	joule per kilogram kelvin	J/kg.K
voltage	volt	V (=W/A)

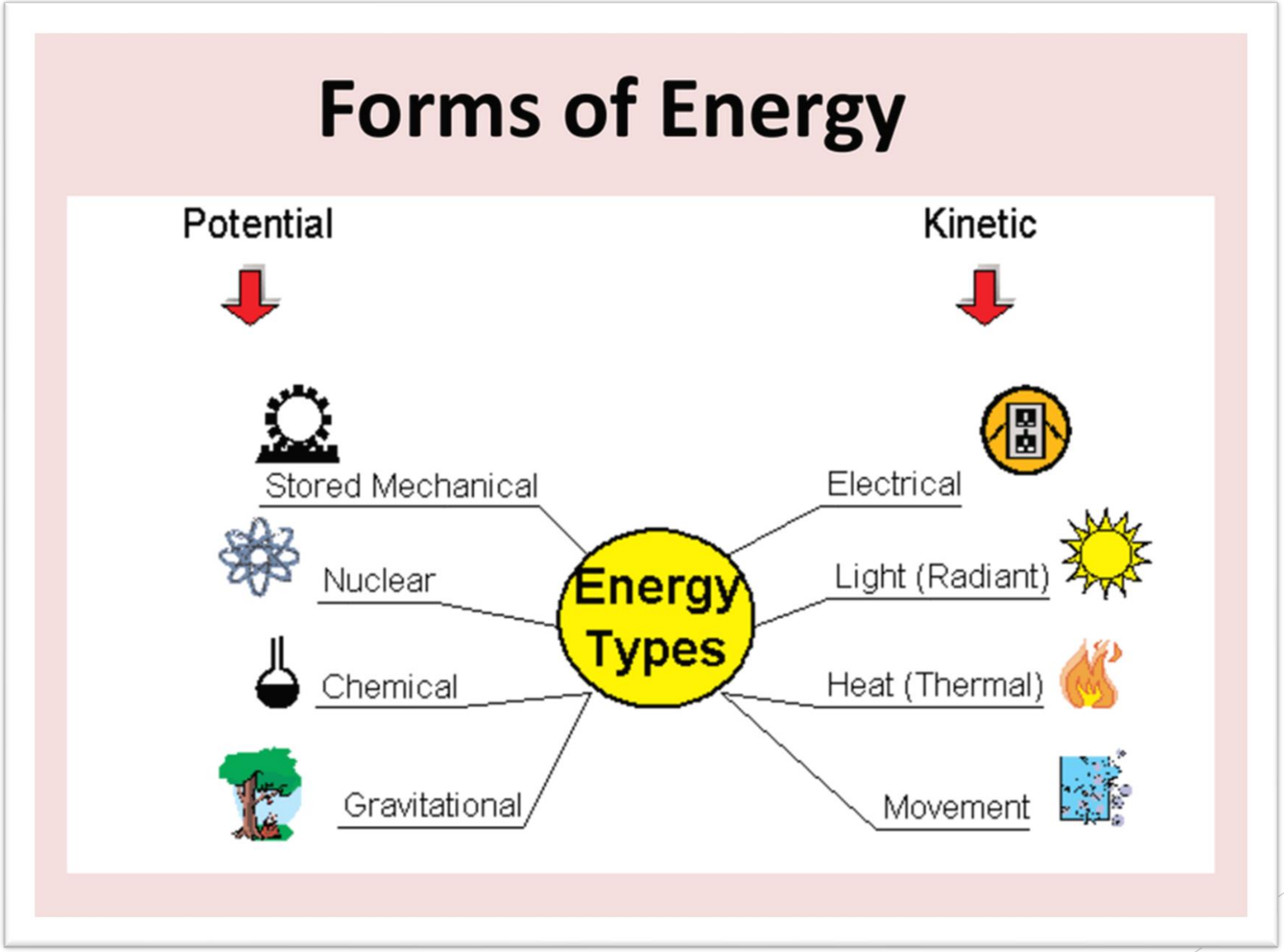
The unit of energy in this unit system is joule (J), and the unit of power is watt (W)

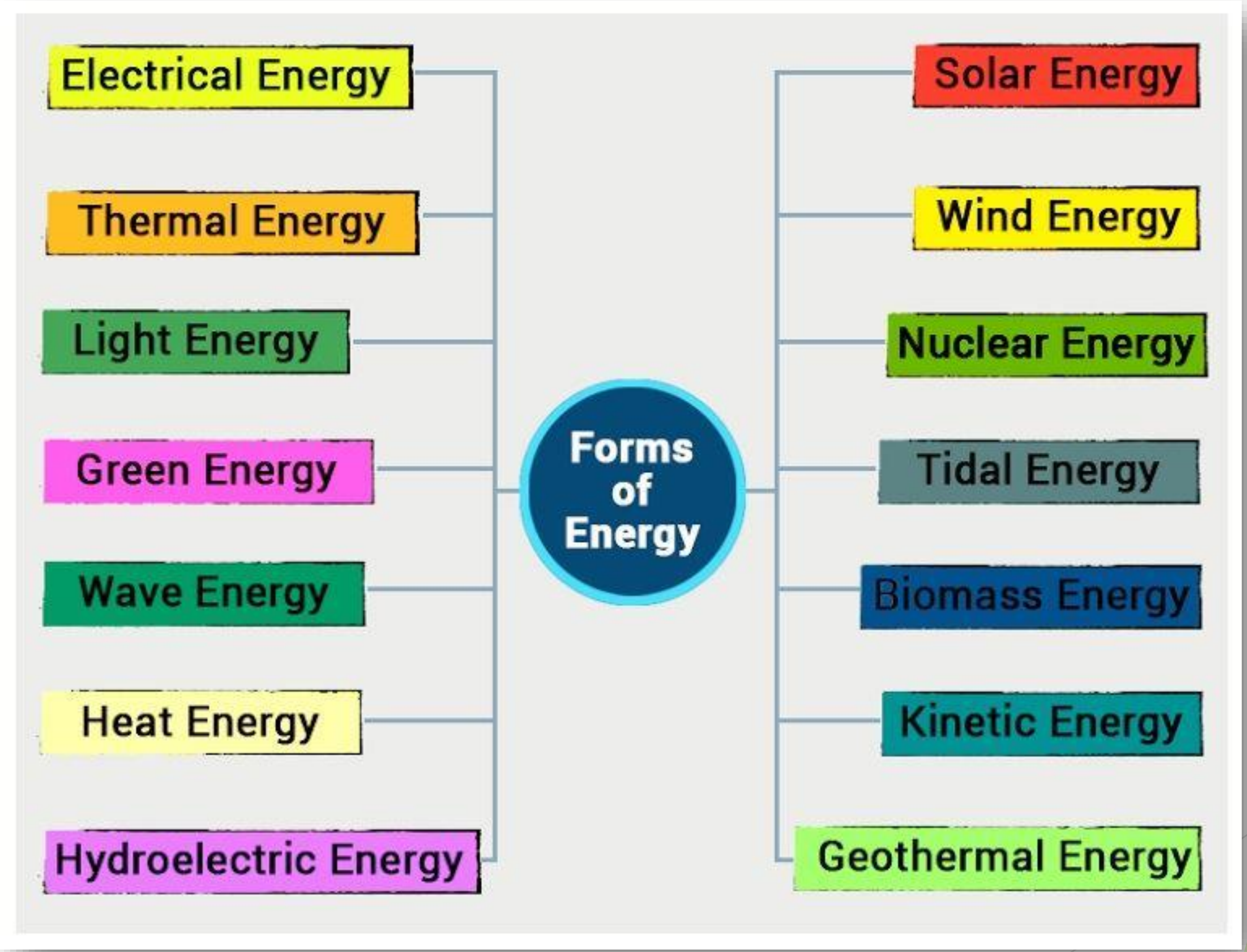
(*) The force exerted by a mass of 1 kg equals ca. 10 N.
(**) The energy required to lift 1 kg by 1 meter. Note that = W.s

Energy Units and Dimensions

- • Tons of Oil Equivalent 1 toe = 41.87 GJ
- • Billion Cubic Metres (of Natural Gas) 1 bcm = 39 PJ (1015J)
- • Barrels of Oil 1 boe = 5.71 GJ
- • Joule = SI Unit of Energy
- • KiloWatt Hour = 1kWh = 3.6 MJ
- • British Thermal Unit (BTU)= 1055 J
- • Calorie = 1 cal = 4.19 J

Important Units

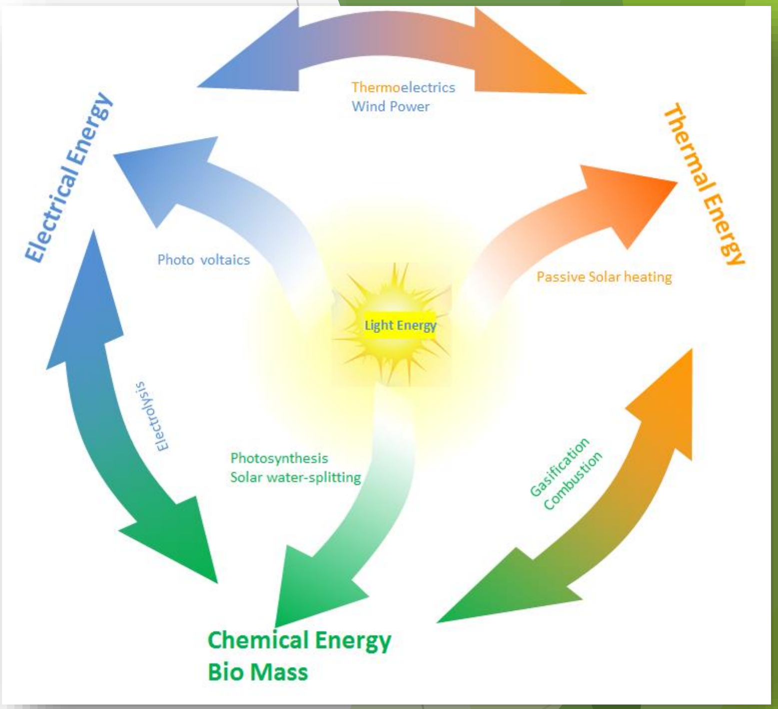

Forms of Energy
Potential
Kinetic
Stored Mechanical
Nuclear
Chemical
Gravitational
Energy Types
Electrical
Light (Radiant)
Heat (Thermal)
Movement


Forms of Energy
Electrical Energy
Thermal Energy
Light Energy
Green Energy
Wave Energy
Heat Energy
Hydroelectric Energy
Solar Energy
Wind Energy
Nuclear Energy
Tidal Energy
Biomass Energy
Kinetic Energy
Geothermal Energy

What is Energy Conversion ?

Energy conversions means converting energy from one form into another.

- No energy can be created or destroyed.
- All we can do is transform or convert energy from one form into another.
- In all conversions, we find that part of the energy is lost. This does not mean that it is destroyed, but rather that it is lost for our purposes, through dissipation in the form of heat or otherwise.

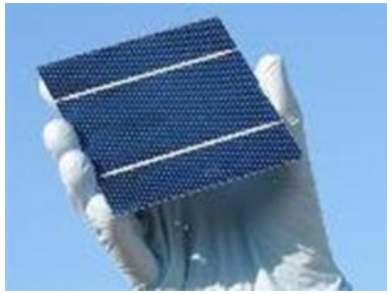


Examples of Energy Conversion

For Power generation we convert potential energy from hydro resources into mechanical energy, but for water pumping for lift irrigation, we do the reverse.

Wind turbine generates energy, which means it converts kinetic energy from wind into mechanical energy.

With Photovoltaic cells we convert radiation energy into electricity, whereas with light bulbs we do the reverse.



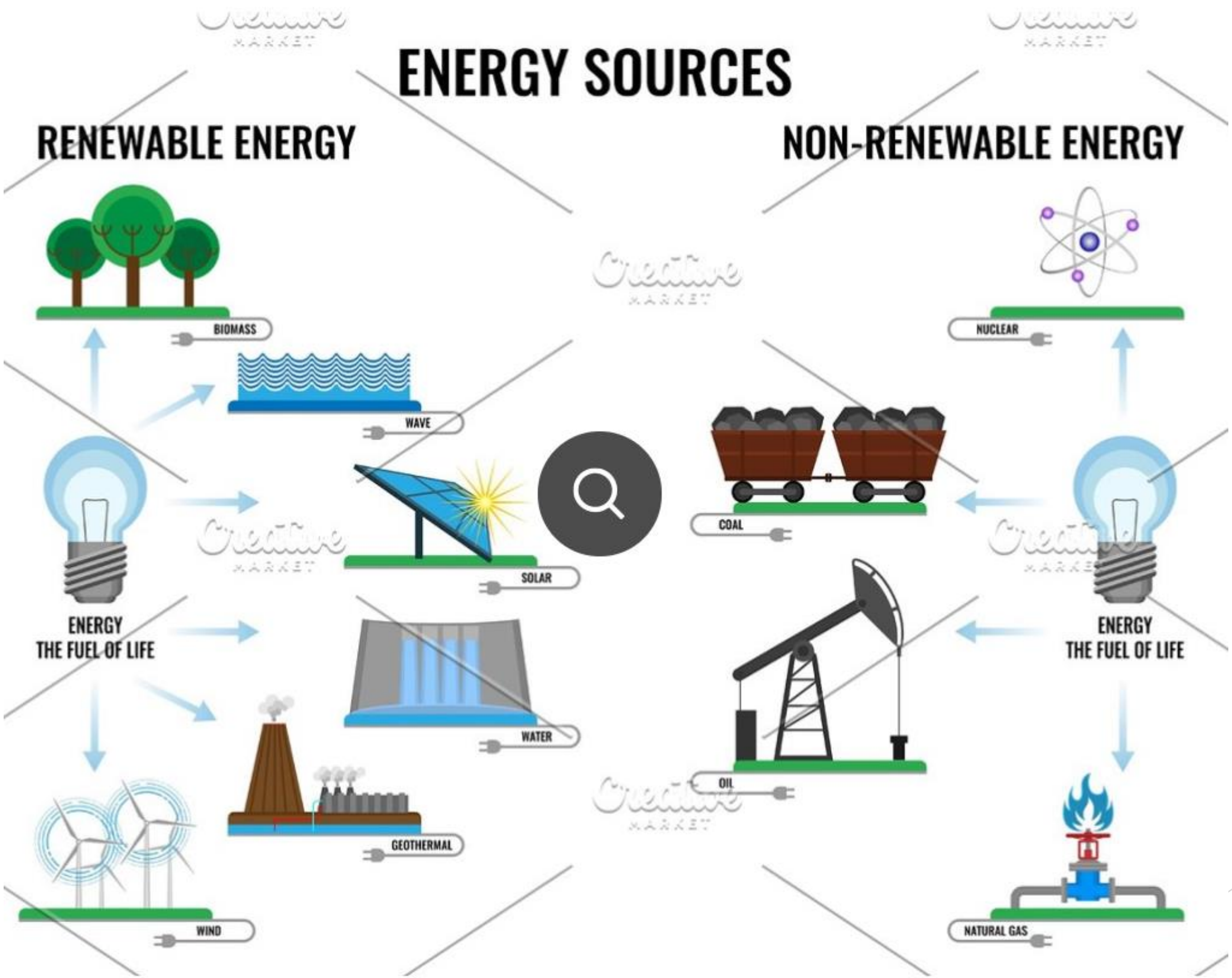
Diesel engine generates energy, which means that the engine converts chemical energy of oil into mechanical energy.

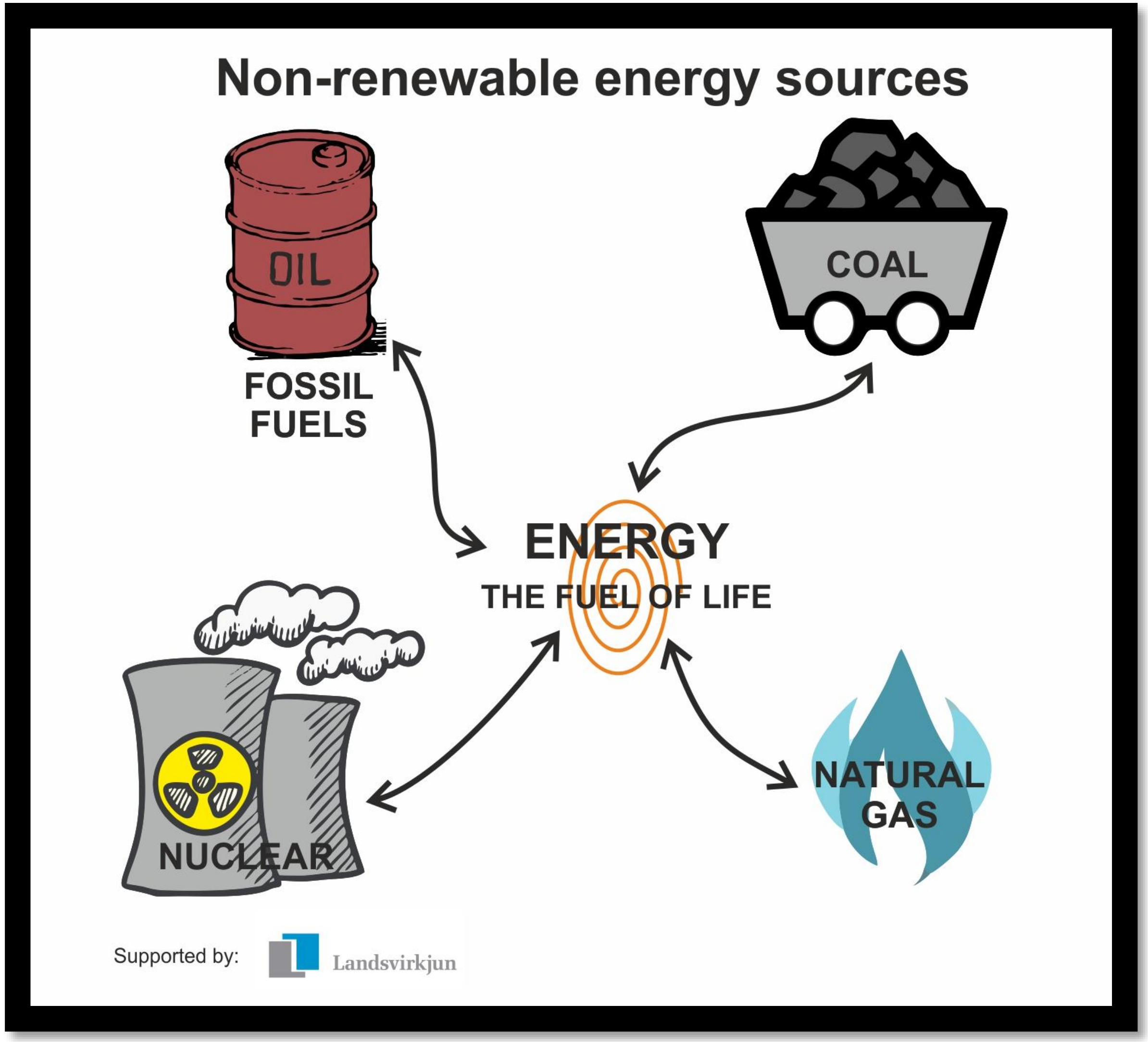
Renewable vs. Non-Renewable Energy Resources

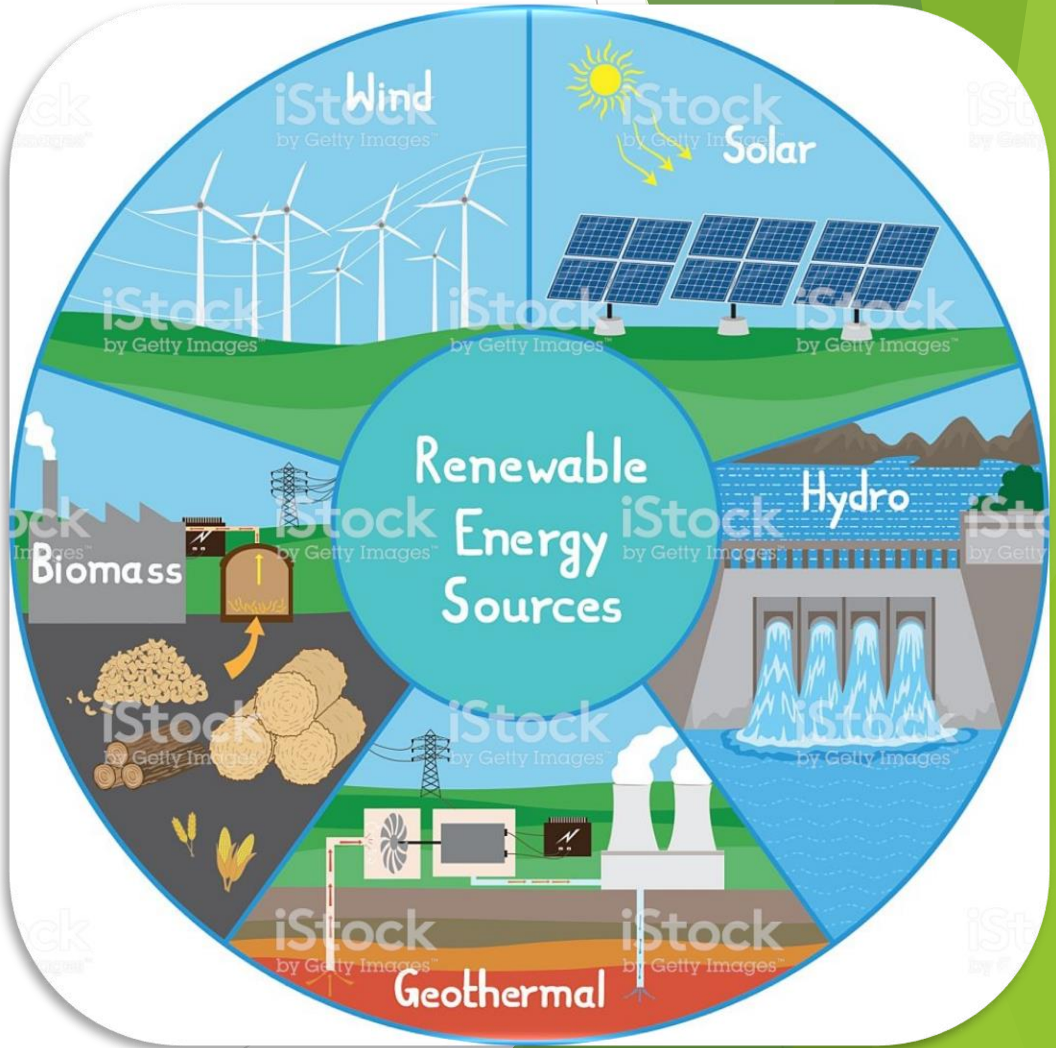
Renewable Energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power, and hydroelectric power. The most important feature of renewable energy is that it can be harnesses without the release of harmful pollutants.

Non renewable energy is the conventional fossil fuels such as coal, oil, and gas, which are likely to deplete with time.

Non-renewable energy comes from sources that will run out or will not be replenished for thousands or even millions of years. Most sources of non-renewable energy are fossil fuels. Fossil fuels were created as the remains of marine creatures decayed millions of years ago, under huge amounts of pressure and heat. Most fossil fuels are burned to create energy and electricity.


ENERGY SOURCES
RENEWABLE ENERGY
NON-RENEWABLE ENERGY
BIOMASS
WAVE
SOLAR
WATER
GEOTHERMAL
WIND
ENERGY
THE FUEL OF LIFE
NUCLEAR
COAL
OIL
NATURAL GAS
ENERGY
THE FUEL OF LIFE


Non-renewable energy sources
OIL
FOSSIL FUELS
COAL
ENERGY
THE FUEL OF LIFE
NUCLEAR
NATURAL GAS
Supported by:
Landsvirkjun


Wind
Solar
Renewable Energy Sources
Hydro
Biomass
Geothermal

Conventional Energy Resources (COAL, OIL, GAS)

COAL

Coal is a solid form fossil fuel that can be classed into three types: lignite, bituminous and anthracite. Lignite coal is found close to the Earth surface, making it easy to mine, but it has high sulfur content. Bituminous coal is the most common coal we burn, and it is less polluting than lignite. Anthracite is the highest quality of coal.

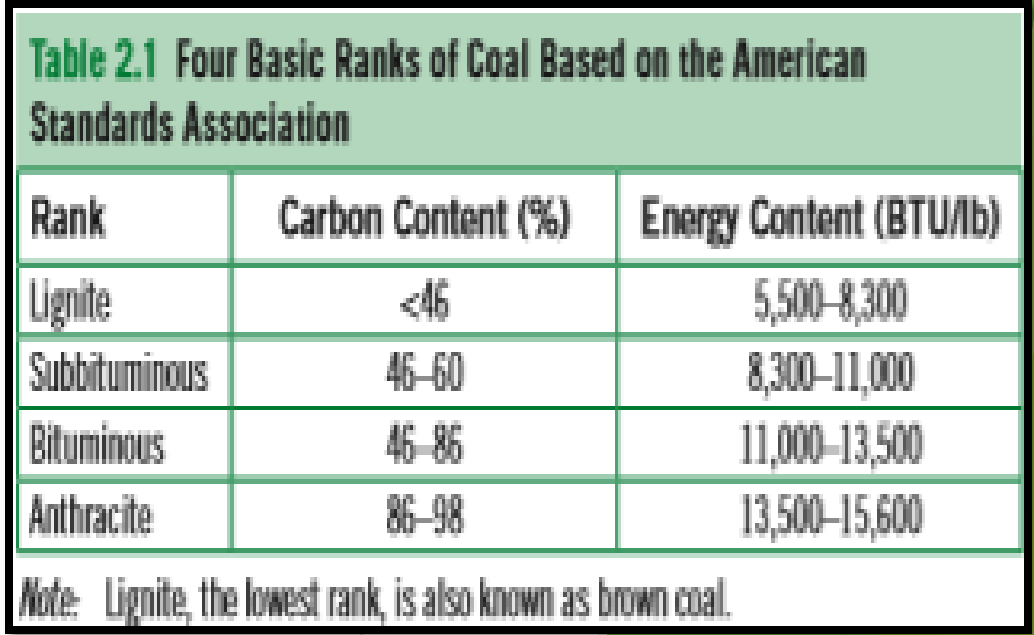


Table 2.1 Four Basic Ranks of Coal Based on the American Standards Association

Rank	Carbon Content (%)	Energy Content (BTU/lb)
Lignite	<46	5,500–8,300
Subbituminous	46–60	8,300–11,000
Bituminous	46–86	11,000–13,500
Anthracite	86–98	13,500–15,600

Note: Lignite, the lowest rank, is also known as brown coal.

OIL

Petroleum or crude oil is a liquid hydrocarbon consisting of many kinds of complex molecules. Its elemental composition includes 83–87% carbon, 10–14% hydrogen, 0–6% sulfur, and under 2% nitrogen and oxygen.

Oil was made out of animal and plant remains, of animals that had lived in water many millions years ago.

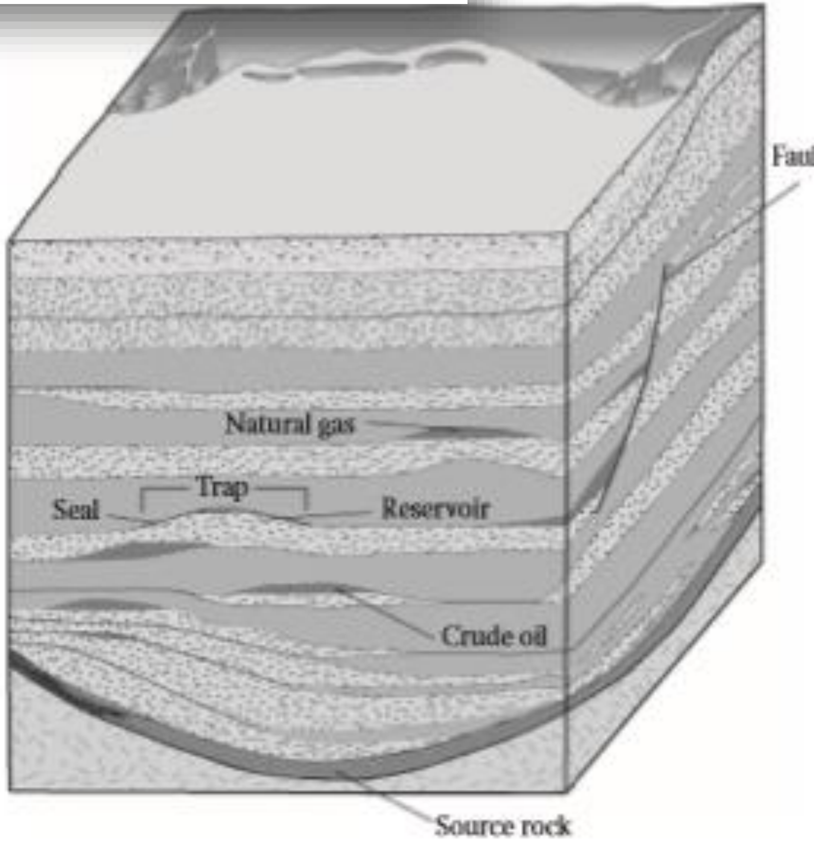
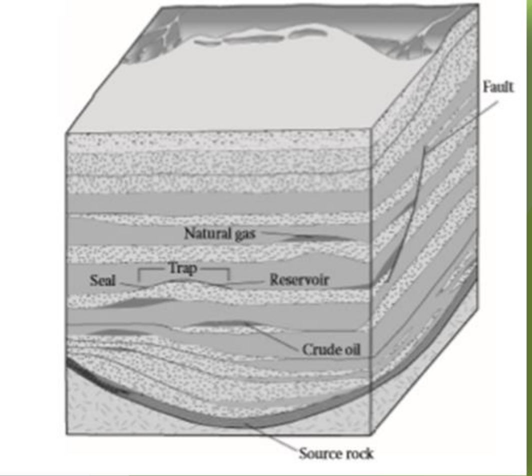


Figure 2.13 Depiction of oil and gas deposits formed under heat and pressure from source rocks and migrating upward through porous rocks and faults until they are trapped below a layer of nonporous rock. (Courtesy of US Geological Survey, Reston, VA, http://teeic.anl.gov/er/oilgas/restech/dist/index.cfm.)

Natural Gas

Natural gas is a gaseous hydrocarbon, primarily methane, CH_4, with up to 20% higher hydrocarbons, primarily ethane

Natural gas is found in underground rocks called reservoirs. The rocks have tiny spaces in them (called pores) that allow them to hold water, natural gas and/or oil. The natural gas is trapped underground by impermeable rock (called caprock), and stays there until it is extracted.



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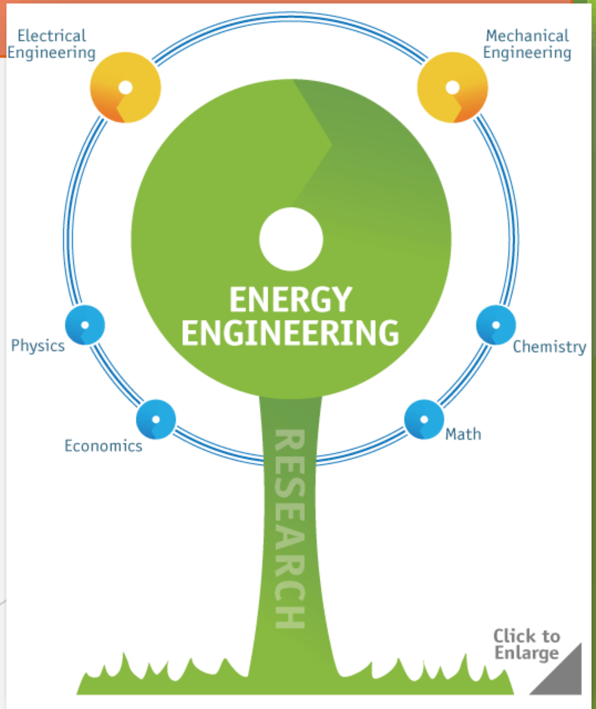
Energy Engineering Discipline and Applications

Energy engineering is a broad field of engineering dealing with energy efficieny, energy services, facility management, plant engineering, environmental compliance and alternative energy technologies.

Energy engineering is one of the more recent engineering disciplines to emerge. Energy engineering combines knowledge from the fields of physics, math, and chemistry with economic and environmental engineering practices. Energy engineers apply their skills to increase efficiency and further develop renewable sources of energy.

The main job of energy engineers is to find the most efficient and sustainable ways to operate buildings and manufacturing processes. Energy engineers audit (inspect) the use of energy in those processes and suggest ways to improve the systems. This means suggesting advanced lighting, better insulation, more efficient heating and cooling properties of buildings. Although an energy engineer is concerned about obtaining and using energy in the most environmentally friendly ways, their field is not limited to strictly renewable energy like hydro, solar, biomass, or geothermal. Energy engineers are also employed by the fields of oil and natural gas extraction.



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