ENE 101 – Introduction to Energy Engineering

WEEK 6

<u>Energy Consumption and Conversion:</u>

- **Energy Conversion Engineering**

- Energy conversion engineering (or heat-power engineering, as it was called prior to the Second World War), has been one of the central themes in the development of the engineering profession. It is concerned with the transformation of energy from sources such as fossil and nuclear fuels and the sun into conveniently used forms such as electrical energy, rotational and propulsive energy, and heating and cooling.

- **Energy Conversion Devices and Their Efficiency**

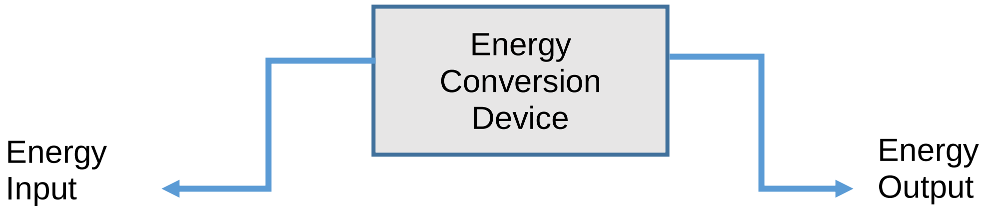
A device is a piece of equipment that serves a specific purpose. An energy conversion device converts one form of energy into another. It is an important element of progress of society. In fact, one can discuss the history of civilization in terms of landmarks in the development of energy conversion devices, as illustrated Table 1.

Table 1. History of Civilization in the Development of Energy Conversion Devices

Landmark Event	Approximate Date
Emergence of man	4,000,000 B.C
Emergence of human civilization	5000 B.C
Development of the water wheel	350 A.D
Development of the windmill	950 A.D
Invention of the cannon	1318 A.D
Development of the first atmospheric steam engine	1712 A.D

Development of modern steam engine	1765 A.D
Development of high-pressure steam engine	1802 A.D
Development of the automobile engine	1884 A.D
Operation of first nuclear power plant	1954 A.D

- **Schematic representation of an energy conversion device:**



Energy Output = Energy Input (1st Law)

Useful Energy Output   Energy Input (2nd Law)

The efficiency of an energy conversion device is a quantitative expression of this balance between energy input and energy output. It is defined as follows:

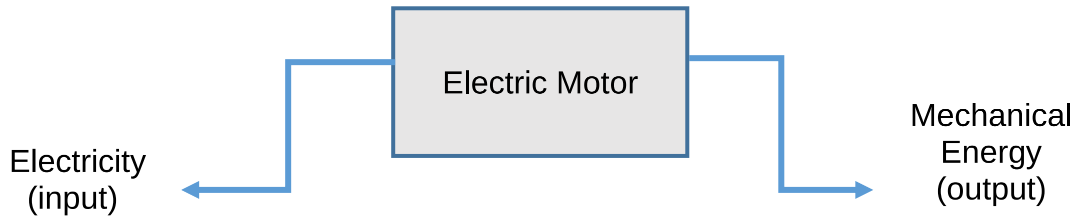
Device Efficiency= Useful Energy Output/ Energy Input

The key word in the above definition is ‘useful’. The first law of thermodynamics tells us that energy is conserved in all its transformations. So the ratio of energy output to energy input is always unity, or 100%.

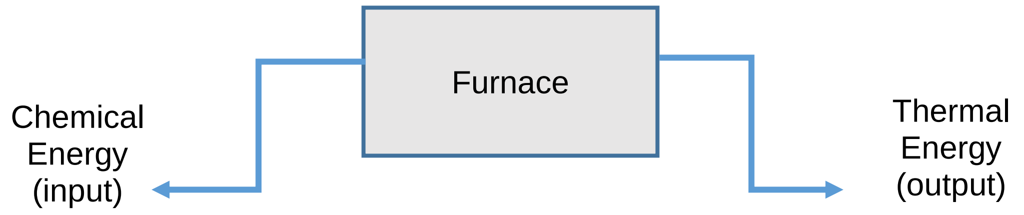
The meaning of the word ‘useful’ depends on the purpose of the device. For example, if the device is an electric heater, the useful energy output is heat, and the energy input is electricity. Electricity is converted to heat. Heat is also obtained from electricity in a light bulb, as we well know. However, this is not the useful energy obtained from a light bulb; the purpose of a light bulb is to convert electricity into light.

Energy Conversion Examples:

Energy conversion in an electric motor (electric-to-mechanical):



Energy conversion in a furnacer (chemical-to-thermal):



The concept of efficiency thus embodies both laws of thermodynamics. It reflects the quantitative equality and the qualitative difference of the various energy forms. Its understanding requires some knowledge of thermodynamics; once understood, it is only this concept – from the entire field of thermodynamics – that is necessary for understanding the principal energy issues facing society today.

Table 2. Tasks performed by common energy conversion devices

Energy Conversion Device	Energy Input	Useful Energy Output
Electric heater	Electricity	Thermal energy
Hair drier	Electricity	Thermal energy
Electric generator	Mechanical energy	Electricity
Electric motor	Electricity	Mechanical energy

Battery	Chemical energy	Electricity
Steam Boiler	Chemical energy	Thermal energy
Furnace	Chemical energy	Thermal energy
Steam Turbine	Thermal energy	Mechanical energy
Gas turbine	Chemical energy	Mechanical energy
Automobile engine	Chemical energy	Mechanical energy
Fluorescent lamp	Electricity	Light
Silicon solar cell	Solar Energy	Electricity
Steam locomotive	Chemical	Mechanical
Incandescent lamp	Electricity	Light

Efficiency Definitions:

$$\text{combustion: } \eta = \frac{Q}{\text{HV}} \equiv \frac{\text{heat released}}{\text{heating value of fuel}}$$

$$\text{heat pump: COP} \equiv \frac{Q_H}{W_C} \equiv \frac{\text{heat into hot reservoir}}{\text{compressor work}}$$

$$\text{refrigeration: COP} \equiv \frac{Q_C}{W_C} \equiv \frac{\text{heat from cold reservoir}}{\text{compressor work}}$$

$$\text{alternator: } \eta \equiv \frac{\dot{W}_e}{\dot{W}_m} \equiv \frac{\text{electrical energy out}}{\text{mechanical energy in}}$$

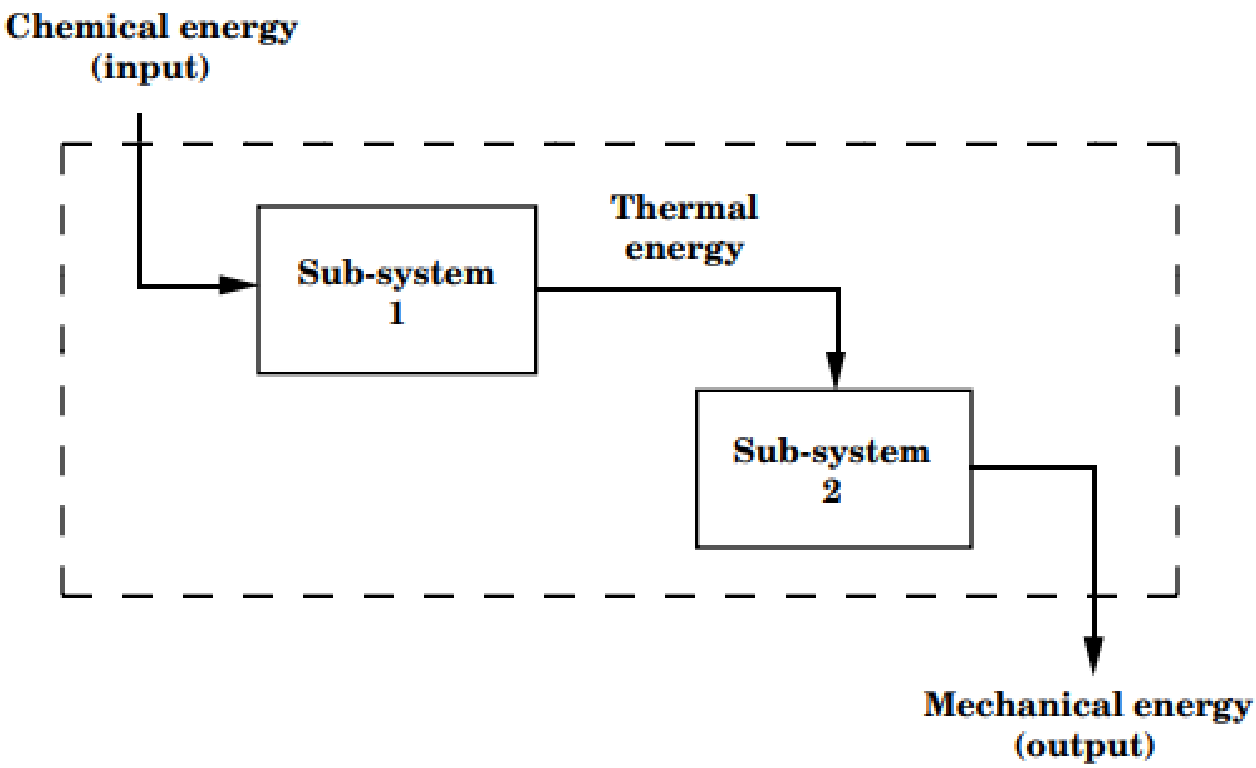
$$\text{battery: } \eta = \frac{\dot{W}_e}{\dot{W}_c} \equiv \frac{\text{electrical energy out}}{\text{chemical energy in}}$$

$$\text{IC engine: } \eta = \frac{\dot{W}_m}{\dot{W}_c} \equiv \frac{\text{mechanical energy out}}{\text{chemical energy in}}$$

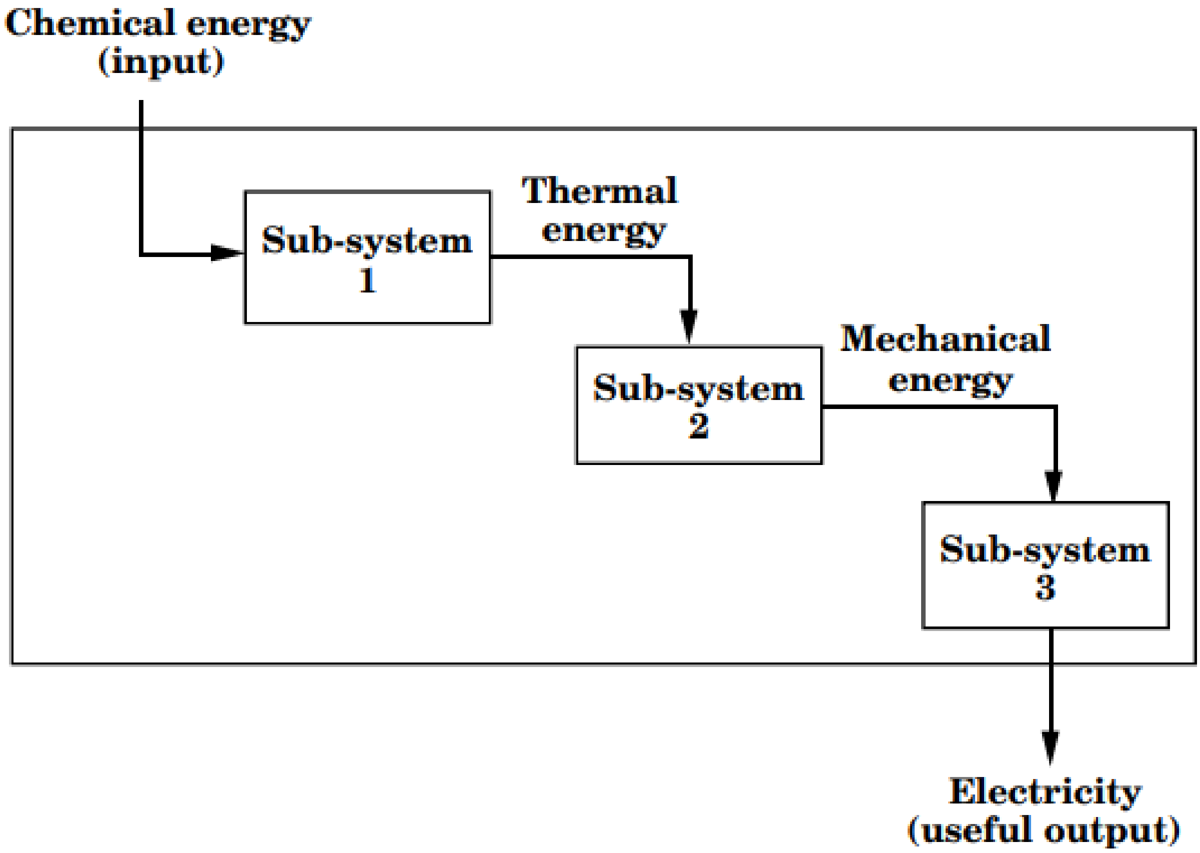
$$\text{automotive transmission: } \eta = \frac{\dot{W}_m}{\dot{W}_m} \equiv \frac{\text{mechanical energy out}}{\text{mechanical energy in}}$$

$$\text{electrical transmission: } \eta = \frac{\dot{W}_e}{\dot{W}_e} \equiv \frac{\text{electrical energy out}}{\text{electrical energy in}}$$

- **Energy conversion in a heat engine:**



- **Energy conversion in an electric power plant.**



One of the most important energy conversion systems in our modern society is the electric power plant. The chemical energy is first converted to thermal energy in the boiler; thermal energy is then converted to mechanical energy in the turbine; finally, mechanical energy is converted to electricity in the generator. System efficiency is, therefore,

$$E_{power\ plant} = [E_{boiler}]\ [E_{turbine}]\ [E_{generator}] =$$

$$= \left[\frac{\text{Thermal energy}}{\text{Chemical energy}}\right] \left[\frac{\text{Mechanical energy}}{\text{Thermal energy}}\right] \left[\frac{\text{Electric energy}}{\text{Mechanical energy}}\right] = \frac{\text{Electric energy}}{\text{Chemical energy}}$$

References:

1.http://pages.mtu.edu/~jstallen/courses/MEEM4200/lectures/Part01_Energy_Introduction_2016_v11.pdf
2. https://www.ems.psu.edu/~radovic/Chapter4.pdf
3. http://www.personal.utulsa.edu/~kenneth-weston/chapter1.pdf
4. https://www.saylor.org/content/weston_energy/Energy_Conversion.pdf