TABLE OF CONTENTS

WEEK 6 – ENERGY AND LIVABILITY I

Carnot heat engine

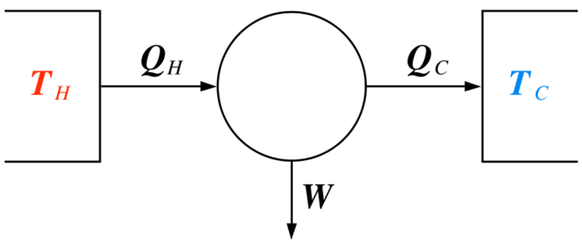
“A Carnot heat engine is an engine that operates on the reversible Carnot cycle. The basic model for this engine was developed by Nicolas Léonard Sadi Carnot in 1824. The Carnot engine model was graphically expanded upon by Benoît Paul Émile Clapeyronin 1834 and mathematically elaborated upon by Rudolf Clausius in 1857 from which the concept of entropy emerged.

Every thermodynamic system exists in a particular state. A thermodynamic cycle occurs when a system is taken through a series of different states, and finally returned to its initial state. In the process of going through this cycle, the system may perform work on its surroundings, thereby acting as a heat engine.

A heat engine acts by transferring energy from a warm region to a cool region of space and, in the process, converting some of that energy to mechanical work. The cycle may also be reversed. The system may be worked upon by an external force, and in the process, it can transfer thermal energy from a cooler system to a warmer one, thereby acting as a refrigerator or heat pump rather than a heat engine” (Wikipedia). The Carnot engine is repeating four steps:

1. The isothermal expansion of the gas volume comes inside the engine at hot temperature. Heat (Q) is absorbed from the source.
2. Isentropic expansion of the gas, resulting in work delivered to the outside. Isentropic means that the entropy remains constant. This step is adiabatic, pressure, volume and temperature change simultaneously.
3. Isothermal compression of the gas. Heat is rejected to the sink.
4. The isentropic compression of the gas, which requires work input. The maximal efficiency is called Carnot efficiency, always smaller than one, and determined by the temperature of heat source and cold sink.

To summarize, the energy flow in a thermodynamic heat engine is thus established by a temperature gradient between a hot and a cold reservoir. As soon as we link both we can extract work.



Wikipedia. *Carnot heat engine*. [online] <http://en.wikipedia.org/wiki/Carnot_heat_engine>
[accessed at 10 June 2015]

First law of thermodynamics

"The first law of thermodynamics is a version of the law of conservation of energy, adapted for thermodynamic systems. The law of conservation of energy states that the total energy of an isolated system is constant; energy can be transformed from one form to another, but cannot be created or destroyed. The first law is often formulated by stating that the change in the internal energy of a closed system is equal to the amount of heat supplied to the system, minus the amount of work done by the system on its surroundings. Equivalently, perpetual motion machines of the first kind are impossible."

First law of thermodynamics = $\Delta U = Q - W$

The change in internal energy U of a closed system is equal to the heat 'Q' added to the system minus work 'W' extracted. Heat and work are therefore different states of energy.

Wikipedia. *First Law of Thermodynamics.* [online]
<http://en.wikipedia.org/wiki/First_law_of_thermodynamics> [accessed 4 June 2015]

Second law of thermodynamics

"The second law of thermodynamics states that every natural thermodynamic process proceeds in the sense in which the sum of the entropies of all bodies taking part in the process is increased. In the limit, *i.e.* for reversible processes, the sum of the entropies remains unchanged. The second law is an empirical finding that has been accepted as an axiom of thermodynamic theory. Statistical thermodynamics, classical or quantum, explains the law. The second law has been expressed in many ways. Its first formulation is credited to the French scientist Sadi Carnot in 1824."

Second law of thermodynamics = $\partial Q = TdS$

Wikipedia. *Second Law of Thermodynamics.* [online]
<http://en.wikipedia.org/wiki/Second_law_of_thermodynamics> [accessed at 4 June 2015)

Energy storage

Energy storage is accomplished by devices or physical media that store energy to perform useful processes at a later time. A device that stores energy is sometimes called an accumulator.

Many forms of energy produce useful work, heating or cooling to meet societal needs. These energy forms include chemical energy, gravitational potential energy, electrical potential, electricity, temperature differences, latent heat, and kinetic energy. Energy storage involves converting energy from forms that are difficult to store (electricity, kinetic energy, etc.) to more conveniently or economically storable forms. Some technologies provide only short-term energy storage, and others can be very long-term such as power to gas using hydrogen or methane and the storage of heat or cold between opposing seasons in deep aquifers or bedrock. A wind-up clock stores potential energy (in this case mechanical, in the spring tension), a rechargeable battery stores readily convertible chemical energy to operate a mobile phone, and a hydroelectric dam stores energy in a reservoir as gravitational potential energy. Ice storage tanks store ice (thermal energy in the form of latent heat) at night to meet peak demand for cooling. Fossil fuels such as coal and gasoline store ancient energy derived from sunlight by organisms that later died, became buried and over time were then converted into these fuels. Even food (which is made by the same process as fossil fuels) is a form of energy stored in chemical form.

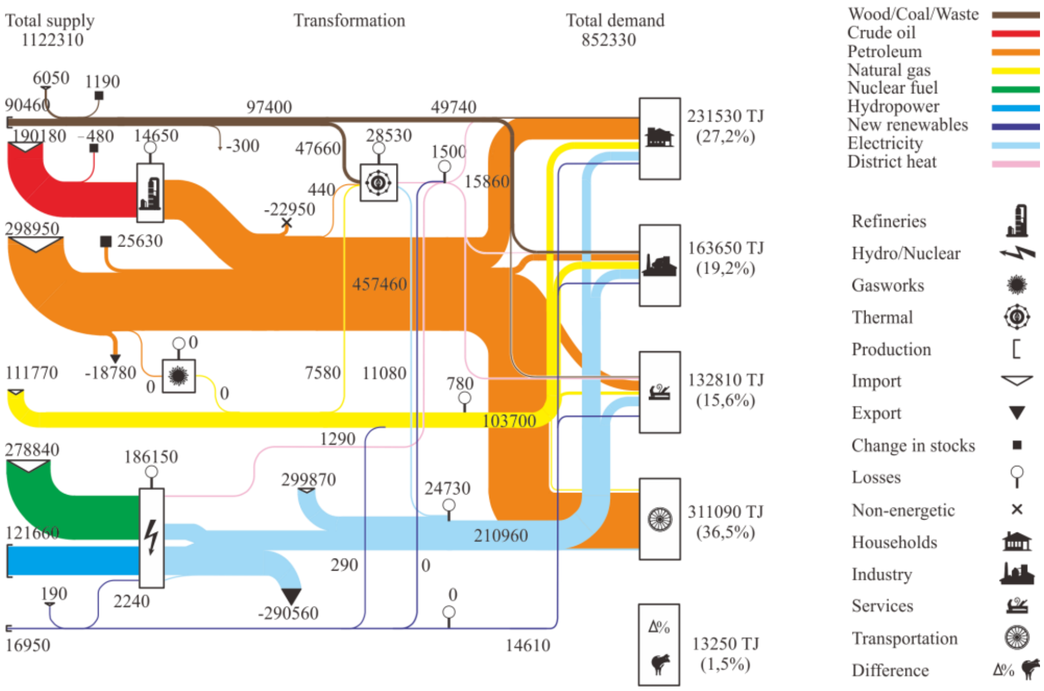
Wikipedia. *Energy Storage*. [online] http://en.wikipedia.org/wiki/Energy_storage [accessed at 4 June 2015]

Sankey Diagram

“Sankey diagrams are a specific type of flow diagram, in which the width of the arrows is shown proportionally to the flow quantity. Sankey diagrams are typically used to visualize energy or material or cost transfers between processes. They can also visualize the energy accounts or material flow accounts on a regional or national level. Sankey diagrams put a visual emphasis on the major transfers or flows within a system. They are helpful in locating dominant contributions to an overall flow. Often, Sankey diagrams show conserved quantities within defined system boundaries.”

History

“Sankey diagrams are named after Irish Captain Matthew Henry Phineas Riall Sankey, who used this type of diagram in 1898 in a classic figure (see panel on right) showing the energy efficiency of a steam engine. While the first charts in black and white were merely used to display one type of flow (e.g. steam), using colors for different types of flows has added more degrees of freedom to Sankey diagrams.



One of the most famous Sankey diagrams is Charles Minard's Map of Napoleon's Russian Campaign of 1812. It is a flow map, overlaying a Sankey diagram onto a geographical map. It was created in 1869, so it actually predates Sankey's 'first' Sankey diagram of 1898.”

M. Berger, Urban heat-balling - A review of measures on reducing heat in tropical and subtropical cities. *Sustainable Future Energy & 10th Sustainable Energy and Environment.* Brunei Darussalam, 2012, pp. 445-51

Wikipedia. *Sankey Diagram*. [online]< http://en.wikipedia.org/wiki/Sankey_diagram> [accessed at 4 June 2015]