Basics of Energy

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Energy Sources	1
Energy Conversion	1
Energy Use	2
References	2

Energy and energy conversion are vital for all life from the survival of a cell to human activities in societies and for countries. The basics of energy include using an energy source and converting part of its energy into useable energy products. During the process, the energy can be transformed in several different steps and into several different forms.

Energy Sources

The incoming, flowing energy to earth is the incoming solar radiation, which has been estimated to be 341 W m^{-2} or in total 174 000 TW. Of this, about 70% is absorbed in the atmosphere and at the surface of the earth. Twenty-three percent of the incoming radiation is involved in the evapotranspiration process (Trenberth et al., 2009).

The solar energy can be used directly or as bioenergy, wind energy, and hydropower. Only a small part of the solar energy that reaches the surface of the earth is used in photosynthesis. The theoretical efficiency for a plant concerning conversion of the irradiated solar energy to energy stored in the biomass is only 4.6–6% (Zhu et al., 2008). Even so, the total estimated biomass production on earth each year, including both marine and terrestrial biomass, corresponds to 4500 EJ or 1 250 000 TWh (Moreira, 2006). According to International Energy Agency, only about 15 000 TWh was used for energy purposes in 2010 (IEA, 2012). Wind energy utilization was 574 TWh in 2012 (IEA, 2013) and the hydropower utilization was 3438 TWh in 2010 (IEA, 2012). The utilization of direct solar energy is very low, about 100 TWh (IEA, 2009).

Fossil fuels and nuclear energy are stored energy resources. During the period from 1973 to 2010, the extraction of fossil fuels has almost been doubled, from 630 000 to 121 000 TWh, and especially, the use of coal and natural gas has increased. The use of nuclear energy is much lower than the use of fossil fuels and was about 8400 TWh in 2010 (IEA, 2012).

The global energy flows are illustrated in Figure 1. The energy sources utilized by the society are dominated by the stored sources (fossil fuels and nuclear), and only a very small part of the flowing solar energy is used.

Energy Conversion

Thermal, chemical, or nuclear energy from the energy source is converted to different forms of energy used, for example, mechanical energy for movement and thermal energy for heat and electricity. On the way from the source to final use, the energy can be converted to several different forms and it can also be stored in the form of mechanical, chemical, or thermal energy.

An important part of the basics of energy are the thermodynamic laws defining the natural science boundaries for energy appearance and behavior. Thermodynamics is the basis for understanding energy conversion processes, and thermodynamic-based tools are used to evaluate the performance of energy processes. An important parameter for evaluation of a system, based on the first thermodynamic law, is the system efficiency, which is the ratio between the outputs from a system and the input used.

Exergy is a thermodynamic parameter, based on the second thermodynamic law that relates a system to its surrounding. Exergy is defined as the amount of work possible to achieve from a system when it, through reversible processes, reaches thermodynamic equilibrium with the surroundings. Exergy analysis is therefore an important tool to determine inefficiencies in a system related to its surroundings (Ahmadi et al., 2011).

The Rankine or steam cycle, the Brayton or Joule cycle, and the engine cycle processes Otto cycle, Diesel cycle, and Stirling cycle are thermal energy processes used for conversion to electricity, electricity and heat, or movement. A working fluid passes through different process steps including heat uptake, expansion, release, and compression. The origin of the thermal energy is usually the chemical energy in different fuels but can also be geothermal, nuclear, and solar energy. The fuel cell is an example of an energy conversion process where the chemical energy in the fuel is converted to electricity directly without a thermal conversion step. In solar cells, the electromagnetic radiation from the sun is directly converted to electricity.

The knowledge used for describing, designing, and operating energy conversion processes includes, besides thermodynamics, many other different knowledge areas such as heat transfer, fluid dynamics, electronics, electromagnetism, mechanics, microbiology, electrochemistry, chemical reaction kinetics, and nuclear physics. Environmental issues are also closely related to energy conversion processes where the influence on climate change is one major concern. Here, the replacement of fossil fuel energy sources with renewable energy sources is an important area.

Figure 1 Global energy flows. Reproduced from Moreira, J. R. (2006). Global biomass energy potential. *Mitigation and Adaptation Strategies for Global*, 11(2), 313–333; Trenberth, K. E., Fasullo, J. T. and Kiehl, J. (2009). Earth's global energy budget. *Bulletin of the American Meteorological Society*, 311–323; IEA, International Energy Agency. (2013). *Technology roadmap – wind energy*. Available at www.iea.org; IEA, International Energy Agency. (2012). *Key world energy statistics*. Available at www.iea.org; IEA, International Energy Agency. (2009). *Renewable energy essentials: solar heating and cooling*. Available at www.iea.org.

Figure 2 The diagrams show the distribution on different sectors of the energy use in the world in 1973 and 2010. The category 'other' includes commercial and public services and residential, agricultural, and other nonspecified purposes. Reproduced from International Energy Agency (IEA). (2012). *Key world energy statistics*. Available at www.iea.org.

Energy Use

Energy use in society is often divided into three sectors: industry, transportation, and buildings, where the energy products used are electricity, heating and cooling, and transportation fuels.

In 2010, the total energy use in the world was 91 600 TWh. The total energy use has increased by 80% compared to 1973. Figure 2 shows the share of the use in the different sectors in 2010 and 1973, respectively, and it can be seen that the shares are about the same. However, considering the use of electricity, as much as 54% of the electricity used in 1973 was used in industry, while the same share was only 42% in 2010. Instead, the use of electricity for commercial and public services and residential, agricultural, and other nonspecified purposes had increased from a share of 44% in 1973 to 57% in 2010 (IEA, 2012).

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