ENERGY SOURCES: NON RENEWABLE AND RENEWABLE

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Summary

Energy is necessary to improve the quality of human life on earth. If only muscle power and open fires were available, *Homo sapiens* could survive only in simple farming and trade communities. Man has always tried to discover and develop new sources of energy. Without energy, modern civilization would not be possible. Production practices made possible due to energy define epochs in the history of humankind, such as, for example, the Bronze Age, the Iron Age and the Industrial Revolution.

The physical and chemical basis for the most important renewable and non-renewable energies will be discussed in this contribution. These energies are in use at the end of the twentieth century and will be used for decades to come. As complete a presentation as possible was chosen because the theme of energy affects all types of work equally. If in the middle of the twenty-first century low cost use of fossil fuels is no longer possible, the food production of the entire planet will be affected if no alternative energy is available.

The identification of useable renewable and non-renewable energy sources is a prerequisite for the conduct of innovative research and development.

1. Definition of Energy

According to Albert Einstein, energy may be expressed in the form of mass and the speed of light according to the formulae:

$$E\ [J] = m\ [kg] \times c^2\ [m^2\ s\text{-}2] \qquad (1)$$

$c = 3 \times 10^8$ m s^{-1}
where J = 1 Joule = 1 Watt second = 1 W s = 1 Newton meter = 1 N m = 1 kg m^2 s^{-2}

At the beginning of the universe, energy was an electromagnetic beam. The expression “In the beginning was … light,” is a physical explanation. Equation (1) shows that all energy has a certain mass and that this mass grows with the energy content. Changes that occur every day, perceivable by man, are so slight, that they need not be considered. That is we do not feel the meaning of equation (1). It is said, that we exist in the area of macrophysics (speed $v \ll c$).

Energy is everything that can be turned into work. The applications are governed by the rules of physics and chemistry, as described in the following sections. The most important renewable and non-renewable energy sources will be explained. The availability of useable energy affects the lifestyle and the sustainable population on the Earth.

2. Forms of Energy and Energy Retention

Energy appears in a variety of forms. It appears as chemical energy, as molecular and atomic energy, as electromagnetic energy, as electrical energy and as mechanical movement (energy with potential and kinetic energy) as well as thermal energy.

The basis of every energy observation is the principle that in a closed system energy can be neither created nor destroyed. Transformation losses create energy and the total addition creates a constant. Out of this constant is formulated the first law of thermodynamics: "Within a system, the sum of external thermal energy and external work is equal to the increase of internal energy."

But not all of the processes possible in this main principle occur in nature. Because it would also have to be possible according to this statement, that an apple which falls from a tree gains energy as it cools, which would allow it to go back up to the tree. Similarly it follows that heat can only be conducted from a body with a higher temperature to a body with a lower temperature, but not in reverse. This process is considered irreversible. That is why the second main principle of thermodynamics limits the first principle "There are no periodically working machines that achieve more as the creation of mechanical work and the cooling of a thermal container." It is not possible to create perpetual motion.

The thermodynamic Carnot-efficiency level is defined through the transformation from heat Q into work W as follows:

η = completed work/heat transfer at high temperature T_1

$$\eta = W/Q1\ (T1) = (T1 - T2)/T1 = 1 - T2/T1 \qquad (\eta < 1) \qquad (2)$$

where $Q_1(T_1) = W + Q_2(T_2)$; $Q_2(T_2)$ = Heat loss by low temperature T_2; T in Kelvin.

3. Energy Transformation, Energy Definition, Energy Supplies

Contrary to popular belief, energy cannot be created. Energy can only be **transformed** out of an existing energy source with the accompanying energy losses. The following breakdown is proposed as a definition:

3.1 Primary Energy

Primary energy is the available energy before the anthropogenic energy transformation. These include fossil fuels such as various coals, crude oil, natural gas, and in the case of nuclear energy the resources uranium or thorium. And renewable energies include solar energy, the surrounding temperature, the kinetic energy from water or wind-power, the energy content of bio-mass, the energy content from ocean waves and tides, the temperatures of ocean water levels and the energy of the Earth magma.

3.2 Secondary Energy

Secondary energy is the energy following the transformation of primary energies or the further transformation of other secondary energies, for example, electricity from coal or solar energy; gas or heating oil from crude oil; briquettes from coal: hydrogen from natural gas or electricity. Steam, electricity, hot water and hydrogen are secondary energy carriers, which are linked to and transported with the secondary energies of heat, electrical energy or chemical energy.

3.3 Useable Energy

Useable energy is the energy that can be used by the consumer. Useable energy makes possible the heat, light, power and communication energy needed by consumers. The goal is the optimal energy transformation at all energy transformation stages. Useable energy is ultimately transformed to heat and dissipates.

3.4 End Energy

End energy is the useable energy from which is created out of the transformation of primary or secondary energy and reduced by the transformation, storage, cable and processing losses.

3.5 Energy Supplies

Energy supplies of the Earth are divided into energy reserves (economically useable) and energy resources (not economically viable at this point in time). It is predicted that the energy reserves of oil and natural gas will be exhausted by the middle of the 21st century, of coal in the 22nd century and of uranium with simple use in the 21st century.

4. Energy Transformation of Fossil Fuels

Fossil fuels are stored energies that have developed in the layers of the Earth from the remains of organic life forms under high pressure and temperature.
Hard coal developed through the accumulation of larger amounts of dead plants on sea and swampland. Bacteria transformed the organic substances and oxygen and nitrogen were emitted. Through this process, carbon content in the plant residue increased. Turf was the first product of this process, which was transformed into brown coal through the pressure of layered sediments such as sand. As a consequence of the changes in the geological formation and under the impact of high pressure and heat, the brown coal layers changed to coal stratums. The hard coal layer was created several hundred million years ago.

Crude oil and natural gas were created for the most part from large amounts of dead plankton which was layered on the floor of the ocean. The solar energy contained in these substances landed in depths of the ocean containing no oxygen. They began to transform and further sedimentary layers placed high pressure on the remains and under high temperature the hydrogen contained in the oil transformed to gas with the separation of vaporisable particles. It is important to note that fossil fuel is not considered a renewable resource because the time periods required are imaginable for homo sapiens but not calculable. Also, the population intensity on the planet no longer permits the existence of long period primeval forests, seas and swamps.

Fossil fuels cover between 80 and 90% of the world's fuel needs at the end of the 20th century. Despite newly found sources, oil and natural gas will only be available to a limited extent to the middle of the next century as a source of combustible energy. The hydrogen contained in crude oil will probably be preferred as a chemical resource by then.

The explanation for the dominant use of fossil fuels in terms of quantity at this time, is, in addition to availability and technology based on these substances, the relatively simple transformation of the stored carbon, or rather, hydrogen, through the linking (oxidation, combustion) with oxygen to carbon dioxide. Thus, energy is created.

An exothermic chemical reaction releases heat into the environment. An endothermic chemical reaction takes up heat from the environment. The heat Q released or taken up in a chemical reaction under constant pressure is defined as reaction enthalpy (heat content) $\Delta_R H$. In order to compare enthalpies with each other, the values for standard pressure generally given are 1013 hPa and 298 K (25°C).

4.1 Combustible Energy

Both of the following chemical reactions show exothermic processes that release useable energy as discussed in this contribution.

$$C + O_2 \rightarrow CO_2 \text{ with } \Delta_R H = (-)394 \text{ kJ} \times \text{mol}^{-1} = (-)4.1 \text{ eV} \times \text{atom}^{-1} \quad (3)$$

One kg pure carbon yields the following heat value:

$(1000/12) \times 6.022 \times 10^{23} \times 4.1 = 2.1 \times 10^{26}$ eV = 1.15 kgSKE

$$0.5\, O_2 + H2 \rightarrow H_2O \text{ with } \Delta_R H = (-)286 \text{ kJ} \times \text{mol}^{-1} \quad (4)$$

One kg pure hydrogen yields the following heat value:

$(1000/2) \times 6.022 \times 10^{26} \times 3.0 = 9.0 \times 10^{26}$ eV = 4.90 kgSKE

[The high energy concentration of hydrogen requires a volume of 14 L for one liter of liquid hydrogen.]

The lower heat value defines the higher heat value minus the evaporation heat of the water. Typical (lower) heat values can be seen in Table 1.

Fuel	Transformation Product	kgSKE	kWh
C	CO_2	1.15	9.36
C	CO	0.32	2.61
CO	CO_2	0.34	2.77
H_2	H_2O	4.10	33.37
Methane CH_4	$CO_2 + H_2O$	1.22*	9.93*
Ethane C_2H_6	$CO_2 + H_2O$	2.20*	17.91*
Acetylene C_2H_2	$CO_2 + H_2O$	2.03*	16.52*
Anthracite		1.02–1.09	8.30–8.87
Hard Coal		0.92–1.09	7.49–8.87
Hard Coal Coke		0.92–1.02	7.49–8.30
Soft Coal		0.34–0.44	2.77–3.58
Soft Coal Briquettes		0.65–0.71	5.29–5.78
Turf		**0.48–0.51**	**3.91–4.15**
Wood		0.27–0.51	2.20–4.15
Ethanol		0.92	7.49
Methanol		0.68	5.54
Benzol		1.37	11.15
Benzene		1.39–1.50	11.31–12.21
Diesel		1.39–1.50	11.31–12.21
Oil		1.36–1.43	11.07–11.64
Petroleum		1.36–1.42	11.07–11.56
Ammonia		0.48*	3.91*
Butane		4.20*	34.19*
Propane		3.18*	25.89*
Sulfur Hydroxide		0.80*	6.51*
City Gas		0.54–0.70*	4.40–5.70*
Natural Gas		≈ 1.1*	≈ 8.95*

* = shown in kgSKE m^{-3} gas fuel under normal conditions
1 Kilojoule (kJ) = 0.2388 kcal = 0.000278 kWh = 0.000034 kgSKE
1 kgSKE = 8.14 kWh (lower heat values);
1 kWh = 3.6 MJ = 0.123 kgSKE.

Table 1. Typical (lower) heat values (heat value per kg fuel).

An exothermic chemical reaction according to Eqns (3) or (4) converts the release energy almost completely into heat. The principle suggested by W. Grove (1839) for a fuel cell is different. Here, the processes are spatially separated from each other. The transfer of ions takes place via an electrolytic medium and the exchange of electrons occurs via a separate electric line.

Both the electrical current and the released heat provide useable energies. Current hopes focus on the further development of fuel cells for the replacement of the combustion engine. Hydrogen as well as methane or methanol can be used as substitute fuels (see below).

4.2 Power Plants/Carnot Process

Due to larger supplies of coal, its use has become more significant worldwide than that of oil and natural gas. Adequate coal supplies will be available well into the 22nd century. The efficiency quotient for heat yield stands as:

Efficiency η_{Heat} = useable heat/released combustible energy

A coal oven can achieve an efficiency of 0.5 to 0.7 (equal to 50% to 70%). Power plants built especially for heating purposes can increase their efficiency to about 90% because they use the hot exhaust gases (see below under power-heat-linkages). And by simple transformation to electrical energy, the following formula applies:

$\eta_{Electric}$ = electrical energy/released combustible heat

The efficiency level of furnaces and electrical generators can be assumed to be over 90%. In contrast, kinetic energy through the turbine (according to the laws of thermodynamics) stands as follows in equation (2):

$$(T1 - T2)/T1 = 500/823 = 0.61 \text{ or } 61\%. \qquad (5)$$

where T_1 = approx. 823 Kelvin; T_2 = approx. 323 K; 273.15 K = 0 °C; 373.15 K = 100 °C.

Equation (5) would be the ideal energy transformation according to Carnot. In the example shown, a higher temperature difference T_1–T_2 would increase the efficiency. But the temperature T has a maximum limit due to the entrance of the turbine and because of the corrosion resistance of steel. At the turbine exit, the temperature T_2 is determined by the air temperature or that of the cooling water. The ideal Carnot efficiency cannot be achieved because of real losses in the process. In modern steam power plants, effectiveness levels of only 35–40% are achieved. Additionally electricity transformation and transfer losses of about 5% must also be included. Therefore a relationship of useable electrical energy from transformed primary energy of about 1:3 can be assumed.

Efficiency improvements through increased waste heat use for the generation of heat energy for consumers are required by power plants. In contrast the environmentally hazardous emissions from the power plants need to be considered. The implementation of Stirling engines (see below) for the use of waste heat can increase the real efficiency of the plants.

4.3 Gas and Steam Plants

An efficiency improvement is a goal of the modern gas and steam power plants. In these facilities the above described steam turbine switches over to a gas turbine for the use of hot combustion gases between the combustion temperature of about 1000 °C and the steam temperature of between 500 °C to 550 °C. Therefore, two circuits exist simultaneously. With these measures, the efficiency for the creation of electrical energy by minimal waste heat temperature can be raised by 50–55%. Natural gas is used to fuel the gas turbine. Since natural gas will be available for only a limited time in the future, the primary fuel coal can be transformed to gas and used instead. Then, however, the total efficiency for the generation of electricity sinks to between 44% and 48%.

4.4 Desulfurization of Coal

Further efforts have the goal of raising both the efficiency level and the desulfurization of coal. The centrifugal layer process is implemented here. Finely ground coal is added steadily to the combustion chamber. A stream of warmed combustion air is slowly directed into the chamber. The addition of limestone makes possible the desulfurization of the coal.

When fossil fuels are used to generate electricity, further efficiency improvements can be targeted with the power-heat linkage. The waste heat is stored in the remote heating system by large power plants, and in the case of small facilities in the nearest heating system. From a physical perspective it is possible to achieve an effectiveness level of 90 percent.

In reality, the effectiveness level is between 70 and 80% depending on the type of facility and its installations, because optimal plant conditions seldom exist (size of the heating system, room temperature requirements, or electricity requirements). The most valuable energy generated in this industrial age, electricity, must also be used immediately, because it is not possible to store it without energy losses. Remote heating requires initial temperatures of between 90 °C and 130 °C which then reduces the temperature difference according to Eqn. (2), and thereby the effectiveness level of the power plant.

4.5 Coal Refining

Due to the significantly larger supplies of coal than oil and gas, vaporization and liquefaction through the refining of coal are very important for the middle term. This is also because the products derived from the refining of coal are suited to mobile use. In coal vaporization, ground coal is put under pressure and high heat in combination with hydrogen or water and is transformed into a synthesis gas mix (CO; H_2) or methane (CH_4). In the liquefaction of coal, one differentiates between the direct process for the production of fuels for Otto engines and indirect processes with coal vaporization as a step in the production of aviation or diesel fuel. For both coal vaporization and liquefaction processing practices are already available.

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Biographical Sketch

Hartwig Irps was born on June 19, 1945 in Lower Saxony, Germany. His parents were farmers with an emphasis on animal husbandry. After completing elementary school, Dr. Irps spent six years working on a variety of farms, completing his apprenticeship, various tests, and agricultural schools. He then received permission to study at the Technical University of Berlin, where he received a degree in Physics in July 1973. He worked as a physicist in the electrotechnics industry in Berlin and then at the Technical University there. He began working in the area of “Farm Animal Ethology”, at the Institute for Animal Production, Dept. of International Agricultural Development at the Technical University of Berlin. Dr. Irps received his doctorate from the Technical University of Berlin in June 1977. Since 1977, he has been on the scientific staff of the German Federal Agricultural Research Center, in Braunschweig, Germany (FAL). The focus of his work in the research center has been on developing animal-appropiate and environmentally-friendly buildings for cattle-keeping. Since 1995, “Renewable Energy” has been the main focus of his work at the national German research facility. He has gathered personal experience and understanding of the need for “Sustainable Development” through stays in Brazil, Bolivia, Peru, Sudan, Egypt, the U.S., Bulgaria, Morocco and in various countries of the European Community.