An overview of energy sources

Strictly defined, energy sources are substances in which energy is stored in physical, chemical, or nuclear form. In a broader sense, today they also include sun, wind, hydropower, and geothermal energy. On the one hand, the energy stored in the energy sources can be converted to useful energy. On the other hand, some energy sources are very good for transporting energy.

What types of energy sources are there?

Primary and secondary

The energy sources available in nature that are suitable for obtaining energy directly are called **primary energy sources**. **Secondary energy sources** are substances that do not naturally occur in a form that is directly usable, such as electric power, heating oil, and hydrogen. Secondary energy sources are suitable for **storing energy** or **transporting energy**.
Primary energy sources such as coal, natural gas, or solar radiation are converted, for example, in a power plant to the secondary energy sources electric power or heat and then transported to the consumer.

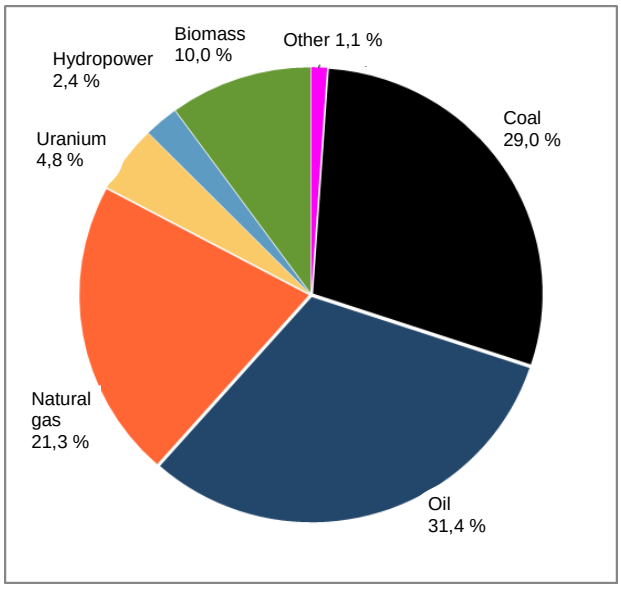

Figure 1: World total primary energy supply (2012): 13,371 Mtoe (Mtoe = “million tonnes of oil equivalent”, 1 Mtoe = $4.1868 \cdot 10^{16}$ J). Source: IEA, “Key World Energy Statistics 2014”

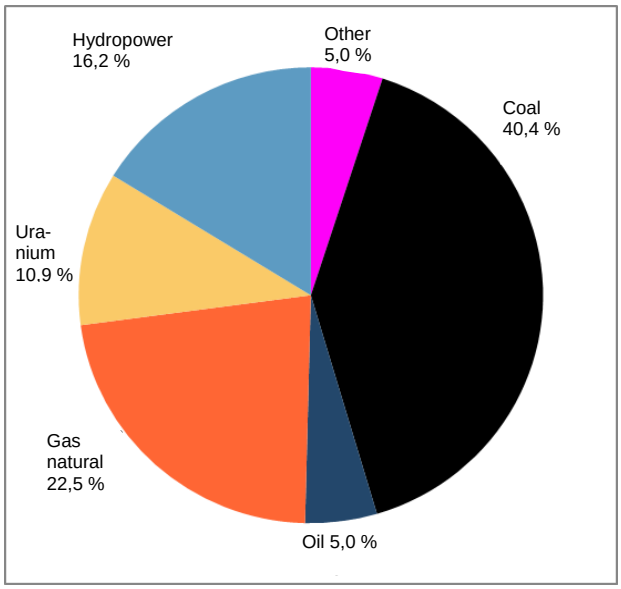

Figure 2: Shares of energy sources in worldwide electricity generation (2012). The electricity generated was 22,668 TWh. Two thirds of the electricity comes from fossil energy sources. Source: IEA, “Key World Energy Statistics 2014”

Fossil, renewable, or nuclear

Non-renewable energy raw materials include fossil energy sources (coal, oil, natural gas), as well as the nuclear energy sources uranium and thorium.
Fossil energy sources were created from organic materials such as plants, algae, and plankton over millions of years through biological, chemical, and physical processes in the Earth’s core. The energy content was concentrated so much in these materials that their use is economically viable. However, fossil energy sources are available only in limited quantities and they release CO_2 when burned (see the “Waste and emissions” information sheet, which is available on the media portal of the Siemens Stiftung). These fossil energy sources are not renewable – they cannot be replen-

ished over the relatively brief lifespan of human existence on the Earth. In just a few decades, humans will have used up the fossil energy that took millions of years to form.
Renewable energy sources are renewed constantly, in contrast to limited fossil energy sources, or their energy continues to flow all the time and without limits, at least by human standards. Among the renewable energy sources, the sun and its radiation are paramount; indirect solar energy is found in wind, hydropower, and biomass. Other non-solar renewable energy sources are (deep) geothermal energy and tidal power. Even though the Earth's core is ultimately cooling irreversibly and the rotation of the Earth is gradually slowing down, these energy sources are inexhaustible by human standards. From this point of view, renewable energy sources are sustainable. In addition, even when they are used all the time, they do not emit any CO_2 or other pollutants.
Nuclear energy sources are the naturally occurring heavy metals uranium and thorium, plus plutonium formed from non-fissile ^{238}uranium in nuclear reactors during nuclear fission through neutron capture. On a large scale, uranium is currently the most widely used chemical element in nuclear power plants as the primary energy source for nuclear fission. In special cases, the natural decay of radioactive substances is used to generate power. The decay heat is converted to electric power in radio-isotope generators ("plutonium battery") using thermocouples. However, this is uneconomical and is used only by the military or in space travel for long-term batteries. Nuclear energy sources are also available only to a limited extent. Energy conversion does not produce any CO_2, but it does produce radioactive waste, which has to be stored safely over extremely long periods due to the highly radioactive, toxic fission products (for example, strontium and plutonium).
In general, it can be said that energy is always used and waste and emissions are produced in the breakdown and treatment of raw materials and in the production and maintenance of power generation plants of all types. These considerations must always be included in any **overall energy balance** and **overall ecological balance** for all energy sources.

Energy source reserves, availability, and years of use left

In 2012, world primary energy consumption was approx. 13.4 billion toe. Distribution of this consumption across the individual energy sources varied considerably. The following section gives concrete estimates and figures for each energy source. An important note in advance: The estimates are based on world energy consumption in 2012. They do not yet take into account the fact that, according to the latest studies carried out by the International Energy Agency (IEA), energy consumption is expected to rise by approx. 33 % by 2035. Skeptics therefore assume that considerably fewer years of use are left. Optimists, however, feel that higher prices would also make uneconomical reserves commercially viable, which means that the accessible reserves would further increase. In addition, higher prices would trigger a more intense search for new reserves. This is balanced by the requirement that industry and end consumers will also need to be able to pay the higher prices. The extraction of fossil energy sources such as natural gas and oil is increasingly expensive (one barrel of natural gas from the most productive conventional sources, for example, in Saudi Arabia, still costs approx. $40, while a barrel of oil from fracking costs at least $60, more likely $90). The increased extraction costs are also the reason why, in 2014, the large oil companies incurred losses for the first time in decades. As a result of increased extraction costs, some companies announced in late 2015 that oil sands mining in Canada is too expensive; other companies decided to abandon oil drilling in the Arctic. In contrast, renewable energy is increasingly cheaper.

However, if the goal declared by the Intergovernmental Panel on Climate Change of limiting global warming to less than 2 °C relative to the pre-industrial level is to be achieved, not all remaining fossil energy sources can be combusted. Scientists have calculated that only one fourth of the

economically recoverable fossil energy sources may be combusted by 2050 in order to not jeopardize the 2 °C goal (Meinshausen et al. in Nature 08017, 2009). The current UN report in late 2014 concludes that the 2 °C goal cannot be reached if carbon dioxide emissions are not immediately drastically reduced (THE EMISSIONS GAP REPORT of November 2014 of the United Nations Environment Programme (UNEP)).

It is therefore necessary to search for alternatives, for example, in the use of renewable energies. Several media packages on the topic of “renewable energies” are available on the media portal of the Siemens Stiftung, for example, the “Electricity from renewable energy sources” content package for interactive whiteboards for elementary school, the “Renewable energies – The future is sunny!” media package, and the “Experimento | 10+: B6 Renewable energies” and “Experimento | 8+: B6 Renewable energies” media packages.

Years of use of energy sources: Estimated use, using data from 2005

Energy source	Known world reserves, million TCE[4]	Reserves (%)	Global annual use in million tSKE	Global use (%)	Remaining years of use
Coal	783,000	59	4,191	30	190
Oil	218,000	17	5,488	38	40
Natural gas	208,000	16	3,522	25	60
Uranium	112,000 (6.8 million t)[1]	8	1,031 (68,000 t)[2]	7	~100 (~100)[3]
Tot. world	1,321,000	100	14,232	100	

Source: World Energy Council, International Energy Agency IEA, Oil & Gas Journal 2005

[1] Deposits with exploration costs of less than $130/kg uranium; additional approx. 5 mil. tonnes of uranium ore and uranium phosphates are stored in the Earth's strata and under the sea bed, for which the exploration costs are over $130/kg.

[2] Current needs currently covered approx. 50 % from uranium ore and approx. 50 % from nuclear weapon disarmament and fuel reprocessing.

[3] Using breeder technology, remaining years of use would be 800–1,000 years.

[4] TCE: tonne of coal equivalent = 29,308 MJ

World electric power generation: Shares of energy sources in worldwide electricity generation (2005 and 2012).

World electric power generation in TWh (as of 2012)						
	Coal	**Nuclear energy**	**Oil**	**Gas**	**Hydro-power and other**	**Total**
2005	7,040	2,640	1,240	3,750	3,550	18,220
Share (%)	38 %	14 %	7 %	21 %	20 %	100 %
2012	9,157	2,471	1,133	5,100	4,805	22,668
Share (%)	40.4 %	10.9 %	5 %	22.5 %	21.2 %	100 %

Source: International Energy Agency 2014