

Energy knowledge

Introduction

In 2010 were consumed every second 1,117 barrels of oil and 32 million cubic meters of natural gas per year (Source: Eni, World Oil and Gas Review, 2011). Average global energy consumption per head is 60 GJ, equal to the average consumption of a West European citizen in the Sixties - today the energy consumption of each North American is 6 times as much, and it is 3 times as much for each European. However, over one and a half billion people live without electricity. Even though this need shall not be satisfied, by 2030 the energy demand is destined to grow 50%. This forecast is amazing because of the quantity of energy that will be required in little more than twenty years. There are two types of answers to meet the increasing energy demand: two different paths, which are not alternative to one another, but must be followed along parallel lines. On one hand it is necessary to promote the use of renewable sources, that are less polluting, to produce energy, on the other it is necessary to introduce a new energy culture, and energy saving: energy is no longer something we can use greedily, but it is a precious resource that must be utilized with care and in a rational manner.

Energy sources

What is energy

All organisms need energy to live. Energy is connected to all human activities: whenever we think or move, we use the energy that is stored in our body and all the objects that we use or that surround us need energy to work or needed energy when they were built. Energy illuminates us and warms our houses, allows us to move, feeds the tools we use to produce food, and so on.

All that produces energy is "an energy source". The Sun is the main source of energy for the Earth.

The Earth receives from the Sun an uninterrupted flow of energy that, as well as supplying all vital processes (both vegetal and animal), melts the ice and supplies the water cycle between the sea and the atmosphere; it produces the wind, favours the growth of those plants that during millions of years have transformed, together with animal remains, into fossil fuels, coal and natural gas.

In general, all the energy available on our planet derives, directly or indirectly, from the Sun: water energy, wind energy, chemical energy of fossil fuels (coal, oil and natural gas) and biomass (i.e. wood); even waves energy.

Tides energy derives from the gravitational fields of the Sun, Moon and Earth.

Geothermal and nuclear energy do not derive from the subsequent transformations of solar energy, but are related to the Earth formation.

Primary and secondary sources

The numerous existing energy sources can be classified in different ways. Primary sources can be used directly, as they appear in the natural environment: coal, oil, natural gas and wood, nuclear fuels (uranium), the sun, the wind, tides, mountain lakes, the rivers (from which hydroelectric energy can be obtained) and the Earth heat that supplies geothermal energy.

Secondary sources derive from the transformation of primary energy sources: for example petrol, that derives from the treatment of crude oil and electric energy, obtained from the conversion of mechanical energy (hydroelectric plants, Aeolian plants), chemical plants (thermoelectric), or nuclear (nuclear plants). Electric energy is produced by electric plants, i.e. suitable installations that can transform primary energy (non-transformed) into electric energy.

Renewable and non-renewable

Some sources are renewable, i.e. they provide energy, which is constantly regenerated by means of chemical transformations (e.g. biomass) or physical transformations (e.g. water power, solar, wind power, etc.). In particular the sun, the wind, the water cycle, the tides, the heat of the Earth are non-exhaustible sources, which are always available

and will never end. Biomass, instead, can re-generate within times that are similar to man's life. With reference to wood, for example, it is always possible to have some combustible available, even though sometimes it is necessary to consume a small quantity of it and reforest in those areas where trees have been cut down.

Non-renewable sources, instead, are characterised by long regeneration times, so long (millions of years) that after they have been exploited they are considered depleted. They are those energy sources that took millions of years to form, like fossil fuels (oil, coal, natural gas) or when our planet was formed, such as uranium. These sources, although there is still plenty of them, are limited and represent a sort of energy warehouse on the Earth.

At present, only 13% of the energy consumed in the world derives from renewable sources. All the rest derives from non-renewable sources, mainly from fossil fuels (71%) and 6% from nuclear plants.

(International Energy Agency (IEA) – Key World Energy Statistics 2011)

Energy measurement

The units of measurement used by human beings to express the quantity of energy sources are numerous. There are measures for physical quantities and measures for the energy or heat content.

The official measurement unit for energy is the Joule (J).

Among the most common units measuring energy mention should be made of the kilowatt/hour (kWh), used especially for electric energy (in fact it is used to calculate electricity bills). In order to measure the production of large electricity plants or the national consumption, the Terawatt/hour (TWh) is used, which corresponds to a billion kWh.

The most common units measuring heat include the BTU (British Thermal Unit) and the kilogram calorie (kg-cal) and especially the Tonne of Oil Equivalent.

The Tonne of oil equivalent is the most common at international level because it is connected to one of the most important and widely used fuels: oil. By measuring the different energy sources in terms of Tonne of oil equivalent, a comparison becomes possible and they can be aggregated, a vital operation to calculate how much energy a country consumes in a year or how much energy is still available under the surface (oil and natural gas fields and coal mines).

But what is Tonne of oil equivalent? Basically, one Tonne of oil equivalent represents the quantity of heat which can be obtained from a tonne of oil. In practice, if we measure coal in terms of Tonne of oil equivalent, it means we are considering the quantity of coal capable of producing as much heat as a tonne of oil.

(Let's remember that: $1 \text{ Kcal} = 4.186 \text{ J} = 1,16 \times 10^{-3} \text{ kWh} = 1 \times 10^{-7} \text{ TOE}$).

How can we calculate the physical quantities corresponding to one Tonne of oil equivalent of coal or natural gas? In other words, how many kilograms of coal are needed to reach one Tonne of oil equivalent of coal and how many cubic metres of natural gas to produce one Tonne of oil equivalent of gas?

To calculate that equivalence and use the units measuring physical quantities (kilograms, litres, cubic metres) of the different energy sources, we resort to calories.

We know that one tonne of oil contains 10 million kilogram calories (kg-cal), whereas one tonne of pit coal contains 7 million kg-cal. Therefore one Tonne of oil equivalent of coal, since it measures the quantity of coal containing as many kilogram calories as one tonne of oil, is equal to approximately 1.43 tonnes (measure of the physical quantity) of coal. Calculations are easier if we take, for example, vegetable fuels, containing 2.5 million kilogram calories per tonne of material. In this case, to obtain 10 million kg-cal (the calorific content of a tonne of petrol) we need 4 tonnes of vegetable fuels; therefore one Tonne of oil equivalent of vegetable fuels correspond to 4 tonnes of vegetable fuels.

If we know the contents, in terms of calories, of the physical units measuring the different energy sources we can calculate all the Tonne of oil equivalent equivalents. The following table reports the "Net Heat Value", i.e. estimates based on international average values leading to the conversion of the content of calories into the various units measuring the physical quantities of some of the most common fossil energy sources.

Forms of Energy

Work and heat energy

he energy mainly comes under two forms: work-energy and heat-energy. The former can be fully transformed into the

latter, but not vice-versa because the heat tends to disperse.

The energy that produces work can again be divided into potential and kinetic energy.

Potential energy is connected to the respective positions of two bodies, for example the gravity pull increases insofar as the distance between a body and the centre of the Earth increases. Kinetic energy is the energy of the chaotic movement of molecules.

By throwing a ball up into the air, its kinetic energy increases. While moving upwards, the ball loses kinetic energy and increases its potential energy. When the topmost point is reached, the potential energy reaches its peak and the kinetic energy is nil, and the ball starts falling down. During its downfall, the ball increases its kinetic energy while the potential energy decreases. By bouncing on the ground, the ball transfers part of its kinetic energy to the Earth as heat.

Where is the energy?

Albeit in different forms, energy is everywhere. However, the energy available which can be controlled, transformed and used by human beings (thanks to today's technology) is only a small part of the energy contained in the primary sources. For example, energy can be found in the chemical bonds of oil, coal and gas (chemical energy turning into heat during the combustion process) or in the power of the blowing wind or water falling from the mountains (mechanic energy which can be transformed into electric energy) or the nuclear bonds (nuclear fuels) which, if they are altered through ad hoc processes caused by human beings, produce huge quantities of heat (thermal energy).

In 2009 approximately 71% of the primary world energy consumed by mankind is made up of fossil fuels: coal, natural gas and oil (*International Energy Agency (IEA) – Key World Energy Statistics 2011*). Those energy sources are under the Earth's surface, however they are not available uniformly in all the countries of the world. In other words they are distributed according to a precise geographical pattern. Great quantities of oil and natural gas can be found in Middle East countries (Saudi Arabia, Iran, Iraq, Kuwait), in the United States, Russia and Europe, in the North Sea; great quantities of coal are located in China and the United States.

Energy transformation

All energy forms can be transformed into other forms of energy: by burning coal we transform its chemical potential energy into thermal energy (heat). Thanks to the steam engine, the heat can in its turn be transformed into kinetic energy, i.e. the motion of the locomotive.

Thermodynamics is the science studying the transformation of energy into work and vice versa. It is based on two principles valid only within closed systems such as the Earth. The Earth is a closed system because it can exchange energy with outside but cannot exchange matter. If it were not able to exchange energy either, it would be defined an isolated system. If it exchanged matter too it would become an open system.

First principle of thermodynamics

There is a natural law limiting these transformations, i.e. the law on the conservation of matter, according to which energy cannot be created nor destroyed ("nothing is created and nothing is destroyed"). The energy can be transformed from a form into another but the sum of the different forms must remain unchanged. Therefore "nothing is created nor destroyed, everything is transformed".

Second principle of thermodynamics

Whereas the first law of thermodynamics deals with the global balance of energy, the second law deals with its transformations and its natural tendency to move towards more degraded forms, which cannot be used any longer. Actually, the second law of thermodynamics includes two wordings. The first states that the heat always moves from a warmer to a colder body, never the other way round. The second unveils the natural tendency to the dispersion of heat, i.e. that the heat from a source cannot be fully transformed into work. This does not mean that the total quantity of energy present in the universe is decreasing, rather that its ability to work is.

The thermodynamic function assessing the degree of energy dispersion is called "entropy". Entropy in the universe tends to increase to reach a state of balance in which the total degradation of energy is achieved corresponding to the complete inability to work. Fortunately, biological systems are open systems, which thanks to the incoming of energy from outside, restore the positive global energetic balance.

Energy efficiency

At this point the notion of efficiency is to be dealt with. As a matter of fact, energy resources are precious goods, which are to be used efficiently and effectively. A basic concept to assess the quality and waste of any human activity is efficiency. Efficiency assesses which part of the energy and materials making up any action or process was successful and which part was lost. Energetic transformations too always lead to some losses. The efficiency of an energetic transformation is measured by dividing useful energy (the difference between the energy input and dissipated or wasted energy) by the energy input. If the efficiency of an energetic transformation amounts to 60%, this means that out of 100 energy units included in a process, 60 were transformed into usable energy forms, whereas the other 40 are transformed into non-usable energy forms.

Two meaningful examples can be produced as regards the efficiency of the petrol we use for our cars and the thermal transformations taking place in a thermoelectric power plant. When we travel by car less than one fifth of the chemical energy contained in the petrol is transformed into mechanic energy, i.e. motion. The remaining part is transformed into heat, which cannot be used any more and is dispersed through the radiator or is discharged through the exhaust gas or warms the passenger compartment. Another part of the energy produced is transformed into heat owing to the friction among gears and is dispersed. The total quantity of energy at the beginning and the end of the process does not change, whereas the its form is changed (from chemical energy to motion and heat) and generally degrades into forms which cannot be used to produce work any longer.

In thermoelectric power plants (where fossil fuels are burned to produce electric energy the transformation and use of which by the final users is easier) the average efficiency amounts to 40%. This means the out of 100 energy units contained in coal, oil or natural gas, only 40 are transformed into electric energy, whereas the remaining 60 are transformed into low temperature heat which often cannot be used. In state-of-the-art thermoelectric power plants using natural gas, new technologies allow higher efficiency levels, i.e. approximately 65%.