

### 1 General Introduction

We use energy to do work. Energy lights our cities. Energy powers our vehicles, trains, planes and rockets. Energy warms our homes, cooks our food, plays our music, and gives us pictures on television. Energy powers machinery in factories and tractors on a farm.

Energy from the sun gives us light during the day. It dries our clothes when they're hanging outside on a clothes line. It helps plants grow. Energy stored in plants is eaten by animals, giving them energy. Predator animals eat their prey, which gives them energy. Everything we do is connected to energy in one form or another.

Energy is defined as: "the ability to do work"<sup>1</sup>. When we eat, our bodies transform the energy stored in the food into energy to do work. When we run or walk, we "burn" food energy in our bodies. When we think or read or write, we are also doing work. Cars, planes, light bulbs, boats and machinery also transform energy into work.

Work means moving something, lifting something, warming something, lighting something. Energy causes things to happen around us and is there as soon as the world changes:

- Change of temperature: energy is involved to heat up or cool down
- Change of state of matter: energy is involved in evaporation (from liquid to gas) or solidification (from liquid to solid)
- Change of speed: energy is involved to speed up or slow down
- Change of shape: energy is involved in the numerous shaping operations in industry
- Change of chemical composition: energy is involved in the multiple chemical reactions in the industry (exothermic or endothermic)
- Change of the position in a field (magnetic, electric, gravity ...)
- Change of atomic composition: energy is involved when an atom loses an electron or when an atomic nucleus breaks up or merge with another one
- Change of the energy or of the number of photons: laser and micro wave

### 2 General principles

In physics, energy is the ability to do work, or the ability to move or elicit change in the state of a system. Energy has a few important properties. For one, energy is always "conserved" — it cannot be created or destroyed. This is the first law of thermodynamics that says that the total quantity of energy in a close system remains constant.

The second law of thermodynamics states that the quality of energy is degrading irreversibly. This is the principle of the degradation of energy or entropic principle: A proxy of the entropy of a system is its energy content divided by its temperature. The entropy of a closed system is always increasing which means that the temperature of a system with no energy input from outside and that provides work or loses energy to the outside can only decrease.

Energy can, however, be transferred between objects or systems by the interactions of forces. For example, the energy in vegetables is transferred to the people who digest them. Another property

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<sup>1</sup> What Is Energy? Joseph Castro <http://www.livescience.com/42881-what-is-energy.html>

of energy is that it comes in multiple forms, and can be converted from one form to another. The two most common or basic forms of energy are kinetic energy and potential energy:

- Kinetic energy is the energy of motion. A ball has kinetic energy as it flies through the air — it has the ability to do work in that it can act upon other objects with which it collides.
- Potential energy is a kind of stored energy that objects have because of their position or configuration. A cup on a table has potential energy; if you knock the cup off the table, gravity will accelerate the cup, and its potential energy will convert to kinetic energy. A stressed bow also has potential energy.

In the early 20th century, scientists theorized that mass and energy are intimately linked. Albert Einstein described this so-called mass-energy equivalence with his famous equation,  $E = mc^2$ , in which "E" stands for "energy," "m" denotes "mass" and "c" is the speed of light.

### 3 How do we measure energy?

Energy is measured in many ways. One of the basic measuring blocks is called a calorie. The calorie or gram calorie (symbol: cal) is the approximate amount of energy needed to raise the temperature of one gram of water by one degree Celsius at a pressure of one atmosphere.

In the International System of units (IS), energy is measured in joules (j), and one joule is defined "mechanically", being the energy transferred to an object by the mechanical work of moving it a distance of 1 metre against a force of 1 Newton<sup>2</sup>. 1 cal = 4.18 joules

So, it would take 50000 cal or 209000 joules to heat 1 litre of water from 20 to 70 degrees.

Around the world, scientists measure energy in joules. One thousand joules defines one kilojoule — "kilo" means 1,000.

A piece of buttered toast contains about 315 kilojoules (315,000 joules) of energy. With that energy you could:

- Jog for 6 minutes
- Bicycle for 10 minutes
- Walk briskly for 15 minutes
- Sleep for 1-1/2 hours
- Run a car for 7 seconds at 80 kilometres per hour
- Light a 60-watt light bulb for 1-1/2 hours

The most common units for **consumers** are the units used on their energy bills: kWh for electricity or gas, litre for gasoline or gasoil, tonne for heavy fuel oil or coal, kg for LPG and m<sup>3</sup> for fire wood.

1 kWh electricity =	3.6 MJ
1 litre gasoline =	33.15 MJ
1 litre gasoil =	36.60 MJ
1 kg GPL =	46.15 MJ
1 tonne heavy fuel oil =	42.18 GJ
1 tonne of Coal =	28.95 - 30.35 GJ
1 m <sup>3</sup> wood =	4.7 – 6.7 GJ

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<sup>2</sup> One newton is the force needed to accelerate one kilogram of mass at the rate of one metre per second squared

The most used unit by **global energy experts** is the tonne of oil equivalent (toe).

$$1 \text{ toe} \approx 41.8 \text{ GJ} \approx 11,600 \text{ kWh}$$

The most used energy in the oil and gas upstream industry is the barrel of oil (bbl) (159 litres) and cubic foot of gas (cft) or million Btu (MMBtu)

$$1 \text{ bbl} = 6.193 \text{ GJ}$$

$$1 \text{ MMBtu} = 1.0551 \text{ GJ}$$

## 4 The changing energy forms

Energy can be found in a number of different forms. It can be chemical energy, electrical energy, heat (thermal energy), light (radiant energy), mechanical energy and, nuclear energy.

Energy can be transformed into another form of energy. But it cannot be created and it cannot be destroyed (1st law of thermodynamics).

Here are some changes in energy from one form to another:

- Stored energy in a flashlight's batteries becomes light energy when the flashlight is turned on
- Food is stored energy. It is stored as a chemical with potential energy; when your body uses that stored energy to do work, it becomes kinetic energy
- If you overeat, the energy in food is not "burned" but is stored as potential energy in fat cells
- When you talk on the phone, your voice is transformed into electrical energy, which passes over wires (or is transmitted through the air); the phone on the other end changes the electrical energy into sound energy through the speaker
- A car uses stored chemical energy in gasoline to move; the engine changes the chemical energy into heat and kinetic energy to power the car.
- A toaster changes electrical energy into heat and light energy (If you look into the toaster, you'll see the glowing wires)
- A television changes electrical energy into light and sound energy.

## 5 Where does the energy come from?

Energy has always been there, in our universe. The energy that cycles through the systems of Earth comes from two locations. The Sun radiates huge amounts of energy. Only a small portion of that energy hits the Earth, but it is enough to light our days, heat our air and land, and create weather systems over the oceans.

Through **photosynthesis**, plants and other organisms convert light energy from the Sun, into chemical energy that can be later released to fuel the organisms' activities (energy transformation). This chemical energy is stored in carbohydrate molecules, such as sugars, which are synthesized from carbon dioxide and water. Oxygen is also released as a waste product. Most plants, most algae, and cyanobacteria perform photosynthesis. Photosynthesis maintains atmospheric oxygen levels and supplies all of the organic compounds and most of the energy necessary for life on Earth.

The Earth also gives off energy. There is a molten outer core of iron (Fe) and nickel (Ni) that radiates heat and creates a magnetic field that surrounds the planet. Current evidence suggests that the inner core temperature is 6,000 degrees Celsius. The asthenosphere and upper mantle also radiate heat from the interior of the planet. Even without the heat of the Sun, the Earth would be warmer than space or a planet with no molten core.

Unless you live on a volcano or a hydrothermal region, the Sun’s energy will affect your life more than any energy from inside the planet.

## 6 Where does our energy come from?

Most of our energy comes from fossil fuels: coal, oil and natural gas. Fossil fuels were formed during the Carboniferous Period (from about 360 to 286 million years ago) many hundreds of millions of years ago before the time of the dinosaurs – hence the name fossil.

Fossil fuels have structured the entire modern world through productivity gains acquired by the supply of large amount of energy and associated technologies.

The stock of fossil energy on earth is finite. Fossil energy inherited from the geologic time is free, as free as wind energy or solar energy. The cost for accessing to fossil energy reservoirs and rewarding the people that have taken possession of those reservoirs (and put their values in their balance sheets) is the driver of the price of fossil fuels. The other driver is the market perception of scarcity of fossil fuels since the reservoir is finite.

**Peak oil**, an event based on Hubbert's theory, is the point in time when the maximum rate of extraction of petroleum is reached, after which it is expected to enter terminal decline. In 1962, Hubbert predicted that world oil production would peak at a rate of 12.5 billion barrels per year, around the year 2000. In 1974, Hubbert predicted that peak oil would occur in 1995 "if current trends continue." Those predictions proved incorrect. However, a number of industry leaders and analysts believe that world oil production will peak between 2015 and 2030, with a significant chance that the peak will occur before 2020. However, the US Energy Information Administration projected in 2014 that world production of "total liquids," which, in addition to liquid petroleum, includes biofuels, natural gas liquids, and oil sands, would increase at an average rate of about one percent per year through 2040 without peaking.

Opponents to the theory of peak oil often cite new oil reserves that have been found, which continue to forestall a peak oil event. This debate is now over.

Indeed, in December 2015, the international community agreed at COP21 in Paris to constrain the combustion of hydrocarbons in an effort to limit global temperature rise to the nominal 2 °C that is consensually predicted to limit environmental harm to tolerable levels.

## 7 Key figures: Typical calorific values of fuels

Fuel	Net Calorific Value (CV) by mass GJ/tonne	Net Calorific Value (CV) by mass kWh/kg	Bulk density kg/m <sup>3</sup>	Energy density by volume MJ/m <sup>3</sup>	Energy density by volume kWh/m <sup>3</sup>
Wood chips (30% MC)	12.5	3.5	250	3,100	870
Log wood (stacked - air dry: 20% MC)	14.7	4.1	350-500	5,200-7,400	1,400-2,000
Wood (solid - oven dry)	19	5.3	400-600	7,600-11,400	2,100-3,200
Wood pellets	17	4.8	650	11,000	3,100
Miscanthus (bale - 25% MC)	13	3.6	140-180	1,800-2,300	500-650
House coal	27-31	7.5-8.6	850	23,000-26,000	6,400-7,300

Anthracite	33	9.2	1,100	36,300	10,100
Heating oil	42.5	11.8	845	36,000	10,000
Natural gas (NTP) <sup>3</sup>	38.1	10.6	0.9	35.2	9.8
Liquid Petroleum Gas (LPG)	46.3	12.9	510	23,600	6,600

Source: [http://www.biomassenergycentre.org.uk/portal/page?\\_pageid=75,20041&\\_dad=portal](http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,20041&_dad=portal)

Net calorific value (CV) or Lower Heating Value (LHV) means that the latent heat of vaporization of the water vapour created by combustion is not recovered by condensation.

## 8 Useful references and links

Energy Quest, energy education website of the California Energy Commission <http://www.energyquest.ca.gov/story/chapter01.html>.

L’Economie aurait-elle un rapport avec l’énergie? – Carbone 4 – Jean-Marc Jancovici [http://www.manicore.com/fichiers/LH\\_Forum\\_27\\_sept\\_2013.pdf](http://www.manicore.com/fichiers/LH_Forum_27_sept_2013.pdf).

What Is Energy? By Joseph Castro, Live Science Contributor <http://www.livescience.com/42881-what-is-energy.html>.

Andrew Rader Studios [http://www.geography4kids.com/files/en\\_intro.html](http://www.geography4kids.com/files/en_intro.html).

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<sup>3</sup> Natural gas contains only methane – NTP means Normal Temperature and Pressure, i.e. 20 °C and 1 atmosphere