ENERGY IN THE UNIVERSE AND ITS AVAILABILTY TO MANKIND

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Abstract

The IMPORTANCE of ENERGY should also be mentioned at our Symposium on Future of Life and our Civilization. Thanks to energy we have reached a high living standard. A fast increase of the world population, the continuing growth of the industrialized world, the natural desire among developing nations to get also a higher standard of living – all that induces an inevitable increase of energy consumption. The contemporary consumption of energy represents about 13 TW (TW is terawatt, or 10^{12} Watt).

BURNING FOSSIL FUELS is the main source of the contemporary energy consumption. They contain solar energy in biomass stored by photosynthesis many millions years ago. The ancient biomass was deposited underground and soiled (*e.g.* by sulphur). Fossil fuels represent valuable material for the chemical industry. Their amount is limited and their prices are rising. The products of fossil fuel burning are harmful to health, are damaging the biosphere and are changing the global .climate. People are killed (in mines and in wars) and life is destroyed on a large scale (e.g. by spilling oil from great tankers). And from a physical and astronomical point of view, burning fossil fuels is the least effective way to get energy from matter.

ENERGY is the capacity of matter and radiation to do work (*en* means in Greek "in" and ergos means "work").. It is everywhere – in matter (Einstein:mc^2), in radiation (Planck: hf) and in space (dark energy). The dark energy is supposed to be the most important energy in the whole Universe. However, its nature and even its existence are still highly hypothetical.

. SOLAR ENERGY represents by far the most important energy source for the Earth, its biosphere and for mankind. There is no doubt, that the energy from the Sun will become the principal energy resource for the future generations in the post-fossil-fuel era. It is pure, of high quality and practically eternal (because the amount of hydrogen in the Sun is sufficient for seven billion years). It is always free for all and everywhere.

The flood of solar radiation falling on the Earth – 180 000 TW – is enormous. How to explain the fact that all the terrestrials together need only 13 TW, whereas they neglect the generous energy gift of the Sun?

WHY do we neglect the solar 180 000 TW and harm at the same time the biosphere? Why do we destroy our cosmic home by using fossil fuels? Why

do we want to pass on a poisoned dump to the next generations instead of the beautiful BLUE PLANET ? Why are people killed and is nature destroyed for the 13 TW ? Why do we pay more and more for our thoughtlessness ? Are the classical philosophers right in defining the human being as intelligent ("Homo creatura rationalis est in qua anima et corpus coniuncti sunt")? Or was Einstein right (?) when he said: "Ich kenne zwei Unendlichkeiten: das Weltall und die menschliche Dummheit. Aber bei dem ersten bin ich mir nicht ganz sicher"

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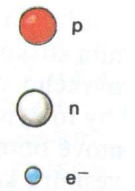
1 Energy of Matter

Our home – the planet Earth – and our organisms are only a tiny part of the Cosmos. All changes in the Cosmos, on the Earth, and in our organism are governed by the energy laws valid in the whole Universe. Energy has a fundamental role in the structure and evolution of the Universe, in life of the biosphere in general and in our organism in particular..

Each matter consists of many elementary particles: protons p, neutrons n and electrons e. Each elementary particle is a droplet of energy. If the particle is isolated and at rest, its energy is called rest energy $m_o c^2$

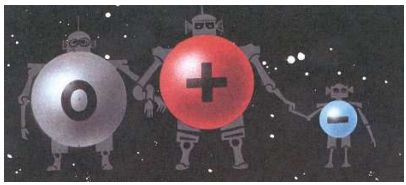


$m_o c^2$

938 MeV

939,5 MeV

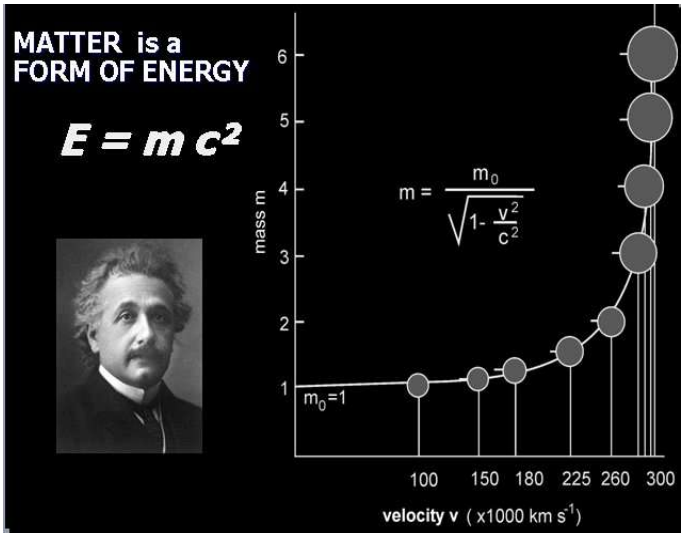
0,5 MeV



Proton is the hero of the Universe. In the core of our Sun it gives away 7 MeV from its rest energy (938 MeV). In this way 560 tons of protons release together $3{,}8 \times 10^{26}$ watt, *i.e.* the solar luminostiy.

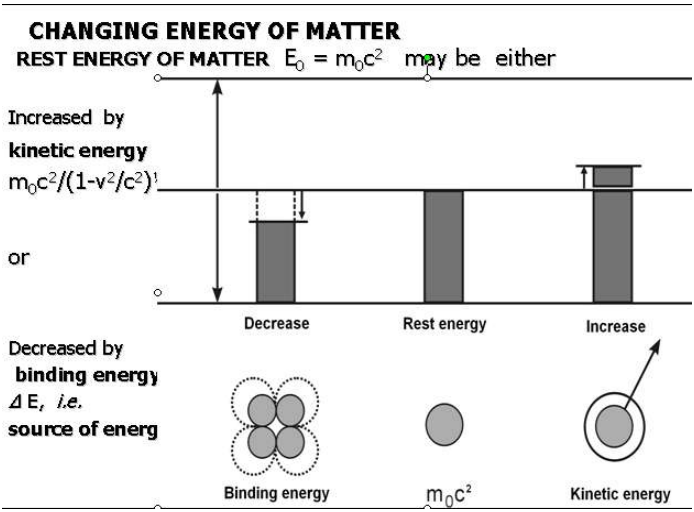
The rest energy may be increased or decreased. The energy used by mankind is drawn from the rest energy of matter (= from agglomeration of elementary particles). One could say that our energy is "squeezed out" from matter. The squeezing out of energy is performed by fundamental forces (interactions) acting between elementary particles : electric, nuclear and

gravitation). In burning fossil fuels the electric force is active, which is the least effective way to get energy.



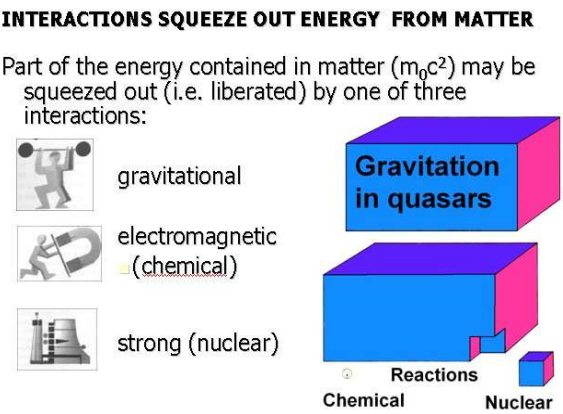
Rest energy m_0c^2 of an elementary particle (or of an object) may be increased by acceleration. The increase is due to increase of its mass as the velocity of light *c* is everywhere and always the same. The Einstein expression shows that no motion of material object can exceed the velocity of light.

A small part of rest energy m_0c^2 may be squeezed out from matter (*i.e.* from a system of elementary particles). The squeezing out is realized by one of the fundamental forces). On the other hand, the decrease of rest energy



represents binding energy of the particle system. *E.g.* by fusion of four protons into one alpha particle in the core of the Sun each proton releases 7 MeV. This is its binding energy in the alpha particle.

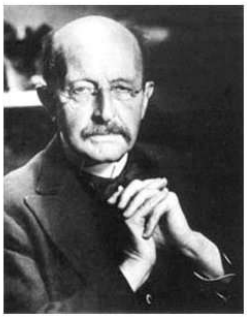
The complete cube represents m_0c^2. Energy can be squeezed out from m_0c^2 by three fundamental forces, *viz.* a) gravitational (*e.g.* in quasars), b) electromagnetic (*e.g.* burning of fuels), c) strong (*e.g.* in stars, nuclear power plants), The yield is worst (10^{-9} mc^2) in burning. It is about 10^{-3} mc^2 for strong interactions and up to 10^{-1} mc^2 for gravitation in the stellar Universe. On the Earth the gravitational energy is much smaller (*e.g.* water in dams).

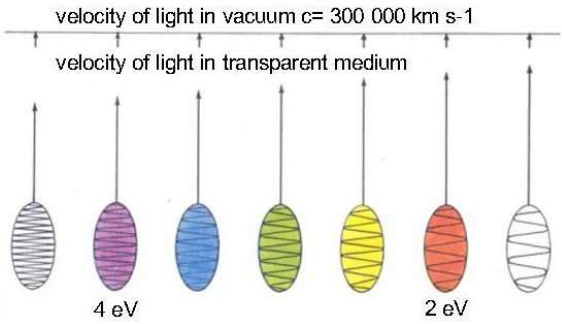


2 Energy of Radiation

Photons are particles (quanta) of electromagnetic radiation. They are little wads of oscillating electric and magnetic force. Each photon is a droplet of energy which depends upon frequency of its oscillation *f* and is determined by *Planck expression* $E = h f$.

The letter *h* in the equation is the universal Planck constant $h = 6{,}6 \times 10^{-34}$ *J s*. Our eyes perceive the photons with energies between 2 eV and 4 eV as light. Photons with higher energy than 4 eV are called ultraviolet radiation, with lower energies than 2 eV are infrared radiation.





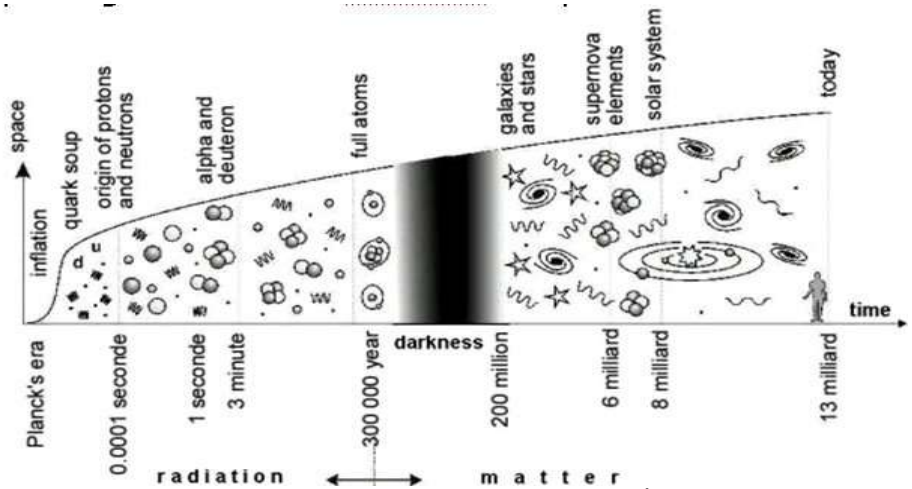
3 Energy in the Universe

History of the Cosmos (*i.e.* of ordered Universe) is History of energy. It began 13,7 billion years ago by Big Bang, when energy was born with radiation, matter, time and space. From chaotic extremely hot and primitive material (called "quark plasma") all the present systems have been created (atoms, planets, stars, galaxies *et all*). Here, in this coin of the Universe – after 13,7 billions of years, on one of the planets (=the Earth) accompanying a star (=the Sun) which is quite a common star among the 150 billion stars of the Galaxy (=Milky Way) – intelligent animals were created.

The law of energy conservation means that the energy can not be destroyed or created from nothing. *It* This implies that any form of energy can be traced backwards in time till the Big Bang when all energy was created. Big Bang means not only the beginning of space and time 13,7 billion years ago , but also of matter and of radiation. But matter and radiation are forms of energy (see.1 and 2).

The horizontal line in our Figure represents the time axis. It is not linear.

Three-dimensional space expansion is represented by one dimension r only, which is the distance of any two points in the Universe.



By increase of r with expansion any volume increases as r^3. The number of particles and the number of photons in the volume decrease equally, *i.e.*as r^{-3}. The energy of particles m_0c^2 is not influenced by expansion, so that energy density of matter ρ_m changes as r^{-3}.

On the contrary, the energy density of radiation ρ_r decreases faster with expansion than the density of matter. The wavelength of radiation λ expands as r. That means that frequency of photons $f = c/\lambda$ decreases with time as r^{-1} so that the energy density of photons ρ_r decreases by expansion as r^{-4}

The number density of particles n_m has always been (and still remains) much smaller than the number density of photons. Immediately after Big Bang the photons had a very high energy (gamma photons). As a result, during the 300 000 years after Big Bang

$$\rho_r > \rho_m$$ (radiation era or photon era)

and later until present

$$\rho_r < \rho_m$$ (matter era or particle era)

After Big Bang the temperature was extremely high, but decreased by expansion. When the Universe was 300 000 years old, its temperature dropped to 10 thousand degrees (K) and all free electrons recombined with protons. This period of the Universe history is called cosmological recombination. Since the time recombination the cosmic space has been transparent. Today, the astronomers can therefore observe very ancient events in the history of the Universe.

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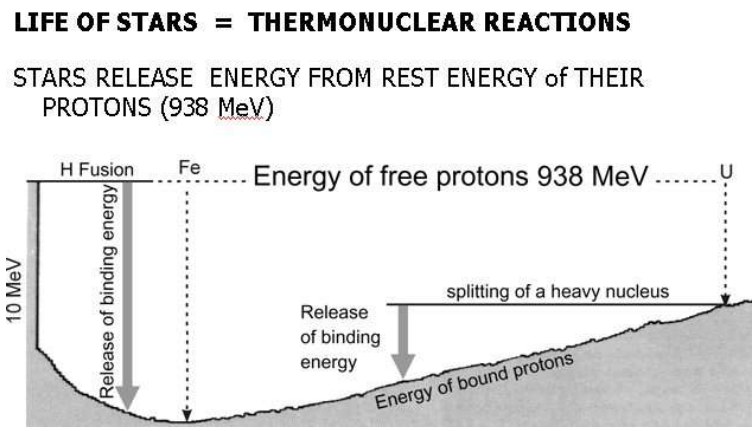
4 **Energy in Life of Stars**

The binding energy of a proton in atomic nuclei is released by nuclear force from proton mass energy $m_0c^2 = 938$ MeV. Protons are fused into nuclei of heavier atoms in the core of stars. The curve in our graph is called *valley of stability*. The number of protons (=atomic number) is on the horizontal axis. The depth of the valley (on vertical axis). corresponds to the binding energy of a proton in nuclei. As may be seen – nuclear fission of heavy nuclei (*e.g.* of U235 in nuclear power-plants) or nuclear fusion of light nuclei (e.g. protons in the Sun) release energy. Produced nuclei are in both cases lower in the valley of stability. The energy difference is radiated away.



The life of a star is determined by gravitational and nuclear energy. The vertical line represents the central temperature of the star. The horizontal line is the time axis. The vertical axis is the temperature in the central core of a star. With age the temperature of the core increases. A globule (= stellar embryo) is very cold (about 10 K, which is -263° C). Its gravitational potential energy is transformed into heat (by contraction). Gravitational contraction and heating are marked by oblique segments of the curve. Thermonuclear fusion produces nuclei of different chemical elements. E.g. fusion of 3 alpha particles at the temperature 100 million degrees results into carbon nucleus (Salpeter reaction). All carbon atoms in the Universe (including our orgasnism) were created by this 3-alpha process.

A dark globule (stellar embryo) is an enormous reserve of gravitational and nuclear energy. Gravitational energy is due to the globule size (a few light years) and the mutual attraction of any pair of its particles (by Newton Law of gravitation). Hydrogen is the most abundant element in the globule and as well as in the whole Universe. It represents the best thermonuclear fuel for the stars. The life of a star consists of getting rid of its enormous reserve of gravitational and nuclear energies.

During the birth of a star gravitation acts as "midwife". Self-gravitation compresses a globule (= a cool cloud of dust and gas in interstellar space). By compression the globule is heated and becomes a radiating protostar. By further compression the temperature reaches 7million degrees (K) in the central part. At such a temperature, protons (nuclei of hydrogen atoms) fuse to alpha particles (nuclei of helium atoms). Nuclear force replaces gravitation in releasing energy and the protostar becomes a grown-up star. The life of a star consists of a sequence of thermonuclear reactions. Each star we see with our naked eye is a thermonuclear reactor.

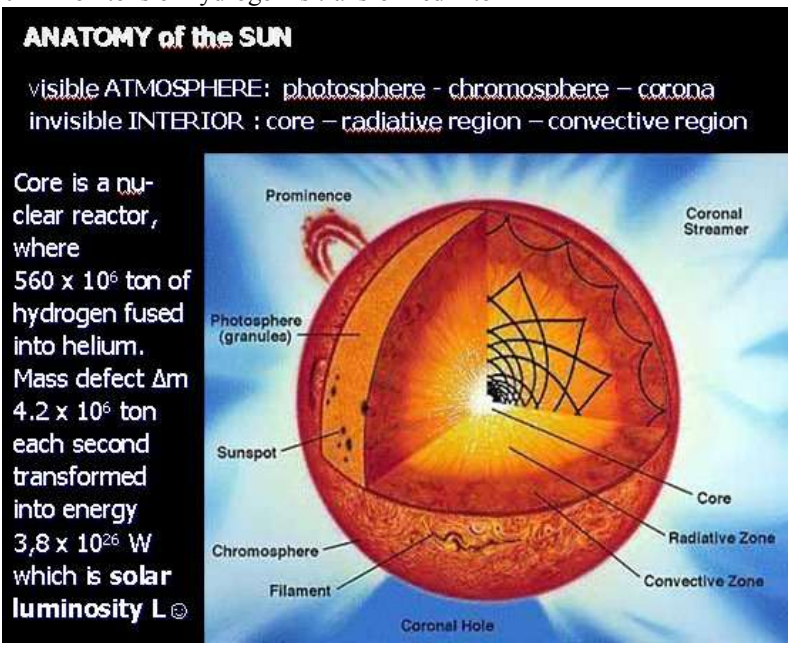
When the nuclear fuel is exhausted, self-gravitation as source of radiation . Gravitation assists also in the final agony as a "gravedigger" of stars. See penultimate graph.

5 The Sun is a perfect fusion reactor

The Sun is the best known star. It is the nearest star, observed continuously in all detail. Its physiology and anatomy is studied by solar physics. It is one of one hundred fifty billions of stars in the Milky Way Galaxy, which itself is one of hundred of billions of galaxies in the known Universe.

The Sun is an enormous ball of very hot gas (=plasma). A jet plane would need nearly half a year to fly around it. Its mass (2×10^{30} kg) is 333 000 masses of the Earth. Nearly all the solar mass is invisible, hidden under the visible surface called the photosphere. The visible part of the Sun is called the solar atmosphere. The hidden part is called the solar interior. The atmosphere is very extended and rarified. The interior of the Sun contains ten billion (10^{10}) times more matter than the solar atmosphere.

The core is the "power plant" releasing $3{,}8 \times 10^{26}$ J s^{-1} ($3{,}8 \times 10^{26}$ W). The energy is released by fusion of hydrogen. Each second 560 million tons of hydrogen is transformed into helium and at the same time mass of 4,3 million tons is transformed into radiation. The core has a temperature of 15 million degrees (K) and the released radiation is in hard X-ray form. The X-ray photons slowly propagate from the core upward to upper cooler layers. They are absorbed and reemitted. Sometimes one photon is absorbed and two photons with less energy are reemitted. On the long journey from the very hot core to the visible and cooler surface (=photosphere), one X-ray photon is being transformed gradually into (approximately) 2 — 3 thousands of light photons. From the photosphere the light photons escape into the surrounding cosmic space. The journey of the photons from the hot core to the visible surface is very erratic and lasts about one million years. (It may be compared to a walk of a drunk man through a forest in a dark night.)



6 Energy of the Earth

The Earth is our cosmic home, moving aroud the Sun like a lonely spaceship with 6 billion human beings on board. It is a blue fragile Beauty with its own energy sources which are limited and soon will be depleted.

The Earth has only two different types of energy resources:

a) Kinetic (revolution, rotation) and nuclear (geothermal and heavy hydrogen). These very old energies were inherited when the Earth was born from the protoplanetary disk 4,5 billion years ago. .

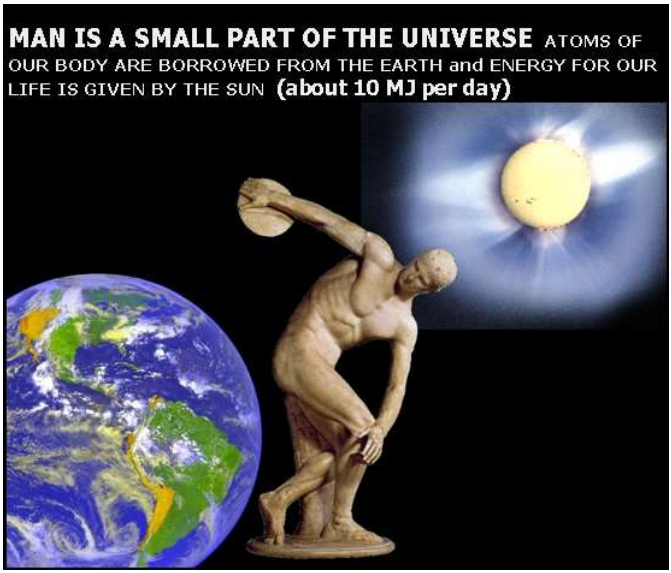
b) An enormous contemporary flood of solar energy is falling upon the Earth. It is nourishing the life on Earth and will do so for the 7 billion years ahead.

Energy given by the Sun to the Earth each second is 180 000 TW , which is 14 thousand times more than 6 billion humans need (*i.e.*13 TW). It is an immense gift of the Sun to all, clean, of high quality, everywhere given free to everybody and inexhaustible. Reserve of the solar fuel – the hydrogen - in the core of the Sun will suffice for the next 7 billions years ($7x10^9$ year).. Inexpensive technologies know how to transform solar radiation in useful forms of energy (chemical, heat, electricity, mechanical energy.)

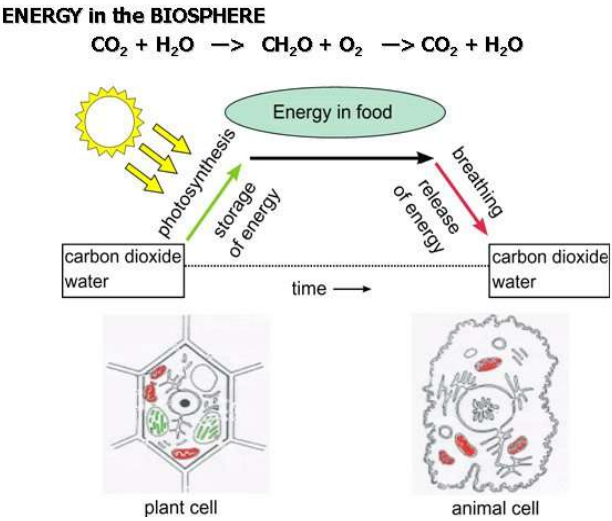
The solar radiation falling on the Earth is being transformed into indirect forms of solar energy, *viz.* wind , currents of water, heat of oceans and continents, waves on water surface and by photosynthesis in biomass. Fossil fuels (oil, coal and earth gas) contain solar energy accumulated by photosynthesis millions of years ago.

7 Energy and Life

Our body is a minute part in the architecture of the infinite Universe and a tiny link in its evolution. But the human beings are enormous by their immaterial soul, because they understand the infinite Universe, predict its future and know how to use its energies.

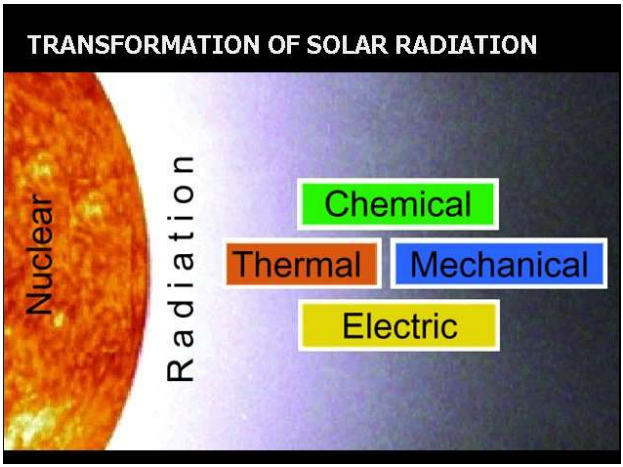


Photosynthesis (in green chloroplasts) deposits solar energy into water (H_2O) and carbon dioxide (CO_2) and releases oxygen (O_2) into the atmosphere. Stored energy is in biomass (in particular in food). We receive the energy stored in food. By oxidization of food in mitochondriae (marked in red) the energy is released. Breathing is a reversed process to photosynthesis.



8 **Solar energy in our service**

Solar radiation cannot be accumulated as such. Instead it can be transformed into a convenient form of matter energy. The term "materia-lization" of solar radiation could be used, because it means (according to Einstein relation) increase of mass.

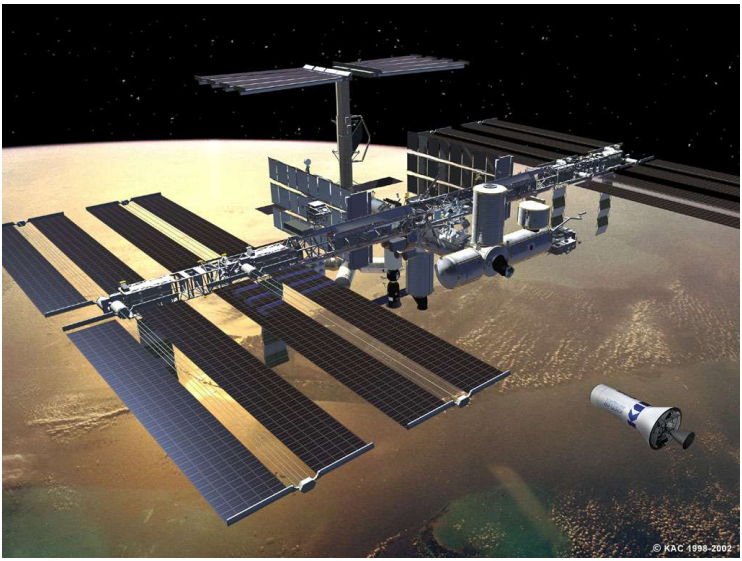


A) **Chemical** - *e.g.* hydrolysis decomposition of water into oxygen and hydrogen. Oxygen with hydrogen used in fuel cells to produce electric current. However, the best known chemialy stored solar energy as biomass energy – solar radiation deposited by photosynthesis. Biomass (organic matter) can be used to provide heat, make fuels, chemicals and other products, and generate electricity.

B) Absorption transforms solar radiation into **heat**. Solar collectors for heating water or air for heating buildings may be seen in many houses. In focus of concentrating collectors water evaporates and the vapor is used in classical powerplants. Nature itself absorbs huge quantities of solar radiation to heat land, hydrosphere and atmosphere. Without this absorption the mean temperature of the Earth would be only minus 260° C. The heat drives winds, water cycle and is used by thermal pumps and oceanic thermal energy converters (*e.g.* OTEC).

C) In photovoltaic (= solar) cells, the incident solar radiation is transformed directly into **electricity.** The cells are still expensive if compared with

normal



powerplants. But in some cases the solar cells are irreplaceable, *e.g.* on lonely places, satellites, spacecraft and International Space Station which needs 110 kW. The International Space Station receives the 110 kW from solar cells on panels
(Columbia edu). Many powerplants use kinetic energy of water or of wind biomass energy – which is transformed solar energy.

D) Solar radiation is transformed **i**nto **mechanical energy** *(i.e.* in kinetical or potential energy).

Indirectly the transformation occurs by biofuels, in heat machines, electric cars or airplanes (see Helios photo of NASA). Our cars and airplanes are also driven by the solar energy – but by the ancient one.

On a huge scale, the solar radiation is being transformed into mechanical energy by nature The kinetic energy of winds and of streaming water, as well as the energy of water circulation is indirect solar energy.

9 **Conclusions.**

It is obvious that the direct solar radiation in the form of photons (180 000 TW) or the indirect solar energy (deposited in wind, water motions, heat and biomass) represent the only energy solution for the Future of Life and for our Civilization. One cannot make an economical comparison with the ancient solar energy used in form of fossil fuels. To their rising price the "price" of many human lives, of a clean healthy environment for our descendents and of a peaceful Blue planet should also be added. Then our discussion will be right.