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ENERGY IN PHYSICS AND IN ECONOMY

Katalin Martinás

Atomic Physics Department, Eötvös Loránd University
Budapest, Hungary

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SUMMARY

In this paper the energy concept used in economic activity is investigated. It is not a "useful" part of physical energy, but an economically defined quantity.

To reach this conclusion we first give a summary of the classification of the different concepts – all bearing the name energy. There are at least six distinct concepts to be distinguished. Three of them are scientific concepts to be differentiated. The physical (conserved) energy belongs to the realm of the first law, the energy as the ability to perform (physical, chemical) work belongs to the second law, the economic (biological) capacity for actions belongs to the (Darwinian Law).

KEY WORDS

energy, history, teaching, interdisciplinarity

CLASSIFICATION

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*Corresponding author, η: martinas@elte.hu; +36 1 2090 555 Ext 6360;
Atomfizikai tanszek, ELTE, Pazmany Peter setany 1, 1117 Budapest, Hungary.

INTRODUCTION

Energy is a unifying concept that spans all the sciences, and is of fundamental importance in issues of social concern such as the environment and the use of fuel resources. Energy is well-known concept. Everybody has an understanding, and the majority has a well defined, contradiction free concept. As a physicist, I had a very clear notion, too. The starting of the interdisciplinary work on the relation of economics and thermodynamics lead to the realisation, that the energy concept of economists is different. The explanation was given by Veronika Poór [1] who said:

“Energy is the quantity which is conserved in physics and which is consumed in biology.”,

“That is why the physical and the biological energy are different quantities”.

A systematic survey lead to the result that there are at least six different categories of the energy. All these energy concepts have some relations (historical or factual) with each other, but from scientific point of view, they are different concepts.

ENERGIES IN THE XXI. CENTURY

There are at least 6 different energy concepts, used in different parts of science or human activity, namely the metaphysical, the psychological, the conserved, the dissipative and the important (human) energies at last but not least we must mention the

E1) ENERGY THE COLLOQUIAL OR THE ENERGIA

The first meaning of the word energy in the Cambridge Advanced Learner's Dictionary: refers to the colloquial usage [2]: „Energy (STRENGTH) is the power and ability to be physically and mentally active.” Examples: “Since I started eating more healthily I've got so much more energy. I was going to go out this evening, but I just haven't got the energy. I didn't even have the energy to get out of bed. Her writing is full of passion and energy (= enthusiasm). I'm going to channel all my energies into getting a better job. I tried aerobics but it was too energetic for me. I felt very energized after my holiday.”

It is clear, that this energy concept does not coincide with the energy of physics.

We argue, that this meaning refers to the original Aristotelian concept.

“Energeia”, which is the root of our word energy, was created by Aristotle. It is generally translated as “activity.” However, it is not necessarily an activity in the sense that we might understand it. For instance, Aristotle describes both happiness and contemplation as activities. In calling happiness an energeia, Aristotle contrasts it with virtue, which he considers to be a hexis, or disposition. That is, the virtues dispose us to behave in the correct manner. Actually behaving according to the virtues, however, is not itself a virtue but rather the energeia of happiness” [3].

By Aristotle the proper function of man is [4] is “activity of the soul in conformity with reason (*psuches energeia kata logon*) (1098a7)”. In the Poetics the word energeia, for Aristotle, refers to the paradox of producing a powerful lifelike effect through words.

In ordinary English, the word energy first appears in the 16th century. For Elizabethans, energy means the vigor of an utterance, the force of an expression, always the quality of a personal presence. A hundred years later the word can qualify an impersonal impact: the power of an argument or the ability of church music to generate an effect in the soul. The term is still used exclusively for psychic effects, although only for those engendered by either a person or a thing. It is the colloquial energy. The online etymological dictionary [5] gives: "energy: 1599, from M.Fr. energie, from L.L. energia, from Gk. energeia 'activity, operation,' from energos 'active, working,' from en- 'at' + ergon 'work' (see urge (v.))." Used by Aristotle with a sense of "force of expression;" broader meaning of "power" is first recorded in Eng. 1665. Energise "rouse to activity" is from 1753; energetic of persons, institutions, etc., is from 1796. Energy crisis first attested 1970."

Crease wrote [6]: "As late as 1842 the Encyclopedia Britannica only gave the word the briefest of entries: 'ENERGY, a term of Greek origin, signifying the power, virtue, or efficacy of a thing. It is also used figuratively, to denote emphasis of speech.'"

This energy concept is present nowadays, too, as the ability to perform an action. This energy has the property that it can be lost and can be created. There were many attempts to find the interpretation of Aristotelian energeia in physics, see as for instance [7, 8], that is to establish the relation between energeia and the energy of modern physics. Nevertheless, they are distinct concepts, and there are only some metaphoric links.

E2) METAPHYSICAL ENERGY - ENERGY AS ARCHETYPE

The 'metaphysical energy' is rather well-spread not only among physicists.. The universe of the contemporary physicist is a world of material objects, and of energy. Matter and energy have been unified by relativity theory into a single substance, 'mass-energy'. Space and time have been unified, also by relativity theory, into a single 4-dimensional entity, 'space-time'. Thus, the modern physicist sees a universe that is quite simple and elegant: mass-energy (in various forms) moving through space-time. This was clearly Einstein's view:

"Matter which we perceive is merely nothing but a great concentration of energy in very small regions. We may therefore regard matter as being constituted by the regions of space in which the field is extremely intense … There is no place in this new kind of physics both for the field and matter for field (i.e. energy) is the only reality." (cited in [9]).

The distinction between mass and energy is considered as artificial. Eddington wrote[10]: "it seems very probable that mass and energy are two ways of measuring what is essentially the same thing, in the same sense that the parallax and distance of a star are two ways of expressing the same property of location".

Russell stated the same idea in 1948, when he claimed that [11]: "it is energy, not matter, that is fundamental in physics"

After a discussion particle-antiparticle annihilation experiments in 1951, Pauli states [12]: "Taking the existence of all these transmutations into account, what remains of the old idea of matter and of substance? The answer is energy. This is the true substance, that which is conserved; only the form in which it appears is changing."

Popper reiterated this view [13]: "matter turns out to be highly packed energy."

This energy concept belongs to territory of philosophy, so we do not deal with it further.

E3) CONSERVED ENERGY

This is the energy of physics. It is taught in the Secondary Schools. The usual introduction is as follows [14]: "Energy is an abstract quantity of extreme usefulness in physics because it is defined in such a way that the total energy of any closed physical system is always constant (conservation of energy). It is impossible to overstate the importance of this concept in all branches of physics from elementary mechanics to general relativity. Energy is measured in units of mass times velocity squared, and the MKS and cgs units of energy are the Joule and erg, respectively. Other common units of energy include the Btu, calorie, and kilowatt hour.

The important quantity in physics known as work, which is the product of applied force over a distance, has units of energy. In fact, the notion that heat is a form of energy was one of the most important developments in classical physics and thermodynamics."

The last sentence already shows the sigh of the great confusion. Heat is not a form of energy. In this respect it is similar to work. No physicist says that work is a form of energy. Work is the transfer of energy from one physical system to another, especially the transfer of energy to a body by the application of a force that moves the body in the direction of the force. It is calculated as the product of the force and the distance through which the body moves and is expressed in joules, ergs, and foot-pounds. The equivalence of heat work was demonstrated by Joule, namely to produce the same heating effect 1 Joule work or 1 Joule heat is needed. Heat, as the work, is the name for energy transfer from a system to an other. If we look for a hot body, it is not a reasonable question: "How much heat does it contain?". Heat is not a form of energy. Heat is a form of energy transport as work.

The sound description of E3 energy was given by the Nobel Prize winning physicist, Richard Feynman, who wrote [15]: "There is a fact, or if you wish a law, governing all natural phenomena that are known to date. There is no exception to this law – it is exact so far as is known. The law is called the conservation of energy. It says that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea because it is a mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same."

In conclusion, the conserved energy of physics does not have form. The forms of energy in physics is a heritage of the Newtonian framework, where the total energy is written as the kinetic energy plus the potential energy and plus the internal energy. Nevertheless, the independence of this terms is not valid in non-Newtonian approach.

E4) ENERGY AS A CAPACITY TO PERFORM WORK

Energy is sometimes defined in physics, too, as the ability to do work. The energy is usually introduced by this concept in schools, as in [16]: "Energy causes things to happen around us. Look out the window. During the day, the sun gives out light and heat energy. At night, street lamps use electrical energy to light our way. When a car drives by, it is being powered by gasoline, a type of stored energy. The food we eat contains energy. We use that energy to work and play."

Here is the explanation of Cambridge Advanced Learner's Dictionary [2]: "Energy is the power from something such as electricity or oil, which can do work, such as providing light and heat."

"The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt-hours, while heat energy is usually measured in British thermal units (Btu)."

In physics that energy, that is the capacity to perform work, is mentioned as the useful part of energy. It has no separate name or symbol. In biology and in ecological economics it is called as “free energy”. Nevertheless, it does not coincide with the results of thermodynamics. Lozada [17] gave a careful and detailed analysis to this problem, and stated that: “changes in free energy as traditionally defined are not, in general, related to the amount of work a system can perform (although they are so related in special cases).”

In the engineering practice that “energy” is a well-defined concept, and it is called exergy [18, 19]. Exergy is the maximum amount of work that can be extracted from a physical system by exchanging matter and energy with large reservoirs in a reference state. This work potential is due to either a potential due to random thermal motion, kinetic energy, potential energy associated with a restoring force, or the concentration of species relative to a reference state. While energy is conserved, exergy can be destroyed. The second law (formulated by exergy) is the principle of exergy dissipation.

In physics the conserved energy and the working ability controversy is “solved” by the statement, that energy is the ability to perform work, but it has available and non-available forms, suggesting that the working ability is always less then the total energy. There are cases when it is right, but it is not always the case. In thermodynamics E3, the conserved energy, U has the form:

$$U = TS + pV + \mu N, \tag{1}$$

where the symbols are S for entropy, V for volume and the N for mole numbers, while T is for temperature, p for pressure, and the chemical potential is μ. The working ability, E4 is the exergy, defined as:

$$B = (T - T_0)S + (p - p_0)V + (\mu - \mu_0)N. \tag{2}$$

The environment is considered as an equilibrium system, with temperature T_0, pressure p_0 and chemical potential μ_0. Exergy can be expressed by as a function of energy as:

$$B = (1 - T_0/T)U + (p_0 - pT_0/T)V + (\mu_0 - \mu T_0/T)N. \tag{3}$$

From the formula it is clear that there maybe cases when $B < U$ and as well as there maybe cases, where $U > B$.

A numerical example to illustrate the case is as follows. Imagine 1 mol helium of temperature 15 K is in a vessel in your room. The internal energy of the gas is given by the ideal gas law:

$$U = 3nRT/2, \tag{4}$$

where n is the quantity of gas, measured in units of mol, T is the temperature and R is the gas constant (8,31451 J/mol K). The exergy (maximum available work) in the 300 K temperature room is (roughly)

$$B = 3700 \text{ J}. \tag{5}$$

The exergy of the gas is much larger (3700 J) then its internal energy. The “useful” energy, used in colloquial physics for exergy, is not a part of the total energy – as the later can be smaller. The exergy is not conserved, but it is dissipated. The Second Law can be formulated as the decrease of exergy.

The source of confusion is that exergy and energy are both measured in Joule units. To emphasize the differences of their nature we propose the use of extropy, which is the entropic measure of the distance form the equilibrium [20 – 22]. There is a paper on the thermodynamics of extropy in the present issue, written by Veronika Poór [23]:

$$\Pi = B/T_0 = (1/T_0 - 1/T)U + (p_0/T_0 - p/T)V + (\mu_0/T_0 - \mu/T)N. \tag{6}$$

Does the extropy have forms? The answer seems to be positive, if we look for the introductory sentences. We can talk about the wind exergy, solar exergy. On the other hand thermodynamics says the opposite. The exergy/extropy value is assigned to a system in its environment. Expression (2) implies that there is a heat exergy, when there is a temperature difference. There is a chemical exergy, when there is a chemical potential difference. But as T, p and μ are not independent – there must be always at least two differences. So we cannot speak about the form of energy or exergy or extropy. As if there was a temperature difference, and there was no pressure difference then there must have been a chemical potential difference, too. Otherwise the positivity of exergy/extropy is not fulfilled. The form of exergy/extropy is superimposed on the actual system by a subjective valuation, as we use usually one form of the difference. The temperature difference in case of heat engines is used. The used, exploited difference is the one which is useful energy for us. Usually it is not the total exergy/extropy of the system, but only a part – which is valuable for us. This is a valued form of exergy which belongs to the biological, economic energy.

E5) USEFUL ENERGY – BIOLOGY AND ECONOMICS

The biological (economic) systems are non-equilibrium systems from the point of view of thermodynamics. We can characterize them by their extropy, which must be positive. The more developed the system the higher is the distance form equilibrium, the higher is the extropy content. Second Law states, that the extropy is always decreasing, so to sustain the state (the activity) extropy input is needed. Nevertheless not only extropy, but extropy in a usable form is needed. The oxygen and hydrogen have more extropy than water, but as Lozada [19] explained: “But suppose I am dying of thirst on a desert island. If I have hydrogen and oxygen but no catalyst (such as platinum) to make them react, I will die; if I have water, I will live.”

As Witt summarized the characteristics of metabolism [24]: “Consider, for example, the more or less complex metabolism of living organisms. The outcome of that production process is organized living substance. It is maintained by the process not least through the transformations by which energy is made available for use by the organism from carbohydrates, fats, and proteins which have ultimately arisen from the photosynthesis of radiant energy provided by sun light. The latter, together with minerals, water, oxygen, and possibly some other organic compounds, represent the ‘inputs’ to that production.”

As it is emphasized by Witts’ summary, in biology and economics only that part of exergy is considered “(free) energy”, which is useful. Biological energy comes from solar energy. The energy from the sun is stored and transported in plants and animals as chemical energy in the bonds between atoms in molecules. Some biological energy is stored in phosphate bonds in a molecule called ATP. ATP can release its energy in many useful ways in cells, but it is not very stable, so it is not be a good way to store energy for long periods of time. For transport through an organism, or for longer term storage, biological energy can be stored in chemical bonds between carbon atoms in more stable molecules called carbohydrates.

Definition given by BEIng (Biological Energy Interest group) [25]: “We use the phrase ‘biological energy’ as a convention to refer to a specific social and technological endeavor: to use the metabolic capacities of organisms to convert some combination of light, biomass, organic compounds, gases and water into useful chemical-bond energy; i.e. storable, transportable, energy yielding molecules as well as industrially useful materials. Examples include hydrogen, methane, alcohols, ammonia and bioplastics.”

Nowadays in economics the energy is considered as fuel. A substance used as a source of energy, usually by the heat produced in combustion. The modern economic energy concept becomes popular with the energy crises, which is a great shortfall (or price rise) in the supply of energy to an economy.

All living organisms including humans dissipate extropy. In any production process an important factors of production can then trivially identified: the matter or materials, i.e. substances of a certain chemical or molecular composition, which are non-equilibrium systems. This inputs are transformed. The production is the transformation of extropy from a less useful to more useful form.

This valuation leads to a thermodynamic based definition of wealth. The economic wealth of an economic agent is defined as the quantities of goods owned by the agent (X_i) times the value of the i-th type of good (ν_i)

$$Z = \sum_i \nu_i X_i \,, \tag{7}$$

where X_i is measured in natural units, (kg, cubic meters or number of items), but there is a natural unit for economic goods, it is the extropy content (Π_i is the extropy content of the i-th type material good), then

$$Z = \sum_i w_i \Pi_i \,, \tag{8}$$

where w_i is the value of the i-type extropy [26, 27].

The energy term in economics is not simply the useful part of exergy, but it contains a valuation, too. That explains the failures to derive economic values from physical (thermodynamic) considerations. On the other hand this explains the emergence of environmental problems. As the “economically” non-useful parts of extropy have (had) zero values, they did not appear in the economic considerations. A very important (material side) of economic activity was neglected.

E6) PSEUDOSCIENTIFIC ENERGY

In the last decades we can feel the ever-growing popularity of different mystic energies (cosmic, Tao, chi). A short description found in the internet is as follows [28]: “When Taoism superseded most religions where the people previously believed in ancestral spirit worship the concept of the spirit was altered to Chi. Later Taoist schools or sects introduced multiple gods associated with fertility and nature and others kept the ancestral spirit aspect. Just as there is no one interpretation of a Christian the same is true of Taoism. Many ‘New Age’ Westerners have studied Taoism and have taken chi as to be more of an energy like electricity. Reiki is a form of acupressure used to stimulate such energy through nodes and energy streams in the body to heal internal and external body ailments. Alternative medicine in the West has associated chi in this concept. Chinese medicine balls twice as large as golf balls or larger are held in the palm of ones hand and are rotated by the fingers. This is believed to stimulate the energy channels in the fingers and heal many ailments. Acupuncture is another way of manipulating these energy flows and nodes on the body and was established by the Taoists.”

There is a confusion about the meaning of _chi. This Chinese term does not correspond to energy in modern physics. People who translate _chi that way usually refer to the old, everyday sense of vigor or vitality. It has nothing to do with the physical sense of the word [29].

Sometimes these mystic energy followers consider these energies as the real generalisation of the energy of the science. For them the secondary school education in physics, that is the Newtonian energy concept – gives the basis to understand these “mystic” energy. According to a 2005 Gallup poll, 55 % of Americans believe in psychic or spiritual healing, based on this New Age energy.

That is the point where we have to mention the "Free energy" cult [30], or with other words, the perpetual mobile constructors. In the last 150 years at least 1400 "free energy" machines were patented in USA. They claim that certain special interest groups are suppressing technologies that would or could provide energy at reduced costs, reduced pollution output, or would or could reduce the energy consumption of various devices. The knowledge given by the education is not sufficient to avoid investments into this "miracle machines". United States Patent and Trademark Office (USPTO) has made an official policy of refusing to grant patents for perpetual motion machines without a working model. One reason for this concern is that a few "inventors" have waved a patent in front of potential investors, who may believe that said patent proves the machine works.

In the next chapter a summary of the historical development is outlined. We look for the answer, how this unifying character of energy did appear. How it is possible that one concept tends to incorporate the first, the second law of thermodynamics and the Darwinian-law.

HISTORY OF THE ENERGY CONCEPTS

E2-E3 THE ENERGY CONCEPT IN PHYSICS 1807-1853

By the middle of the nineteenth century the concept of energy was being employed to provide the science of physics with a new and unifying conceptual framework, which brought the phenomena of physics within the mechanical view of nature, embracing heat, light and electricity together with mechanics in a single conceptual structure. The establishment of the mechanical view of nature, which supposed that matter in motion was the basis for physical conceptualization, as the program of physical theory, and of the concept of energy and the law of the conservation of energy as principles unifying all physical phenomena, was the distinctive feature of the conceptual structure of nineteenth-century physics [31].

The concept 'energy' stemmed from Leibniz's vis viva and Mme. Du Châtelet's demonstration that earlier experiments showing that weights dropped onto a clay floor had impact depths proportional to the square of the velocity supported conservation of vis viva rather than momentum. The energy story begins with the work of Thomas Young 1807, when he proposed energy instead of vis viva. Thomas Young, lecturing to the Royal Institution on collisions in 1807, said that: "the term energy may be applied, with great propriety, to the product of the mass or weight of a body, into the square of the number expressing its velocity", thereby tying the word, apparently for the first time, to its modern concept. But Young's "energy" was not ours. It referred only to what we now call kinetic energy and did not even use our formulation of $mv^2/2$, it was the vis viva with a new name [32]. Sometimes it is said, that Thomas Young made up the word "energy" from a Greek expression that means "work inside". Energy is something that has "work inside it". You can use that energy and get work out of it. The only problem with this explanation is that the modern concept of work appeared as late as 1829 in physics. Coriolis studied mechanics and engineering mathematics, in particular friction, hydraulics, machine performance and ergonomics. He introduced the terms 'work' and 'kinetic energy' with their present scientific meaning. Coriolis began developing his ideas in 1819 and he showed some papers to Poncelet in 1824. Both Coriolis and Poncelet published in 1829; the paper by Coriolis being "Du Calcul de l'effet des machines". Despite the two papers appearing in 1829 there was no argument as to who initiated the idea, with Poncelet acknowledging that the word "work" was brought in by Coriolis [33].

Mayer in 1842 argued that lifting a weight of one kilogram to a height of 365 meters required the same Kraft or "force" as raising the temperature of one liter of water by 10 ^{o}C. This Kraft was the conceptual precursor of energy.

Helmholtz in 1847 did not use the word energy, his paper was about the Conservation of Force (KRAFT). In 1842 Justus von Liebig attempted to reestablish the mechanical theory of animal heat. Liebig tried to do this by experiments, whereas Helmholtz took a much more general path. Having mastered both physics and mathematics, Helmholtz could do what no other physiologist of the time could even attempt – subject the problem to a mathematical and physical analysis. He supposed that, if vital heat were not the sum of all the heats of the substances involved in chemical reactions within the organic body, there must be some other source of heat not subjected to physical laws. This, of course, was precisely what the vitalists argued. But such a source, Helmholtz proceeded, would permit the creation of a perpetual motion machine if the heat could, somehow, be harnessed. Physics, however, had rejected the possibility of a perpetual motion machine as early as 1775, when the Paris Academy of Sciences had declared itself on the question. Hence, Helmholtz concluded, vital heat must be the product of mechanical forces within the organism. From there he went on to generalise his results to state that all heat was related to ordinary forces and, finally, to state that force itself could never be destroyed. His paper "On the Conservation of Force", which appeared in 1847, marked an epoch in both the history of physiology and the history of physics. For physiology, it provided a fundamental statement about organic nature that permitted physiologists henceforth to perform the same kind of balances as their colleagues in physics and chemistry. For the physical sciences, it provided one of the first, and certainly the clearest, statements of the principle of the conservation law [34 – 35].

The problem of thermodynamics that time was articulated by Kelvin [1852], who wrote [36]: "The whole theory of the motive power of heat is founded on the two following propositions, due respectively to Joule, and to Carnot and Clausius.

- Prop. I. (Joule) – When equal quantities of mechanical effect are produced by any means whatever from purely thermal sources, or lost in purely thermal effects, equal quantities of heat are put out of existence or are generated.
- Prop. II. (Carnot and Clausius) – If an engine be such that, when it is worked backwards, the physical and mechanical agencies in every part of its motions are all reversed, it produces as much mechanical effect as can be produced by any thermodynamic engine, with the same temperatures of source and refrigerator, from a given quantity of heat."

Clausius in his 1854 paper [37] showed that in a heat-engine operation two kinds of heat transformations occurred at the same time. In each cycle of operation, the transmission transformation took place in its natural direction (heat dropped from a high to a low temperature), while the conversion transformation proceeded in its unnatural direction (heat converted to work). He recognised the conservation law, but he called the new quantity (u) as Sensible heat. Clausius has shown that in a conversion transformation

$$\mathrm{d}Q = \mathrm{d}U + p\mathrm{d}V \tag{9}$$

where U is a state variable, dependent only on the state-determining variables t and v (temperature and volume). Nevertheless he read it, that the heat supplied to the system could become either "sensible heat", or it could be converted into work.

ENERGY IN THERMODYNAMICS

Rankine in the 1853 – 55 papers, entitled as "Nature of the Science of Energetics" introduced the word energy to thermodynamics [38]: "Energy, or the capacity to effect changes, is the common characteristic of the various states of matter to which the several branches of physics relate; if, then, there be general laws respecting energy, such laws must be applicable, mutatis mutandis, to every branch of physics, and must express a body of principles to physical phenomena in general.”

The term “energy” comprehends every state of a substance which constitutes a capacity for performing work. Quantities of energy are measured by the quantities of work which they constitute the means of performing.

“Actual energy” comprehends those kinds of capacity for performing work which consists of particular states of each part of a substance, how small so ever; that is, in an absolute accident, such as heat, light, electric current, vis viva. Actual energy is essentially positive.

“Potential energy” comprehends those kinds of capacity for performing work which consists in relations between substances, or parts of substances; that is in relative accidents. To constitute potential energy there must be a passive accident capable of variation, and an effort tending to produce such variation; the integral of this effort, with respect to the possible motion of the passive accident, is potential energy, which differs in work from this – that in work the change has been effected, which, in potential energy, is capable of being effected.

Already in the XIX. century the Beneck Foundation asked to answer the question whether Young’s and Thomson’s concept of ‘energy’ were equivalent to what Helmholtz called ‘force’. There were two entries, but no first premium was awarded. The young Max Planck won the ‘second premium’ with a book-length essay [39] entitled “Das Prinzip der Erhaltung der Energie”, Leipzig: Teubner Verlag, 1908 (1887).

ENERGETICS 1870-1945

“Energetics Movement” associated with Wilhelm Ostwald around the turn of the 20th Century. Ostwald advocated a World Government based on the use of “energy” as the universal, unifying concept not only for all of physical science, but for economics, psychology, sociology and the arts. Ostwald argued that all observable phenomena should be reduced to the principle of energy, and he proposed the development of all scientific fields in terms of energetics [40]. At first only inanimate matter was to be reduced to this principle, then the phenomena of life were included, and finally, from 1900 onwards, Ostwald attempted to account for psychological phenomena as energetic processes.

Although the energeticists are now mostly forgotten, the Cult of Energy remains deeply embedded in European culture. Over the course of the 20th century, modern physicists gradually developed our present conception of energy. Einstein had showed that mass, in itself, was energy. Energetics found its consummation and ultimate articulation in Einstein's theory of relativity, in which he formulated the famous equation $E = mc^2$, showing that matter and energy were, in fact, fundamentally equivalent. The concept of a single entity, mass energy, resolved much of the tension between competing theories of matter and the theories of energy, unifying the two concepts in larger, transcendent framework.

Our unified energy concept is the child of energetics. That is the root of the energy cult, and the root of the popular opinion that all the changes can be described as transformation of energy from one form to an other form.

This energy concept problem is not a mere grammatical problem. It is not a question that distinct concepts bear a common name. The problem is that they are not distinguished. The resulting chaos deeply effects the learning and understanding of physics in the schools. Further it has a serious impact on the handling of energy issues.

PRESENT – ENERGY PROBLEM APPEARING IN THE LITERATURE

Energy (nowadays) is the capacity to perform actions. That thing we call energy in day-to-day usage is not always the energy of science. It is not the conserved energy. Not even close! On the other hand in science it is considered that there is only one energy, the conserved one, and physics also talks about the energy forms. The confusion is well demonstrated, and well investigated in the schools. There is a serious problem with the teaching of energy in schools. It is not a school problem, as those, who did not get a solid energy concept in the school, will not have the opportunity later to get it.

Trumper and Gorsky [41] investigated the energy concept of children. They identified nine distinct conceptual frameworks, cited by Sefton [42]. Characteristics of these broad conceptions what they found that refer to capacity to perform actions. It is clear, that in spite of all the efforts of education of physics the conserved energy concept is far from the students.

In the following we give a correspondence between our classification and the conceptual framework of Tumper and Gorsky. As the two classification is based on different principles, the relation is not very solid. Nevertheless Tumper and Gorsky prove that E3 – E5 appears. Definitions belong to the evaluation of the children, and the E numbers to our classifications.

Table 1. Correspondence between work of Tumper and Gorsky and classifications of energy.

Tumper&Gorsky	**E**					
	1	**2**	**3**	**4**	**5**	**6**
1. Energy is associated with people	+				+	+
2. Things possess and expend energy	+	+	+	+	+	
3. Energy causes things to happen				+	+	+
4. Energy is an ingredient in things and can be released by a trigger				+	+	+
5. Energy is associated with activity	+	+	+	+	+	+
6. Energy is created by certain processes	+				+	+
7. Energy is a generalized kind of fuel associated with making life comfortable				+		
8. Energy is a kind of fluid which is transferred in some processes			+			
9. A scientific conception in which energy is transferred from one system to another			+			

Gregg Swackhamer gave a very concise summary of the problem, in his draft “Cognitive Resources for Understanding Energy” [43]. Here are some important statements:

- “One hundred and sixty years after its advent energy has become an indispensable concept for describing and explaining our world scientifically. Therefore it is now ubiquitous in school science curricula worldwide and regarded as of first importance universally by scientists and educators alike. Nonetheless, energy is not well understood by our students. Students graduating from secondary schools generally cannot use energy to describe or explain even basic, everyday phenomena.”
- “Energy as presented in school science is not a single, coherent concept, and it is not always consistent with the scientific energy concept. Furthermore the energy concept in the professional science education literature is not even unitary. As a result energy is not treated in consistent ways from year to year and from discipline to discipline in our schools. Today’s school science energy concept has retained and acquired connotations that contradict the modern scientific energy concept and that hinder its comprehension by teachers and students alike.“

The problem of the different connotations was already mentioned in 1914 by a Hungarian writer – Ferenc Móra [44]. Mora wrote a short article in a newspaper about Robert Mayer, with a good introduction of the First Law of Thermodynamics. He stated the grave conceptual problem as: “If I say that I do not believe in the conservation of energy than the Professors of

Physics will say that he is asinine, as he is a layman. If I say that I do believe in the conservation of energy than the Reader of this Journal will say that He is asinine, as he is a scientist."

Móra said, that he does not believe in the conservation of energy, as his energy disappeared: "Where is that Robert Mayer who can tell me where is my childhood's energy?"

This problem of understanding of energy is a problem of the schools. It is a grave problem, as the majority after the secondary school stops the education in natural sciences. My personal statistics support this result. The majority of non-natural scientists do not feel the energy concept, and the only understandable version is the E6.

The problem ican be summarised as Robin Jean did [46]: "It looks as if the first principle of thermodynamics and the word which is its stenographic token ('energy') had been allowed to be the Trojan horse for a contagion not only by ecologically and socially unsound, but also by culturally and symbolically destructive thought habits. Is perhaps the energy concept – the intellectual cathedral of 19th Century physics – a cultural equivalent of AIDS when it escapes from the lab and invades concrete life? Is the synonym-less word energy the vector of an acquired cultural immunodeficiency syndrome, as soon as it ceases to be strictly a technical term of a well-defined science, thermodynamics?"

CONCLUSIONS

E1-E6 energy concepts are basically different quantities, of different properties, which deserve a distinct name. From the list, E3-E4-E5 mean the real confusion, as they are usually measured in the same (energetic unit), and E4-E5 is considered in physics as part of E3, suggesting that the values (expressed in Joule units) satisfy the rule:

$$E3 > E4 > E5. \quad (10)$$

This inequality is not always valid. It is valid only in some restricted cases (encountered mainly in textbooks). E3, the conserved energy is assigned to a system, the numerical value depends on the selection of the reference system. E4 refers to the actual environment, it measures the difference between the system and its environment. It can not be created. E5 refers to a human (or in biology to an organism) – it is the actual ability for action of the human. It is a valuated sum of the E4 energies. As Sung Tzu said 2500 years before in his work "The art of war" [28]: "Energy may be likened to the bending of a crossbow, decision, to the releasing of a trigger".

In this example E3 is the wood of the crossbow, E4 is the crossbow, E5 is the bended crossbow, which can be released. The E5 energy contains a valuation. It is not measured in Joule units, but in some subjective units. It is worthwhile mentioning that E5 is also a measurable, and well defined quantity in case it is connected with the economic wealth.

The following table summarises the properties of E3-E5. It compares the economic and physical and engineering energy concepts.

Table 1. Energy.

	E3 PHYSICS Total energy	**E4 Engineering Extropy**	**E5 Economy**
characteristics	neutral	neutral	valued
	abstract	abstract	human-specific
more like	mass	form	form
time behaviour	$dE_3 = 0$	$dE_4 < 0$	$dE_5 > 0$
governing law	conserved, First Law	dissipated, Second Law	can be produced, Darwinian law

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ENERGIJA U FIZICI I EKONOMIJI

K. Martinás

Odsjek za atomsku fiziku, ELTE
Budimpešta, Madžarska

SAŽETAK

U radu se razmatra koncept energije u ekonomskim aktivnostima. To nije "koristan" dio fizikalne energije, nego ekonomski definirana veličina.

Radi izvođenja tog zaključka prvo je sažeto izložena klasifikacija različitih koncepata – koje se sve naziva energija. Pritom treba razlikovati bar šest koncepata. Među njima su tri znanstvena: fizikalna (sačuvana) energija uključena je u prvi zakon termodinamike, energija kao sposobnost obavljanja rada (fizikalnog, kemijskog) pripada drugom zakonu termodinamike dok ekonomski (biološki) kapacitet djelovanja pripada Darwinovom zakonu.

KLJUČNE RIJEČI

energija, povijest, učenje, interdisciplinarnost