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Question marks related to energy security and environmental safety

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Abstract

Global energy perspectives and the relationship between energy and environment are summarized from the viewpoint of earth- and environmental science. Instead of the terms "renewable" and "non-renewable", it would be more precise to use the terms "stock-kind energy" and "flow-kind energy". Among the environmental impacts of energy production and consumption, a list of various multidimensional and very specific (among other non-linear and retarded) environmental impacts of (1) the production of primary energies, (2) their transformation to secondary- and (3) tertiary energies, and finally (4) the environmental impacts of the end-use of energy (i.e. the consumption) is given. The intensity of human activity is characterized by a primary energy use of 18 terawatts. By using this huge power, human beings do the following activities: transformation of continent surfaces, pollution of waters, soil and air, influencing the climate, depletion of natural resources (both raw minerals and energy sources), increasing the number of nature-humanity interactions called "natural catastrophes", the global trade (leading to species invasion, biodiversity and ecosystem collapse). The way of life of the Homo sapiens leads to physical and mental degradation, but humans still seem to need even more and more products and services. Knowing all these multidimensional consequences, to concentrate exclusively on CO_2 emission is equivalent to hiding – either in a naïve or deceptive way – the causal relationships. Both of the two main issues (satisfaction of energy demand and its environmental impacts) are found to be alarming. A global consuming society is surely not sustainable. We should prepare ourselves to situations and processes, which are very different from those of the recent past. Hungary's natural resources have become important, but the long-term energy security depends on the availability of a larger amount of local energy sources.

Keywords: limits to growth, Future Earth, sustainability, fossil energy, stock (exhaustible) energy, flow (renewable) energy

Introduction

Energy, fresh water, soil (food), raw material, and appropriate natural environment: these are essential but also limited preconditions for the human society. If these are missing, social tensions will develop. In this study book, the definition of safety and security is "a notion related to the threat of existence of groups of the state, the society, and/or the citizens (related to the possible occurrence of a situation sharply or drastically differing from the normal lifestyle)" (Tálas, 2016). The definition of energy security according to the International Energy Agency: "the uninterrupted availability of energy sources at an affordable price" (IEA, 2017). This also shows that studies about energy security (in fact about the future availability of energies, and the connection of energy and the environment) mainly apply an economic, financial, and political approach. Considering the fact that (1) the non-renewable (stock-kind) energies are connected to geological formations that are generated through specific geological processes, (2) the so-called renewable (flow-kind) energies are also parts of the natural system, and (3) the presentations of the environmental impacts of energy are usually connected to some interest; therefore this study expressly aims at taking an earth- and environmental scientific approach to the issues of energy- and environmental security. The conclusions reflect the author's personal opinion.

Energetic experts have always shared the opinion and usually think (see e.g. Vajda, 2014) that humanity will find the solutions to meet energy needs – as always did in the past. The green approach has changed a lot in the past decades, and today's situation is rather contradictory. Some issues of environment pollution, and even the disruptions occurring in the natural cycles, have been attracting the attention since the sixties (Carson, 1962; Ehrilch, 1968; Jócsik, 1971). But at the Stockholm World Environment Congress in 1972, they came to the conclusion: "only the potential of well-developed industries and agricultures are able to produce the sums and assets necessary for the prevention of further environmental pollution and for the restoration of the disrupted biological balance" (Kocsis, 1976). At the same place, the countries of the so-called third world declared that they would have liked to have big industries and also big environmental problems. Then, in the 1980's, several companies recognized that financial performance could be improved through focusing on environmental aspects (Zilahy, 2017). The concept of ecological footprint gained ground in the nineties. Even though today we already consume 1.4 times the Earth's capacity, the aspects of greenhouse effect have been prioritized. Namely, the emission reduction commitments – due to the mutual cooperation of the states and the companies – have become a means of further economic growth and environment transformation (Kondor–Kovács, 2017). The turning point might have been when Al Gore, former US Vice President, having extensive interests in the green economy, was awarded the Nobel Peace Prize in 2007. Today's so-called green paradigm focuses on reducing CO_2-emissions (and thus retaining global warming under the 2 °C level). Thus, the so-called green idea in fact has become one of the means and ways of further economic growth.

So far as earth- and environmental science is concerned, it is obvious that ultimately we get all of our resources from nature. Therefore, we must examine the balance of humans and the environment, including the possibility of a green economy. Quoting Gyulai (2010): "the most magnificent mission today's science can have is to research whether 6–10 billion people may live on the Earth – what is more: with the tigers also surviving…". Al Gore:

According to the ethic message of his book *An inconvenient truth* (which was cut out from the Hungarian version): "Now it is up to us to use our democracy and our God-given ability to reason with one another about our future and make moral choices to change the policies and behaviors that would, if continued, leave a degraded, diminished, and hostile planet for our children and grandchildren – and for humankind" (GORE, 2006; SZARKA, 2007). In accordance with CRUTZEN (2002), due to the ever growing and unstoppable intervention into nature, we talk about a new age, called the Anthropocene age. In my opinion, today the question is not whether we have entered the Anthropocene, but how long the Anthropocene age will last with the accelerating economic growth.

In the section overviewing energy sources, you will see that quite many facts and concepts needed for judging energy security is not so clear – even though energy is an exact physical concept. The issue of the security of energy supply (in natural resources aspects, but also touching the technical side), the controversial relationship of energy- and environmental security, and the hypotheses related to the two major potential dangers (possible energy shortages and the destruction of nature) will also be discussed. For a relative good energy security of Hungary in the future, I think focus should be put on achieving a greater share of local energy sources.

Energy sources

Energy is one of the most general properties of the material. In the common formulation, energy is the work potential of the system while it is transforming from one state to another – in accordance with the thermodynamic principles. To understand this in practice, you need to know some classic energetics textbooks and monographs (e.g. VAJDA, 2001; 2004; 2006; 2009; 2014; BÜKI, 1997). For example, the work of HULSCHER (1991) provides an excellent overview, available on the Internet. In order to have a concept about the theoretical possibilities of the various types of energy, Table 1 shows the energy content of several materials weighing 1 kilogram, being surprisingly diverse.

Table 1

The energy content of various energy sources

Energy source (1 kg)	Specific energy content (MJ/kg)
mass-energy equivalence	89 876 000 000
hydrogen-helium fusion	645 000 000
uranium (235)	80 250 000
liquid hydrogen	130
natural gas	50
crude petroleum	40
coal	30
methanol	20
dried wood	20

lignite	15
dried plants	15
straw	13
raw firewood	8
domestic waste	8
water, condensation heat	2.257
water (between 100–0 °C)	0.418
water, freezing heat	0.334
batteries (from lead to lithium)	0.1–2.5
mass, falling from 100 m	0.001
mass with a speed of 10 m/s	0.0005

Source: Wikipedia; SZARKA (2010)

Energy types from natural resources are called primary energy. These are transformed – through producer transformation – into secondary and then tertiary ("ready for consumption") energy, of which the consumer disposes. Unfortunately we cannot avoid the usage of the word "energy consumption" which is incorrect in the physical sense.

Stock-kind and flow-kind energy types

Energy types are commonly classified as not renewable and renewable. In my opinion, the usage of the term *renewable energy* (the origin of which can be traced back only to the 1970s – even though almost exclusively only these kinds of energy: firewood, windmills and watermills were used until the industrial revolution) is not appropriate, as it may give an improper impression (challenging the law of the conservation of the energy). That is why I recommend that primary energy sources should be grouped into *stock-kind* and *flow-kind* groups. So, the stock-kind energy has been generated by accumulating through a terrestrial process (*terrestrial stock*), while the flow-kind means the energy that we get through tapping the current natural processes. Coal, hydrocarbons, and nuclear fissile materials are stock-kind; and the geothermal energy is basically also stock-kind. The solar-, hydro-, wind-, biomass-, and even the wave energy is flow-kind: they all are taken from tapping the natural processes controlled by the Sun. Tidal energy (as a renewable energy) comes from the interaction of the Moon and the Earth. The Earth's rotational (kinetic) energy is stock-kind, as if it was utilized, then the rotation would slow and stop after some time, having consequences. An "inexhaustible" energy may self-evidently come only from an extraterrestrial source.

The boundaries between stock and flow, i.e. non-renewable and renewable energies are not necessarily definitive. (There is a significant overlap in case of biomass.) To judge whether an energy is exhaustible you must consider the scale of time and space. For example, the huge geothermic energy stocks (as a terrestrial kind of energy) can only be reached locally and very slowly – through water heat mining, which may seem to be flow-kind. However, the energy captured through near-surface heat pumps, commonly classified as geothermic, utilizes the heat of sunshine stored in the ground, so that is clearly renewable. Whether or not a source of energy is exhaustible is shown also in the classification of renewable energies (Table 2): Goldemberg–Coelho (2004) has classified biomass – considering possible overuse – within the non-renewable group.

Table 2

Classification of so-called renewable energy sources

"New" renewable energies sun (heat and electric), wind, tidal, geothermic (heat and electric)	"Modern" biomass (heat, electric, ethanol)	Hydropower	Conventional biomass (renewable)	Conventional biomass (non-renewable)
"New renewable energy sources"				
Renewable energy sources				Non-renewable biomass

Source: Goldemberg–Coelho, 2004

The origin of coal, hydrocarbons, nuclear energy, and earth heat

Coal is plant material which has been buried at rich-coastal and land swamps with rich vegetation, and transformed due to the temperature- and pressure rise; the name of its lignite variant refers to firewood (lignum = tree, wood). Petroleum and natural gas are generated through the transformation of plankton and algae in ocean sediments, at temperatures of 80–200 °C. Petroleum and natural gas – moving away from the place of creation – accumulates in "stratigraphic" or "structural" traps. The common characteristic of so-called non-conventional hydrocarbons is that they are less mobile. Oil sand, heavy oil, and oil shale are such kinds of petroleum. Basin-centered gas accumulation *(BCGA*), the so-called methane hydrates, and the methane (as a coal seam gas) are classified as non-conventional natural gases. All coals and hydrocarbons are so-called fossil energy sources (containing living organism residues). These mineral fuels, having organic material origin, are the solar energy conservations of earth ages. They are being generated today as well; but not as fast as we are consuming them. With regard to the pace of extraction, we are right calling this energy source exhaustible. Another stock-kind energy is the fission-based (or *fissile*) nuclear energy, the geological deposit sites of which are the enrichments of uranium, which is present in the Earth crust at an average of several ppm (uranium ^{235}U isotope, and thorium which is similar to uranium). Some (great?) part of the internal heat of the Earth is in fact the consequence of the natural radioactive decay. The other part of the internal heat of the Earth derives from phase transformation processes (the continuous solidification of the inner rim of the liquid outer core, i.e. the slow growing of the internal core).

Energy generation, transformation, utilization

The utilization of natural forces is a multi-step process – as shown in Table 3 – with overall fairly low (less than 15–25%) efficiency (as regards the “effective” results).

Table 3

Primary, secondary, tertiary, and effective energies, and their generation, with examples

Energy	**Technology**	**Examples**
natural properties		places where terrestrial energy may have accumulated; sunny or windy places, rivers, forests
	generation: extraction, collection, capturing, by various means	*mining (coal, hydrocarbon, uranium ore mining), logging, production of energy capturing equipment: windmill (wind turbines), solar panels, photovoltaic transformers, dam construction*
primary energy		coal, petroleum, natural gas, uranium ore, biomass, hydro-, geothermic-, solar-, and wind energy
	transformation	*power plant, burning furnace, finery*
secondary energy		refined petroleum, electric energy, heat, biogas
	transportation/ transfer	*freight transport, pipeline, power line*
tertiary energy		coal, diesel oil, gasoline, charcoal, electric energy, heat, biogas
	transformation	*engines, heaters, stoves*
effective energy		end use *(shaft power),* heat, light

Source: using: HULSCHER (1991)

Primary and secondary energies belong to the production sector. The consumer gets the so-called tertiary energy. This is utilized in the form of mechanic work, transport, heating and cooling, lighting, IT, communication, etc.

The history of energy

In the beginning, the energy source at man’s disposal was human force. Various other energy sources (animal power, biomass for fire, and then hydro- and wind energy) were involved with a slowly increasing intensity. With the industrial revolution, energy usage grew steeply (through the use of coal as energy source). For further growth, man found energy source in another solar energy conservation of the earth history: the hydrocarbons (first petroleum, later natural gas); and then later, the second half of the 20th century saw the arrival of the nuclear age, but its growing faltered in 1986 (and also in 2011). Hydrocarbons have become the ideal fuel of transportation in the 20th century, and also played an important role in heating and – in the 1970’s – in the production of electricity. Electricity production was launched in the second half of the 19th century: from coal and hydropower, roughly at the same time. Nuclear energy has played a role in electricity production since the middle of the 20th century. Today, the world's nine largest power plants are hydropower plants (the largest, in China "Three Gorges Power Plant", with an output of 22.5 GW).

Emission

As the so-called energy- and climate politic aspects have come to the fore, energies have been recently and mainly classified on the basis of emissions narrowed down to the so-called greenhouse gas emissions. The first step of turning fossil energy types (mineral fuels) into electric energy is a chemical reaction (burning), which generates heat and CO_2 – and, in case of hydrocarbons, also water. As a result of the primary energy distribution under Table 4a. and 4b. (coal: 26–30%, hydrocarbon: 52–56%) and the reaction equations below:

$$C + O_2 \rightarrow 394 \text{ kJ/mol} + CO_2,$$

and

$$CH_4 + 2\ O_2 \rightarrow 802 \text{ kJ/mol} + CO_2 + 2\ H_2O,$$

roughly the same molecular number of CO_2 and water is released. Current CO_2 emissions from the burning of mineral fuels and biomass are about 40 gigatons/year, and water release is also significant. When biomass is generated, the same amount of water and CO_2 is bound as is released when biomass is burnt. The equation of photosynthesis:

$$6\ CO_2 + 6\ H_2O + \text{energy (sunshine, min. 540 kJ/mol)} + \text{chlorophyll} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Thus, the three basic methods of anthropogenic decrease of the atmospheric CO_2 level are represented by the processes described by the above equations. (Besides biomass and organic sediments, the generation and weathering of carbonate rocks play also an important role in carbon circulation.) The CO_2-emission of natural processes is much greater and more diversified than the anthropogenic one.

In addition to greenhouse gas emission, the emissions may have a number of other chemical (e.g. aerosols, soot among others) and physical (e.g. heat, electromagnetic, acoustic) forms. Most of the energy used by mankind is released into the environment as heat – due to the bad efficiency of the production, transformation, and utilization of energy sources. Further examples: geothermic water heat mining may cause the emission of the most various chemicals; while in case of nuclear energy, precautions must be taken in order to prevent radioactive emissions. (Nuclear energy is "emission-free" in the greenhouse gas sense.)

Energy situation

The distribution of the world's primary energy production by energy types in 2014 is shown in Tables 4a. and 4b. – according to two different sources. Table 4a. also includes the estimated value of the non-commercial conventional biomass energy; while Table 4b. only includes various commercial energies; but even apart from this there is some difference between these two. The total amount of the generated and used primary energy increases every year also today.

Table 4a

The distribution of the world's primary energy production by energy types in 2014

Coal: 26.1%	CO_2-emitting fossil energy	Fossil and fissile energy
Hydrocarbons (petroleum and natural gas): 52.2%		
Nuclear energy: 2.6%	CO_2-free fissile energy	
Conventional biomass: 9%	Conventional renewable energy	Renewable energy
Water (electric): 3.9%	Modern renewable energy	
Electric (wind, solar, geothermic): 1.3%		
Heat (modern biomass, geothermic, solar): 4.1%		
Fuel-biomass: 0.8%		
Primary energy total: 100%		

S*ource:* WIKIPEDIA

Table 4b

The distribution of the world's primary energy production by energy types in 2014

Coal: 30%
Petroleum: 32.6%
Natural gas: 23.7%
Nuclear energy: 4.4%
Water: 6.8%
Renewable (without water): 2.5%
Primary energy total: 100%

Source: BRITISH PETROLEUM, 2015

The ratio of the different energy types have hardly changed at all in the past decades: the ratio of fossil energy has been slowly decreasing (by less than 1% per year). The world's energy production was about 18 TW power in 2014 (that is 18 terajoule = 18×10^{12} J per second); while in 2008, it amounted only to 15 terawatts. Depending on whether conventional (non-commercial) biomass is taken into account, coal and hydrocarbons amount to 78–86%, nuclear energy to 3–4%. Hydropower and other modern renewable energies (wind-, solar-, geothermic energy, biomass, biogas, etc.) together represent less than 10%, and the greatest of them is the hydropower.

The geological reserves embodied in the energy sources may change (grow) as a result of the continuous geological-geophysical exploration; however, the exploitable reserves depend on the current economic and rationality conditions. (For example, on whether more energy must be invested than can be extracted.) Reserves estimations are based on very heterogeneous "guesses". We do not have reliable information even about the amount of conventional biomass; and, regarding fossil energy sources (especially hydrocarbon reserves), we are likely to experience conscious disinformation. The data of British Petroleum are most commonly used (British Petroleum, 2015). For this reason, the opinion of some Hungarian experts should also be taken into account (e.g. BÁRDOSSY et al., 2008; KOVÁCS, 2012; PÁPAY, 2015). During the international year of the planet Earth (2007–2009), the global petroleum reserves were estimated to last forty years; natural gas – seventy years, coal – two-hundred years, and nuclear energy – several hundred years (with the production levels of that time).

Table 5. illustrates the increase of energy use in a fifty years scale. The most amazing information of the table may be the fact that in the 15 years between 2000–2015, we consumed almost as much energy (two-third) as in the half century from 1950 to 2000. The world's energy use has also been continuously increasing since, and this increase seems to be unstoppable. The energy used from 1800 to 2015 amounts to more than 30 ZJ (1 zettajoule = 10^{21} joule). For comparison: the total fossil energy reserves of the Earth are estimated about 39 ZJ. These data (if they are true) warn that we have used up about a half of the fossil energy stocks.

Table 5

Humans' energy production (usage) since 1800 and projected until 2050, in zettajoules (ZJ), in fiftyyears intervals, calculated for the time beginning from the industrial revolution

Time period	Energy of the period	Time period	Sum of energy
1800-1850	1 ZJ	1800-1850	1 ZJ
1850-1900	1.5 ZJ	1800-1900	2.5 ZJ
1900-1950	7.5 ZJ	1800-1950	10 ZJ
1950-2000	13.75 ZJ	1800-2000	23.75 ZJ
2000-2015	9 ZJ	1800-2015	32.75 ZJ
2015–2050 without further growth	**23 ZJ**	**1800–2050 without further growth**	**55.75 ZJ**

Source: SZARKA, 2017

The future of energy provision

According to most energy experts, we do not have to be afraid of the depletion mineral fuels (there are enough prospective reserves: GLOVER–ECONOMIDES, 2010). There is a lot of non-conventional deposits, the arctic areas are also accessible, and they also list many possibilities of alternative substitutions. According to these views, the use of coal, petroleum, and natural gas will be decreased due to "environmental protection causes", and their place will be taken over by nuclear energy and renewable energy types (TUCKER, 2008). The past years have seen a number of energetic novelties (the peddle-bed "city supplier" module reactor, new developments regarding fuel cells and batteries, the methane hydrates, nuclear fusion) (LETCHER, 2008). The second 2013 edition of Letcher's book (LETCHER, 2013) includes further 11 chapters (solar thermal power plant, developing countries, energy sources of oil- and gas producers, arctic drillings, non-conventional petroleum and gas, thorium in the field of fission, ethanol- and other transportation fuels, stratum fracturing, intelligent networks, new battery types, environmental respects, and the energy future of China). Regarding exhaustible energies – if the utilization of ^{238}U and the more frequent thorium is successful – the possibilities of nuclear energy usage may be significantly extended. Among the renewable energies (see Rybach, 2010; 2014) the geothermic HDR *(Hot Dry Rock),* EGS *(Enhanced Geothermal System),* and HWR *(Hot Wet Rock)* are noteworthy but fairly limited. Their common precondition is to have hot (about 200 °C) magmatic or metamorphic rock masses, reaching deep in the ground. Such may occur everywhere, regardless of the local geothermic conditions.

There are more and more prognoses impairing the concept about the richness of energy sources. For example, it seems that the rate of hydrocarbon production cannot be increased any more. The energy demand growing in the future as well will probably lead to a quasi-total depletion (all stock-kind energies, i.e. Earth energy reserves will run out sooner or later). We do not expect the implementation of nuclear fusion (hydrogen-helium fusion going on inside the Sun) on Earth, nor any other yet unknown solutions in the coming decades.

If the so-called renewable energies are unable to meet today's – rather intense – demand, energy poverty may occur. According to the EU document draft issued in the middle of May 2016 (not public at that time) (Szegedi, 2016a), the European Committee would still encourage members to use nuclear energy. Among others, the Committee promotes the construction of so-called mini nuclear plants. According to an interviewed expert, nuclear plants are needed until "energy storages is achieved" (Szegedi, 2016b). However, the chance of storing that amount of energy is quite low...

Besides pumped water reservoirs, there is no substantive progress in the issue of energy storage, there are only several ideas, such as compressed air preparation or hydrogen production. Batteries need a lot of materials; while the hydrogen produced from water through electrolysis is difficult to store and dangerous to handle. Every high-power energy storage is in fact like a highly explosive material (Gyulai, 2010). As regards hydropower (the energy of rivers), we find that a power plant has been built at most of the places having good features. The use of flow-kind energies broadens very slowly (its increase rate seems to be high only in comparison to itself; and it is hopelessly far from being comparable with coal or hydrocarbons). The so-called Energy Return on Energy Invested *(EROEI) indicator becomes ever lower.* Regarding EROEI, there are doubts about many renewable energy kinds and non-conventional hydrocarbons. For example, we may query about the so-called "Bio-Energy with Carbon Capture and Storage" *(BECCS)* process, where the basic idea is that the CO_2 generated during the burning of biomass for electric energy shall be stored under the ground. Even the simple Carbon Capture and Storage *(CCS)* may significantly lower EROEI (in any case, it makes the utilization of coal quite expensive).

Al Gore and Vaclav Klaus have contrary opinions regarding the possibilities of renewables. The former American Vice President is unlimitedly optimistic, while the former Czech President thinks "the aim behind the scare stories about the greenhouse effect and global warming, and the violent propagation of so-called renewable energy kinds is the interested (research, enterprise) lobbies' aspiration for tapping the central (state) budget" (Szarka, 2009). The doubtful situation of renewables is expressively illustrated by the Italian electric energy import, coming from the Swiss water reservoirs, which are in turn not filled by mountain creeks in Switzerland, but by the electric energy generated in nuclear plants in France. Italy buys that "laundered" (Courtillot, 2015 – oral communication). Several theoretical and practical discussions[1] show that the possibilities of renewable energies do not reach the level of the current energy demand.

In summary, we can conclude that significant research & development works are being carried out for the energy supply of the future, with uncertain results. In the following parts, the role and possibilities of energy will be reviewed from the point of view of the nature.

Energy and nature

Nature is a more general expression, and environment is more anthropocentric (meaning the natural elements held important by humans). The direct living space of humans is in fact the biosphere (a part of lithosphere, hydrosphere, and atmosphere where there is life and biologic processes take place). Considering the 20 km thick spherical shell from the seabed to the stratosphere as the biosphere, then its volume is less than a seven-millionth of the volume of the solid Earth. (If the Earth is considered to extend to the magnetopause, being ten times of the Earth radius far, then the biosphere would be nano range in comparison.)

Mankind has used up about 30–40 ZJ primary energy since the industrial revolution. As a comparison, let's have a look at several natural energies.

1. During an earthquake, as much energy may be released as we have utilized since the industrial revolution in total. (The energy of the earthquake at the Indian Ocean on 26 December 2004 amounted to 40 ZJ.)
2. The heat released during basaltic volcanism is probably very large, too; e.g. about 10 thousand ZJ in case of the 2.5 million cubic kilometer basalt generated through the basaltic volcanism in the Central Atlantic.
3. The amount of solar energy coming to the Earth is about 40 ZJ in less than three days (15 ZJ/day, meaning 17 thousand TW power).
4. The heat content of the upper 1 km crust of the Earth is 40 thousand ZJ (the Earth heat released to the atmosphere amounts to 40 terawatt, more than twice as much as the energy usage).
5. The kinetic (rotational) energy of the Earth is 200 million ZJ.

The amount of energy used by mankind is surprisingly small compared to these. That is why many people think that stock-kind energy sources are 100% replaceable by the flow-kind energies derived from the Sun and the inside of the Earth. (We do not know – today – about any utilization ideas regarding earthquakes and vulcano eruptions which have unpredictable place and time, or about the artificial slowing of Earth rotation…)

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[1] For example, look at McKay's (2006) calculation regarding the case of Great Britain possessing huge marine *(offshore)* areas.

Tapping possibilities of natural energies

The energy of the Sun – which is the source of all renewable energies except the geothermic – really seems to be *abundant.* In each second, the amount of fossil energy used by humans today is more than 1/10,000 (1/7000) of the energy of the sunshine reaching the Earth; and the amount of renewable energies used is about one millionth of the energy of sunshine. We would raise the question whether we can produce energy of 1/10,000 of the Sun's energy or even more, by tapping the currently available energy of the Sun? Considering the fact that half of the Sun's energy that reached the Earth is responsible for driving the photosynthesis of the plants growing, and that plants store about 130 TJ energy every second through photosynthesis (that is, their power is 130 TW, hardly seven times the humans' primary energy use), we find we should handle this carefully. The tapping of solar energy shall certainly not be increased significantly, because that would be an excessively strong intervention in the order of nature, as this would involve the transformation of the main force creating and shaping nature.

The utilization of the solar energy reaching the Earth is limited also according to another approach (independent from the above, based on the greenhouse effect) (Meadows et al., 1972). That is, if 5/10,000 of it (three and half times the current energy usage) is freed up as surplus – in any clean ways –, the Earth's average temperature will rise by appr. 1 °C (Gyulai, 2010).

Environmental impacts of energy production and usage

The environmental impact means all consequences of human interventions in the environment. As the consequences of the human interventions in the natural processes are non-linear and very long term, the environmental impacts are hard to estimate. I would recommend taking the intensity of human activities (intervention in natural processes) into account, as that provides a fairly accurate amount of the produced and used energy. We should classify environmental impacts related to the production and usage of energy in accordance with the rows of Table 3.

The environmental impacts related to the production (extraction, collection, capturing) of primary energies from the environment imply mining in case of stock-kind terrestrial energies, and usually surface transformation in case of flow-kind energies. Considering the fact that the territorial energy density of flow-kind energies is low, large areas will probably be used. Mining is also necessary for some capturing tools: the production of wind turbines and solar panels requires the intensive mining of rare earth metals. On the other hand, biomass (especially bioethanol and biodiesel) demands a huge water intake (and CO_2-intake). Non-conventional hydrocarbon production implies a higher risk, mainly due to the possibility of contaminating strategic (underground) waters (Papp–Parragh, 2015).

The transformation of primary energy into secondary energy is very specific, depending on the type of energy source. For example, the transformation of fossil energy types into electric energy is carried out through a chemical reaction (burning), generating heat and CO_2 (and, in case of hydrocarbons, also water), and heat is converted into electric energy – with limited efficiency. Fission ("fissile") energy is converted into heat and then – with a certain efficiency – into electric energy. Regarding greenhouse effect, there are no emissions involved here, but they must take care of preventing the release of radioactive materials. The conversion of secondary energies into tertiary energies (i.e. supplying them to the consumers through sea- or land transport, pipelines or power lines) also imposes a burden on the environment. The conversion of tertiary energy into effective energy involves the generation of heat, and the end usage causes direct changes (mechanical, work, heat, light). Humans have transformed about half of the original surface of the continents, partially irreversibly, while producing, converting, and "utilizing" energy sources.

We do not know about a fully comprehensive comparison of the environmental impacts occurring during the production of various energy sources. A comparison was made only regarding the so-called climate protection (primarily CO_2-emission) (Láng, 2008). CO_2-emission (by which we try to estimate the extent of human intervention in the greenhouse effect, among the environmental processes) is really one of the possible measures; however, there are numerous other consequences (water-, soil-, air pollution, and other nature destructions) to be taken into account – as can be seen in the list. It would be impossible to take all of these into account and compare them, since the environmental consequences of the production of various energy types are too specific. For example, we can consider a nuclear plant as potentially dangerous; but the overuse of biomass energy would surely be destructive. In the generally accepted definition of the R risk, $R = W \times K$ – where W ($0<W<1$) is the probability of occurrence, K is the severity of the consequence. In the nuclear plant case, the consequences of a low-probability incident can be severe, and in the biomass case: the possibility of occurrence of even "slight" consequences is 100%, i.e. $R = W \times K$ may be greater than in case of the nuclear plant case. (All nuclear plant accidents are attributable to human failures, and could have been avoided with greater care.) In Chernobyl for example, the combination of several small, untreated problems led to the explosion; while, in the case of Fukushima, the invited experts – perhaps deliberately rather than mistakenly – previously stated that such a tsunami might occur only every 10 thousand years, which led to the "omission" of this possibility during the dimensioning of the plant. But a tsunami of this scale (15 m high) may in fact occur there hundred times more often (appr. every 100 years); so they should not have saved money on that during the construction.

The Energy Research Center of the Hungarian Academy of Sciences (MTA) − which was established through the 2011/2012 reform of MTA's research network − and one of its institutes, the Energy- and Environmental Security Institute systematically studies the environmental impacts and the systems of energy conversion. We think − in the frames of an academic committee (Németh et al., 2014) − that the overall environmental impacts of the production of various energy types primarily depends on the amount of produced energy, and not the type of the energy source. Therefore, the environmental impacts related to the production of various energy types can be well estimated from the share of energy types themselves in the energy portfolio.

Taking primary energy into consideration, the intensity of human activity is characterized by 18 terawatts power. By using this huge power, human beings do the following activities: transformation of continent surfaces, pollution of waters, soil and air, influencing the climate, depletion of natural resources (both raw minerals and energy sources), increasing the number of nature-humanity interactions called "natural catastrophes", the global trade (leading to species invasion, biodiversity and ecosystem collapse). There are different effects in different parts of the world. While the major part of mankind has to live in every growing misery, the Western people have reached a comfort level which even causes physical and mental damage to them, and they still demand more products and services.

Driving and pulling force

Even though energy is the "driving force of civilization" (Szergényi, 2015), it is not the energy sector that is responsible for growing energy usage. Energy is the driving force, and the global consumption, having an endless demand for growth (the total consumption of more than 7.4 billion people), represents the pulling force.

The consumption demand for goods keeps increasing, but the available natural resources and the humans' living space on Earth are finite (Boulding, 1966; Szarka, 2008; Vida, 2009; 2011; Szarka–Brezsnyánszky, 2012). Therefore, economic growth – if further coupled with increasing energy- and material usage – is leading to an inevitable disaster: either due to the depletion of resources or the destruction of the environment. Consequently, the current human lifestyle cannot be continued for a long time. Due to the above, the growing (or perhaps the current, already high) energy demand should not be met anyway – in addition to the fact that it probably cannot be met in energetic aspects.

So, the issue of energy – and environmental security is dominated by the ever growing tension between endless growth – and finite nature. Jared Diamond lists a number of historical examples for local collapses that occurred due to insufficient resources and/or the destruction of the environment (Diamond, 2009). In the next part, you will get an insight into views regarding global collapses.

Endless growth?

The possible shortage of natural resources needed for growth has been known since the end of the 18th century. Malthus (1798) visioned a catastrophic end in his study about the laws of demography – based on the assumption that food production grows by an arithmetic progression, but the population grows by a geometrical progression.

The expansion of energy sources (coal at the industrial revolution, and then later petroleum and natural gas) improved the possibilities. Of course, there have always been critical opinions (e.g. Adams, 1907). Energy consumption per capita was first considered a key parameter by Ackerman (1933). An American geophysicist was the first to warn the world of the finite nature of fossil energy sources. According to Hubbert (1949), if the energy usage per capita is not decreased in an orderly manner (with consumption consolidating at a much lower level at the end), there will be a collapse after a quick ramp-up. The possibility of overrunning and then collapsing in the world's economic-, population-, and ecologic dynamics – in accordance with system theory – was first demonstrated by Forrester (1971): "The greatest challenge is the management of the transition from growth into balance. Folklore and success stories celebrate growth and expansion; but that is not the way of the future." The report of the Club of Rome was released a year after Forrester (1971) (Meadows et al., 1972). The report warned that if the tendencies of the 1970s are maintained in regard to population, agricultural production, natural resources, industrial production, and environment pollution (i.e. the endangering of the biological balance of the biosphere), then a steep decline shall be expected. Both of these works were accepted by a flood of criticism. NORDHAUS (1973) accused Forrester of using groundless data, and therefore rejected him. About the report of the Club of Rome – as KOCSIS (1976) summarized various opinions, – they thought "the human goodwill, moral power, not measurable by computers, […] was omitted from the calculation". Growth continued even if the limitedness of resources was pointed out both in geologic (YOUNGQUIST, 1997; 1999), and economic (e.g. BOULDING, 1986) points of view. According to the puritan (Quaker religion) economist: "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist".

The Olduvai theory

DUNCAN (2001) based the so-called Olduvai theory on the change of energy per capita over time *(e)*. Around 1930, the *e* first reached about one-third of its peak 1980, and a very fast increase started in 1945, which was then followed by a slower increase around 1970. Since 1979, *e* has not been increasing any more. The end of the platform was around 2004, and 2008 was described by Duncan as the brink of an abyss. The *e* may fall back to appr. one-third of its peak in around 2030. So, according to this theory, the life expectancy of the current industrial civilization is the century lasting from 1930 to 2030. The name reflects the Olduvai Gorge in Tanzania (mankind's past- and suspected future stone age life). The author tracks the theory year by year and updates it by analysis of the different situations of economic areas (OPEC, non-OPEC, USA) (DUNCAN, 2005; 2006; 2007a; 2007b; 2009; 2013; 2015).

Considering the fact that the "most useful" energy is the electric energy (available everywhere thanks to the networks overarching continents, and we use it as freely as we can); according to Duncan, the greatest risk is that the safe operation of high-voltage networks might become impossible. If there is nobody to maintain energy systems, then there will be ever longer and broader power outages. According to Duncan, this phenomenon might be a direct cause of the collapse of the industrial civilization – even if it seems banal. Analyses made around the thirty- and forty years anniversary of Limits to Growth (MEADOWS et al., 2004; LOVELOCK, 2010; BARDI, 2011; RANDERS, 2012) are similarly alarming. The lack of investment funds is also mentioned by the Club of Rome (as an indirect, delayed effect cause). Worries about disinterest in investment were expressed also in an EU report in the Spring of 2016 (ALPHANDÉRY et al., 2016).

Our Future on Earth

Instead of sustainable development, the concept of *resilience* is coming to the fore. Many works (Milleneum Ecosystem Assessment, 2005; BADDOE et al., 2009) have been published about the fact that human activities are plundering the Earth's natural reserves, burdening the environment in a way that endangers the survival of the future generations in our planet's ecological system. The aim of the *Future Earth* program of International Science Council

(ICSU) launched in 2014 is to "summarize the measureable consequences of global environmental changes, and provide credible information for the understanding of possibilities of sustainability and the definition of the necessary steps".

Unfortunately, we cannot stop the reduction of the exploitation of natural resources, and shocks are sure to come. Experience shows that in the end, technological improvements demand more and more energy and materials – contrary to expectations and promises. (According to the Jevons paradox[2]: if technological development makes the use of a resource more efficient, the speed of use will not decrease but increase.) In today's perspective, I think that the situation is unsolvable, even by the circular economy (Stahel, 2016). According to Turner (2014) it is time for preparing for the collapse of the global systems, instead of trying to avoid it.

It is becoming more and more certain that – in spite of politically correct opinions – we are heading towards a totally new, unknown, and much harder world. This is exactly preceived, among others, by Náray-Szabó (2006), Almár et al. (2011), Boia (2014), Szergényi (2015) and also Végh (2016).

Environmental science, and even the views of decision-makers have been dominated by a paradigm evolving in the past two decades, according to which the greatest problem is the "global warming caused by CO_2-emissions", and the climate change is in the focus of environmental problems. It seems that the whole energy policy is subordinated to the aspects of "climate protection"; but that is only one of the environmental indicators, and not the most important one: it is like a fever symptom of a patient having cancer. If we go on focusing only on climate change, we will surely not realize that the main threat to mankind is the ever growing global consumption demand, the economic growth itself (Szarka, 2008; 2010; 2012; 2013; Szarka–Brezsnyánszky, 2012; Paulik, 2016). Useable energy-, water-, soil-, and mineral raw material reserves are finite, and the future of energy supply is more uncertain than ever before. We should not believe that the destruction of the environment can be stopped by controlling only one environmental indicator (e.g. a CO_2-emission). The belief that the current level of comfort can be maintained by the so-called "green economy" is also a misconception.

Inequalities

One reason of the increase of global consumption is the growth of the population, and the other is the increase of consumption per capita. In the period 1912–2012, the population of the Earth increased to about fourfold, global energy consumption to more than twelvefold, and production to twenty times! If the energy use per person *(e)* was expressed by the work ability of humans (taking 60 W and 7/24 mode in account), today it is as if everyone had one hundred imaginary slaves. It is one thousand in Trinidad and Tobago, five hundred in the Arabic sheikh states and the United States, and two in Afghanistan – these make an average of one hundred. So, inequalities are huge. What's more, consumer mentality is growing even in poor countries. The Western civilization is not reducing consumption, instead, we see masses of people joining in global consumer society. What about those following the

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[2] See for example: Lovas (2012)

conservative values, remaining at their place? The inequality of natural resources is also expressed by the fact that a few dozens of people are together as rich as the poorest half of humanity in total (OXFAM, 2015).

A natural science (microbiological) experiment related to the "Momentum program" of MTA showed a nightmare about a possible globalization model. "Selfish" and "cooperative" bacteria living partially separated, in fragmented living spaces, both survived (with domination of the cooperative bacteria). When the living spaces became less and less fragmented, the "selfish" became more and more dominating. Opening the living space into one homogenous living space, the selfish bacteria killed the cooperative ones, then they started eating up themselves (Hol et al., 2015).

The energy- and environmental security of Hungary

To develop the steps for energy security of Hungary, we should know not only the global background processes, but also the natural resources, and within that the energy reserves and future energetic possibilities of the country. In Hungary, the number of imaginary energy slaves is about two hundred, twice the world average. Our homeland belongs neither to the poor nor the richest countries: we are slightly over-consumers.

Of course, environmental impacts related to the production of energy sources and energy usage inevitable occur. Thus, the greatest potential lies in energy saving, which shall include not only the reduction of wasting but also the reduction of unreasonably increasing demands. Of course, this approach must not be limited to energy, it shall prevail also regarding freshwater, soil (food), raw materials, all products, and wastes – in order to preserve the natural environment.

The energy situation and possible ways

First of all, let's have a look at Hungary's mineral fuel- and fissile material reserves according to the Hungarian Mining and Geological Office (Hungarian Mining and Geological Office, MBFH, 2016).

Table 6

The data of Hungary's known mineral energy stocks

Mineral fuel- and fissile material	**Production (2014)**	**Geological reserves (2015. 01. 01.)**	**Exploitable reserves (2015. 01. 01.)**			
	Mm^3	**kt**	**Mm^3**	**kt**	**Mm^3**	**kt**
Conventional petroleum		616		232.397		21.545
Non-conventional petroleum		10^{-1}		418.947		45.643
Conventional natural gas	1943.11		185.475		73.778	
Non-conventional natural gas	3.17		3.923.342		1.565.354	
Black coal		10^{-1}		1.625.051		*1.915.401
Brown coal		636		3.194.637		2.240.049
Lignite		8918		5.715.122		4.271.037
Uranium ore		0		26.769		26.769

Notes: 1000 m^3 gas = 1 t; exploitable reserves= geological reserves + thinning – loss – pillar;
*Loss is smaller than thinning

Geothermic energy exploited in 2014: 2,078,001 GJ. Hungary's geothermic geological reserves (technical potential): 100 ZJ (Mádlné Szőnyi, 2006)

Source: MBFH (2016)

The energy strategy of Hungary is known from NFM, 2012. The most comprehensive and scientifically valid updates were summarized by an ad hoc presidential committee at the Hungarian Academy of Sciences (Lovas, 2012), and the academic journal *Hungarian Science* also published a number of studies (most of which include papers presented at conferences organized by the Energy and Environment Sub-Committee of the MTA Environmental Presidential Committee). Several hardly accessible and therefore less known summarizing works have also been prepared (e.g. Benkő et al., 2012).

Hungarian coal reserves are relatively high (lignite, brown coal, black coal can be found), coal supplies per capita are 2 to 6 times the world average (Kovács, 2013). Nevertheless, the rate of coal utilization has been significantly decreased and – as stated by Kovács (2013) – that is contrary to the world tendency and the intention of reducing energy dependence. Coal would be an especially useful energy source in crises, Practical experts (e.g. Verbőci, 2010; Gagyi Pálffy, 2013) recommend the opening of lignite-, brown coal-, and black coal mines (mainly strip mines), and applying various clean coal technologies. It is doubtful whether the *in situ* gasification of coal should be classified as a clean coal technology. Most of the conventional hydrocarbons have been extracted, and the future extractability of the non-conventional hydrocarbons (e.g. the BCGA gas found in the vicinity of Makó and the methane content of the coal in the Mecsek) has been found as uncertain at an academic conference (Ádám–Pápay, 2015). Smaller petroleum- and natural gas areas might be discovered, especially if the exploration is made using new geological concepts. Such a research might have realistic chances not only in the field of fossil but also the fissile energy sources. Besides the possible energy source, we should also mention the non-energy ore- and other mineral raw materials, which have a strategic importance but are ignored – unreasonably (Földessy, 2011; Gagyi Pálffy, 2013; NFM, 2013).

The assessment of the geothermal opportunities of Hungary has quite wide boundaries (see e.g. Mádlné Szőnyi, 2006; Bobok–Tóth, 2010). The heat of thermal water can be utilized in local heating, and not much in electricity production. Hungary also has some hot dry (granite) rocks at reachable depth (4–6 km) from where some electric energy can be produced in the future. The spreading of heat pumps would also facilitate auxiliary heat supply (recovering solar energy stored in the soil): with 1 unit of energy investment, 3-4 times of the energy can be recovered. The solar energy (heat- and electric supply) possibilities were last summarized by Farkas (2010). (In the Summer of 2016, another academic conference was held about this theme.) The contradictory situation regarding wind energy was described by Szalai and et al. (2010). Energetic experts find the introduction of electric energy generated through solar and wind energy to large networks unreasonable when there are no proper energy storage possibilities (e.g. water reservoirs). Dinya (2010) reviewed the possibilities and limits of biomass-based energy production as a part of the so-called sustainable energy management. Regarding hydropower, there is a huge contradiction between the Hungarian approach not willing to use the rivers' energy and the practice of the world around us (Szeredi et al., 2010; Fáy, 2013; Gerse, 2014; Ijjas, 2014; Mészáros, 2014; Németh et al., 2014; Szeredi, 2014).

Apart from the Paks nuclear power plant, the Mátra lignite power plant, and several gas-heated plants, we do not have any electric energy capacities at our disposal. The sources of electric energy import are Ukrainian, Polish, and Czech (mostly outdated) coal power plants, which cannot be counted on in the long run. In order to increase our electricity production capacities – considering the fact that Hungarian renewable energy sources are more suitable for heat supply than electricity production – Járosi (2010) and the Energy Policy 2000 Association (2015) recommends the construction of nuclear plant units and gas turbine plants as soon as possible. They consider these necessary in order that renewable energies may play a significant role in the Hungarian electric energy system. Thus, the expansion of the Paks plant does not exclude renewable energy plants. I think that there are no realistic alternatives of the Paks expansion, even if some people recommend other things (e.g. Lechtenböhmer et al., 2016). For the security of electric energy system, all other possibilities (e.g. coal and hydropower) can be rethought in the long term; and at the same time, renewables are recommended to be used for meeting local, scattered demands.

Most (more than two-third) of the domestic heat energy demand is covered by import (mainly Russian gas). In heating supply, the most important task would be the replacement of import natural gas by local energy sources. The MTA Environmental Presidential Committee and other professional organizations have elaborated a concrete plan for that (based on Büki et al., 2014), available on the Internet (Settlement heat supply through local energy, 2015). Table 7. summarizes the domestic energy source possibilities that may be involved in heat supply. This program would cost HUF 150 billion/year for forty years, half of which would be covered by subsidies.

Table 7

Objectives, determined by the academic conference: Settlement heat supply through local energy (2015)

	Units realizable yearly	**Units realizable in forty years**	**PJ/ year**	**PJ/ 40 years**
Earth heat (by heat pump)	10,000	400,000	1.2	48
Biomass (including waste)	20,000	800,000	2.325	93
Solar energy	25,000	1,000,000	0.25	10
Total	55,000	2,200,000	3.775	151

Source: Settlement heat supply through local energy (2015)

By the involvement of local energy sources, the energy structure of Hungarian heat supply is forecast as follows (in place of current values stated in parentheses): geothermic 18% (1.2%), solar: 4% (0%), biomass (including biogas and wastes): 47% (11%), natural gas: 31% (87.8%). Communities' energetic developments might mean a good opportunity for the development and production of innovative products (e.g. heat pumps, biomass boilers) which are competitive in international markets.

Energy security considerations

Even if some warn about our lack of energy sources and vulnerability (e.g. Rémenyi, 2009), there are possibilities to decrease the portion of import energy (on the one hand the reduction of energy demand, and on the other hand the extension of energy sources). Steps to be taken for energy security shall obviously be determined by taking the international environment into account. A decade ago, Varró (2007) focused on the strengthening of international relations instead of aiming at self-supplying: "the main task of energy policy is therefore to properly manage international relations, and not pursuing autarky".

Forward planning involves the understanding of the possible processes of the future, including considering the worst scenario. From this point of view, the high ratio of electric energy import and the huge amount of natural gas import both mean a significant supply security risk and even jeopardize the survival of Hungary among tolerable conditions. The recommended guiding principle for Hungary is partial fragmentation – not only in the field of energy security. The most important might be to put an end to the illusion of security. For these reasons, the further increase of state involvement is inevitable.

The energy situation of the European Union is very fragile, and it is questionable that pursuing only the energy union and the European energy- and climate policy principles contributes to the energy security of Hungary. We must emphasize the need for cooperation with countries and regions that have own energy sources. It is also possible that the value of basic natural resources will be more appreciated than high technology in the future!

Hungary has a huge potential in energy sparing, rationalization of energy usage, and change of consumer attitudes. We should use our natural resources (both stock- and flow-kind energy sources) taking our real possibilities into consideration. The energetic utilization possibility of geothermic thermal water is rather heat supply and not electricity generation. Focus should be put on local use (instead of large-scale biomass production, which is doubtful in energetic regards) in case of bioenergy, local usage or timely more consistent production in case of wind energy (e.g. through water storage), the enhancement of the local supplementation role in case of solar energy, while regarding hydropower there should be a total re-thinking without any politics involved (Németh et al., 2014). In my opinion, decision-makers should ultimately decide whether the goal is to create a better energy security needed for the vital interests of Hungary, or to implement the energy- and climate policy forced by external entities.

Environmental security

Among measures taken for energy security, only the saving and reducing ones will have favorable environmental effects. The environmental impacts of energy production will be negative in all cases. Pursuing the so-called “circular” economy might only somewhat mitigate the rate of deterioration.

There are natural disasters that are independent from humans, since we live on a dynamically changing planet. According to the general definition, a natural disaster is an event occurring due to natural causes, suddenly and significantly negatively influencing the living circumstances of a large number of humans or other creatures for a shorter or longer time, and occurs unexpectedly and unavoidably. In fact, among the various natural disasters, there are ever more biological, geophysical, and hydro-meteorological disasters which are the long-term, non-linear consequences of human intervention in the order of the nature. Namely, there were induced earthquakes due to the dam at the Nile at Aswan, the geothermic power plant of Basel, and the formation fracturing gas production in the Netherlands. Similar long-term effects are caused by the drying due to groundwater utilization, flood level rise due to the reduction of rivers’ flow cross section (Schweitzer, 2011), the increase of flood risk due to clear-cutting of mountain forests. The increase of the number of natural disasters in the past one hundred years is due to this kind of causes (and not or not only the climate change).

The list of natural dangers below shows that you cannot always clearly distinguish real natural disasters from induced ones. Temperature extremes, droughts and floods are common phenomena in Hungary. Due to water regime, inland water, slop, bank erosion may occur, and there may be significant mass movements as a result of water flow (landslide, flowage, bank collapse). Unfavourable geological conditions (swelling clay, peaty areas, drift sand, caves, solifluction or liquefaction) may cause local damages. Underground peat- and coal fires might cause problems, too. Due to fluid mining, there may be regional surface subsidence; and due to basements or mines, there may be local surface collapses. The risk of volcanic eruptions is not significant in Hungary, but there may be CO_2- and methane release due to post-volcanic (or hydrocarbon transformation). Natural background radiation (Rn, Th, U) significantly exceeding the average level occurs at some places. According to experience, strong earthquakes causing huge damages (with a magnitude of 5.5–6) occur every 40–50 years. (The last such great earthquake – of a 5.6 magnitude, VIII intensity – happened on 12 January 1956 in Dunaharaszti.) The construction of earth and/or satellite monitoring *(early warning)* systems should be considered.

Summary

Mankind shapes the environment by 18 terawatts (TW) power today. We go on using up natural treasures, taking the place of nature, polluting water, soil, air, inducing disasters we call "natural", transporting natural resources and products (including invasive species) globally from one place to another, collapsing biodiversity and the ecosystem. Through these, we of course influence – among others – the climate. The so-called "developed" world has reached a comfort level which even causes physical and mental damage to them, but due to the consumer attitude they still demand more products and services (and thus more energy). Since the industrial revolution mankind has used at least 30 ZJ energy, almost as much as can be taken from the current total fossil energy stocks of the Earth – according to certain data. Nevertheless, the tremendous power of nature is indicated by the facts that (a) the energy of one single strong earthquake may be as high as 40–50 ZJ; (b) the total energy of the sunshine reaching the Earth is almost ten thousand times our current energy usage. The views regarding the unlimited possibilities of renewable energies is based on the latter fact.

In my opinion, in this theme, there must be no techno-optimism. Due to the fact that renewable energies have a small territorial energy density (and technical issues related to the huge energy demand unsolved); only a very small part of the sunshine reaching the Earth may be taken away from the nature without consequences. Moreover the energy sources may be any "clear", the environmental impact of energy use will still primarily depend on the amount of energy and not the type of the energy source. Namely, all energy types have a disadvantage or environment damaging effect. Historically, the effect of fossil fuels was air pollution (today the CO_2-emission is also considered as "air pollution"), the effect of nuclear energy is the risk in operational safety, and the effect of renewables is the need for large areas and the complicated technology (including the need for special mineral raw materials). Ultimately, the produced energy will be converted into nature shaping work and heat – regardless of the type of energy. The so-called renewable energies at a scale similar to the current fossil energy (if possible at all) would be similarly destructive to nature as the conventional energy types.

For the condition of the natural environment, the only effective measure could be the drastic reduction of energy use (thereby immediately reducing also CO_2-emissions – according to the burning reaction equation of fossil energy sources). The growth demand of the consumer society is infinite. We can envisage the encountering of natural limits as an inevitable disaster, perhaps a fast collapse. There is a global fight for still available natural resources, disguised by various means (not least by distraction about the CO_2 risks and overestimation of green energy sources). Unfortunately, the "green idea" has become a server of business circles, because it hides the causal link existing between the scale and intensity of human intervention into natural processes (energy usage continuously growing since the industrial revolution) and its consequences (the *Global Environmental Change,* GEC).

The situation is unsolvable, as nobody will withdraw voluntarily. That is why the future energy security of Hungary depends on the availability of enough and securely accessible (preferably local) energy sources. Besides energy sparing (including the reduction of demands), the conservation of nature is a very important aspect but difficult to achieve. Instead of consumer attitudes, we should perhaps pursue the aim set down in the Book of Proverbs: "Give me neither poverty nor riches; feed me with the food that is needful for me!" (Proverbs 30:8).

References

Ackerman, Fredrick L. (1933): The technologist looks at social phenomena. *Introduction to Technocracy,* Scott, Howard, John Day Co., New York.

Ádám József – Pápay József (2015): Nem konvencionális szénhidrogének – magyarországi lehetőségek – bevezető. *Magyar Tudomány,* Vol. 176, No. 11. 1282–1284.

Adams, Henry (1907): *The education of Henry Adams.* Privately printed, Washington, DC.

Almár Iván – Csaba László – Csányi Vilmos – Czelnai Rudolf – Falus András – Fürst Zsuzsanna – Kroó Norbert – Pataki Ferenc – Székely János – Varga János (2011): *Válság és apokalipszis.* Éghajlat Könyvkiadó, Budapest.

Alphandéry, Edmond et al. (2016): *Fostering Investment in Cross-Border Energy Infrastructure in Europe. Report of the High-Level Group on Energy Infrastructure in Europe.* Source: www.ceps.eu/system/files/Fostering%20Investment%20in%20Cross-border%20Energy%20Infrastructure%20in%20Europe%20-%20A%20report%20by%20the%20High-Level%20Group%20on%20Energy%20Infrastructure%20in%20Europe.pdf

Bardi, Ugo (2011): *The Limits to Growth Revisited.* Springer, New York.

Bárdossy György – Lelkesné Felvári Gyöngyi – Pogácsás György (2008): Szénhidrogének. Geológia – a jelen helyzet – a jövő kilátásai. *Tanulmányok a magyarországi energetikáról,* Szentgyörgyi Zsuzsa (ed.), Magyar Tudományos Akadémia, Budapest.

Beddoe, Rachael – Costanza, Robert – Farley, Joshua – Garza, Eric – Kent, Jennifer – Kubiszewski, Ida – Martinez, Luz – McCowen, Tracy – Murphy, Kathleen – Myerse, Norman – Ogden, Zach – Stapleton, Kevin – Woodward, John (2009): Overcoming systemic roadblocks to sustainability: The evolutionary redesign of worldviews, institutions, and technologies. *PNAS,* Vol. 106, No. 8. 2483–2489.

Benkő Zsolt István – Bulla Miklós – Domokos Endre – Horváth Róbert – Nagy Géza – Pitrik József – Tóth Péter (2012): Környezetvédelmi energetika. Környezetmérnöki tudástár, Domokos Endre (ed.), 21. kötet, Pannon Egyetem Környezetmérnöki Intézet, Veszprém.

Bobok Elemér – Tóth Anikó (2010): A geotermikus energia helyzete és perspektívái. *Magyar Tudomány,* Vol. 171, No. 8. 926–936.

Boia, Lucian (2014): *A Nyugat hanyatlása.* Koinónia, Kolozsvár.

Boulding, Kenneth (1986): Proceedings of the 7th Friends Association for Higher Education Conference, Malone College. Idézte: Hammond, Debora (2003): *The Science of Synthesis.* University of Colorado Press, Colorado.

British Petroleum (2015): *BP Statistical Review of World Energy.* Source: www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2015/bp-statistical-review-of-world-energy-2015-full-report.pdf

Büki Gergely (1997): *Energetika.* Műegyetemi Kiadó, Budapest.

Büki Gergely – Metzing József – Orbán Tibor (2014): *Településenergetika, távhőellátás, távhűtés.* Mérnöki Kamara Nonprofit Kft., Budapest.

Carson, Rachel (1962): *Silent Spring.* Houghton Mifflin, Boston.

Crutzen, Paul J. (2002): Geology of mankind. *Nature,* Vol. 415, No. 1. 23.

Diamond, Jared (2009): Összeomlás. Typotex, Budapest.

Dinya László (2010): Biomassza-alapú energiatermelés és fenntartható energiagazdálkodás. *Magyar Tudomány,* Vol. 171, No. 8. 912–925.

Duncan, Richard C. (2001): World Energy Production, Population Growth, And the Road to the Olduvai Gorge. *Population and Environment,* Vol. 22, No. 5. 503–522.

Duncan, Richard C. (2005): The Olduvai Theory. *The Social Contract,* Vol. 16, No. 2.

Duncan, Richard C. (2007a): The Olduvai Theory. Terminal Decline Imminent. *The Social Contract,* Vol. 17, No. 3.

Duncan, Richard C. (2007b): America: A Frog in the Kettle Slowly Coming to a Boil. *The Social Contract,* Vol. 18, No. 1.

Duncan, Richard C. (2009): The Olduvai Theory – Toward Re-Equalizing the World Standard of Living. *The Social Contract,* Vol. 19, No. 4.

Duncan, Richard C. (2013): The Olduvai Theory – Heading into the Gorge. *The Social Contract,* Vol. 23, No. 2.

Duncan, Richard C. (2015): The Olduvai Theory – Back to hunting and gathering. *The Social Contract,* Vol. 25, No. 2.

Ehrlich, Paul R. (1968): *The Population Bomb.* Sierra Club–Ballantine Books, San Francisco.

Energy Policy 2000 Association (2015): *Mentsük meg a hazai villamosenergia-ellátást!* Source: www.enpol2000.hu/dokumentumok/allasfoglalasok/article/67-%C3%81ll%C3%A1sfoglal%C3%A1sok%20/539-mentsuk-meg-a-hazai-villamosenergia-ellatast

Farkas István (2010): A napenergia hasznosításának hazai lehetőségei. *Magyar Tudomány,* Vol. 171, No. 8. 937–946.

Fáy Árpád (2014): A vízenergia hasznosításának nemzetközi helyzete, EU-s tervek. *Magyar Tudomány,* Vol. 175, No. 7. 773–778.

Forrester, Jay Wright (1971): *World Dynamics.* Wright-Allen Press, Cambridge.

Földessy János (ed.) (2013–2014): *CriticEl monográfiasorozat I–X.* Milagrossa Kft., Miskolc. Source: http://kritikuselemek.uni-miskolc.hu/

Gagyi Pálffy András (ed.) (2013): *Hazai ásványi nyersanyagaink hasznosítási lehetőségei – Összefoglaló tanulmány.* Kézirat. Országos Magyar Bányászati Kohászati Egyesület, Budapest. Source: www.ombkenet.hu/images/tanulmany.pdf

Gerse Károly (2014): A vízenergia-hasznosítás hozzájárulása a fenntarthatósághoz. *Magyar Tudomány,* Vol. 175, No. 7. 779–789.

Glover, Peter C. – Economides, Michael J. (2010): *Energy and Climate Wars: How naive politicians, green ideologues, and media elites are undermining the truth about energy and climate.* Continuum, New York–London.

Goldemberg, Jose – Coelho, Suani Teixeira (2004): Renewable energy – traditional biomass vs. modern biomass. *Energy Policy,* Vol. 32, No. 6. 711–714.

Gore, Al (2006): *An invonvenient truth.* Rodale, New York.

Gyulai József (2010): *Klímapolitika, fizikusi megközelítésben.* 103. Energiapolitikai Hétfő Este előadás. Source: www.enpol2000.hu/szakmai-keres/klimavedelem/list/Szakmai%20keres%C5%91/30-Kl%C3%ADmav%C3%A9delem?filter4%5B0%5D=RHIuIEd5dWxhaSBKw7N6c2Vm

Hol, Felix J. H. – Galajda, Peter – Woolthuis, Rutger G. – Dekker, Cees – Keymer, Juan E. (2015): The idiosyncrasy of spatial structure in bacterial competition. *BMC Research Notes,* Vol. 8, No. 245.

Hubbert, Marion King (1949): Energy from Fossil Fuels. *Science,* Vol. 109, No. 2823. 103–109.

Hulscher, Suzanne (1991): Chapter 1 – Basic Energy Concepts. *Training Materials for Agricultural Planning,* Vol. 23, No. 1. FAO, Róma.

Ijjas István (2014): A vízenergia-hasznosítás tervezésére és működtetésére vonatkozó környezeti előírások. *Magyar Tudomány,* Vol. 175, No. 7. 800–809.

Járosi Márton (2010): Magyar energiapolitika. A magyar energetika szellemtörténeti vázlata és stratégiai kérdései. *A Lévai örökség és a magyar energetika,* Járosi Márton (ed.), Püski, Budapest.

Jócsik Lajos (1971): *Az öngyilkos civilizáció.* Közgazdasági és Jogi Könyvkiadó, Budapest.

Klaus, Thomas – Vollmer, Carla – Werner, Kathrin – Lehmann, Harry – Müschen, Klaus (2010): *Energy target 2050: 100% renewable electricity supply.* Federal Environment Agency, Dessau-Roßlau.

Kocsis Elemér (1976): Felelősségünk az emberre bízott világért. *Theologiai Szemle,* Vol. 17, Nos. 1–2. 2–8.

Kondor Attila – Kovács Zoltán (2017): A CO_2-kibocsátás csökkentésével kapcsolatos vállalások kritikai földrajzi értelmezése. *Magyar Tudomány.* Forthcoming.

Kovács Ferenc (2012): Szösszenetek a nemzeti energiastratégia (2030) kapcsán. *Magyar Tudomány,* Vol. 173, No. 12. 1499–1504.

Kovács Ferenc (2013): *Magyar energiastratégia a világ energetikai irányainak tükrében.* 126. Energiapolitikai Hétfő Este előadás. Source: www.enpol2000.hu/rendezvenyek/enpol-hetf/article/Rendezv%C3%A9nyek/6-H%C3%A9tf%C5%91%20est%C3%A9k/350-126-energiapolitikai-hetfo-este

Láng István (2008): Megújuló energiaforrások pro és kontra. Nap-, szél-, geotermikus, bioenergia – környezet és gazdaságosság. *Tanulmányok a magyarországi energetikáról,* Szentgyörgyi Zsuzsa ed., MTA, Budapest, 191–198.

Lechtenböhmer, Stefan – Prantner, Magdolna – Schneider, Clemens – Fülöp Orsolya – Sáfián Fanni (2016): *Zöld Magyarország – Energia Útiterv.* Zöld Műhely Alapítvány, Budapest.

Letcher, Trevor M. (2008): *Future Energy.* Elsevier, Amsterdam.

Letcher, Trevor M. (2013): *Future Energy: Improved, Sustainable and Clean Options for our Planet.* Elsevier, Amsterdam.

Lovas Rezső (ed.) (2012): *Áttekintés Magyarország energiastratégiájáról.* MTA Köztestületi Stratégiai Programok. Magyar Tudományos Akadémia, Budapest.

Lovelock, James: *Gaia halványuló arca*, Akadémiai Kiadó, Budapest, 2010.

MacKay, David J. C. (2011): *Fenntartható energia mellébeszélés nélkül.* Typotex, Budapest.

Mádlné Szőnyi Judit (2006): *A geotermikus energia.* Készletek, kutatás, hasznosítás. Grafon, Budapest.

Malthus, Thomas (1798): *An Essay on the Principle of Population.* Printed for J. Johnson, in St. Paul's Church-Yard, London.

MBFH (2016): *Ásványvagyon.* Aktuális változat (2015. január 1. szerint). Source: www.mbfh.hu/home/html/index.asp?msid=1&sid=0&hkl=72&lng=1

Meadows, Donella H. – Meadows, Dennis L. – Randers, Jørgen – Behrens, William W. (1972): *Limits to Growth.* Universe Books, New York.

Meadows, Donella H. – Randers, Jørgen – Meadows, Dennis L. (2004): *Limits to Growth: The 30-year Update.* Chelsea Green Publishing, White River Junction.

Mészáros Csaba (2014): A vízenergia-hasznosítás hazai lehetőségei és korlátozó tényezői. *Magyar Tudomány,* Vol. 175, No. 7. 790–799.

Náray-Szabó Gábor (2006): *Fenntartható a fejlődés?* Akadémiai Kiadó, Budapest.

Németh Tamás – Ádám József – Szarka László (2014): Bevezető. *Magyar Tudomány,* Vol. 175, No. 7. 770–772.

NFM (2012): *Nemzeti energiastratégia 2030.* Source: http://2010-2014.kormany.hu/download/4/f8/70000/Nemzeti%20Energiastrat%C3%A9gia%202030%20teljes%20v%C3%A1ltozat.pdf

NFM (2013): Ásványvagyon-hasznosítási és készletgazdálkodási Cselekvési Terv. Source: http://2010-2014.kormany.hu/download/c/6a/c0000/%C3%81CsT_02%2012.pdf

Nordhaus, William D. (1973): World Dynamics: Measurement Without Data. *The Economic Journal,* Vol. 83, No. 332. 1156–1183.

OXFAM (2015): *Wealth: Having It All and Wanting More.* Source: www.oxfam.org/en/research/wealth-having-it-all-and-wanting-more

Pápay József (2015): Konvencionális és nem konvencionális kőolaj- és földgázkitermelő eljárások és várható szerepük az energiaellátásban. *Magyar Tudomány,* Vol. 176, No. 11. 1285–1294.

Papp Katalin – Parragh Dénes (2015): Magyarországi palagáz-forradalom az USA-beli sikerek nyomán? A környezetvédelmi felvetések mérlegelése és vizsgálata. *Magyar Tudomány,* Vol. 176, No. 11. 1322–1329.

Paulik Katalin (2016): Az emberiség legnagyobb dilemmája. *Innotéka.* Source: www.innoteka.hu/cikk/az_emberiseg_legnagyobb_dilemmaja.1362.html

Randers, Jorgen (2012): *2052: A global forecast for the next forty years.* Chelsea Green Publishing, White River Junction.

Rényi Károly (2009): Az energiastratégia sarokpontjai. *Magyar Tudomány,* Vol. 170, No. 3. 323–333.

Rybach, Ladislaus (2010): *The Future of Geothermal Energy and Its Challenges.* Proceedings World Geothermal Congress, Bali. Source: http://globalatlas.irena.org/UserFiles/Publication/The%20future%20of%20Geothermal%20Energy%20and%20Challenges.pdf

Rybach, Ladislaus (2014): Geothermal Power Growth 1995–2013. A Comparison with Other Renewables. *Energies,* Vol. 7, No. 8. 4802–4812.

Schweitzer Ferenc (2011): *Katasztrófák tanulságai.* MTA Földrajztudományi Kutatóintézet, Budapest.

Settlement heat supply through local energy (2015): *A „Települési hőellátás helyi energiával" című MTA-konferencia állásfoglalása.* Source: http://old.mta.hu/data/cikk/13/70/94/cikk_137094/Allasfoglalas_20151005_22h_MTA.pdf

Stahel, Walter R. (2016): Circular economy. *Nature,* Vol. 531, No. 7595. 435–438.

Szalai Sándor – Gács Iván – Tar Károly – Tóth Péter (2010): A szélenergia helyzete Magyarországon. *Magyar Tudomány,* Vol. 171, No. 8. 947–958.

Szarka László (2007): Kellemetlen igazság. *Természet Világa,* Vol. 138, No. 4. 149.

Szarka László (2008): Globális kihívások „a Föld bolygó nemzetközi éve" tükrében. *Globális kihívások, Millenniumi fejlesztési célok és Magyarország,* Gömbös Ervin (ed.), Magyar ENSZ Társaság, Budapest, 21–34.

Szarka László (2009): „Globális felmelegedés" és kritikai gondolkodás. Gondolatok Vaclav Klaus: Kék bolygó zöld béklyóban könyve kapcsán. *Természet Világa,* Vol. 140, No. 5. 214–215.

Szarka László (2010): Szempontok az energetika és környezet kapcsolatához. *Magyar Tudomány,* Vol. 171, No. 8. 979–989.

Szarka László (2012): Critical remarks addressed to climate fanatics and climate sceptics. *Periodica Oeconomica,* No. 1, 133–143.

Szarka László (2013): Globális kihívások a "Future Earth" (A Föld a jövőben) című ICSU program küszöbén. *Hadtudomány,* Vol. 23, Special Issue, 425–434.

Szarka László (2017): A mai globális környezeti kihívások függetlenek az éghajlatváltozás éppen aktuális tendenciájától. *Magyar Tudomány.* Forthcoming.

SZARKA László – Brezsnyánszky Károly (2012): Globális környezeti alapkérdésekről. *Környezetipar, újraiparosítás és regionalitás Magyarországon,* BARANYI Béla – FODOR István (eds.), Institute for Regional Studies at the Centre for Economic and Regional Studies of the Hungarian Academy of Sciences, Pécs, 355–362.

SZEGEDI Imre (2016a): Mit hoz a jövő? *Innotéka.* Source: www.innoteka.hu/cikk/mit_hoz_a_jovo.1348.html

SZEGEDI Imre (2016b): Atomerőművek biztonsága. *Innotéka.* Source: www.innoteka.hu/cikk/atomeromuvek_biztonsaga.1354.html

SZEREDI István (2014): A piaci feltételek változásainak hatása a vízenergia hasznosításának eszközeire. *Magyar Tudomány,* Vol. 175, No. 7. 810–827.

SZEREDI István – ALFÖLDI László – CSOM Gyula – MÉSZÁROS Csaba (2010): A vízenergia-hasznosítás szerepe, helyzete, hatásai. *Magyar Tudomány,* Vol. 171, No. 8. 959–978.

SZERGÉNYI István (2015): *Energia, civilizáció, szintézisigény.* Typotex, Budapest.

TÁLAS Péter (2016): *Rövid összefoglaló a biztonság fogalmáról.* Unpublished.

TUCKER, William (2008): *Terrestrial Energy: How Nuclear Energy Will Lead the Green Revolution and End America's Energy Odyssey.* Bartleby Press, Washington–Baltimore.

TURNER, Graham (2014): *Is Global Collapse Imminent?* MSSI Research Paper No. 4. Melbourne Sustainable Society Institute – The University of Melbourne, Melbourne.

VAJDA György (2001): Energiapolitika. *Magyarország az ezredfordulón. Stratégiai tanulmányok a Magyar Tudományos Akadémián 2001,* Hungarian Academy of Sciences, Budapest.

VAJDA György (2004): Energiaellátás ma és holnap. *Magyarország az ezredfordulón. Stratégiai kutatások a Magyar Tudományos Akadémián,* Center for Social Research of the Hungarian Academy of Sciences, Budapest.

VAJDA György (2006): Energia és környezet. *Ezredforduló,* No. 2. 3–7.

VAJDA György (2009): *Energia és társadalom.* Center for Social Research of the Hungarian Academy of Sciences, Budapest.

VAJDA György (2014): *Okok és következmények az energetikában.* Akadémiai Kiadó Zrt., Budapest.

VARRÓ László (2007): Az energiaellátás biztonsága és a magyar külpolitika. *Külügyi Szemle,* Vol. 6, No. 1. 64–78.

VÉGH László (2016): *Fenntartható élet.* DE TTK – ATOMKI Környezetfizikai Tanszék. Source: http://w3.atomki.hu/kornyezet/f16t.pdf

VERBŐCI József (2010): *Magyarországi szénkitermelés és hasznosítás jövőbeni lehetőségei. „Tisztaszén technológiák (clean coal)" használatának, a „metanol gazdaság" magyarországi kiépítésének fontossága, lehetőségei.* Kézirat. Magyar Mérnöki Kamara Szilárdásvány Bányászati Tagozat, Budapest. Source: www.mmk.hu/tudastar/dokumentumtar/segedlet.../szbt_szentermeles.pdf

VIDA Gábor (2009): Véges Föld és végtelen vágyak. *Az erőszak kultúrája. Fenntartható-e a fejlődés?* KÓRÓDI Mária (ed.), Pallas, Budapest.

VIDA Gábor (2011): Globális energiagondok. *Biokontroll,* Vol. 2, No. 1. 4–11.

YOUNGQUIST, Walter (1997): *GeoDestinies: The inevitable control of Earth resources over nations and individuals.* National Book Company, Portland.

YOUNGQUIST, Walter (1999): The post-petroleum paradigm-and population. *Population and Environment,* Vol. 20, No. 4. 297–315.

ZILAHY Gyula (2017): Az üzleti szféra szerepe a klímaváltozásban és a következmények kezelésében – se veled, se nélküled. *Magyar Tudomány.* Forthcoming.