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How much? What is how much?
A Study from the Energy Working Group of the Batthyány Society of Professors

The captain shouts down to the engine room to the furnaceman: "how much?".
"Thirty" is the answer.
"Thirty what?" - asks the captain.
"What is how much?" asks the furnaceman.
(Known as an old joke in Hungary)

OVERVIEW

In order to deal meaningfully with the issues of future energy supply, it is first of all necessary to get rid of unclear definitions and narratives that are far removed from physical reality. Seeing the dramatic European energy developments and feeling our common responsibility for domestic energy policy, the members of the Energy Working Group of the Batthyány Society of Professors (Professzorok Batthyány Köre, PBK), established in the summer of 2022, feel it necessary to summarize the basic questions that have arisen.

Energy is the basis of our civilization. Our energy carriers come from the conversion of natural energies. Humanity, whose total mass is only 0.01 percent of the total biomass of the Earth, uses only a few tenths of a percent of the natural energy flow. Globally, the energy used from nature from year 1800 to the present is about as much (40 ZJ) as the total energy of the December 26, 2004 earthquake in Indonesia. The answers that can be given to the basic questions of the Earth-mankind relationship, including the question of energy, largely depend on the human values we start from. Among other things, whether we admit that nature can be made more beautiful by humans. Answering this question is especially critical nowadays, when so many people confuse environmental protection with climate protection.

The concept of decarbonization referring to climate goals (55% CO_2 emission reduction by 2030, "net zero" emissions by 2050) means withdrawing coal-based energy, which accounts for four-fifths of current energy carrier consumption. Since carbon is the fourth most common element in the universe and the basis of life on earth, the very term decarbonization gives rise to serious misunderstandings regarding the consequences.

Feasibility and impact studies supporting the necessity and possibility of a forced rapid energy transition do not exist. What's more, the mainly German experiences in the field of wind and solar energy production, heralded as the leading "renewable" types of energy, are disappointing. On the other hand, the demand for metals, rare metals and graphite required for the production and operation of windmills and solar panels for a single generation (with a useful life-span of 20–25 years) is much greater than the known quantities of these materials that can be foreseen to be extracted and produced. The associated need for raw materials and land is enormous, and the recycling technology of the huge amount of hazardous waste after their amortization is far from being resolved. Their energy return index (EROI) is low, compared to the EROI of nuclear (~80), hydro (~50) and fossil (~20) energy.

Imposing decarbonization as a political goal leads to economic and social decline. The justification for the alleged climate emergency is lame. Conscientious consideration of natural resources and their environmental impacts suggests a slow, continuous energy transition towards more and more efficient energy sources, as has been the case throughout history.

In this study - on the basis of the moral worldview represented by the PBK - we try to provide a comprehensible overview of these extremely complex and interrelated technical and social topics, and help in orientation and adaptation. We also offer an exact definition for the concept of sustainable development.

As for the immediate challenges: the terrorist action against the Nord Stream presents us with a threateningly uncertain future. Energy security requires an increase in domestic fossil-based electricity production, with adequate internal security protection. In order to increase the production capacity of the current (energy) generating units in the short term, we recommend assessing the technical possibilities and costs; in the medium term, examine the possibility of reactivating previously planned (but, for various reasons, dropped) coal and hydrocarbon research and production ideas; and, as soon as possible, on the basis of new, domestic and regional geological examples, enhance research of prospective coal and hydrocarbon occurrence sites and underground formations. Our national so called natural possibilities in the field of renewables must also be considered soberly. In the field of hydropower, a complete, non-political rethinking is offered as the most important possible objective, and in the field of other renewable energies, the promotion of local use. It is reasonable to connect wind and solar energy to the electricity network only to the extent of the capacity of the pumped water potential energy reservoirs.

SUSTAINABLE DEVELOPMENT AND ENERGY

Sustainable development. As a definition of sustainable development, public opinion today considers the UN's "Sustainable Development Goals" (SDG, 2015-2030, today known as Agenda 2030) as authoritative. Definition of 17 goals: 1. Eradication of poverty; 2. Ending hunger; 3. Good health; 4. Quality education; 5. Gender equality; 6. Clean water and public cleanliness; 7. Affordable and clean energy; 8. Good job opportunities and economies; 9. Innovation and good infrastructure; 10. Reducing inequality; 11. Sustainable cities and communities; 12. Responsible use of resources; 13. Action against climate change; 14. Sustainable oceans; 15. Sustainable land use; 16. Peace and justice; 17. Partnership for sustainable development[1]. The SDG is apparently unorganized, its elements can be interpreted as desired.

There exist also consistently prioritized systems. Such is the sequence recommended by Nobel laureate Richard Smalley: I. Energy (and raw materials); II. Fresh water; III. Farmland (food); IV. Environment; V. Social issues (poverty, terrorism and war, diseases, education, democracy, population)[2]. The latter points to the easy-to-see connection that sustainable social development and the so-called “The prerequisites for a "sustainable" society” are all tied to nature. In Smalley's order, energy is the most important, because if enough energy is available, drinking water can also be produced (from seawater), then the land can be cultivated with the help of energy and water, and then - having energy, fresh water and food - the human environment can be made healthier. It can be seen that the basis of the existence of human civilization is energy.

Energy as a natural resource. The word "energy" comes from the ancient Greek ἐνέργεια (energeia; "en": in-; "ergon": work), from Aristotle. The physical definition is "accumulated capacity to perform work". In practice, it means the ability to perform work, the ability to interact, the ability to change the state of a body or physical field. It is important to know that energy is not created. It comes from transformation of natural energies (so-called primary energies).

Accessing a natural energy source is equivalent to finding treasure. The discovered energy carrier is made valuable by the energy that can be extracted from it and can be put to the service of humanity. It is more valuable if the so-called energy density is higher (a given amount of material contains higher amount of energy) and if the so-called power density is higher (the amount of energy that can be extracted from a unit of area in a unit of time). To extract the discovered energy, extraction and energy conversion devices must be produced, the operations of which also require energy. The energy that can be typically extracted from nature by investing a given amount of energy is defined by the EROI (Energy Return Of Investment) indicator, by analogy with financial investment. The so-called net energy gain resulting from EROI, defined as 100x(1–1/EROI), tells us what percentage of the energy extracted from nature can be used for other purposes (economic, social, luxury, etc.) in addition to the operation of the energy extraction and conversion system[3]. In case of EROI=1, the net energy gain is 0, i.e. no energy is used for anything other than the maintenance of the energy source; in case of EROI=2 it is 50%, i.e. half of the extracted energy can already be used for non-energy sustaining purposes; in case of EROI=10 it is already 90%, i.e. 90 percent of the extracted energy can be utilized in such a way that it is possible to progress even further in Smalley's logical sequence of natural and social issues.

Figure 1 shows the relationship between EROI and net energy gain. It is also called energy cliff, which illustrates that the energy sector within the economy can decrease below 10 %, only if the EROI is higher than 10. With EROI=20, there is already plenty of energy to support such social objectives as culture and art.

When calculating the EROI, the energy consumption for the safe design of energy production must also be taken into account. For example, some empirical EROI values are given here for different energy sources: coal, petroleum and natural gas: approx. 20-30, hydropower: 40-50, nuclear power: approx. 80, photovoltaic (PV) solar energy and wind energy: 6-10. The specific EROI values are bounded from above rather than from below. The EROI of biomass is highly volume-dependent: the interval ranges from 95, which is approximately typical for a backyard economy, down to a value of approx. 5. The list is not exhaustive. There may be unknown or already theoretically known energy carriers (such as fusion energy) whose EROI is higher than that of all known energy carriers.

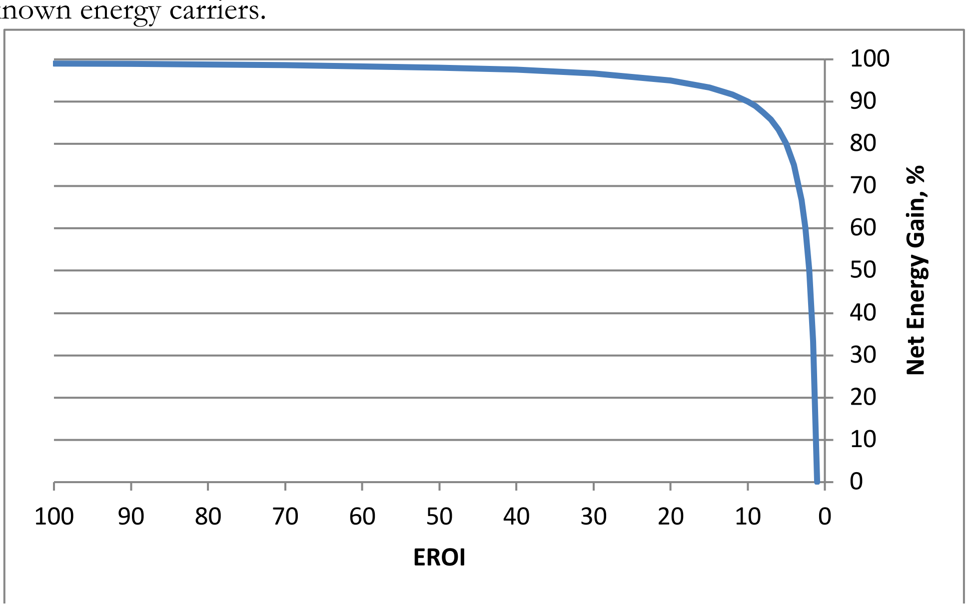

Figure 1: Relation between the EROI and net energy gain

Figure 2 shows the evolution of the annual use of primary energy sources in absolute value, and Figure 3 shows their ratio. The changes in the structure of energy consumption can be attributed to the appearance of coal, then petroleum and natural gas, but their expansion also took place over a relatively long period of time - several decades. Thanks to energy types with high EROI, such prosperity has never been possible any time earlier in human history. Globally, of course, there is great inequality, but the fact is that where there is a secure energy supply, more and more people are rising out of extreme poverty.

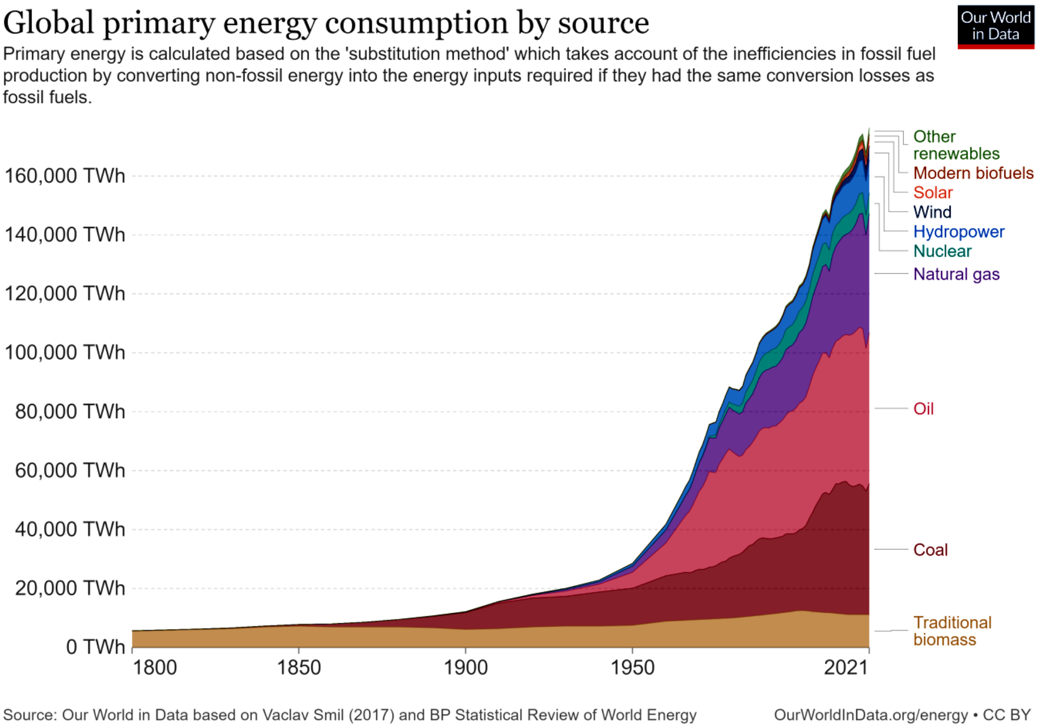

Figure 2: Distribution of primary energy sources by source between 1800 and 2021[4].
Note: conventional energy sources in all figures and data are considered based on the so-called substitution method.

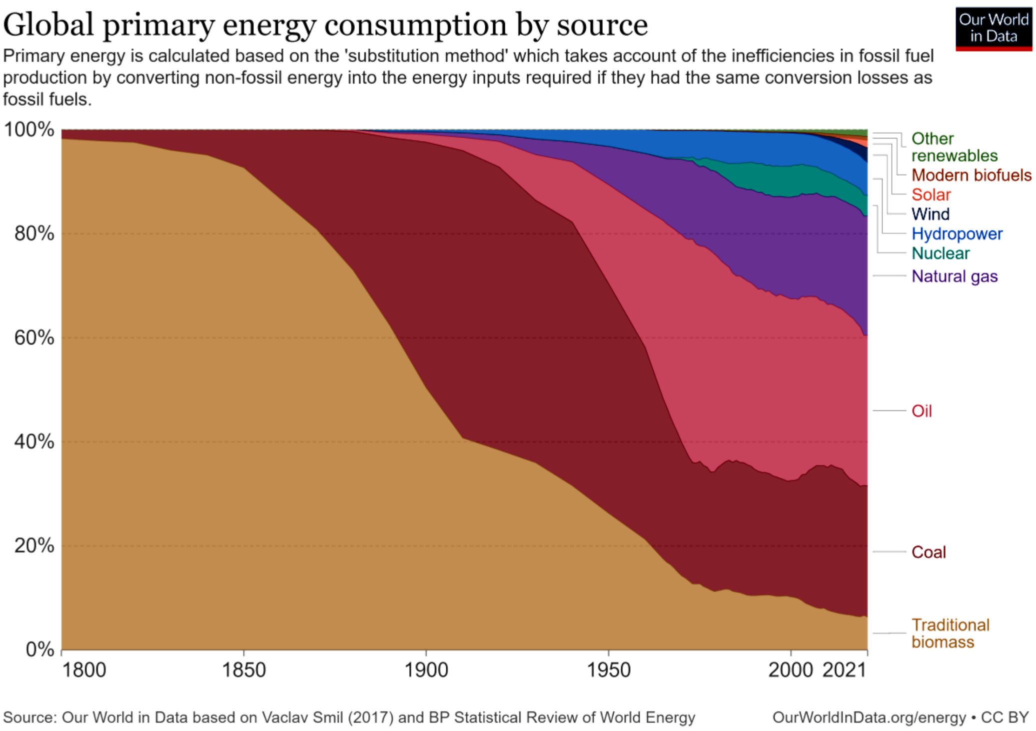

Figure 3: Percentage distribution of primary energy carriers by source between 1800 and 2021[5]. The distribution in 2021: Other renewable: 1.35%, Modern biofuel: 0.65%, Solar: 1.53%; Wind: 2.76%; Water: 6.34%; Nuclear: 3.99%; Natural gas: 22.88%; Petroleum: 29.00 %; Carbon: 25.2%; Conventional biomass: 6.3 %.

Traditionally, man has used thermal energy and mechanical energy. The distinction is important, since mechanical energy can essentially be completely converted into thermal energy, while thermal energy can only be converted into mechanical energy with limited theoretical efficiency. In this sense, electricity, which is now indispensable, also acts as "mechanical energy". Electricity is not included in Figures 2 and 3 because it is a so-called secondary energy, i.e., in all cases it must be produced from some primary energy carrier.

Globally, the primary energies were used in the following approximate proportion between the individual sectors: industry: 51.7%, transport: 26.6%, population: 13.9%, trade: 7.8%. A safe electricity supply is indispensable in each sector, without which 21st century technology (e.g. IT) would not function at all. Figure 4 shows the global use of the primary energy carriers of electricity. Their relative distribution in 2021: coal: 36.4%, natural gas: 22.1%, water: 15.4%, nuclear: 10.0%. wind: 6.7%, solar: 3.7%, petroleum: 3.0%, bioenergy: 2.4%, other renewables: 0.3%.

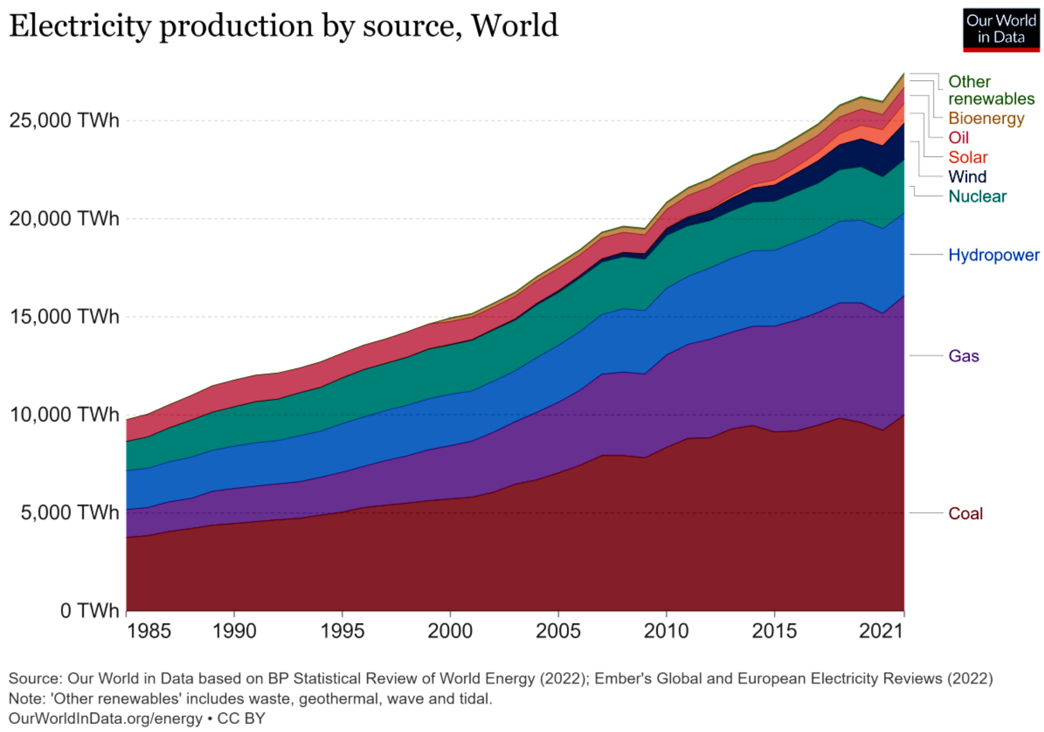

Figure 4: Distribution of primary energy carriers for electricity production[6].

Over the past decades, on the one hand, due to the limitation of possible energy carriers (the so-called sources), and on the other hand, due to the inevitable environmental consequences of the use of natural resources (in short: the sinks), there has been a growing concern: are we not (or have we already been) bumping into some kind of planetary limitations?

Scarcity or abundance? The answer that can be given with the best conscience largely depends on our value-system used when we approach this question.

For our part, we consider authoritative the value-system of a cautious person who accepts the idea of the Earth as a gift and rejects both extreme selfishness and extreme altruism. In scientific knowledge, we therefore consider the facts and not the prevailing opinions to be decisive. Despite the answers offered on the fast-food tray, the most fundamental questions of the Earth-mankind relationship are unclear, and our answers are uncertain. The reason for this is basically that what seems huge to humans is small from the point of view of Nature. Regarding the issue of "overpopulation", for example, we can factually say that the total mass of humanity is about

500 million tons, or 0.01 percent of the total biomass of the planet Earth[7]. The energy we have used from nature from year 1800 to the present can be estimated at a global value of somewhere around 40 zettajoules (1 ZJ = 10^{21} J), which is a huge amount of energy measured by individual human standards, but it is only an insignificant amount compared to the scale of natural energy sources. The total energy of a single major earthquake can reach this magnitude. (The total energy of the earthquake in the Pacific Ocean that caused the tsunami on December 26, 2004, was approx. 40 ZJ.) Human use can be measured only in thousandths of the natural energy flow[8, 9]. Perpetual concern over the eventual depletion of natural resources has always been moral and appropriate, but the less pessimistic view has always been equally moral and appropriate. In reality the natural resources have always proved to be much greater than the estimation of any time of consideration[10].

The fossil (petroleum, natural gas and coal) and fissile (fissile material) stocks available on Earth are obviously limited, as the size of the Earth itself is. According to lower estimates, at today's level of use, the production of hydrocarbons is sufficient for at least a few decades, coal for at least one and a half centuries, and fissile materials (largely because of the technical development of the past decades) can ensure the safe energy supply of mankind for at least a thousand years. At the same time, types of energy derived from the tapping of natural processes (called "renewable", but in fact these are water, wind, and PV-solar) are also limited. Their use inevitably affects the natural system itself.

Can we trust the future? Can the supply of energy sources that have created prosperity so far be expanded by surprise? Can we hope for new (so far unknown or only theoretically known) natural energy carriers? What are our possibilities in tapping natural processes of the "flow" type?

It is important to rationally consider the expected development of today's opportunities based on the facts, and to constantly research the opportunities and limitations related to all possible energy carriers today and in the future.

Environmental considerations. The concept of the so-called environmental impact creates a negative association in the people nowadays, despite the fact that most creations of human society (church, school, hospital, farmland, factory, roads, etc.) are specifically and distinguishably have been created to serve people. According to Roger Scruton, nature can also be made more beautiful by humans[11]. Our ability to influence nature (both good and bad way) is undoubtedly determined by the amount and type of energy consumption.

Regarding the consequences of each type of energy, it can be generally stated that all energy, some through work, eventually turns into heat. Each type of energy has many specific consequences influencing the nature. Individually, all environmental effects can be quantified quite well, but the various consequences are difficult to compare with each other. As a general conclusion, it can be stated that by replacing energy sources of high density of energy and power (practically characterized by high EROI) with energy sources of low density of energy and power, the area required for energy production increases dramatically. Producing the same amount of energy from primary energy sources with low EROI means a greater environmental burden than from more concentrated energy sources. Therefore, research and use should strive to use energy sources with the highest possible EROI. The environmental impact can also be reduced by striving for the local use of local energy sources.

Professional judgment. Looking at the opportunities with the highest EROI, we see that while the natural endowments of hydropower plants are limited, the use of nuclear energy is essentially unlimited. In the field of fusion energy, there are still significant and uncertain research and development tasks, as in the field of many other possible energy carriers. The structure of the traditional energy carrier-based energy network, which has been supplying the world safely until now, can be changed reasonably only in small steps and gradually (over decades).

Taking everything into account, it is logical to implement the transition from the scarcest fossil energy types gradually (which globally shows no sign of diminishing) to much less limited energy carriers with a high EROI. According to experts, the gradual replacement of fossil energy carriers could ideally be started with nuclear energy. The decision-makers, on the other hand, say the same about solar and wind energy, characterized by low EROI, and even consider the idea what they call a green transition not only possible, but downright urgent!

How could this contradiction arise?

WRONG WAY

Forced decarbonization. Instead of an objective and complex evaluation of energy types and their environmental effects, the prevailing view in the last decade became the so called fight against CO_2 emissions. Even as far as the index-number called ecological footprint is concerned, almost half of its value is attributed to anthropogenic CO_2 emissions. The CO_2 footprint is not only quantified numerically, but also sanctioned. The reason given for this special attention is the claim that CO_2 emissions have already caused unprecedented climate change. It has been proposed that climate change can be stopped by reducing the atmospheric CO_2 concentration, i.e. with the so-called decarbonization: the proposal is to stop the climate change by the withdrawal of using coal, oil and natural gas that means approximately 80 % of important current energy sources."

The 13th goal of the UN SDG ("act against climate change") has therefore become paramount. Encouraged by the UN and WEF (World Economic Forum), the world is being forced into the accelerated decarbonization energy transition (55% emission reduction by 2030, complete net climate neutrality by 2050) in the belief that the energy to be abandoned (80% of the actual energy use) can be replaced with "renewable energy" (solar and wind energy). However, neither a feasibility study nor an impact study exists for this. Actually, 586,000 new, average-sized, non-fossil-fueled power plants would be required on a global level to build and operate the planned new, completely renewable-based energy system. There are currently only 46,000 such plants, which means ten times the current number will be need to be built. From this, one can get an idea about the time required for the transition[12, 13]. Knowing all this, two questions must be asked: 1. Why does the World need to build a new system under the (unintelligible) slogan of "decarbonization", composed of elements with low efficiency, which has not been tested anywhere yet, and why is it necessary to build an immeasurably expensive new system, to put sovereign countries into unprecedented debt? 2. Why must we give up within an unfeasibly short period of time the balanced industrial ecosystem based on fossil energy carriers, which has been working reliably for many decades, the construction of which took more than a century, the operation of which was possible with the help of high fuel density and cheap energy sources (petroleum and natural gas)?

The EROI of fashionable solar (PV) and wind energy is inherently insufficient. Their special material requirements increase the production of mineral raw materials to a critical level, due to the weather-dependent capriciousness of their operation, their use for continuous energy supply could only be solved by energy storage, but its possibilities are very limited[14, 15, 16, 17, 18, 19].

It is becoming more and more obvious that the acceleration of decarbonization was not born because of professional consideration. The lack of professionalism is already evident from the fact that it is unrealistic and impossible to implement such a turnaround so quickly (by 2030 or 2050). Figure 5 illustrates the impossibility of achieving the Paris climate goals[20, 21].

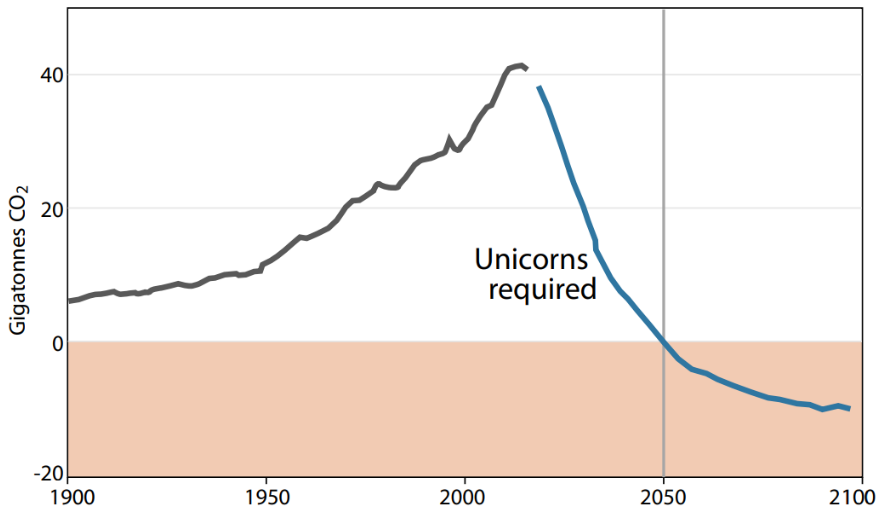

Figure 5: The evolution of the annual amount of global carbon dioxide emissions so far (in black) and the schedule for meeting the "carbon neutrality" climate goals until 2050 and beyond (in blue). The magnitude of the task is such that it would require miracle-working unicorns ("unicorns required")[20, 21].

Focusing on a single selected element from the complex issue of energy can only lead to a bad political decision. In this case the "threatening climate change" is the only argument taken out as a reference for decarbonization. In the following, we look at the validity of decarbonization from this point of view, but only to the extent that is inevitably necessary[22].

Climate change: reason or excuse? The climate of our Earth, which revolves around the Sun, rotates on its own axis and is mainly covered by water of all three phases, is determined by the balance of incoming solar radiation and outgoing thermal radiation, and the dynamics of atmospheric and oceanic energy transfers. From the cosmos to the internal structure of the Earth, there are many other influencing factors. In the most diverse range of space and time, everything varies forever. Weather extremes, but also trends dominating for several decades, are completely natural. The current climate change is not at all unprecedented within the time scale of human history. Nature can produce much larger fluctuations.

In climate change, which is declared as the basis of reference for decarbonization efforts, neither the paleoclimatic facts nor the earth-physical and oceanic processes that can be observed today are taken into account. An exponentially growing mass of data has become known about them in recent years.

It does not help understanding, that the UN Framework Convention on Climate Change has excluded natural causes from the definition of climate change and tries to claim natural variability as insignificant. (According to Article 1 of Act LXXXII of 1995 on the Promulgation of the UN Framework Convention on Climate Change, “Climate change” means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”) This opened up the possibility for some to claim that all kinds of climate change could be attributed to purely anthropogenic effects.

Seeing this kind of influence from outside science, it is not surprising that, according to the cited definition, climate change is initially attributed to a trace gas, carbon dioxide, which makes up to 0.04 percent of the atmosphere, a gas which is not a "harmful substance" at all, but one of the basic components of life. Energy policy decisions referring to climate change (the so-called climate goals) are made on the basis of models that do not match the facts known retrospectively. According to the data in Figure 6, the claim that climate change would cause more and more deaths is not correct either[23].

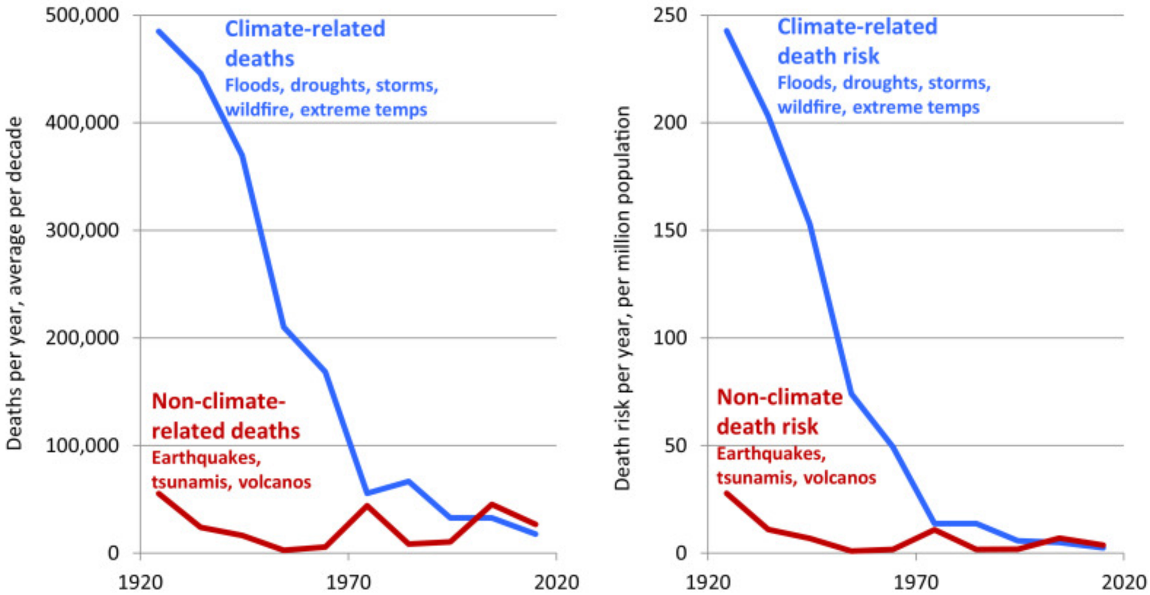

Figure 6: The number of deaths from natural disasters that can be linked to climate change and that are certainly independent of climate change since 1920[23]. Blue: flood+drought+storm+wildfire+extreme weather. Red: earthquake+tsunami+volcanism. On the left: the number of deaths per year averaged over a decade. On the right: Annual number of deaths per million people.

Based on newer and newer observations, any previous hypothesis in science can be questioned. Due to the unilateral interventions in science from the outside and the accumulated contradictions, the issue of climate change is not closed in the scientific sense. Without a thorough and clear knowledge of the Earth's energy systems, it is a phantasy-world idea to prevent climate change through the forced reduction of human CO_2 emissions. We should rather adapt to the current climate change, as man has always done for the past two hundred thousand years, since he had no other choice.

In summary: current climate change is not unprecedented, the Earth's climate system has not collapsed in any sense, and we do not even know the sign of future change. Justifying the need for decarbonization referring to a climate threat is scientifically baseless.

Our concern. Forced decarbonization is energetically unprofessional, debatable in terms of its scientific basis, and humanly intolerable, yet it has started despite all of this. Looking at the beneficiaries of the process, it can rightly be assumed that the propagandistic presentation of climate change as a global threat to our future and the hastening of decarbonization are nothing more than the psychological preparation for the concrete implementation of the Great Reset. Let's think back to Smalley's list of priorities: removing the most important natural prerequisite for sustainable development is suitable for making people vulnerable. It is a fact that large investment funds, using the so-called ESG (Environmental, Social and Governance) guidelines, are forcing companies to fulfill the decarbonization expectations they have developed in a coordinated manner, at the same time withdrawing resources from energy investments needed for stable and safe electricity supply[24, 25]. It is as if the primary reason for the price increase of energy carriers is basically the decarbonization energy policy. Our biggest concern is that there is purely political intent behind the push for decarbonization.

RETURNING TO THE COMMON SENSE

It is a fact that the developed world has reached an abundance of energy leading to enormous waste, while the poorest countries lack the secure energy supply. Compassionate concern for humanity naturally offers unselfish austerity to serve the most efficient way the goals of help were needed (the very approach actually has been betrayed by the "World-saving" elite by the establishment of the global consumer society), and on the other hand, helping the poorest countries to utilize their own natural energy resources.

As Pope Emeritus Benedict XVI (who died on December 31, 2022) in his papal encyclical Caritas in Veritate c. wrote: "Questions linked to the care and preservation of the environment today need to give due consideration to the energy problem. The fact that some States, power groups and companies hoard non-renewable energy resources represents a grave obstacle to development in poor countries."[26]

A gradual energy transition will definitely be necessary for the sake of the future. On the other hand, it is desirable that its rational planning (the creation of a network of operational units of nuclear power plants or other, as yet undeveloped, processes characterized by a high EROI value) should be the work of researchers, engineers and reality-based economists[27].

Instead of the make-believe proposition of a necessary immediate energy turnaround ("Energiewende"), a slower, gradual, well-thought-out energy transition ("Energy Transition") may be therefore the only viable path, as has been the actual case so far. We have time! The energy transition will naturally involve the reduction of anthropogenic CO_2 emissions (if you like, the "decarbonization"), which will thus not be an imposed goal, but only one of the collateral side effects!

Energy investments necessary for a stable and reliable electricity supply must be replaced, and the use of unsteady, intermittent sources (wind, solar energy, or tide) must be kept within reasonable limits.

Although this study is aimed at clarifying questions of principle, to ensure the continuity of domestic energy security, we cannot ignore the consideration of direct challenges. We must clearly see that the terrorist action against the Nord Stream 1 and 2 pipelines will radically change the energy policy aspirations and ideas regarding the continuous, safe, and affordable supply of energy to the world, including Hungary, which will affect the entire economy, both on global and local levels, too. This event crossed a line that was tacitly accepted and respected even in the darkest years of the Cold War: the inviolability of (international) energy production, transportation, and service infrastructure systems (the pipeline systems). With this, the illusion of a continuous, safe, and affordable energy supply disappeared. From there, it is only a matter of time before someone may target an (offshore) drilling rig, mining facility, transmission line, LNG or oil tanker, port facility, LNG terminal, electrical transmission line, or even a (nuclear) power plant[13]. In today's situation, energy security can therefore only be guaranteed through domestic fossil energy carriers, with adequate internal security protection. In order to increase the production capacity of the current (energy) generating units in the short term, we recommend assessing the technical possibilities and costs; in the medium term, assess the possibility of reactivating coal and hydrocarbon research and production ideas that were previously planned but dropped for various reasons; and based on new, domestic and regional geological examples, we recommend that prospective coal and hydrocarbon occurrence sites and underground formations be searched as soon as possible. Regarding the so-called renewable and our natural possibilities, we must follow common sense. In the field of hydropower, a complete, non-political rethinking is offered as the most important possible objective, and in the field of other renewable energies, the promotion of local use. It is reasonable to connect wind and solar energy to the electricity network only to the extent of the pumped energy storage and the variable water reservoir capacity.

DESTINED FOR SUSTAINABLE DEVELOPMENT

Returning to the principal questions: Smalley's list is not complete. It tells nothing about another physical concept, entropy, equally important as energy. The average person only knows about entropy, that it means "disorder" and that processes left to themselves always go in the direction of disorder, i.e., their entropy increases. The term entropy was coined by Rudolf Clausius in 1865, based on the word *energy*. By keeping the prefix en and replacing the word ergon (work) with tropé (τϱοπε = turning), he tried to characterize the molecular disorder of material systems in thermodynamics.

Amid the talk of the so-called entropy growth, it was almost completely forgotten that the open Sun-Earth-space system takes care of the reduction of Earth's entropy, i.e., the global increase of "order", as a matter of course. As shown in Figure 7, the Earth absorbs energy from a warmer body (the Sun) at a higher temperature and gives it to a much colder medium (outer space) at a lower temperature. In short, it can be said that the Earth is sustained by the Sun. This natural decrease in entropy (negentropy) is the source of life on earth, a truly sustainable development! At the same time, this is Csernai's theoretical (physical) definition of sustainable development[28, 29, 30].

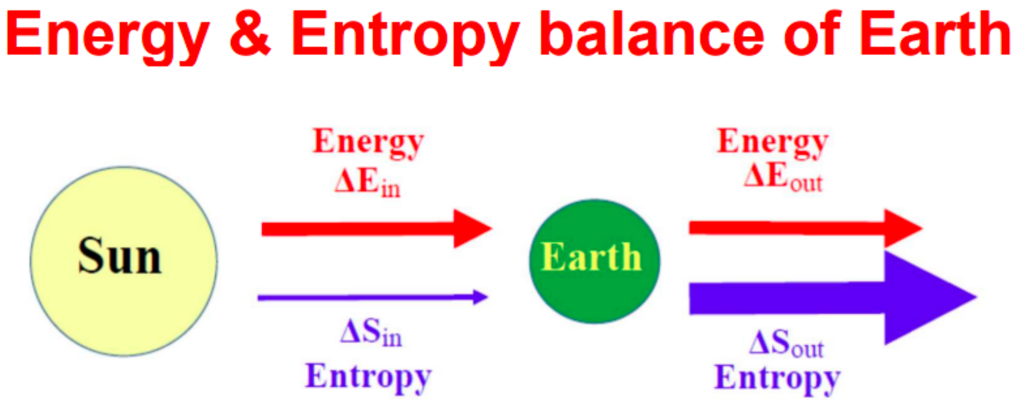

Figure 7: In the Sun-Earth system, the entropy balance of the radiation energy balance of the Earth (ie the quantity $\Delta S=\Delta E/T$, where T: temperature, E: energy, S: entropy) is negative at every instant of time. The so-called negentropy (i.e. the continuously increasing orderliness) is due to the fact that the entropy absorbed from the Sun due to the temperature of the solar surface of around 6000 K is significantly lower than the entropy given off in the form of thermal radiation from the surface temperature of around 300 K. An essential condition for ensuring negentropy is the tempering effect of H2O (liquid water, water vapor, snow, ice) covering the earth's surface[28, 29, 30], which compensates the small (< 1/340) radiation imbalances of the Sun-Earth system.

The framework of sustainable development, which has acquired an exact meaning in this way, is set by negentropy. Human sustainable development therefore points in the direction of increasingly complex systems.

Our goal may be to always produce energy with the smallest possible entropy production at all times. From this, in terms of the so-called renewable energies, it follows directly that the hydropower plant is the best possible option, and the wind power plant is the worst possible option. And the use of photovoltaic energy is forward-looking only as long as it does not occupy productive land. The role of water is extremely important. In addition to the maintenance of negentropy in the Earth's radiation balance, water, in three phases of matter ensures that pure water is the most important basic ingredient of human life. On top of all that, it is the only energy storage alternative that is able to store large amounts of energy with good efficiency to balance renewable energy production working only from time to time.[31]

The best prospect for the present and the future is nuclear power, which produces the most energy with the least amount of fuel and the least amount of space. Finally: fusion energy production - if realized - does not increase entropy on earth, but itself contributes to the increase of orderliness.

We have a responsibility, but we also have hope.

NOTES

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31. Appendices discussing many technical details, are available only in Hungarian the Hungarian version at: https://pbk.info.hu/archiv/pbkforum/PBK_ENERGIA_2023_02_21.pdf I: Concepts, II: Energy policy suggestions for Hungary, III: Mobility, IV: On carbon neutrality, V: Substitution of hydrocarbons, VI: Mineral raw material demand, VII: Michael Kelly: Energy Utopias and Engineering Reality. Illustrations of the GWPF Annual Lecture presentation.

English version of April 28, 2023

Hungarian version (with attachments) was published January 14, 2023.
The final version of February 21, 2023 is available at the link:
https://pbk.info.hu/archiv/pbkforum/PBK_ENERGIA_2023_02_21.pdf

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