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Leszek S. CZARNECKI
Life Fellow IEEE, Alfredo M. Lopez Distinguished Professor, Louisiana State University, USA, e-mail: lsczar@cox.net

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Sources of Electric Energy. Important Questions and Strange Answers

Źródła energii elektrycznej. Ważne pytania a dziwne odpowiedzi

Abstract: *The paper compiles, in a critical manner, various opinions that occur in the public domain in a debate on what sources should be used for production of electric energy, which is needed for normal operation of our technological civilization. The author does not express his own opinions in this matter but rather a form of amazement at some common views and their genesis.*

Streszczenie: *Przedmiotem artykułu jest nieco krytyczne zestawienie różnych opinii pojawiających się w przestrzeni publicznej w dyskusji na temat, z jakich źródeł winno się czerpać energię elektryczną, potrzebą do normalnego funkcjonowania naszej technicznej cywilizacji. Nie będąc w przedmiocie artykułu ekspertem, autor nie przedstawia własnych opinii, lecz raczej wyraża rodzaj pewnego zadziwienia różnymi na ten temat powszechnymi poglądami i ich genezą.*

Keywords: *Sources of Electric Energy, opinions*

Słowa kluczowe: *źródła energii elektrycznej, pytania*

1. INTRODUCTION

The author of this article does not claim to be an expert on technical or economic/ecological issues associated with generation of electric energy. His proper field is description of the phenomena accompanying the transmission of electric energy and improving effectiveness of such transmission via compensation. The author's original power theory of electric circuits, based upon the idea of Currents' Physical Components (CPC) is at present the most universal tool for describing power phenomena in electric circuits, it also constitutes the basis for compensation.

However, work on power theory of electric circuit is one way or another related to generation of electric energy. The author has been keeping an eye on the ongoing discussions about economic/ecological aspects of energy generation. The current article contains some observations on the subject. It was read as a keynote lecture [1] during 4th International Conference on New Energy and Future Energy Systems in Macau, China, 2019. Since the author is, strictly speaking, not an expert on the subject, please treat this critique as an essay rather than a complete scientific paper.

An adult human being needs about 2000 kcal of energy daily (in the form of food). This is energy indispensable to maintaining body temperature at c. 37°C (this is accomplished by burning, i.e. oxidizing carbon contained in the food), while the outflow of thermal energy from the body to the surrounding environment (with temperature usually c. 20°C) is continuous. Even with long-lasting physical effort, only a very insignificant amount of energy contained in food is consumed. For instance, two hours of gym exercise will take up c. 200 kcal of energy, which is more or less the equivalent of a small bottle of Coca-Cola.

Mechanical power of a man (if we consider a man as a working machine) is not high. For instance, when we climb the steps, a man attains 50 to 150 watts (and that depends on speed). During usual office work or home activities, power is no more than a few watts.

This is too little to provide a human being with life necessities such as food, home and its furnishings, clothes, roads, cities, cars and fuel. The modern answer to all these needs lies in electric energy. For instance, in the US the power

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produced by electric power stations totals c. 2800W per person. Only a small portion of this power (more than ten per cent) is consumed directly by people. The prevalent portion is used up in the manufacture of steel, aluminium, cement, chemicals and plastic, gasoline, fertilizers, cars, planes or ships. Electric energy expended by a single high-power furnace arc used in steel production is comparable with energy used up by a city populated with a million people.

Industrial-scale amount of electric energy may be obtained from a few sources only: fossil fuels such as coal, oil or gas, potential or kinetic energy of water, atomic bond energy, geothermal energy, wind or solar radiation. Accessibility to these primary energy sources varies from country to country and it results in the prices of electric energy differing also. The price of electric energy is also more and more influenced by the awareness of the ecological consequences of energy production.

Large-scale production of electric energy requires enormous investments; this is possible in the case of big companies or governments only. Such investments last for decades. This promotes the creation of monopolies and, in turn, fosters the elimination of market mechanism: monopolies start to dictate the prices of electric energy. The ecological component in energy price may also be omitted on purpose.

The cost of electric energy is present in nearly every product and service. Apart from taxes, no other price component is as universally present as energy cost. So, the issue of energy source, cost of production and ecological impact is all-important and is of primary prominence in personal and state budgets. Still, this question is often answered in a curious and surprising manner. In the following sections, I present several such answers.

2. FUKUSHIMA DISASTER: GERMAN AND AMERICAN INFERENCES

11th March, 2011: an 11-meter-high tsunami wave caused by Pacific Ocean earthquake surges over the protective barriers of nuclear power plant in Fukushima. At the same time, the earthquake damages the electric network of reactor's emergency cooling system. Three out of six nuclear cores are melted. The hydrogen tanks explode and buildings are destroyed, the reactors become exposed. The radioactivity increases rapidly. 180,000 people must be evacuated from the area of 20 km radius. Another tsunami spreads over the rest of the world: the fear of nuclear power engineering. Chernobyl disaster is recalled. The German government consults power engineering experts and decides to terminate the operation of nuclear power plants.

This decision is pregnant with consequences, both economic and ecological. Replacing of a single nuclear power plant of 1000 MW power with thermal (oil) power plant, requires burning about 13 million barrels of oil per year (1 barrel=159 litres of oil). Since one oil barrel cost about 100 dollars in 2011, disconnection of one nuclear power plant from the system requires a financial outlay of c. 1300 million dollars, just for the purchase of oil. This decision also means that 7.6 m of tons of carbon dioxide (CO_2) will be emitted into the air.

At the same time and several weeks after the Fukushima disaster took place, Mr. Barack Obama, the then President of the US, stated publicly that in accordance with opinions of his power engineering experts, "nuclear energy is the cheapest, the safest and has the least environmental impact. Following this line of reasoning, the US starts a program of setting up 31 new nuclear power plants".

Since there is no reason to conclude that professional training of American and German experts is so very diverse, the formulation of totally contradictory expert opinions is at least most remarkable. It may of course raise some very serious doubts as to the credibility of these opinions.

3. WIND ENERGY REPLACING NUCLEAR ENERGY

I am employed in the Louisiana State University in Baton Rouge. A nuclear plant is situated not far away, in River Bend, on the Mississippi river. In the wake of President Obama's nuclear initiative, it was resolved that River Bend reactor could produce enough steam to drive a turbine of 1500 MW generator. Nowadays this power plant operates at 1500 MW nominal power. Still, it is a nuclear power plant and recollection of Fukushima disaster is still fresh. There are some opinions that a wind power plant would be both safer and more ecological. These opinions are supported by many people, including some of my students and colleagues. 1500 MW electric power of River Bend power plant

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is equivalent to the power of 500 wind turbines, each running at 3 MW; such turbines would require towers 110 m high. Still, this is the level of installed power rather than real (i.e. available) power. In accordance with measurements of Prof. Lubośny from Gdansk University of Technology, output power of 11 selected Polish wind power stations with installed power of 455.5 MW varies during the year, which is shown in Fig.1.

The red line in the chart shows the average ordered power, i.e. total time over a year when wind farms operate at definite power level. The black line shows average power in a year, it is equal to 78.8 MW. So, if we assume that wind power in Louisiana is similar to wind power in Poland and if we require that annual output of wind farm should be equal to the River Bend nuclear power plant output, number of wind turbines should be increased to:

$$N = 500 \times 455.5/78.8 = 2890 \text{ turbines.}$$

Now, if we realise how much of Earth's resources, electricity and water go into the manufacture of steel, cement and almost 3000 generators needed in this farm (and appropriate land area is also indispensable), then it is hard to believe that replacing River Bend nuclear power plant with a wind farm should contribute to the protection of the natural environment. Moreover, the lifetime of nuclear power plant is eighty years, while a wind farm will last for 20-30 years only.

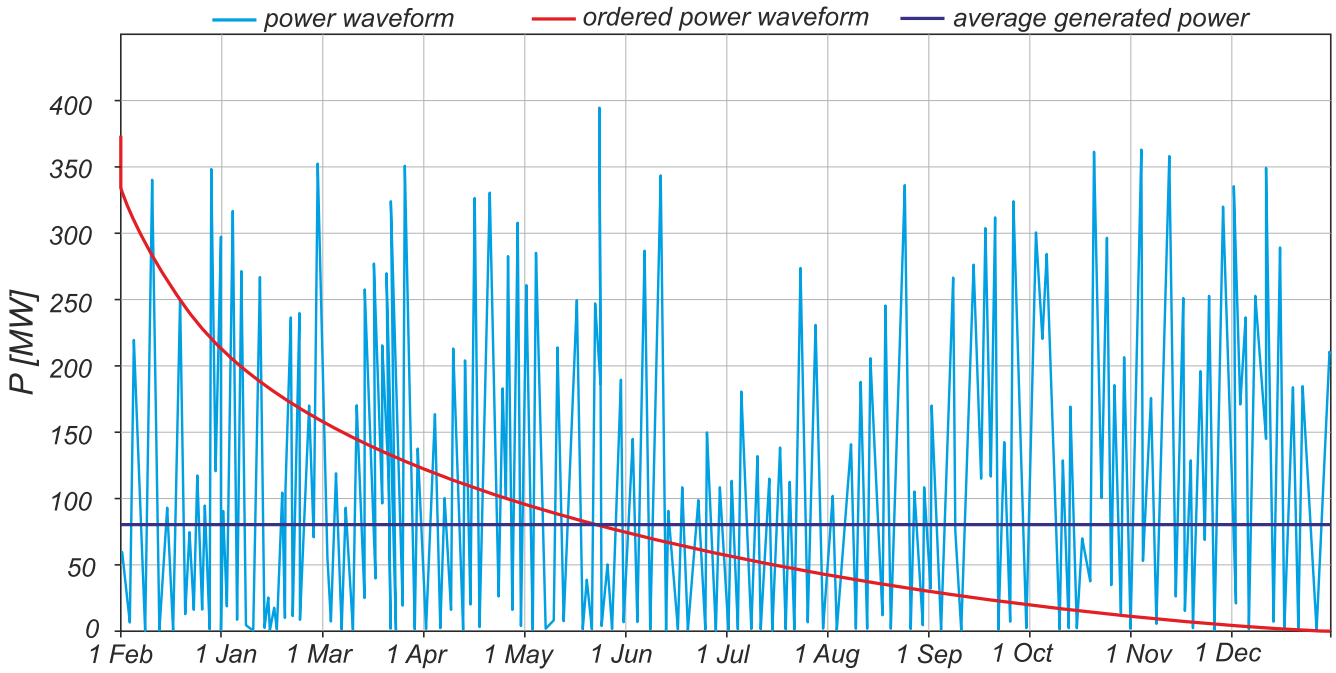

Fig. 1. Annual variation of the power, according to Prof. Lubośny, of 11 Polish wind farms with installed power of 455.5 MW

Still, even if we construct a wind farm containing 2890 wind turbines, we must realize that for more than seven months in a year it will not provide necessary energy (cf. Fig. 1). This means that some other power station with controllable and sufficient capacity must be present in reasonably near vicinity in order to ensure continuous power delivery. Taking all these factors into account, it makes it difficult for me to partake in my students' enthusiasm for replacement of nuclear power engineering with wind power engineering. Somehow, I cannot perceive environmental protection in this exchange. On the contrary, if we believe in some research, the construction of wind farms takes up 30 times more of Earth's resources than nuclear power plant of identical power.

Nevertheless, if ecological arguments are not too convincing, perhaps we should get rid of nuclear power plants on account of life and health issues?

4. LIFE AND HEALTH HAZARDS

I took my students for a trip to oil-driven Baton Rouge electric power plant. The Chief Electrical Engineer drew a bar chart on the board (see Fig. 2) and said: *"The cost of oil in electricity produced here is 95 cents for every 100 cents of electricity cost. Investment, maintenance and profit is just 5% of electricity bill. In River Bend nuclear power plant the balance is much better – they pay only 5 cents for the fuel".*

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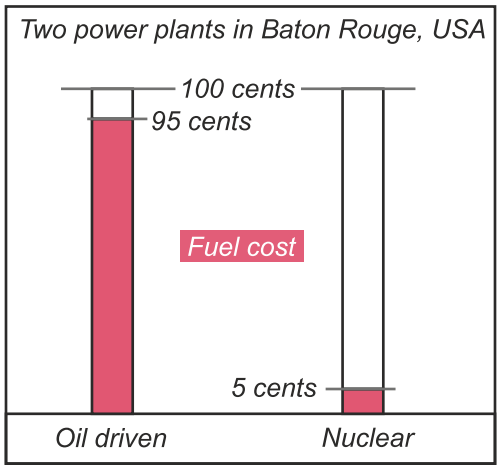

Fig. 2. Fuel cost of gas- and nuclear- driven power plants

Even if one is not an expert on power engineering (as, indeed, I am not), we may start to suspect that the remaining 95 cents of River Bend electricity bill are artificially added so that the bills from both power plants should be identical. After all, no one would buy more expensive energy from oil-driven plant and power station should go bankrupt. In the US, only 14% of energy is generated by nuclear power plants. We may conjecture that different technical bodies working on safety standards in power engineering contain no more than 14% representatives of nuclear energy. Thus, it may be quite easy to enforce appropriate standard and test levels (and, consequently, number of employees) so that energy produced by nuclear power plant should not be cheaper than that generated by other means.

When fuel prices are low, any competitor is potentially threatening. However, there is a weak side. We all are aware how dangerous nuclear energy is. We all remember Hiroshima and Nagasaki. Natural disaster, technical error, war or terrorism may transform each nuclear power plant into atomic bomb. The nuclear waste cannot be hidden away – if it does not emerge in a thousand years, then it will surface in a million years. The mysterious, invisible and lethal radiation from which we cannot run away has replaced the kind-hearted witches and ghosts in folklore . Any politician, who is not aware of this threat and inadvertently will say something positive about nuclear power engineering is excluded from politics; the electorate will never forgive such views and he/she will fail in any election. In the seventies the construction of more than ten nuclear power plants was abandoned in the US. Competition was taken out of the equation

Are we sure that the conventional power engineering is the principal enemy of nuclear power engineering? Or am I not mistaken? I am going over the old proceedings of American Power Conference, 1975. The keynote speech was given by President of the biggest American power engineering company (The Edison Power Company). In dramatic words he compared abandoning the development of nuclear power engineering to a national catastrophe. The States do not hold sufficient resources of oil or gas requisite for driving power plants which could replace nuclear power plants. Enormous amounts of fuel have to be imported. The power independence is lost together with astronomical sums of money.

My conjectures prove to be flawed. However, if conventional power engineering did not want to eliminate nuclear power, who did? The answer seems obvious: countries possessing oil/gas resources and profiting from the proceeds from their sales. Elimination of nuclear power is equivalent to increased demand for fossil fuels and rise in their market price. Which countries do we mean? Iran? Saudi Arabia? Libya? Nigeria?..... Well, they virtually rely on oil, but do they have adequate propaganda machine to manipulate voters in a foreign country?

What remains is the Union of Soviet Socialist Republics (USSR). Its economy in a permanent decline , with insatiable armament industry, its income in the sixties is based mainly upon the sale of raw materials including oil and gas from seemingly inexhaustible deposits under the steppes of Kazakhstan. Its propaganda machine is powerful: it is called Greenpeace. When I attended high school, I used to sign, along with millions of other kids, Greenpeace appeals for discontinuation of American nuclear tests. I watched on TV Greenpeace ships attempting to block nuclear tests in Bikini atoll. Since similar blocking did not happen to tests conducted in Novaya Zemlya, it is easy to surmise who

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commanded the Greenpeace organisation. However, Greenpeace protested not only against (American) nuclear weapons, but also against nuclear power engineering. Let me recall the movie called "Chinese Syndrome". It starrs Jane Fonda, who is well-known for her Greenpeace sympathies. In this movie, the melting core of American nuclear power plant reactor threatens to penetrate the Earth crust all the way through to China. Any viewer watching this production and living in a democratic country will not allow the construction of nuclear power plant. In Russia or China, the governments do not ask the people such questions. That is why in the current decade 60 new nuclear power plants will be built in China. In Russia, a decision was reached in 2003 to double the number of existing nuclear power plants (then 39) by 2020. It is quite possible that money expended for these plants comes from the sale of Russian oil to German oil-driven plants, since the Germans had closed their own nuclear power plants. After all, energy-consuming industrial processes such as steel, aluminum or cement production cannot depend on the sun shining or wind blowing…

For the principal propaganda argument, promoted abroad, about the danger posed by nuclear power engineering, Chernobyl seems to be sent from heaven. Nobody can doubt any longer. The US nuclear power engineering undergoes a steady decline and will not rise again. The oil and gas demand grow together with market prices. This is a real smash to American economy and it is carried out by American voting population. Half of electric energy (51%) must be generated by coal-fired plants, since everybody knows by now how nuclear power engineering endangers the mankind.

During debates on nuclear power engineering hazards it is never mentioned that about 30 miners perish every year in coal mines in the US; the coal mines excavating coal for power plants mostly. Since the seventies, casualty count could be as high as c. 1500. On the other hand, total power of nuclear power plants in US is c. 120 000 MW and no one has died there so far. Nonetheless, it is said that these very power plants endanger the mankind and natural environment. And what about billions of tons of CO_2 emitted to the atmosphere by coal-fired power plants? Millions of tons of sulphur oxides and other toxic gases, millions of tons of carcinogenic microparticles?

There is another important aspect of proper selection of primary energy sources. The cost of obtaining electric energy is a significant component of a state budget; decisions as to selection of primary energy sources may make the country richer or poorer to a considerable degree. The relevance may be even greater. Earth's climate changes due to global warming, immense areas of Africa, Asia or Australia are turning into deserts. Humanitarian crisis is impending, together with inescapable migrations of starving nations. Obtaining huge amounts of water for areas undergoing desertification is the only way to slow down or stop these processes. If generation of electricity becomes cheaper, then it will also be easier to obtain water.

In other words, protection of natural environment and the fight against the effects of global warming will be carried out by rich countries only, since they and only they will be able to afford it. The poor countries cannot meet the expenses of environmental protection. A shining example is relatively poor Brazil destroying the "Earth's lungs", by allowing the Amazonian rain forests to be destroyed for the sake of money. Cheap production of electricity by means of nuclear power plants ensures maintaining the costs at low level; which helps to keep the states affluent and is one of the most important factors facilitating the protection of Earth's natural environment.

5. SOURCES OF ENERGY AND OPINION FORMING

Our opinions on what possible electric energy sources should be used may be completely diverse (this was demonstrated in previous sections). It might be worthwhile to sit down, concentrate and try to understand those diversities. The whole subject is of utmost importance for the economy as well as for natural environment. It seems that these diversities are in no way related to one's education, since opinions of even highly educated individuals, (including experts on power issues) may be poles apart . This is even more true in the case of persons who are not profoundly aware of these problems, which means the majority of population in every country.

By the time we finish with the schooling, our knowledge is general and common to all. As we age, our awareness starts to diversify. Traditional and principal means of communication, by which we are able to acquire new facts are reading, radio, TV; nowadays it is also internet. Nonetheless, usually we do not know who stands behind the news. Are

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these agencies propagating particular ideas? Corporations? Governments of some states? Political parties? Religious or anti-religious organizations? Single and perhaps fanatic individuals? Often, we are at the receiving end of news media and we cannot discover the source of certain information. Usually, we are also unable to check the credibility of the information. Moreover, quite often we do not feel the necessity to check.In the case of a typically educated human this is absolutely normal. Still, the same rule may apply to highly educated people, including scientists.

One might point out that this opinion is not warranted and unjust, so let us try to justify it. The justification might be provided by author's many years of experience in research on power theory in electric circuits and systems with non-sinusoidal waveforms. The author has undermined the correctness of several theories and definitions of power [2-4], which have been universally accepted by engineers and scientists and even recognised as international standards. They used to function in electric circuit theory for the simplest of reasons: nobody questioned their correctness and nobody wanted to take any pains to prove that they were faulty (even though it was not difficult to demonstrate the errors). We are unfortunately liable to repeat and follow some accepted set patterns, and in particular those repeated by a large number of people. The statement "everybody knows!" appears as a frequent argument even during scientific discussions. I will discuss two examples to explain this opinion.

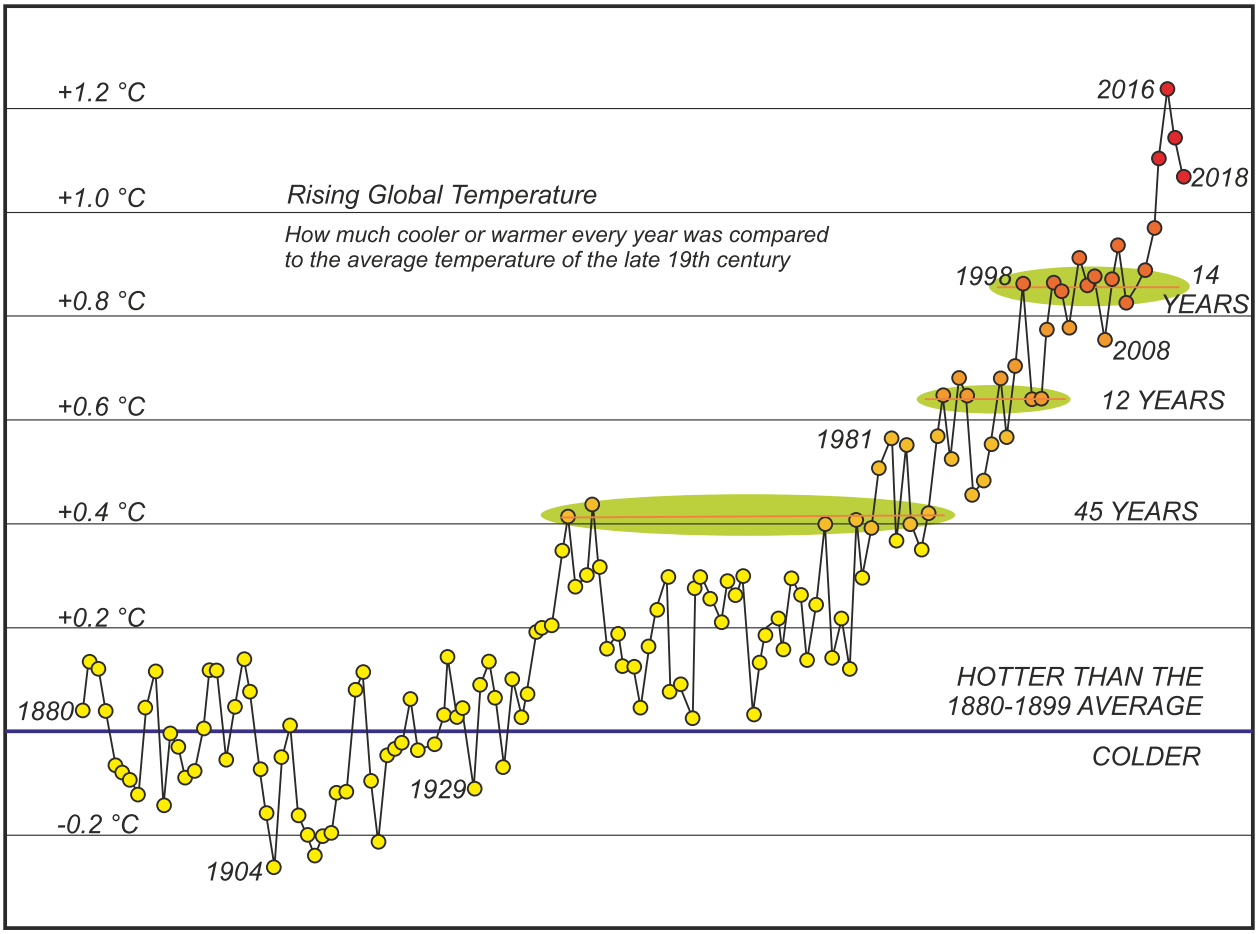

Fig. 3. Variation of the Earth's average temperature according to NASA

A year ago, NASA scientists have revealed the results of the measurements of Earth's average temperature recorded during the last century. This was published as front-page news by The New York Times journal and entitled "Effects of Human Activity on Global Warming" (these results are shown in Fig.3).

Since generation of electric energy is a very significant element of human activity, its impact on climate should be considered in this article. If we take into account the fact, that each measurement point shown in Fig.3 is the result of averaging hundreds of thousands (possibly even millions) of individual readouts done on a daily basis throughout the year and on locations scattered around the globe, the statistical error of these results may be extremely small, so that we may resolve that the results are very credible.

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Any Reader who is completely sure that human activity is responsible for global warming, should not go over this drawing in detail.

However, if we observe this drawing closely, then we shall notice that back in 1986 average Earth's temperature was approximately identical to temperature 45 years previously (and mankind was pretty active then!). What did people do in 1987-1988, what were the particular events which led to increase of this temperature by 0.2°C and did not affect this temperature in any manner during twelve subsequent years? The same pattern occurs in 2000-2001 and again temperature oscillates around a new average for consecutive 14 years. Well, maybe it is really human activity that causes global warming; however, it is very doubtful if we can prove this with the help of Fig. 3. This drawing could be used to support a completely opposite thesis. Surely, the total activity of entire population of the Earth does not change in a step-like manner.

Average temperature of Earth's surface depends on many factors including thermodynamic processes taking place in the Sun, magnetospheric processes (magnetosphere protects the Earth against the cosmic radiation), thermodynamic processes inside the Earth or ocean currents conveying huge amounts of heat to the atmosphere and continental masses.

These processes influence Earth's temperature. The attempt to relate average Earth's temperature to one factor only, namely: human activity - while numerous other factors affecting the temperature may be present and they are ignored – is seriously methodologically flawed. Our understanding of thermodynamics of the Sun or Earth's magnetosphere, Earth core or ocean currents is not yet sufficient to estimate their impact on Earth's average temperature. Instead of advancing risky hypotheses we should just honestly admit that we do not know e.g. how the processes inside the Sun influence Earth's temperature. In fact, we do not understand what goes on inside the Sun, and yet the Sun is the primary source of energy for the Earth. We do recognize Sun's 11-year activity cycle; this is reproduced on the Earth and mirrored by the intensity and number of hurricanes and frosty winters. The Sun probes have only lately started to provide the data, but we still cannot make out the slowly-varying Sun's processes; it follows that Earth's slow-varying processes are also only slightly identified, in particular the slow-varying average Earth's temperature. During the latest 1.5m year era, the variability period of Earth's average temperature (c.11°C) reached approximately 110 thousand years.

The universal belief in our impact on Earth's temperature may be just an indicator of human conceit. We are very well capable of cementing lands, covering the oceans with plastic waste, poisoning the animals. This is obvious. However, even the weakest natural phenomena such as hurricane exposes this conceit: we cannot stop the wind or change its path. What about ocean currents, carrying millions of cubic kilometres of water, which cools or warms air and continents? Power essential to alter Earth's temperature may be many times greater than that available to us today. Unfortunately, the present power resources seem very adequate to destruction of natural environment.

Accidentally, I participated in a seminar on climate [5] and saw the results of research on Earth's temperature and carbon dioxide atmospheric content during last 450,000 years. This data is given in Fig.4, average Earth's temperature is marked in blue, while CO_2 content is marked in red.

Again, any Reader who is utterly convinced that carbon dioxide is responsible for global warming, should not go over this drawing in detail.

Observing the results closely, we may see that during some periods carbon dioxide content varies first, and afterwards temperature changes (delay is present); this is a mechanism to be expected, if we take global warming seriously. However, there are also periods (and actually they prevail) when temperature changes first and only then carbon dioxide content varies. We cannot draw any conclusions as to what is the cause and what is the effect of changes. One gets the impression that temperature variation as well as carbon dioxide content are due to some unknown factor. Sometimes we observe changes in CO_2 content first; sometimes temperature changes first. Still, this conclusion would go against universally accepted knowledge about the impact of carbon dioxide on global warming. So, we are faced with the dilemma: what should we choose? Universally accepted knowledge or perhaps the results of measurements shown in Fig.4?

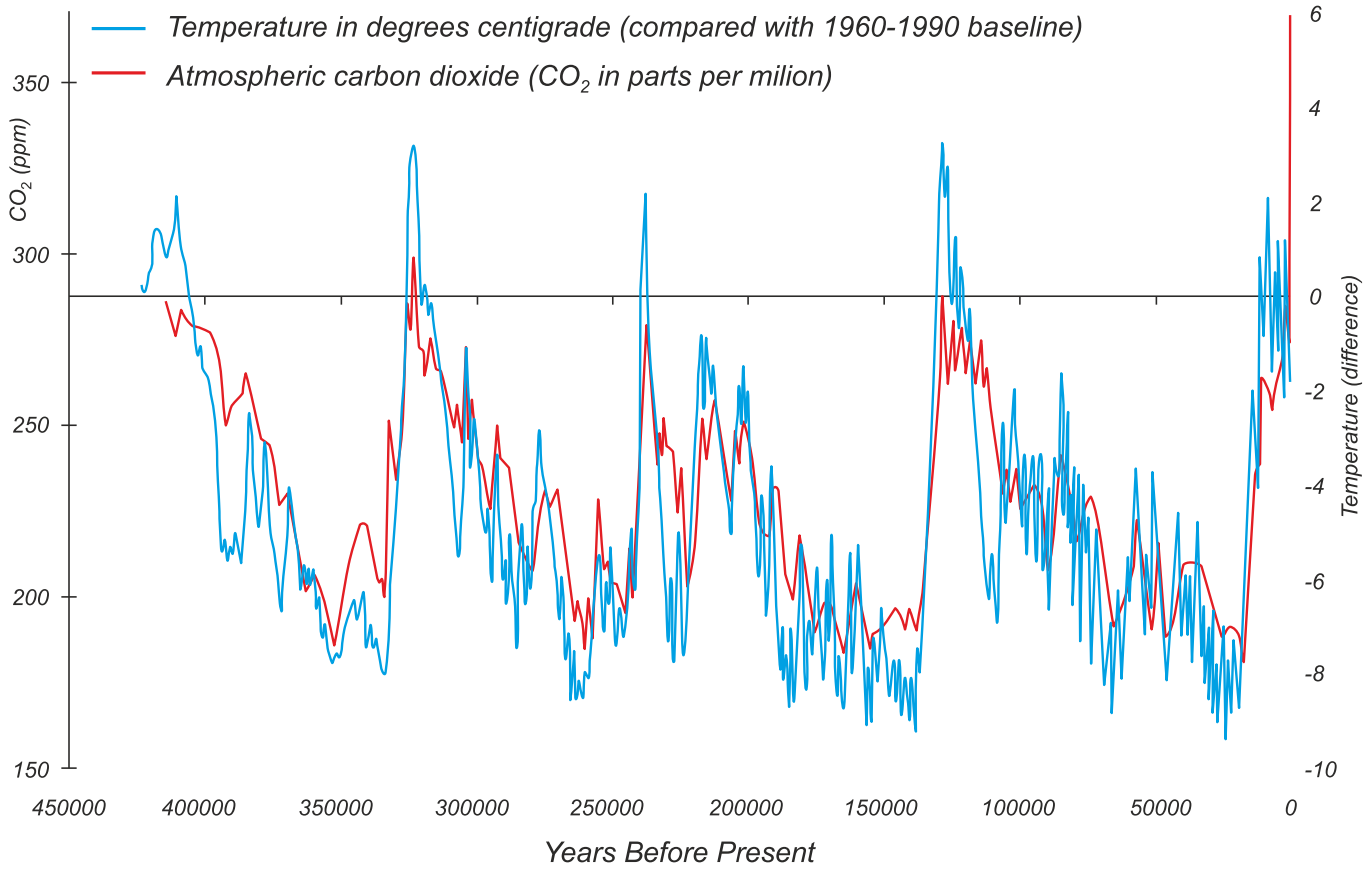

Fig. 4. The Earth's average temperature and atmospheric carbon dioxide

Luckily, there is another answer to this dilemma: we might follow the footsteps of Old Wise Men learned in lore. They refused to look into Galileo's telescope (which was directed towards Jupiter moons), since universally accepted knowledge stated that there could not be any moons out there. If we take this stand, then the dilemma vanishes…

6. CONCLUSION

To sum up this article, the author wishes once more to emphasize that he is not a power engineering expert and especially not a climate expert. He has just tried to describe certain opinions and observations. However, as a researcher with general scientific practice, he wishes to question specific issues. He is also astonished by some generally acknowledged answers. He does not feel sufficiently qualified to try and provide his own answers.

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