Problems in the Relationship between CO_2 Emissions and Global Warming

Ferenc Kovács[1]

Abstract

In the analysis of environmental conditions and impacts, the viewpoint that greenhouse gases, primarily anthropogenic (industrial, human) carbon dioxide, play a determining role in the change of global temperatures, (the increase experienced in the last one and a half decade), has been given widespread publicity recently. Coal-fired power plants are the first to blame for the increase in atmospheric CO_2 concentrations in the last two centuries. The study indicates possibilities to increase the efficiency of coal-fired power plants, which would involve a considerable reduction in CO_2 emissions with an identical production volume of electrical energy. On the basis of the analysis of the amount of fossil fuels used, the amount of CO_2 emissions and changes in the concentrations of atmospheric CO_2, it is shown that no correlation can be proved between the factors investigated and changes in global temperatures.

Key words: *CO_2 Emissions, primarily anthropogenic.*

Introduction

Recently, the human society has been showing an increased concern about both the natural phenomena and the political and economic problems. The development of telecommunications devices makes it possible to receive an almost immediate information about events taking place in every corner of the world, and it is not rare, either, that the media exaggerate or overestimate the importance of certain events.

Nowadays, the greenhouse effect, and in relation to it, the global warming are two of the hot issues, which are the recurring subjects of international conferences, declarations and research projects, for which emission quotas are specified, and planned to be marketed, bought and sold. In the everyday communication and often in superficial professional publications, too, the verdict is clear: fossil fuels, and among them carbon dioxide (CO_2) produced in the combustion of coal are named as the primary cause of the greenhouse effect. As a result of the greenhouse effect, there is a global warming on the Earth: according to climate model calculations, there will be a 1,5-4,5°C warming in the 21st century, which may raise sea levels by 10 metres as a consequence of the melting of polar ice, deserts will be formed and the existence of ecosystems is endangered. According to a partly different (contrary) opinion, the melting of the polar ice will result in a reduction of the salt concentration of the seas, significant currents will cease to exist and Europe is threatened by a new Ice Age.

In relation to these problems, now we only mention the expected possibility of increasing the efficiency of coal-fired power plants, and are going to investigate with a statistical analysis whether the amount of coal and hydrocarbons used, the amount of carbon dioxide emissions and atmospheric CO_2 concentrations actually have the significant impact on the change in time of global temperatures.

Expected energy demand

The round 6 billion population of the Earth consumed exactly 400 EJ (10^{18} J) energy with a specific consumption of 60 MJ/person/year at the turn of the millenium (in 2000). According to a forecast, the energy demand of the 8 billion people living in 2100 may be 1,600 EJ/year with a specific consumption of 200 MJ/person/year if we assume a significant rise in living standards. Others expect a demand of similar order by 2060. Naturally, it is hard to estimate the future distribution of fuels, however, there is high probability that for decades, the present primary fuels will continue to play a decisive role in meeting the demands for the electrical energy, now most modern and comfortable, as according to current forecasts, it will take thermonuclear fusion another 30-50 years to become a reliable source of energy.

The rounded figures of the electric energy production of the world (OECD countries) nowadays are: nuclear energy 23 %, water energy 15 %, fossil fuels (coal, oil, gas) 60 %. This means that if the uranium base material of heating elements is considered to be a mining product, the combined rate of mineral raw material production is 83 %. As the water energy is basically dependent on natural conditions and cannot be transported in its primary form, the decisive role of nuclear energy and fossil fuels (a rate of 3/4) can be predicted for decades. In my opinion, this will be so despite the fact that certain professional circles, social movements and politicians who seek the popularity campaign against both nuclear energy and coal. If one takes a strictly professional standpoint, it can hardly be questioned that modern nuclear reactors are both technically and environmentally

[1] p*rof. Dr. h. c. mult. Dr. Ferenc Kovács*, Department of Mining and Geotechnology, bgtkf@uni-miskolc.hu
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reliable and generally profitable, as well. It is another question that severe breakdowns may arise from human errors and neglect. Luckily, this happens very rarely. It may serve as an example of a positive social approach that 77 % of the energy production in France, 58 % in Belgium, and around 40 % in Sweden and Switzerland is currently provided by nuclear power plants. It cannot be denied that these countries have widespread social democracy.

In the OECD countries primary fossil fuels (coal, mineral oil and natural gas) account for a round 60 % of the electrical energy production with a rate above 50 % in 17 countries. In China, India, Indonesia and other developing countries, the rate is even higher. Arguments for the use of fossil fuels include the facts that there is no limit to their storage and transport and the resources will not run out practically for centuries.

In a remote perspective, it is an important question to evaluate their use realistically from the technical, economic and environmental viewpoints alike.

Climate changes in the history of the earth

Paleoclimatology provides several evidences of the fact that the climate of the Earth has been changing continuously. (Pidwirny) On the basis of research results, it is likely that in some periods of the Earth's history global temperature was 8-15°C higher than nowadays. Naturally, there were colder periods, as well. In the last one billion year of the Earth's history, there started bigger ice ages 925, 800, 680, 450, 330 and 2 million years ago. At the time of the 'hardest' ice age (800 million years ago), the ice front line got 5 degrees nearer to the equator. (Pidwirny) On the other hand, in the carboniferous period, which was 300-360 million years ago, sedimental coal was formed from a huge amount of tropical vegetation in the Vorkuta area lying beyond the Arctic Circle (68-69 degrees, north latitude). The last great Ice Age started about 2 million years ago, when the greater part of North America, Europe and Asia was covered with ice, and at the height of the **Pleistocene**, global temperatures were 4-5°C lower than the present average value. The 'end' of the last Ice Age began in the **Holocene**, about 14,000 years ago. Around 3000 BC, when man had already appeared on Earth, there was a 'cold' period, with the Sahara having thick vegetation and stockbreeding, followed by desert formation in a 'warm' period around 2000 BC. In the Modern Age, in the 14-18th centuries AD, there was a small Ice Age with a 0,3-0,9°C cooling in a cold period (Matthews,1976).

We have possessed measurement data about global temperatures since 1861. In this 140-year period, four periods of a different character can be distinguished. (Fig. 3) Between 1860 and 1910, in the northern hemisphere there was an about 0,2°C decrease in global temperatures (when the consumption of coal multiplied ten times) and then between 1910 and 1940 there was an about 0,4°C increase. Between 1940 and 1980, global temperature averages remained constant both in the northern hemisphere and in the world. (A Meteorológiai Világszervezet állásfoglalása az éghajlat 2000) Similarly to the tendency between 1910 and 1930, global temperatures have increased by 0,4-0,6°C since the 1860s up till now. According to measurements, during the 140 years' period between 1861 and 2000, the **total temperature change** could have amounted to 0,4-0,8°C. In some cases, a similar fluctuation or 'leap' comes about in temperature from year to year. In the past there were significantly bigger changes in temperature without human intervention than the warming in the last 150 years. Opinions of scientists investigating the temperature changes in the Earth-atmosphere system (in the fields of physics, earth sciences, meteorology, climatology) converge in that the total radiation balance of the system equals zero and the Sun is the basic source of radiation. Balance will be maintained even if the inner conditions of the system change. Therefore, if there is a higher amount of greenhouse gases (H_2O, CO_2, CH_4, etc.) in the atmosphere, it is not the output energy but the atmospheric temperature that changes so the air will become warmer. This change extends to the whole atmosphere so the warming of the earth surface may be of a global nature.

As the Sun is the main source of the radiation getting to the Earth's surface, the outstanding representatives of earth sciences point to **the amount and surface distribution of the solar radiation getting to the Earth as the primary cause of the changes in the temperature of the Earth's surface.** The relative position of the Earth's orbit to the Sun is determined by the changes in the eccentricity and the tilting of the axle of the orbit and the movement (precession) of the rotation axis of the Earth. These parameters change periodically in 100,000, 41,000 and 19-23,000 years. Changes in these orbit parameters bring about a 15 % change in the intensity of solar radiation.

Depending on the abovementioned parameters of the Earth's, the solar orbit radiation has been continuously exerting an effect during the history of the Earth it evidently is doing so now, and will do so in the foreseeable future, as well.

I think in relation to this question it is worth quoting the statement of György Vajda, a member of the Hungarian Academy of Sciences: '**Solar radiation** forms the **climate and weather** determining living conditions.' (Vajda, 2001, p. 73.)

Another group of factors influencing the changing of the temperature of the Earth's atmosphere is the greenhouse effect affecting atmospheric heat flow. Experts uniformly accept its existence, what they differ in is the role and importance of the particular impacts. From among the influencing factors, the role of atmospheric water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous gases (NO_x, N_2O), fluorocarbons ($CFCl_3$, CF_2Cl_2, CF_2ClH, CH_3CCl_3), halogen compounds (CF_3Br), sulphur compounds and aerosols are generally referred to. The **carbon dioxide equivalent** of the particular elements is, however, very different: that of methane is 20 units, that of nitrogen oxides is 200 units and that of halocarbons is 10-15,000 units. Some aerosols are considered to have a cooling effect (Nagy).

In their publications, different experts put forward different opinions and evaluations about the impact of the two components water vapour and carbon dioxide.

As early as at the end of the 19th century, S. Arrhenius (1896) named **water vapour** and **carbonic acid** as two main factors influencing the 'transparency' of air. According to Tyndall, water vapour has the greatest impact. De Marchi (1895) says that the 'transparency of the atmosphere is mainly determined by its water content'. Lechner and Pernter attribute a greater importance to carbonic acid.

Present publications also indicate different impacts. According to the 2001 IPCC report (Fig. 1), 60 % of the greenhouse effect (which is not identical with the change and increase in global temperatures) is caused by carbon dioxide, 20 % by methane (CH_4), 14 % by halogenised hydrocarbons (halocarbons) and 6 % by N_2O gas. This source overlooks the impact of water vapour. With some goodwill, it can be assumed that the rates given indicate the rates (%) of the elements causing the greenhouse effect beyond the impact of water vapour. (A Meteorológiai Világszervezet állásfoglalása az éghajlat 2000) At the same time, publication [13] indicates the impact of water vapour as the factor most responsible for the greenhouse effect (approx. 64 %), puts down 27-28 % to the impact of the total carbon dioxide in the atmosphere and estimates other impacts at 4-5 %. Anthropogenic effects (human industry) is approximated with the effects of 1-2 % carbon dioxide and other gases (Figure 2).

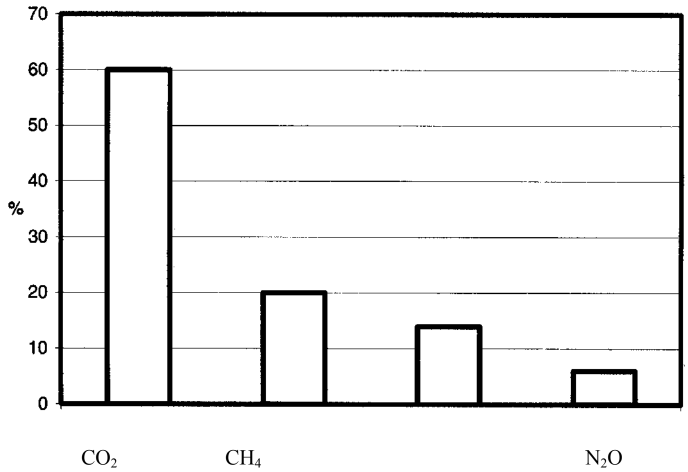


Fig. 1. Impact of factors influencing the greenhouse effect (IPC 2001).

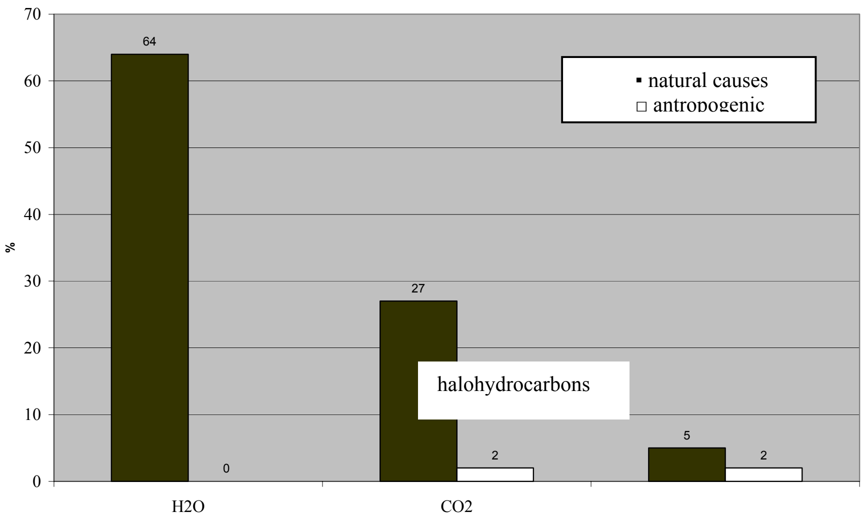


Fig. 2. Factors influencing the greenhouse effext (Wilke,2003).

On the causes of global warming

The author of publication (Ónodi, 2003) attaches the same importance to the impact of water vapour: **'…due to its amount and efficiency, water vapour is the most efficient greenhouse gas…'** and then on the basis of the comparison of the absorption parameters of the particular atmospheric gases, he asserts that **'… in reality, 95% of back radiation, which can be regarded as identical with the greenhouse effect, is caused by water vapour in the troposphere.** In the stratosphere, this rate changes: 80% of the greenhouse effect can be put down to CO_2 and 20 % to ozone and water vapour, while the effect of all the other gases can be neglected boldly. It is to be noted that the whole stratosphere has a little effect on the radiation.'

In relation to the role of greenhouse gases, let me quote György Vajda's book: 'The absorption of rays with greater wavelengths mostly takes place in the troposphere, **with water vapour having the biggest impact,** especially in the infrared range, but the role of other molecules (CO_2, O_2, N_2O, CH_4, etc.) is not negligible, either.' 'In the changes of energy conditions, a distinguished role is played by multiatomic molecules in the atmosphere (greenhouse gases, e.g. $\mathbf{H_2O}$, CO_2, CH_4, etc.)' (Vajda, 2001, p. 84.)

In the light of the conclusions in the latter publications (Ministry of Environment Protection and Water Management, 2003;Ónodi, 2003;

Vajda, 2001), the 'fashionable' statement of our time that the primary cause of the greenhouse effect is anthropogenic carbon dioxide is quite **questionable**.

In relation to the whole issue, the author of study (Ónodi, 2003) concludes from the evaluation of statistical data: **'Data in the last 100 years do not indicate either warming up or cooling down.** In fact, we can witness the weather of the late antiquity and Early Middle Ages coming back.'

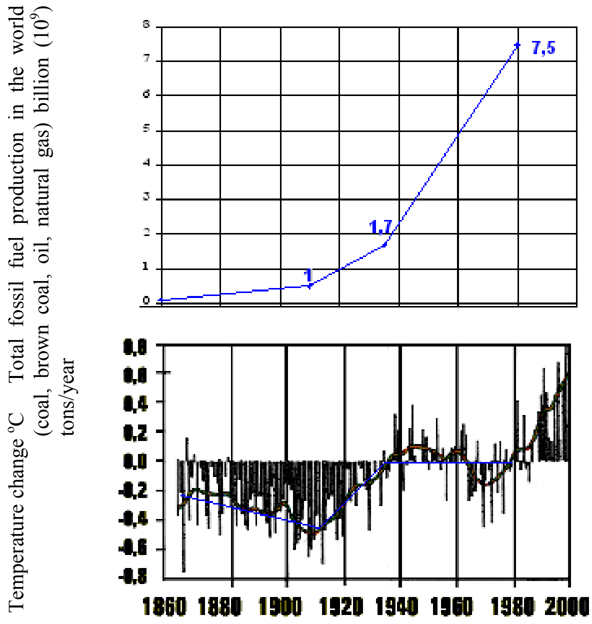


Fig. 3. Mean temperatures in the northern hemisphere (north of latitude 30°) and the amounts of fossil fuels between 1861 and 2000 (Képes politikai és gazdasági világatlasz,1974).

Changes in global temperatures, fossil fuel consumption, the amount of CO_2 in the atmosphere and atmospheric CO_2 concentrations

In the last few years, a great number of publications on the subject – especially ones handling the topic on the level of journalism – as well as proceedings of national and international conferences declare that the increase in the atmospheric greenhouse gas concentrations is leading to the global warming, which may have 'unforeseeable' consequences in the future, that this impact is basically due to anthropogenic (industrial and human) carbon dioxide and therefore 'everything' should be done to reduce the amounts of fossil fuels (coal, hydrocarbons) produced and used. Advocates of this theory boldly overlook the many times verified greenhouse effect of the **water vapour content** of the atmosphere emphasiting only the impact of carbon dioxide. They primarily put the blame on the carbon dioxide emitted by coal-fired power plants as, of course, they cannot risk the suggestion that cars (motorization) or the very widespread and also indispensable use of gas should be given up. They neglect such findings as that of S. Arrhenius (1896), according to whom the CO_2 formed in the combustion of 500 million tons of coal per year gives one thousandth of the atmospheric carbonic acid content (which means that the round 8 billion tons of fossil fuels per year gives 16 thousandth or 1.5%), or that of Ernő (Mészáros, 2001; 2003), according to whom only 15-16% of the national CO_2 emission is of industrial origin, or that according to the source (Wilke, 2003), anthropogenic carbon dioxide is only responsible for 2% of the greenhouse effect (and not for global temperature changes).

Next, we are going to investigate the postulated or real correlation between the factors (features) concerned using only actual 'official' (IPCC) temperature data, world production statistics, and CO_2 emission data and data of the changes of atmospheric CO_2 concentrations in publications (Ministry of Environment Protection and Water Management, 2003), 'accepting' the primary impact of anthropogenic carbon dioxide.

Almost every author gives global temperature data, even for the different continents, referring to IPCC reports so I will follow this practice here. Fig. 3 shows mean temperatures in the northern hemisphere between 1861 and 2000 and the world production data for fossil fuels (coal, lignite, oil, natural gas). Between 1860 and 1980, three characteristic periods can be distinguished. In the years of massive industrialisation (machine manufacturing, metallurgy, railways, sailing, coal-fired power plants after 1890), the use of fossil fuels (almost exclusively that of coal) multiplied five or six times between 1860 and 1910, which evidently triggered a parallel increase in CO_2 emissions. At the same time, global temperatures in the northern hemisphere (where most of the coal was used) decreased by 0.2°C. During and after World War I and the world economic crisis, there was only a modest demand for fuels (production and use), but despite this there was a steep rise in global temperatures. In the 40 years between 1940 and 1980, at the time of the rebuilding after World War II and of the worldwide industrial and economic development (developing countries), the production and use of fossil fuels showed an exactly five times increase and evidently, CO_2 emissions increased at this rate, too. In spite of this, global temperatures remained constant for 40 years, moreover, there was a 0.2-0.4°C decrease in the 1970s.

Fig. 4 shows mean temperatures on the Earth between 1861 and 1989 (Mészáros, 2003; A Meteorológiai Világszervezet állásfoglalása az éghajlat 2000). In some periods, the main tendency is similar to that in Fig. 3. In Fig. 5, the period between 1930 and 1990 in Fig. 4 is highlighted, with the detailed and cumulative data of fossil fuel production displayed in the figure. It can hardly be overlooked that in the 40 years between 1940 and 1980 global temperatures remained constant despite of the fact that both the amounts of fossil fuels and the CO_2 emitted during their use (if almost the same technical level is assumed) multiplied 3.5-4 times. If we believe in facts, then it is evident that the four times (400%) increase of the anthropogenic CO_2 emission had no impact on global temperatures. This fact raises doubts about a certain statement!

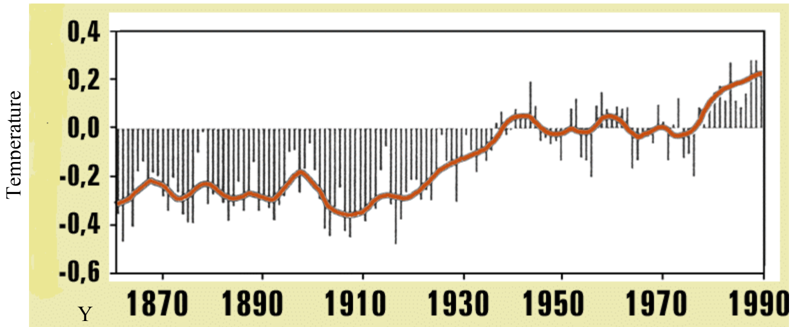


Fig. 4. Global mean temperatures between 1861 and 1989 in relation to the average of the years 1951-1980 (Mészáros, 2003; A Meteorológiai Világszervezet állásfoglalása az éghajlat 2000).

If we look at the figure, it can be plainly seen that anthropogenic CO_2 emissions did not affect global warming considerably.

Still, let us examine this problem with the method of classical mathematical statistics, as well. Let us examine if a causal relation can be detected between the changes (increase) in the amount of the fuels and the fluctuations in global temperatures between 1940 and 1980. In other words, let us define how close the stochastic relation (correlation) is between the two variables. For this purpose, the method of regression analysis is applied. A linear regression is assumed, i.e. that there is a linear relation between the two variables. No other type of relation can be postulated.

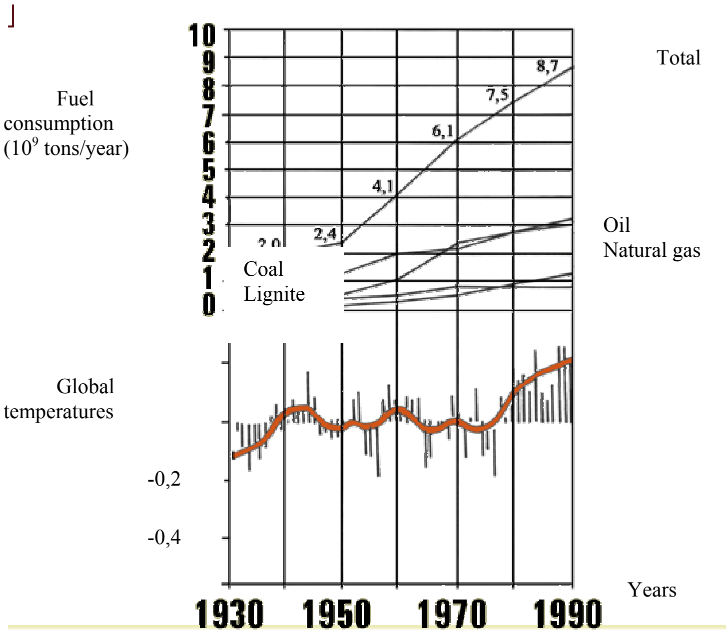


Fig. 5. Fuel consumption and global temperatures in the years 1930-1990 (0 °C line representing the average of the years 1951-1980).

The data (pairs of data) necessary for the calculations were extracted from Fig. 5 at five-year intervals (sampling). In Fig. 6, points corresponding to these data pairs can be found with the x-axis showing the fuel use and the y-axis showing the changes in the global temperatures. The figure includes the regression line, as well. **It can be seen that there is negligible increase in global temperatures as a function of the fuel use** because the direction tangent of the regression line is a very low value, tg α = 0.00145. According to this, 7x10^9 t fuel use causes an expected temperature increase less than 0.02°C.

The value of the correlation coefficient is 0.094, which according to the usual statistical evaluation means that the relationship between the change in temperature and the amount of fuel **is practically uncorrelated.** In the present case, this very loose relationship reveals that the two variables are practically independent of each other (despite the fact that uncorrelatedness is generally not equivalent to independence).

In connection with the result, I should like to note that such a presentation of data (data pairs) suggests from the outset that the little increase is the sole consequence of fuel use. This, however, is influenced by other factors, as well. Thus the abovementioned investigation method gives a less favourable picture of the impact of fuel use than what the reality is.

Fig. 9 (global surface mean temperatures between 1861 and 2001) and Fig. 2 (global CO_2 emissions coming from the combustion of fossil fuels and cement production) in paper (Ministry of Environment Protection and Water Management, 2003) give the possibility of analysing the relationship between the anthropogenic CO_2 emissions and the global warming. Fig. 7 shows the picture we get if we copy these two figures on each other. Fig. 8 shows the data pairs referring to anthropogenic CO_2 emissions and global temperatures at the same time (period). The parameters characteristic of the relationship between the independent variable (CO_2 emission) and the dependent variable (global temperatures) were defined with the usual regression method. The result given in the figure is: the five times increase in anthropogenic CO_2 emissions between 1940 and 1980 did not change global temperatures considerably (tgα = -0,00305) there was a slight decreasing tendency - as the 0,08 correlation coefficient indicates that the two variables are 'uncorrelated', CO_2 emissions **had no impact on global temperatures.** (Here is the answer to the question whether global temperatures are **really** determined by anthropogenic CO_2!)

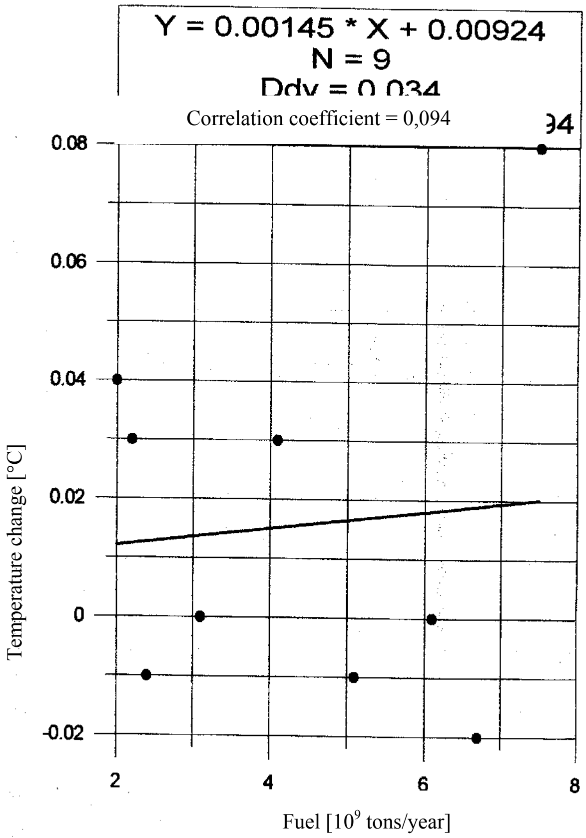


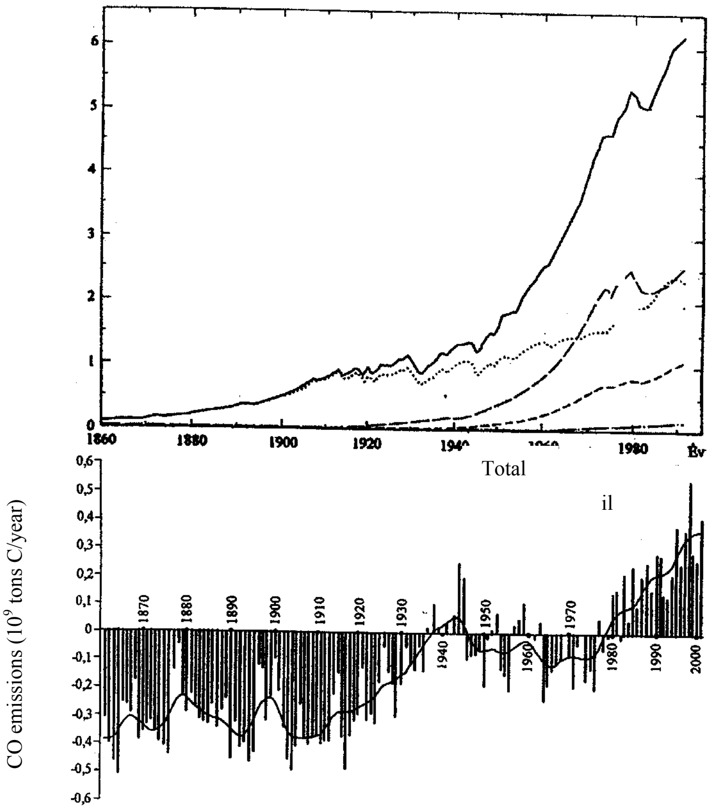
Fig. 6. Fossil fuel consumption and global temperatures in the period 1940-1980.

Fig. 8 (climate changes in the Eastern Europe in the last 1,000 years) and Fig. 1 (CO_2 concentrations in the last 1,000 years) in the paper (Ministry of Environment Protection and Water Management, 2003) make it possible to examine climate changes as the function of CO_2 concentrations in the atmosphere of the Earth. If these two figures are copied on each other (Fig. 9) it becomes evident that contrary to the widely aired views, the cause of the 'Small Ice Age' between the 14th and 19th centuries **is not the change (decrease) in the CO_2 concentrations of the atmosphere** as it is practically a constant value in the given period but rather the impact of one or two or all of the factors that have recurringly led to the much colder 'Ice Ages' than that in the 14th-18th centuries in the Earth's history, in given cases independently from the CO_2 concentrations in the atmosphere of the Earth and from anthropogenic CO_2 emissions and the combustion of coal present only since the 1850s and from the coal-oil-gas-fired power plants appearing in the 20th century.

The statistical analysis of the global temperature data pairs on atmospheric CO_2 concentrations and global temperatures at the same time (period) has also been performed. Zero (0.0) temperature in the figure is the minimum temperature in 1650 (the 1650s). Data and figures in Figure 10 indicate that global temperatures (cooling) practically **came about** independently from the CO_2 concentrations in the atmosphere of the Earth.

The 0.33 (33 %) correlation coefficient of the data set also proves that the two variables (atmospheric CO_2 concentrations and global temperatures) are uncorrelated.

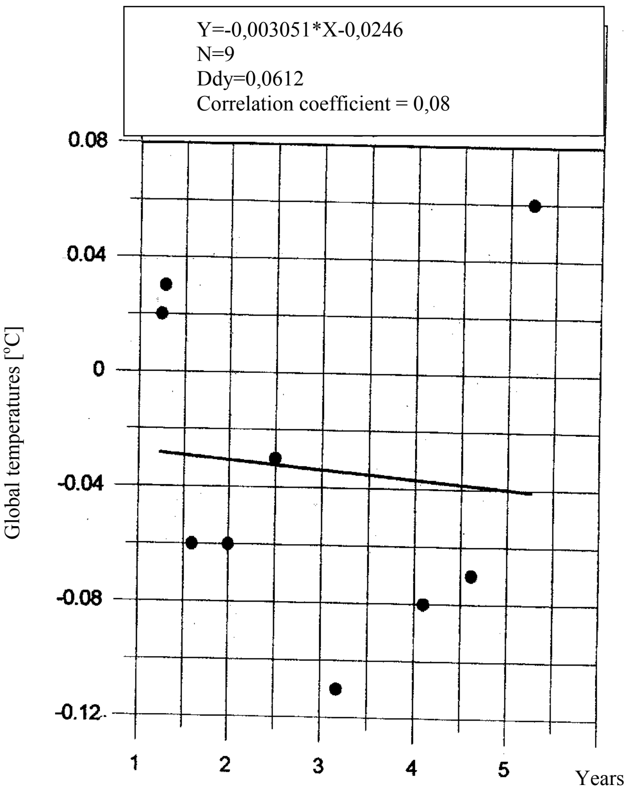
At this point, let me remark that according to the evaluation of the regression analysis presented, the correlation coefficient shows to what extent the standard deviation of the independent variable is accounted for by the relationship between variables x and y (Ezekiel, Fox, 1970; Buócz, Janositz, 1976).



Global CO_2 emissions from fossil fuel consumption and cement production. (Source: McElroy 2002) The Atmospheric Environment, Princeton Univ. Press-Princeton and Oxford.

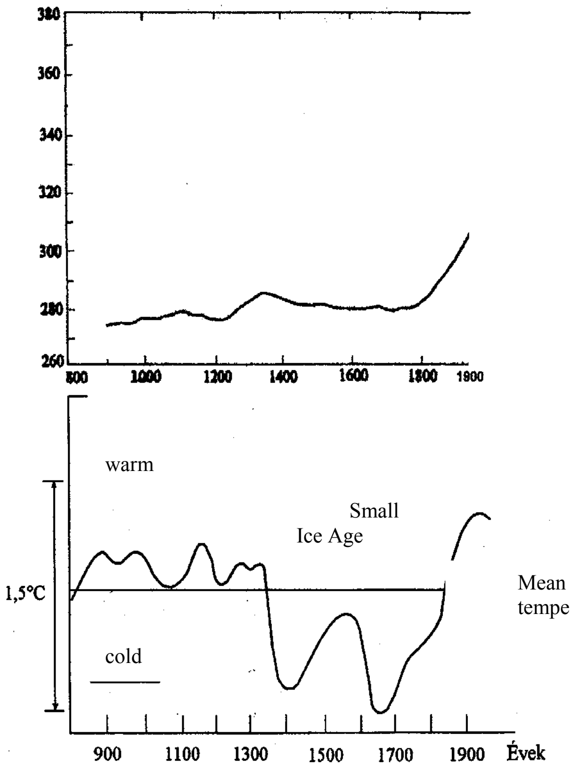
Global surface mean temperatures in the years 1861 – 2001. (O representing the average of the years 1861 – 1990) Source: Handley – Centre, WMO 2001.

Fig. 7. Global temperatures and annual CO_2 emissions into the atmosphere from fossil fuels



At the same time, it is remarkable that the r=0.33=33 % 'closeness of the relationship' atmospheric CO_2 concentrations account for 33 % of the standard deviation of global temperatures – is nearly the same as the data in Fig. 5, according to which the atmospheric presence of the CO_2 gas (and not its emissions in a given period) accounts for 27-29 % of the greenhouse effect, which is naturally only one influencing factor in the fluctuation of global temperatures. On the basis of the results of the investigation, it can be concluded that during the history of the Earth there have been several considerable (in some cases 8-15°C, in the average of 10,000 years 3-5°C) recurring warming-ups and Ice Ages, and since the appearance of mankind there have been climate changes severely affecting the fauna of the different continents without the production and use of fossil fuels and the formation of anthropogenic carbon dioxide, as well.

Fig. 8. Atmospheric CO^2 emissions from fossil fuels and global temperature changes.



CO_2 concentrations in the last 1,000 years reconstructed from the examination of ice inclusions and on the basis of the measurements in Hawaii (Mauna Loa) since 1958. Source: McElroy (2002) The Atmospheric Environment, Princeton Univ. Press-Princeton and Oxford

Climate fluctuations in Eastern Europe in the last 1,000 years. Source: Varga-Haszonits (2003) Analysis of the impact of climate change on agriculture, climatic scenarios. (Agro-21 füzetek, No. 31.)

Fig. 9. Atmospheric CO_2 concentrations and global temperatures in the last millennia [13]

The detailed statistical analysis of the total atmospheric carbon dioxide concentrations (Fig. 9 and 10), the amount of anthropogenic CO_2 emissions into the atmosphere (Fig. 7 and 8), the amount of fossil fuels produced and used (Fig. 5 and 6) and global temperature (Earth, northern hemisphere, Eastern Europe) data in the period between the 14th and 20th centuries indicate that no correlation can be revealed by statistical analysis between temperature conditions and the parameters investigated (CO_2 concentrations, anthropogenic CO_2 emissions, the amount of fossil fuels used). On the basis of these, the following questions arise:

- Is it likely that solar radiation and the parameters of the orbit of the Earth, causing 3,5-1,5°C changes in the temperatures and climate of the Earth for millions and billions of years in the Earth's history, no longer exert an influence in the present age, in the 21st century?
- Why is it so 'deadly' certain that the 0.3-0.5°C temperature increase in the past decades (in some years) represents a permanent tendency and will continue in the 21st century, as well?
- Is it really anthropogenic carbon dioxide produced in the combustion of fossil fuels that is a decisive factor in the changes of the temperature of the Earth's atmosphere?

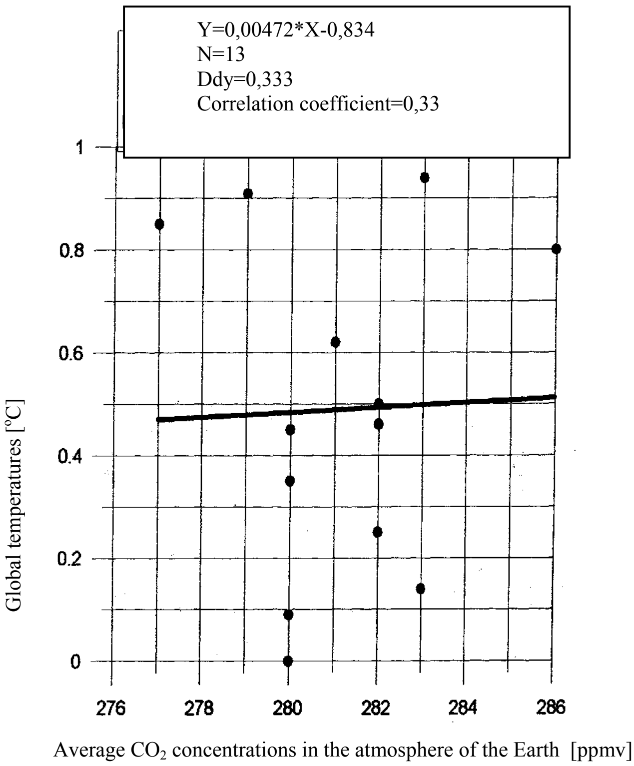


Fig. 10. Relation of atmospheric CO_2 concentrations and global temperatures in data from the 14th-19th centuries.

A possibility of reducing the CO_2 emissions of coal-fired power plants

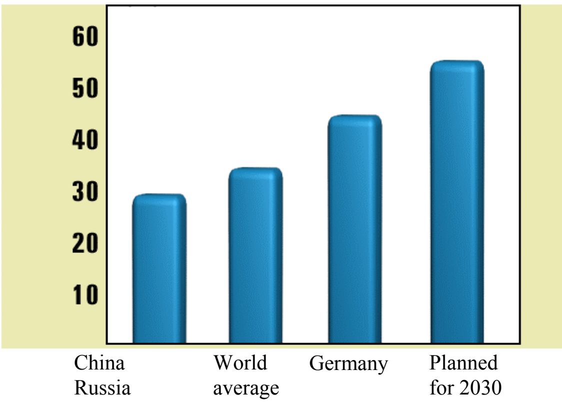


Fig. 11. Thermic efficiency of coal-fired power plants now and in the future.

Undoubtedly, the operations of coal- and hydrocarbon-fired power plants involve the formation of a considerable amount of CO_2 as a gas combustion product. In the coal- and hydrocarbon-fired power plants, different amounts of CO_2 gas per unit (kWh) of electrical energy are formed depending on the type and quality of the fuel.

In this respect, the gas combustion is the most favourable while relatively the greatest amount of carbon dioxide is formed in the course of the coal combustion. Naturally, another disadvantage is the formation of cinders and flue-ash as well as the sulphur dioxide emissions for some coal types. Despite all these disadvantages, in the foreseeable future coal will remain an indispensable energy source as the fuel of coal-fired power plants in accordance with what has been said in the section 1.

Therefore, it is an important task to reduce the specific CO_2 emissions of coal-fired power plants. The primary opportunity to reduce the amount of carbon dioxide per electrical energy unit is offered by increasing the overall thermic efficiency of coal-fired power plants (although there are somewhat obscure, divergent technical developments in this direction now). Fig. 11 shows the present situation and the expected results of the developments under way without going into details about the possibilities of technical development. In this field, there is a 1 billion dollar R&D project going on in the US-German cooperation.

As the figure indicates, power plants using the traditional technology have 30-35 % thermic efficiency, the world average including the new power plants is 35-38 %, while the reconstructed German power plants operate with a round 45 % efficiency (desulphurising included). The development objective of the abovementioned project is to achieve a 62-63 % thermic efficiency. On the world average, coal-fired power plants constructed nowadays and in the future are expected to provide a 55 % efficiency for the 2030s.

The primary environmental advantage of the increase in the efficiency lies in the reduction of specific CO_2 emissions. According to the data in paper (Ministry of Environment Protection and Water Management, 2003), at present a round 3 billion tons of coal are emitted into the atmosphere every year in the form of CO_2 during the combustion of the 7,5-8 billion tons of fossil fuels (coal, lignite, oil, gas), which amounts to only 0,25 % of the about 765 billion tons of coal in the atmosphere. In the optimal case, the increase in the efficiency of combustion equipment and internal combustion engines may make it possible that the amount of anthropogenic carbon dioxide in the atmosphere will not increase at a considerable rate due to the use of fossil fuels.

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