Anthropogenic Heat Estimate from World Energy Production: Effects on Ice Loss, Global Warming and Humanity

Michel Vert*

Institute for Biomolecules Max Mousseron, UMR CNRS 5247, Department of Artificial Biopolymers, University of Montpellier-CNRS-ENSCM, Faculty of Pharmacy, 15 Avenue Charles Flahault, BP 14491, 34093 Montpellier Cedex 5, France

*e-mail: michel.vert@umontpellier.fr

ABSTRACT:
The information provided by greenhouse gas experts is worrying. Dramatic ncreases in ocean level and atmospheric temperature are predicted due to an increase in the "greenhouse effect" caused by anthropogenic carbon dioxide. Considered negligible in the past, the release of anthropogenic heat resulting from the production and the exploitation of the different sources of energy around the world is increasingly seen as a factor that can affect global ices and climate. To go further, the main problem is the estimation of the global anthropogenic heat release. As a new approach, an estimation of the anthropogenic release heat was made from the main sources of energy exploited in the world for the 1994-2017 period after conversion to oil equivalents. The 6.7 Zj estimate was compared to the 9.34 Zj that were necessary to melt the ices lost recently reported as about 28 trillion tonnes for the same period,. The two energies being of the same order of magnitude, it was concluded that the anthropogenic heat released into the environment had been sufficient to melt the ices lost during the selected 23-year period. In addition, it was shown that lost ices and equilibria between the different physical forms of water acted as thermal buffers thus explaining why the overall variations in atmospheric temperature and sea level are still small compared to the considerable loss of ices now evident. A few years should be enough to confirm or invalidate the climate control attributed to anthropogenic thermal energy and water interphase equilibria, especially if the loss of ices and the anthropogenic heat release continue to increase while the anthropogenic production of CO2 decreases. In case of confirmation, it is control of the population and of the energy bulimia that will have to be promoted.

RESUME:
Les informations fournies par les experts en gaz à effet de serre sont préoccupantes. Des augmentations spectaculaires du niveau des océans et de la température atmosphérique sont prévues en raison d'une augmentation de «l'effet de serre» causé par le dioxyde de carbone anthropique. Considéré comme négligeable dans le passé, le dégagement de chaleur anthropique résultant de la production et de l'exploitation des différentes sources d'énergie à travers le monde est de plus en plus considéré comme un facteur pouvant affecter les glaces et le climat mondiaux. Pour aller plus loin, le principal problème est l'estimation du dégagement global de chaleur anthropique. Dans le cadre d'une nouvelle approche, une estimation de la chaleur dégagée anthropique a été réalisée à partir des principales sources d'énergie exploitées dans le monde pour la période 1994-2017 après conversion en équivalents pétrole. L'estimation de 6.7 Zj a été comparée aux 9.34 Zj nécessaires pour faire fondre les glaces perdues récemment déclarées à environ 28 billions de tonnes pour la même période. Les deux énergies étant du même ordre de grandeur, il a été conclu que la chaleur anthropique libérée dans l'environnement avait été suffisante pour faire fondre les glaces perdues au cours de la période de 23 ans choisie. De plus, il a été montré que les glaces perdues et les équilibres entre les différentes formes physiques d'eau agissaient comme des tampons thermiques expliquant ainsi pourquoi les variations globales de la température atmosphérique et du niveau de la mer sont

encore faibles par rapport à la perte considérable de glaces désormais évidente. Quelques années devraient suffire pour confirmer ou infirmer le contrôle climatique attribué à l'énergie thermique anthropique et aux équilibres interphases de l'eau, surtout si la perte de glaces et le dégagement de chaleur anthropique continuent d'augmenter tandis que la production anthropique de CO2 diminue. En cas de confirmation, c'est la maîtrise de la population et la boulimie d'énergies qu'il faudra promouvoir.

Keywords: global energy production, anthropogenic heat release, AHR, ice loss, ice imbalance, global warming, water-interphase equilibria.

INTRODUCTION

As a neophyte in climate change prediction, the chemist I am is puzzled by the information that is disseminated by greenhouse gas experts and revived at every turn by media, politicians, environmentalists and various associations. What do we hear? "Climate changes are caused by an increase in the natural “greenhouse effect" due to the release of anthropogenic carbon dioxide and other atmospheric greenhouse gases (methane from herbivorous animals and from natural gas, and even nitrous oxide N_2O of whipped cream) [1]. These increases are said causing planet heating via infrared radiations and are all related to human activity. Decreasing the sources of anthropogenic CO_2 is the systematical and universally recommended solution today [2].

However, there seem to be arguments against the surplus of greenhouse effect [3-5]. Some opponents (climate-sceptic) contest predictions based on hypotheses and calculations. Others emphasize the absence of correlation between the present small atmosphere and ocean temperature increases and the relatively important loss of the different forms of ice, or oppose fundamentals of interactions between infrared electromagnetic waves and molecules [4]. From what I know about the absorption of visible and ultraviolet electromagnetic waves by the atoms and electrons of chemical functional groups present in organic molecules, I was unable to find flaws in [4] relative to the questioning of CO_2-related radiative heating. In general, alternatives to the “greenhouse effect” dogma and consideration to conductive effects related to heat exchanges by inter-matter conduction were missing until recently, something which is changing [5].

Let us forget polemics and religious-like arguments to retain the following indisputable facts: - “Earth is losing more and more ice from glaciers, permafrost, floating ice and polar ice caps” [6-8], and - “Humanity is using more and more energy from different sources with anthropogenic heat release (AHR) as consequence”. Until recently, AHR was considered negligible relative to global warming. This is no longer the case. Some scientists are now paying attention to local AHR relative to climate changes although the challenge is at the global level [9-10].

The aim of this work was to compare ice loss and anthropogenic heat release in the light of some fundamental facts and annual global energy production; this with the perspective of showing some effects on the present climate perturbations and on the future of humanity.

ICE LOSS OR ICE IMBALANCE

On Earth, the balance of the annual ice formation-disaggregation cycle, the so-called ice loss or ice imbalance, is not constant. Therefore, to investigate whether there is a correlation between AHR and ice loss, comparison must be made over a long period of time to minimize the effects of annual fluctuations. In a recent review, authors combined satellite observations and numerical models to estimate the global ice loss between 1994 and 2017. This approach led to a global loss of c.a. 28 ± 2 trillion tonnes of ice over these 23 years [11]. The thermal energy necessary to melt this huge amount of ice was c.a. $9.34 \pm 0.6 \times 10^{21}$ joules or c.a. 9.34 Zj, according to the enthalpy of fusion of ice: 333.55×10^{3} J/kg.

PHYSICAL AND CHEMICAL FUNDAMENTAL FACTS

1) When ice is in the presence of heat, it melts and form water which turns to vapour if heating persists. In contrast, vapour in contact with a cold environment condenses back to liquid water and ice if cooling persists.

2) The annual temperature variations of the oceans and the atmosphere in the hemispheres are mainly dependent on the Sun radiative energy, and on its irregular cyclic emissions.

3) When two media are brought into contact with each other, the hottest transfers heat to the coldest. The temperature of two media changes in opposite directions, except in the case of an interphase equilibrium during which the temperature is fixed [12].

4) Anthropogenic sources of heat include losses at the production stage, animal and human metabolisms, combustions of oil-based products, natural gas, and biomass (including forest wildfire), as well as nuclear and thermal power plants and machines producing work, all difficult to quantify at the globe level.

5) The different sources of energy are not equivalent relative to CO_2 production. When burned in the presence of atmospheric oxygen (O_2), charcoal (C) generates hot carbon oxides (CO and CO_2) but no primary hot water vapor. In contrast, the combustion of hydrocarbons composed of carbon and hydrogen (oil, peat, lignin,

natural gas, wood, and even animal and human metabolisms) generates CO_2 plus hot vapor, both hotter than the atmosphere. In all cases, atmospheric oxygen is consumed. There has been indeed a slight decrease in its proportion in the air and in the oceans over the years [13]. As for the production of electrical energy by nuclear power plants and by renewable resources, it does not generate CO_2 but it generates heat immediately during the production and later on during the exploitation of electricity (electric radiators, TVs, lightings, smartphones, etc., all heat). Even electric trains and cars give off heat. So, all sources of heat and not just fossil fuels disperse heat into the atmosphere and more generally into the environment [14].

6) Once cooled, the hot gas and vapor produced by the combustion of carbon-containing sources of energy integrate the corresponding atmospheric pools. CO_2 is captured by seas, by some alkaline minerals and by plants with regeneration of oxygen (inverted lung) while condensed water is managed by terrestrial absorption, by ice formation, by evaporation ↔ condensation equilibria involved in the formation of clouds and rains, or by reintegration into natural living matter via biochemistry;

7) Chemistry teaches three important fundamentals: 1) in a closed world like Earth "nothing is created, nothing is lost, everything is transformed" (this holds for electromagnetic radiations through absorption, transmission and refraction phenomena); 2) solid ↔ liquid (ice ↔ liquid water) and liquid ↔ vapor (clouds and rains) interphase equilibria consume or generate thermal energy according to the direction they move, and 3) an interphase equilibrium always evolves at constant temperature, that is to say without temperature change during the energy transfer (ice melting or boiling water). For instance, on a sunny day ice in a glass of water melts to bring and maintain the temperature of the water at 0°C until the ice disappears. Then, the temperature of the water increases. In humans and animals, perspiration and evaporation are used to maintain the temperature of the organism fixed (37 °C for man) despite internal or external heating by metabolism and Sun, respectively. When sick, a mammalian organism gets inflammation and fever, i.e. faces extra heat, a situation quite comparable with anthropogenic and wildfire heats in the case of the planet.

8) In the past, huge quantities of fossil energy sources (actually solar energy stored in the distant past) have already been consumed and transformed in parts as heat, water, CO_2 and biomass. Large quantities of heat are still stored (oil, coal, gas, radioactive minerals) or are going to be produced (electricity) in the future. This new thermal energy will supplement the anthropogenic heat already released in the environment.

9) Based on the energy preservation principle, the AHR generated by the combustion of fossil charcoal, oil, gas and biomass, by electricity-producing plants and alternatives, and by machines and devices using this electricity is transferred to the components of the environment, in particular to atmosphere and

ocean water. In general, nothing is seen but, for instance, the hot vapor becomes visible if it is cooled rapidly. In winter, it can be seen from lung exhalation, from car exhausts at the start or in the upper atmosphere behind planes. It is the same from the evaporators of nuclear plants topped with large clouds.

What can be said from these facts in relation to ice loss and climate perturbations? Nothing if the anthropogenic heat energy is negligible except calling on the effect of anthropogenic greenhouse gas. This is what has been done universally, so far, to the chagrin of climate-sceptic people. However, AHR is less and less regarded as negligible. Today some scientists are more and more interested to the role that Anthropogenic Heat Release (AHR) may play relative to climate changes and global warming, as emphasized before.

ANTHROPOGENIC HEAT RELEASE ESTIMATE

A recent article recalled the historical evolution and proposed a novel method based on a new algorithm to provide an estimate of global AHR from data on urban zones with emphasis on the limits of the approach [15]. AHR can hardly be consistently quantified because each source of energy is particular, and each application has its own characteristics in terms of work and heat. So far, local thermal data and calculations have been used mostly in relation to the climate change and sea level rise [9-10, 15].

Another means to estimate AHR is consideration of AHR as a fraction of the global energy produced annually from the different sources homogenized by conversion in Tonnes of Oil Equivalent (Toe). Table 1 shows data on the global energy produced over the 1900 – 2018 period of time obtained from different sources [16-20].

According to Table 1, the increase in converted global energy was c.a. 100% between 1900 and 1950, 500% between 1950 and 2000, and c.a. 150 % in 18 years from 2000 to 2018-2019. The problem is now the evaluation of AHR from such global data that includes energies exploited as work and as heat (direct production) to which residual heat from work is to be added. For instance, cars or trains are using energy to move (work) but part of it is released as heat depending on the yield in work. In addition, these machines also release part of the kinetic (work) energy when they brake (brakes heats up) [14]. Therefore, only estimation of AHR as part of the global produced energy can be done reasonably.

Whereas the scientific literature is silent relative to global data on energy production and consumption, estimations were found in official reports providing information on global energy consumption [18] that is smaller but very close to the global primary energy production [19]. To estimate the global anthropogenic heat released over the 1994 – 2017 period selected for comparison with ice loss, global energy data from [19] were selected because they were converted in MToe according to conversion factor specific of each fossil source and, in the particular case of electricity, using the respective yields of production plants. The converted total energy consumed during the 1994 – 2017 reference period was 268,400 MToe, an estimate corresponding to c.a. 11.2 ZJ heat energy on the basis of oil combustion that produces 333.55 kJ/kg heat energy. This rough estimate gives an idea of the maximum value of AHR which is rather close to the 9.34 Zj estimated to melt lost ice over the same period. Taking into account the energy used to produce work estimated as 40% of the total energy [14], the minimum of AHR is c.a. 6.7 ZJ. It is important to note that the heat from more frequent and intense forest combustion (from humans or from wildfire) is not included. Therefore, one can conclude that AHR was large enough to have caused the melting of all or at least of a large part of the ice lost over the selected period of time.

Table 1: Evolution of the estimated from the global annual primary energy deduced from main sources of energy converted in zeta Joules (10^{21} J) when available in millions of equivalent of oil (MToe).

Year	Coal	Oil	Natural gas	Biomass	Electricity	Renewable	Total
1900	480	25	5	580			1,100 0.046 a)
1950	955	505	153	545			2,158 0.090 a)
2000	2,116	3,542	2,206	465	1,096		9,242 0.394 b)
2018	0.158	0.191	0.139		0.061	0.026	0.576 b)
2019	0.158	0.193	0.141		0.073	0.029	0.584 b)

a) Converted in Zj from data in Mtoe from [16] using the 1 Mtoe = 4.18 x 10^{10} j equivalence
b) In Z j From [19]

Whereas the scientific literature is silent relative to global data on energy production and consumption, estimations were found in official reports providing information on global energy consumption [18] that is smaller but very close to the global primary energy production [19]. To estimate the global anthropogenic heat released over the 1994 – 2017 period selected for comparison with ice loss, global energy data from [19] were selected because they were converted in MToe according to conversion factor specific of each fossil source and, in the particular case of electricity, using the respective yields of production plants. The converted total energy consumed during the 1994 – 2017 reference period was 268,400 MToe, an estimate corresponding to c.a. 11.2 ZJ heat energy on the basis of oil combustion that produces 333.55 kJ/kg heat energy. Taking into account the energy used to produce work as 40% of the total energy [14], the minimum of AHR is thus 60% of the global exploited energy c.a. 6.7 ZJ. It is important to note that the heat generated by the more frequent and intense forest combustion and by volcanos is not included. Therefore, one can conclude that AHR was large enough to have caused the melting of all or at least of a large part of the ice lost over the selected period of time.

WHAT ABOUT CLIMATE PERTURBATIONS?

In the past, the number of humans on Earth was small and AHR was negligible. Only the Sun heated the planet with ice melting and reformation, atmosphere and ocean heating over summers and winters alternately in the northern and southern hemispheres, this including effects of greenhouse gas. Today, the anthropogenic heat diffused in the environment comes in addition. It increases rapidly and complements the Sun heating even if its contribution estimated as 0.0163 % of the contribution due to the huge solar energy supply is very small [14]. From a thermodynamic viewpoint, anthropogenic heat affects ice ↔ liquid water, liquid water ↔ vapor (cloudiness, rainfall) equilibria that are theoretical sources of temperature constancy, the latter depending on the presence of solutes like salt in sea water [21] These interdependent phase equilibria shift in one direction or the other depending on the amount of cold or heat to be managed. Theoretically, the global temperature should remain balanced. However, the Earth is very large and complex, and it is submitted to chaos. What are observed locally are temperature wells and peaks, formations and disappearances of clouds, floods and droughts, etc. Basically, the corresponding opposite thermal effects should be balanced through water evaporation from warm oceans and condensation in the cold upper atmosphere in association with ice melting and reformation. This is not the case because these fluctuations are far from those scientists are used to play with in a laboratory. Global averaging is impossible because of the relative slowness's of some equilibria evolutions and of turbulences in air and water (atmospheric pressure, high winds, heavy rainfalls, hurricanes, oceanic streams Labrador and Gulf stream, Niño and Niña, summer and winter, etc.). In contrast, solid ices are not dramatically perturbed by turbulences though their melting depends on them. It is therefore preferable to monitor the annual ice imbalance (in mass and not in surface) to try predicting the evolution of the planet climatic environment on the basis of thermodynamic phenomena. Whether the thermal energy to be absorbed comes from an excess of greenhouse effect or from the anthropogenic thermal energy, or from both, the trend is clear: on continuous heating the buffering effect of ice melting will be progressively transferred to the buffering effect of evaporation-condensation transitions involving water.

In summary, the preceding analysis leads to consider that AHR is absorbed by water interphase exchanges, an absorption that may explain the far-from-equilibrium slight increases in air and ocean temperatures detected so far. According to this logic, anthropogenic thermal energies transferred via atmosphere and oceanic water turbulences are sooner or later going to cause ice melting, something which is predominantly observed today. With more thermal energy to transfer turbulences that normally handle solar heat (hurricanes, thunderstorms, tornadoes, oceanic movements) should increase in strength and frequency locally without affecting importantly and permanently the global oceanic and atmospheric temperatures. There are already climatic signs in this direction [22]. Furthermore, ice loss is predominant in the northern hemisphere relative to the southern one in agreement with greater production and consumption of energy in the northern hemisphere [20]. Therefore, the few tenth of a degree Celsius and the few mm raises of atmospheric temperature and ocean level reported respectively so far may be another version of the half-full or half-empty bottle ambiguity, meaning that small increases may be viewed or not as beginning of dramatic deviations. This ambiguity fuels the polemics relative to climate evolution. It is important to note that anthropogenic $CO_{2,}$ is indirectly related to thermal energy production via combustion and thus to AHR.

In the far future, when all global ice is melted, the absorption of anthropogenic heat will be supported by the sole back and forth evolution of water evaporation-condensation equilibria which will evolve towards the formation of more and thicker clouds. The resulting screen will reflect more and more the solar energy and thus will cause surface cooling of the Earth with, at the end of the process, reformation of the ice on the planet as it was in the distant past [23]. Cumulated anthropogenic energy diffusion will result in shortening the time scale of the evolution that, fortunately, remains of the order of thousands of years presently.

IF THIS IS THE FUTURE, WHAT SHOULD BE DONE?

If the global anthropogenic heat energy is source of ice loss and climate perturbations as suggested before, replacing the fossil sources by other sources of energy to keep the global energy consumption growing without CO_2 production may appear like a plaster cast on a wooden leg. As a matter of fact, the Earth suffers of a kind of cancer and the tumor is humanity because of a quasi-exponential growth of population and a bulimia of energy whose negative effects on the planet go get worse if nothing is done. The treatment may be a reduction of the anthropogenic CO_2 that is connected to the demand in energies but, according to the present approach, it is the origin of the harm (the total anthropogenic heat energy dissipated in the environment) and the excessive demand of energy that have to be treated. To repel such evolution, the economy will have to be curbed in order to reduce the production of goods and of energy-consuming means needed today to provide remunerative work and to satisfy the lure of profit. Consequences are well discussed in a recent newspaper article [24]. Greenhouse effect or not, it appears necessary to act without waiting for Nature to limit the human population and its worship of consumption otherwise increasing anthropogenic heat might lead to humanity disappearance as it may have been for dinosaurs in the distant past [25]. After the anterior historical pandemics, the newly appeared SARS-CoV-2 corona virus may be a good example how Nature herself can proceed. In a close future, the buffering effects of ice melting, and of the evaporation-condensation of ocean and atmospheric water should continue to keep ocean and atmosphere temperatures globally stable even if enhanced local fluctuations are observed. It is probably a matter of millennia but it is better to anticipate fighting AHR. Despite the lack of consistent data at the global level, all partial data available on Arctic, sea ice, Antarctic and land ice losses [11] and on global energy production [19], have all increased between 2000 and 2014 whereas the atmospheric temperature remained rather stable with no more than a slight increase during the last years [26].

CONCLUSIONS

Taking into account chemistry and thermodynamics fundamentals combined with global data published in reports led to the conclusion that annual AHR was large enough to justify ice losses observed so far. Complementary or alternative to the greenhouse effect of the anthropogenic surplus of CO_2 in the atmosphere, the heat balancing role assigned to thermodynamic exchanges and to equilibria of water phase transitions led to propose maintenance rather than increase of global oceanic level and atmospheric temperatures in the future. It also suggested that turbulences should be increased with local consequences worsened in frequency and intensity. The Sun governed the climate for billions of years. The novelty is that during the last hundred and fifty years, humanity has been freeing increasing parts of the huge heat energy stored as fossil or radioactive matters. Coming in addition to the action of the Sun energy on the climate, AHR might alter the climate ups and downs evolutions in force for billions of years if it continues to grow over the next years. The emphasized trends are not proofs but a few years should be enough to confirm or refute the roles assigned to thermodynamics and physical phase-transfer equilibria, especially if annual ice imbalance progresses while the sources of anthropogenic CO_2 are driven down.

REFERENCES

1) IPCC, 2019; Climate change and land: an IPCC special report on climate change, land degradation, sustainable and management, food security, and greenhouse gas fluxes in terrestrial ecosystems, Sukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., et al., in press.

2) Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13, December 2015, UN Framework Convention on Climate Change, (https://unfccc.int/resource/docs/2015/cop21/eng/10.pdf)
3) Coleman, J., Global Warming Greatest Scam In History!, Global warming and the climate, 2006-2016. Per Strandberg, Evanger, Hordaland, Norway (http://www.global-warming-and-the-climate.com/arguments-against-global-warming.html) and contributions therein.
4) Richard, K. 2017. New paper uses physics laws to disassemble greenhouse theory (https://notrickszone.com/2017/06/01/3-chemists-conclude-co2-greenhouse-effect-is-unreal-violates-laws-of-physics-thermodynamics/)
5) CO_2 is not driving the global-warming, 2018, Tower of Reason, (https://towerofreason.blogspot.com/2018/04/co2-is-not-driving-global-warming.html).
6) Rignot, E., Mouginot, J., Scheuchl, B., van den Broeke, M., van Wessem, M.J., Morlighem, M. 2019. Four decades of Antarctic Ice Sheet mass balance from 1979–2017, Proceedings of the National Academy of Sciences, 116**:** 1095-1103. (https://www.pnas.org/content/116/4/1095).
7) Ramp-Up in Antarctic Ice Loss Speeds Sea Level Rise. 2018. Perthmedia, (https://news.perth.media/2018/06/14/ramp-up-in-antarctic-ice-loss-speeds-sea-level-rise/).
8) Shepherd, A., Erik. I., et al. (IMBIE team). 2018. "Mass balance of the Antarctic Ice Sheet from 1992 to 2017", Nature, 558 (770):219–222. (doi:10.1038/s41586-018-0179-y).
9) Chen, B., Dong, L., Liu, X., Shi, G.Y., Chen, L., Nakajima, T., Habib, A. 2016. Exploring the possible effect of anthropogenic heat release due to global energy consumption upon global climate: a climate model study, International Journal of Climatology., 36:4790–4796.
10) He, Y., Pan, Z., Song, Y., Long, B., Huang, N., Zhang, N., Wang, J., Ma, S., Han, G., Pan, Y., 2019. Impact of the anthropogenic heat release on the energy balance of land–atmosphere system, Geophysica. Research Letters, Published On line. (Doi.org/10.1002/essoar.10501240.1).
11) Slater, T., Lawrence, I.R., Otosaka, I.N., Shepherd, A., Gourmelen, N., Livia Jakob, L., Tepes, P., Gilbert, L., Keeling, R. 2020. Modern Records from Scripps Institution of Oceanography, CDIAC, Review Article: Earth's ice imbalance, The Cryosphere, Preprint. Discussion started: 14 August 2020, (https://doi.org/10.5194/tc-2020-232).
12) Ellgen, P. 2020. Equilibrium and reversibility - phase equilibria, in Thermodynamics and chemical equilibria, LibreTexts, Chemistry, Chap. 6.3, last update 2020. (https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Book%3A_Thermodynamics_and_Chemical_Equilibrium_(Ellgen)
13) Keeling, R.F. 2013. Modern Records of Atmospheric Oxygen (O2) from Scripps Institution of Oceanography, CDIAC, Oak Ridge National Laboratory, U.S. Department of Energy. (https://cdiac.ess-dive.lbl.gov/trends/oxygen/modern_records.html).

14) Manowska, A., Nowrot, A. 2019. The Importance of Heat Emission Caused by Global Energy Production in Terms of Climate Impact, Energies, 12:3069. (doi:10.3390/en12163069w).
15) Yang, W., Luan, Y., Liu, X., Yu, X., Miao, L., Cui, X. 2017. Data Descriptor: A new global anthropogenic heat estimation based on high-resolution night-time light data, Sci. Data 4:170116. doi: 10.1038/sdata.2017.116
16) Consommation mondiale d'énergie 1800-2000 : les résultats. (https://www.encyclopedie-energie.org/consommation-mondiale-denergie-1800-2000-les-resultats/).
17) Ressources et consommation énergétiques mondiales, Wikipedia, (https://fr.wikipedia.org/wiki/Ressources_et_consommation_%C3%A9nerg%C3%A9tiques_mondiales)
18) World energy consumption, Wikipedia, (https://en.wikipedia.org/wiki/World_energy_consumption).
19) BP Statistical Review of World Energy, All Data, 2020, 69th edition. (https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html)
20) Global Energy Statistical Yearbook 2020, Enerdata, (https://yearbook.enerdata.net/total-energy/world-energy-production.html).
21) Salhotra, A.M., Adams, E.E., Harleman, D.R.F. 1985. Effect of Salinity and Ionic Composition on Evaporation: Analysis of Dead Sea Evaporation Pans, Water Resources Research., 21:1336-1344.
22) Buis, A. 2020. How Climate Change May Be Impacting Storms Over Earth's Tropical Oceans, NASA Global climate Signs, Vital sign of the planet, Blog, (https://climate.nasa.gov/blog/2956/how-climate-change-may-be-impacting-storms-over-earths-tropical-oceans/)
23) Bardeen, C.G., Garcia, R.R., Toon, O., Conley, A.J. 2017. On transient climate change at the Cretaceous−Paleogene boundary due to atmospheric soot injections, Proceedings of the National Academy of Sciences, 114:E7415-E7424; (doi.org/10.1073/pnas.1708980114)
24) Brook, D., Schwartz, R.H., 2020. Climate change: An existential threat to humanity and how we can survive, The Jerusalem Post, 2020, September 23 (https://www.jpost.com/jerusalem-report/climate-change-an-existential-threat-to-humanity-and-how-we-can-survive-643267).
25) Chiarenza, A.E., Farnsworth, A., Mannion, Ph.D., Lunt, D.J., Valdes, P.J., Morgan, J.V., Allison, P.A. 2020. Asteroid impact, not volcanism, caused the end-Cretaceous dinosaur extinction, Proceedings of the National Academy of Sciences, 117: 17084-17093. (DOI: 10.1073/pnas.2006087117).
26) Global Temperature Report for 2018, Berkeley Earth, (http://berkeleyearth.org/2018-temperatures/).