TECHNISCHE UNIVERSITÄT
ILMENAU

Heinrich Arnold

Global Warming by Anthropogenic Heat, a Main Problem of Fusion Techniques

Summary:

The role of anthropogenic heat for global warming in the middle and far future is often underestimated. In the 4th IPCC report of 2007, it has been treated only casually, and in its 5th report of 2013/14 it was not mentioned at all. The latter holds also for commercial applications of nuclear fusion techniques that are driven by contrast on expensive international projects. Due to the anthropogenic heat production, these techniques are not sustainable - contrary to the claims of their advocates.

Under those aspects, the online publication „Global Warming by Anthropogenic Heat Release" of 2009 (URN: urn:nbn:de:gbv:ilm1-2009200065) has been updated and extended, again starting with the fundamental model calculations by Robert Döpel of 1973 (https://www.db-thueringen.de/receive/dbt_mods_00012380).

Key Words:

Anthropogenic Heat Forcing (AHF); AR4; AR5; global energy production; IPCC; ITER; limits of growth; non-renewable energies; photovoltaics; solar energy; STEFAN-BOLTZMANN-Equation; sustainability

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Global Warming by Anthropogenic Heat, a Main Problem of Fusion Techniques

Heinrich ARNOLD[1]

Abstract

Avoidance of greenhouse gases, which are the main cause for current global warming, is a fundamental argument for nuclear techniques. Given its smaller radioactive waste and resource problems compared to fission, fusion is often called sustainable. But this view ignores anthropogenic heat, another fundamental cause for global warming. It could become noticeably as of the end of our century, especially if fusion techniques would make cheap energy available for more and more people.

Worldwide and regional warming by anthropogenic heat has been discussed repeatedly in the 1970s and was *"rediscovered"* in our century. This applies widely to simple models, while the more complex computer simulations, which are discussed by the International Panel on Climate Change (IPCC) in its last Assessment Report (AR5) from 2013/2014, remain globally limited to the anthropogenic enhancement of the greenhouse effect and related phenomena. This limitation applies also to the forecasts of the AR5 for coming centuries and millennia. However, starting with the end of our century, the *Anthropogenic Heat Flux* (AHF) will become increasingly important, if the global consumption from non-renewable sources continues to increase.

In this work, the acronym AHF is interpreted also as *Anthropogenic Heat Forcing*, and it is classified as a *Nonradiative Forcing* (Non-RF). This is in contradiction to the 4th IPCC report (AR4) from 2007, but not to the new AR5. The two reports are not concordant in using the term “Nonradiative Forcing”, which has been proposed in 2005 by a common publication of Research Committees of the US National Academy of Sciences.

For renewable energies, there are limits of growth that were also estimated already in the 1970s and rediscovered recently. Assuming moderate growth rates and excluding non-renewable sources, these limits would be reached in a few centuries. So, transition to constant energy consumption in global average has to be aspired, even with renewable sources.

[1] Ilmenau University of Technology, Institute for Chemistry and Biotechnology, PO Box 10 05 65, D 98684 Ilmenau

1. Introduction

This publication is an updated end extended version of the online paper *„Global Warming by Anthropogenic Heat Release"* from 2009 /1/. Its title had been taken literally from the heading of section 2.5.7 in the 4th IPCC assessment report, Working Group I, from 2007 /2.I/. There it is named as a 'non-initial radiative effect', which 'is not a radiative forcing'. This has been discussed under the headings "*Terminology and Attribution Problems"* and *"About IPCC Reports"* in a booklet *"Robert Döpel and his Model of Global Warming"* from 2013 /3/ that included the results from /1/. Both papers were based on Robert Döpel's work on the geo-physical limit of industrial energy production /4/. – As in /1/ and /3/, the terminus *"climate forcing"* for the Anthropogenic Heat Flux (AHF) will be preferred here.

In 2013, the IPCC WGI /5.I/ seems to have excluded the anthropogenic heat (release) from its global considerations. "Non-RFs" are listed (in Chap. 8), but without AHFs. (See section 3.3 for comparison with /2.I /.)

Only *"anthropogenic heat fluxes for large cities"* are mentioned by WGII /5.II/, citing (among others) two papers /6, 7/ that integrated AHFs into complex climate models. The continental effects that are predicted in /6/ have not been mentioned there, due to the heading of the corresponding Chapter 8 ("Urban Areas")[2]. In AR5 scenarios until year 3000 with results as they are shown in our appendix, AHFs also do not appear.

Assuming current global growth rates of non-renewable energy consumption, as they hold since the late 1970s, in /6/ continental scale contributions to surface warming of 0.4 – 0.9^{o}C are reported by an AHF scenario for the year 2100 (whereas for 2040 there resulted no effect). It is emphasized that energy *"sources that could sustain such growth … include nuclear fusion …"* /6/.

With the same energy scenario a simple model calculation similar to that by Döpel (compare sec. 2) resulted in a 3^{o}C global rise in about 280 years, which is supported by arguments from Flanner /6/. Such time horizons (up to the year 2500) are covered by the *"Summary for Policymakers"* in /5.I/ where AHFs are not mentioned (e. g. in section C. *"Drivers of Climate Change*").

Returning to the problems of terminology due to /2.I/ with which we started, in a 2009 presentation /8/ corresponding to /6/ Flanner designated the anthropogenic heating flux as a climate or *"thermal"* rather than *"radiative"* forcing, and he started with the heading: *AHF or "Waste heat"*.[3] But in AR5 merely waste heat utilization for mitigation aims is discussed in /5.III/, as it is mentioned in the Syntheses Report /5.SyR/, too. In /3/ this terminus was used as synonym for anthropogenic heat (due to it brevity), but sometimes it describes merely a

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[2] By WGI /5.I/, the papers /6, 7/ have not been cited, even in the context of the often mentioned *"urban heat islands"* where they are important. – See also /3/ about /6, 7/.

[3] Quotation marks from the original.

special form of room heating and similar activities, especially in climate models for urban regions /9/. Therefore it is used here also in restricted sense.

Here, the terminus *anthropogenic heat flux* is preferred with the abbreviation AHF, that can interpreted as *anthropogenic heat forcing*, too. On the other hand, *„thermal forcing"* reminds of *thermal pollution* which was formerly in general use since the 1970s (see e.g. /10/, citing /11/). - Owing to the founded and dominant role of the IPCC, a terminology that is compatible with the AR5 from 2013/14 (but not with the 2007 AR4) is given in sec. 3.3, basing on a subdivision of forcings into two groups.

Prior to this section and thereafter in sec. 4, actualized results of Döpel's work /4/ are given and discussed. Then, under 5. aspects of nuclear fusion techniques and related possibilities of geo-engineering are treated. Finally, the conclusion is given in 6., and in an appendix (7.) calculations of long-time carbon dioxide action on global temperature from the AR5 are presented for comparison and for discussion of combination problems.

2. Calculations according to *Dö*pel

As can be seen from /3/, Robert Döpel (1895–1982) was a famous nuclear physicist and the most famous scientist who had worked at the Ilmenau Institute (now University) of Technology. In this small Thuringian city he spent the last 25 years of his life. As one of the first, in /4/ he dealt with the climatic consequences of growing energy production, including the possibilities of nuclear fusion with its hardly limited resource base.

For his calculations of global warming, he used a simple planetary radiation balance model. In the radiative equilibrium of the earth, the net energy from the sun is equal to the energy emitted by high layers of the atmosphere, which acts as a black body radiator. Due to the STEFAN-BOLTZMANN law, the global radiation balance is

$$\sigma\, T_e^4 = (1-A)\, l_o/4 \;=\; l_s \qquad (1)$$

$\sigma = 5.67 \cdot 10^{-8}$ W$m^{-2}K^{-4}$: Stefan-Boltzmann Constant.

T_e = 255 K : Effective balance temperature of a fictitious atmosphere layer, acting as black emitter.

A = 0.30 : Planetary reflection coefficient, according to a planetary albedo of 30%.

$l_o = 1\,367\; W\, m^{-2}$: Solar constant**.** It has to be divided by 4 due to the conversion of the cross section area of earth into the surface of the globe.

$$l_s \;= 239\,\frac{W}{m^2} \qquad (2)$$

is the radiation flux into and out of the atmosphere, the latter flux becoming modified slightly by the anthropogenic heat flux. Approximating the differential quotient dl_s/dT_e by the difference quotient results in[4]

$$\Delta T_e = \frac{T_e}{4l_s}\Delta l_s = \lambda_e\,\Delta l_s = \lambda_e F_w, \quad with \quad \lambda_e = 0.27\frac{Km^2}{W}. \tag{3}$$

In a contemporary terminology, λ_e is the climate sensitivity parameter with respect to the atmosphere. The additional flux of energy Δl_s is the climate or anthropogenic heat forcing F_w. Other forcings were not included in Döpel's model, which includes the greenhouse effect only implicitly by the empirical difference of 33 K between the mean global surface temperature T_s = 288 K and the effective atmospheric temperature T_e = 255 K.

He assumed an exponential increase for F_w with an annual enhancement coefficient q (corresponding to a growth of [q–1] % p.a.) :

$$F_w = F_{w,o}\exp([q-1]\cdot\Delta t/a) \approx F_{w,o}\cdot q^{\Delta t/a}. \tag{4}$$

For calculations starting with the year 2000, $F_{w,o}$ was set as[5] 0.023 W/m^2, which yields the solid curves in Fig. 1.

[4] This is more straightforward than Döpel's procedure in /4/ with his approximated eq. (1), which corresponds to eq. (4) in /3/. There, a further (binomial) approximation step provides the result (from footn. 38) that follows here.

[5] Thereby, 13% were subtracted from the total value due to regenerative energies.
This results from detailed tabular representation of the German Advisory Council on Global Change (WBGU). Tab. 4.4-1 in the WBGU report 2003: World in Transition – Towards Sustainable Energy Systems. Earthscan London 2003 and: http://www.wbgu.de/en/home .

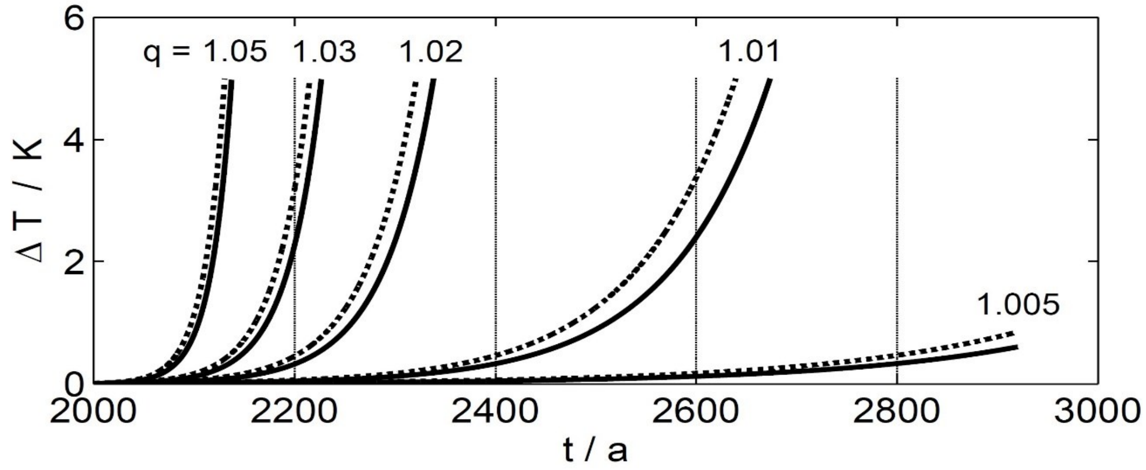

Fig. 1: Time-dependent increase of the global temperature as a function of the rate of annual increase in Anthropogenic Heat Forcing by the factor q, up to the year 3000.

Solid lines: $\Delta T = \Delta T_e$, lower limit for the change of the effective temperature of the atmosphere (T_e = 255 K) due to anthropogenic heat release (corresponding to the curves for T_e by Döpel /4/).

Dashed lines: $\Delta T = \Delta T_{ob}$**,** which is a "very probable" lower limit for the change ΔT_S of the mean global surface temperature T_s (= 288 K or 15°C) in the "surface variant" of Döpel's model.

The radiative forcings from, e.g., greenhouse gases are assumed to be constant for this figure, whereas its variations and the combined action with the anthropogenic heat on global temperatures are discussed in the Appendix.

Since Döpel's starting year 1970, the annual increase has been approximately 2% in average /3/. Consequently, his curve for q = 1.02 is approximately consistent with the data in our Fig. 1. The differences versus Döpel for the other q values are also marginal, since the influence of changes in the pre-exponential factor is small compared to the influence of q.

This factor has to be enlarged due to feedbacks (owing, e.g., to additional clouds and melting ice sheets), which have not been taken into account quantitatively by Döpel. Instead of this, he declares ΔT_e as the lower limit of the increase of the global mean surface temperature change ΔT_s due to the anthropogenic heat release: As the upward transport of this additional heat is driven by the difference between T_s and T_e, the temperature T_e cannot become smaller than T_s.

A factor of 1.5 was used for a so-called surface variant of the Döpel model /1, 3/ to calculate the dotted curves in Fig. 1 as ΔT_{ob} (from German "Oberfläche" = surface). This factor has been made plausible by comparison with the feedback in the case of greenhouse gases and with older feedback calculations for fictive variations of the solar constant I_o or an unknown *"ghost forcing"* /13/.

With

$$\frac{\lambda_{ob}}{\lambda_e} = 1.5 \qquad (5)$$

we get in analogy to eq. (3):

$$\Delta T_{ob} = 1.5 \cdot \Delta T_e = 0.41\, F_w \,\frac{K\, m^2}{W} \quad with \quad \lambda_{ob} = 0.41 \frac{K\, m^2}{W}\,. \qquad (6)$$

The small differences of the dotted compared to the solid curves in Fig. 1 demonstrate that changes in the pre-exponential factor have relatively little impact as long as one keeps anthropogenic heat growing exponentially. - More reflections were done in / 1, 3 /, how far is the real increase of the surface temperature above ΔT_{ob}. However, these feedback considerations remained rather complicated and uncertain.

*"***Most intense technical exploitation of irradiated solar energy***"*

With these words Döpel /4/ captioned his section 5.3, treating the hypothesis of an exclusive use of photovoltaic (PV) energy as an example for renewable energies, which result in a constant global temperature.

He assumed a PV efficiency of 20% (that should be exceeded commercially in our future). The usable part of the mainland area - 30% of the globe - he estimates to be 10%, which seems rather ambitious.

The utilization coefficient for the whole irradiated solar energy is then

$$K = 0.2 \cdot 0.3 \cdot 0.1 = 6 \cdot 10^{-3} \qquad (7)$$

For the solar radiation arriving at the earth's surface here about half of the radiation $I_o/4$ into the atmosphere from eq. (1) has to be inserted /2.I, 5.I/, that is $I_o/8$. Together with eq. (4) results:

$$\frac{8\, F_w}{I_o} = \frac{8\, F_{w,o}}{I_o}\, q^{\Delta t_k/a} = 6 \cdot 10^{-3} \qquad (8)$$

with the global energy demand F_w and its seed F_{wo} . The global temperature would remain constant if photovoltaic electricity is used exclusively until the *"photovoltaic time horizon"* Δt_k is reached. But then a further growth of energy demand must be covered from other sources.

If these additional contributions would be unsustainable, the lower limits ΔT_e or ΔT_{ob} for the global temperature rise would grow again after the time Δt_k according to eq. (3) or (6), but with these additional contributions instead of F_w. With eq. (8), this time can be calculated from[6]:

$$\frac{\Delta t_k}{a} = (ln\,q)^{-1}\,ln\frac{0.75\cdot 10^{-3}\,l_o}{F_{w,o}} \approx \frac{4}{q-1} \qquad (9)$$

Resulting value pairs are, for example:

q	$\Delta t_k/a$
1.05	80
1.02	200
1.01	400
1.005	800

The times of constant temperature Δt_k shall apply also from the year 2000 chosen for Fig. 1 as a start[7]. Starting with the year 1970 and an annual increase of the anthropogenic heat release by 5%, which was slightly below the increase rates of those times, Döpel calculated the *"photovoltaic time horizon"* for the middle of the 21st century, corresponding to 80 years for q = 1.05 within the table. - Of course, these values not as a prediction, but as cautionary scenarios were given, as well as the curves in Fig. 1.

3. Discussion about anthropogenic heat

3.1 Publications from the 20th century

Two years after Döpel, a more general paper on anthropogenic warming /14a/ used a similar approach with the simple planetary balance model for the *"Derivation of order-of-magnitude temperature-energy relationships"* (Appendix I), but without scenario-based time-temperature calculations. Refining the "zero-dimensional" treatment with the differentiated Stefan-Boltzmann balance in eq. (3), a one-dimensional vertical averaging procedure for temperature and humidity over the globe yielded a similar correction for the surface temperature change ΔT_s than ours. So, a selective result (in endnote 16) is almost the same as from our eq. (6), and it is declared as an underestimate, too.

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[6] Due to footnote 56 in /3/, this expression has been corrected versus /1/, but the Δt_k values are the same.

[7] Each further bisection of annual percentage growth increases Δt_k about to double (due to $\ln q \approx q - 1$).

As another and actually dominant influence, carbon dioxide has been included in /14a/, which Döpel had excluded from his considerations. The latter was due to the *"global cooling"* in the 1960s and early 1970s (see /3/, Fig. 1) together with a "*carbon dioxide-climate confusion"* /14b/.

There are also some earlier works with warnings about anthropogenic heating, e.g. /15, 16/. In /15/ it is stated that *"with an annual increase in the output of energy by 4 %, the total production of energy would reach the magnitude of the radiation balance of land areas within 200 years."* The consequences are called *„probably a slight exaggeration*" in /16/, but it is said approvingly *"that eventually man may inadvertently generate his own climate"*.

3.2 Publications from the 21th century

In 2014, Chaisson published a cosmological study /17/ repeating his 2008 treatment of "*Long-Term Global Heating From Energy Usage*"[8], that has been compared with our similar analysis in /3/. He started with the Stefan-Boltzmann balance for the earth's surface with an effective surface emissivity of 0.61, a procedure which is similar to our surface variant with eq. (5) and 1/1.5 = 0.66, but without mentioning that this is a lower-limit.

For his example with 2% annual growth of nonrenewable energy production he received the 3^oC global rise in 280 years, as already mentioned in our introduction in context with Flanner's far more refined and confirming calculations /6/ It lies only slightly above the dashed line in Fig.1. So, the concept of Döpel[9] and – to a certain degree – of Schneider /14a/ was rediscovered after decades.

Following Chaisson and in contact with him, Nickolaenko /18/ obtained similar results, supplemented by some astrophysical considerations. Different from Chaisson, he ignored the possibilities of renewable energies. Wood is included into his calculation of anthropogenic heat forcing together with fossil fuels, which has been shown to be wrong already by Budyko /19/.

In /8/, Flanner gives an anthropogenic heat forcing AHF = 0.19 W/m^2 for the year 2100, if non-renewable energy consumption continues to grow at 2%/a. He started with 0.03 W/m^2 for 2005 (corresponding to 0.023 W/m^2 in our eq. (4) for the year 2000)[10]. With our eq. (6) this results in the lower ΔT_s limit $\Delta \mathrm{T_{ob}} = 0.08^oC$ versus his "continental scale" $0.4 - 0.8^oC$ from the complete model /6/. Even if one takes into account that the temperature rise over the sea

[8] From the Harvard Community: https://dash.harvard.edu/bitstream/handle/1/15217701/eos_agu_transactions_chaisson_8_july_08.pdf?sequence=1 .
Together with further papers from 2007 to 2009 discussed in /3/.

[9] Döpel's work from 1973 is online since 2009 /4/, and the report about it in English /1/ also.

[10] The total anthropogenic radiative forcing for 2011 relative to 1750 is reported 2.3 W/m2 in /5.I/, where the proportionality factor to ΔT_s (from table 3 in /3/) is significantly larger than in our eq. (6).

is lower than over land by some tenths of a degree and that the global warming ΔT_S lies in between[11], a remarkable large difference remains. - In every case, the AHF has to be included in the discussion of the 2-degree-target[12], which has not done in the IPCC's AR5.

With regard to the actual *AHF of 0.03 W/m²*, the statement in /3/ (p. 39) about the unbalanced presentation of smaller forcings in the AR4 is even more serious in the AR5 for the example of *0.01 W/m²* radiative forcing for contrails from aircraft. In /5.I/ is written to FAQ 7.1: *"More recent estimates tend to indicate somewhat smaller RF … An additional RF of 0.003 W/m² is due to emissions of water vapor in the stratosphere by aviation …".*

The actually 10-fold and continuously growing AHF has not been mentioned, which could be understood in this RF context (see our section 3.3), but it is not at all mentioned in /5.I/ (see our sec. 1).

In contrast to the publications mentioned so far, Nordell wrote in 2003 /20/ , that the global heating of 0.02 W/m² *"has so far resulted in a global temperature increase of* 0.7^oC*"* since 1880[13]. Instead, this increase was attributed to the greenhouse gases by the IPCC /2.I/ and many others. In 2009 Nordell and Gervet /21/ wrote (without mentioning /20/): "*It is concluded that net heat emissions contributes to 74% of global warming. The missing heat (26%) must have other causes, e.g., the greenhouse effect, …".*

3.3 Grouping of climate forcings

A further contribution of the Nordell Group /22/ lists two causes of anthropogenic global warming:

(i) Greenhouse gas emission, and (ii) heat emissions.

The third principal cause listed by Graßl[14] are anthropogenic changes of the diffuse reflectivity of the earth surface and its atmosphere with clouds and emitted aerosols. Since it is taken into account by changes of the albedo (e.g. A in eq. (1) globally averaged), the term "albedo-forcing" is used for instance in the IPCC reports as a special case of radiative forcing. Since the

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[11] See for example in /5.I/ Fig.10.21

[12] See the subsection under this title in /3/, pp. 74-76.

[13] The other extreme is represented by the answer to a FAQ from the website of the Max Planck Institute for Meteorology <http://www.mpimet.mpg.de/en/communication/climate-faq/> which starts with *"No."* (See Footnote 40 in /3/, where also contrails from aircraft are discussed, as in our Sec. 3.2.)

[14] Hartmut Graßl was from 1994 to 1999 Director of the World Climate Research Programme, one of the main contributors to the IPCC Assessment Reports, especially by WGI. With this suspension, he was Director at the Max Planck Institute for Meteorology in Hamburg from 1989 until his retirement in 2005.

attribution occasionally is not sharp[15], it can collected with other special cases as the first of again two cases of

Anthropogenic Climate Forcings:

(I) Radiative Forcings (RFs), with greenhouse gas emissions (i) as most important at all - presently and in the near future.

(II) Nonradiative Forcings (Non-RFs), with anthropogenic heat forcing (ii) as most important at all already in the medium-term future.

The terminus (II) has been defined by the Board on Atmospheric Sciences and Climate of the National Research Council of the US National Academies /24/ as *"a climate forcing that creates an energy imbalance that not immediately involve radiation".* Citing this source , the AR4 said in /2.I/[16] that instead of Non-RF *"this report adopts the similar term 'non-initial radiative effect'. "* (See the beginning of our introduction.) An example is discussed in sec. 2.5.8 under the heading *"Effects of Carbon Dioxide Changes on Climate via Plant Physiology"*: 'Physiological Forcing'. Such *"physiological impacts of CO_2 "* are an example for non-RFs in the AR5 Chapter 8, where no source or definition is given for this terminus[17], however.

Despite the irritating history with AR4, it can be assumed that the anthropogenic heat forcing would have been classified as a non-RF in AR5, if it would have been borne in mind. Independent of this assumption, the groups of Jacob /24/ and of Flanner /8/ are reliable sources for the terminology presented here.

4. Discussion about
"Most intense technical exploitation of irradiated solar energy"

Under this heading in sec. 2 the computation of growth limits for photovoltaic (PV) energy by Döpel /4/ has been reported.

[15] For example, in the legend to Fig. SPM.5 of /2.I/ is written: *"Albedo forcing due to black carbon on snow and ice is included in the black carbon aerosol bar"* within the bar representation of the figure for radiative forcings. – Because such cases a pragmatic summary under radiative forcings is usual.

[16] In the Index is mentioned the often used terminus *"**Climate forcing.** See Radiative forcing".* In the AR5, "climate forcing" is completely absent - due to the comeback of Non-RFs. It has been used by the author already in /1/ and /3/, but including nonradiative forcings due to the Glossary of /24/: *"**Climate forcing**: An energy imbalance imposed on the climate system either externally or by human activities.*"

[17] "Non-RF" as well as "nonradiative forcing" are missing in index and glossary of /5.I/.

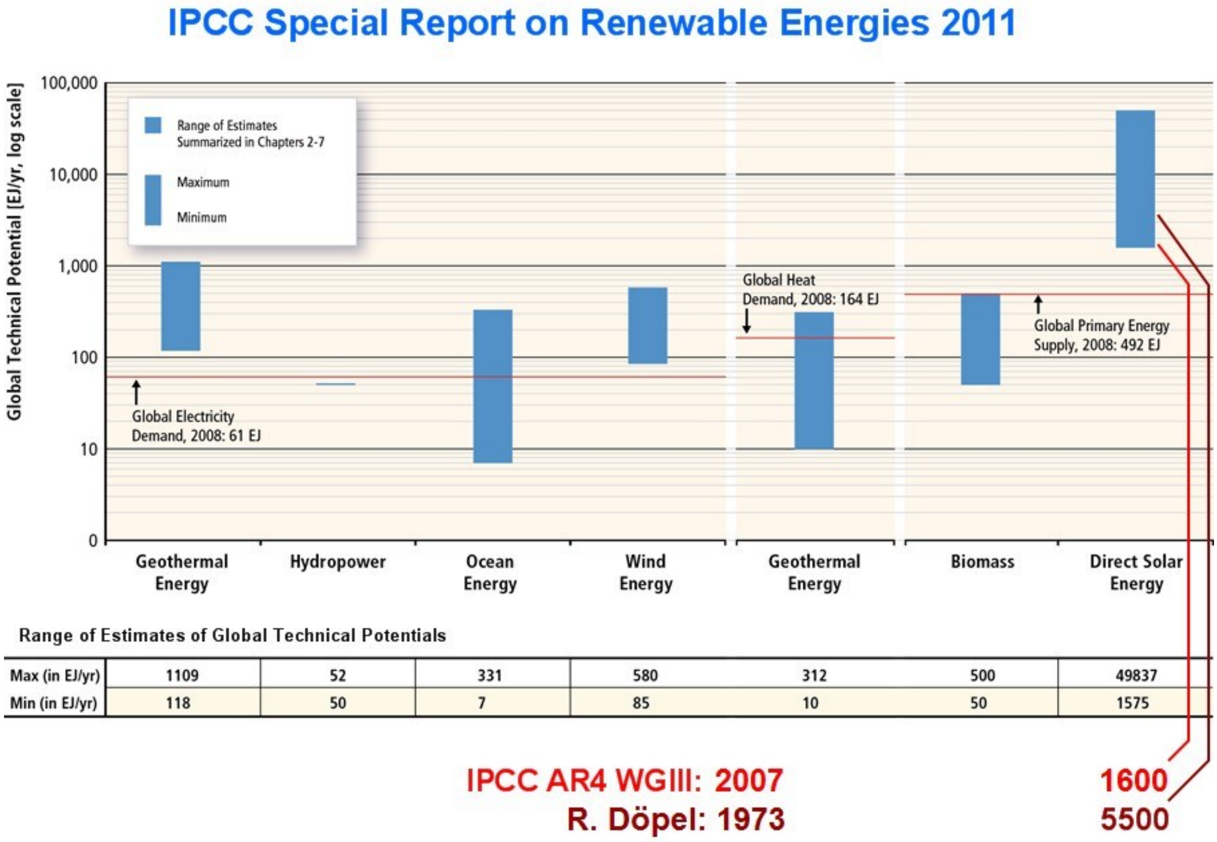

Fig. 2 is from /25/[18] (with the lowest two text rows and the lines from them supplemented in)

"Figure SPM.4 | Ranges of global technical potentials of RE sources derived from studies presented in Chapters 2 through 7. Biomass and solar are shown as primary energy due to their multiple uses; note that the fi gure is presented in logarithmic scale due to the wide range of assessed data. [Figure 1.17, 1.2.3]

Notes: Technical potentials reported here represent total worldwide potentials for annual RE supply and do not deduct any potential that is already being utilized. Note that RE electricity sources could also be used for heating applications, whereas biomass and solar resources are reported only in primary energy terms but could be used to meet various energy service needs. Ranges are based on various methods and apply to different future years; consequently, the resulting ranges are not strictly comparable across technologies. For the data behind Figure SPM.4 and additional notes that apply, see Chapter 1 Annex, Table A.1.1 (as well as the underlying chapters)."

[18] The legend follows here completely due to the IPCC instructions. (In the last row, it has to be corrected : "Table 1.A.1" due to p.206 in the annex.) - The SPM editors have to be given, too: O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow.

In Fig. 2, the 5 500 EJ (bottom row) result from eq. (7) and the subsequent statement for the solar radiation arriving at the earth's surface result. It has to be compared with the value above it from / 2.III / and with the blue 2011 IPCC bar for the technical PV potential from /25/, where it lies well inside.

Döpel's model calculations for the *"photovoltaic time horizon"* (sec. 2) on this basis were rediscovered in 2011 by Tom Murphy in his blog /26/. The legend under his first figure says:

"Global power demand under sustained 2.3 % growth on a logarithmic plot. In 275 … years, we demand all the sunlight hitting land, assuming 20% … conversion efficiencies, ..."

This is the same order of magnitude than from /4/, comparable to the 200 years for an annual growth of 2% from our table in sec. 2 with 10% instead of 100% of the land area, corresponding to the factor 0.1 in eq. (7). (An annual growth of 2.3% was chosen in /25/ because of the factor of 10 for 100 years. Our 2% correspond to /8/ and /17/.)

Murphy's conclusions in /26/ correspond to Döpel's, and he gives good arguments that hold for the other results in sec. 2 (from Fig. 1), too[19] :

"This analysis is an easy target for criticism, … . Chiefly, continued energy growth will likely be unnecessary if the human population stabilizes. … But let's not overlook the key point: continued growth in energy use becomes physically impossible within conceivable timeframes."

This became often overlooked, as for example by Chaisson /17/. He stated that *"… there is plenty of solar energy, far more than needed to power civilization today—as well as into the indefinite future."*

In the same sense, the German *Renewable Energies Agency* has in its URL /27/ *"endless energy",* and the corresponding ∞ sign in its logo. (It is supported by the Federal Government and provides advocacy for the *"Energiewende"* in Germany.) - Internationally, the *"Renewable Energy Policy Network for the 21st Century"* /28/ supplies realistic reports updated each year.

5. About Nuclear Fusion Techniques

The opinion that nuclear fusion[20] is a sustainable option for the decarbonization of the energy systems globally is as widespread as questionable. It is wrong except in the case of zero growth of non-renewable energies (below 0.5 %/a, confere Fig. 1). The latter condition is not included into the sustainability argumentation, e.g. from the actors of the most important research

[19] See also the subsection „Prospects for Energy Production and Population Growth" in /3/.

[20] See within /3/ in sec. 4.1 "Nuclear Energy?" the subsection „Nuclear Fusion". As a nuclear physicist, R. Döpel was probably the first who considered the fusion technique in connection with its anthropogenic heat problem in /4/, starting with sec. 1: "Increase of production and global energy supplies".

project, the *International Thermonuclear Experimental Reactor* (ITER[21]) /30/ ("*ITER as a sustainable energy source."* See under *"ITER and the environment",* too).

"Is nuclear fusion a sustainable energy form?"

is the title of a publication /31/, which considers, however, only the sustainability with respect to the problems of nuclear waste and of the consumption of natural resources with a virtual limitlessness of supply. The latter has been stated already by Döpel in 1973 /4/. In contradiction to his arguments, the question mark would be cancelled due to /31/, and to later work /32/, too. Moreover, in /33/ a concept of *"weak sustainability"* has been created for nuclear power at all.

In 2013 /3/, the author wrote in sec. 4.1: "*Basically it holds that the fusion is desirable to bridge in CO_2 avoid."* This error was shared with a majority of the scientific-technical community. In this context, the AR4 from 2007 (/2.III/, sec. 4.3.2.5 *"Nuclear Fusion"*) will be cited: *"Commercialization of fusion-power production is thought to become viable by about 2050, assuming initial demonstration is successful".* For Table 4.2, the fusion energy resources were estimated as $5 \cdot 10^9$ EJ globally. With a constant primary energy supply of 500 EJ (due to Fig. 2 for 2008), these resources would be sufficient for 10^7 years.

However, in the AR5 from 2013 /5/, nuclear fusion is only mentioned in context with *"research areas of more fundamental science without larger commercial interests (for example, the ITER fusion reactor and the CERN supercollider)"* (in /5.III/ under the heading "*International collaboration to encourage knowledge development*"), in contrast to /30/. In sec. 7.4.3 *"Nuclear Energy"* of /5.III/ (same heading as 4.3.2 of AR4), it is not mentioned at all. The same holds for /5.Syr/ with the special sec. 4.4.4. *"Investment and Finance"*. This topic is new for AR5, but the huge governmental investments on fusion techniques are omitted.

For ITER, the 35 countries sharing the cost of the Project are estimated at approximately 13 billion € /30/**.** Several countries have additional national research projects, so Germany with his Stellarator /34/ for approximately a further billion €.

[21] The Latin signification ("The way") is interpreted by the EU representation Fusion for Energy /29/ with the slogan "ITER, the Way to Sustainable Energy".

H. J. Schellnhuber[22], Director of Germanys most important institute for climate research, wrote in the Pontifical Encyclical *"Common Ground"* 2015 /35/:

„While we have been working decade after decade on developing an incredibly expensive fusion reactor, we are already blessed with one that works perfectly well and is free to all of us: the Sun. Photovoltaics, wind and energy from biomass are ultimately all powered by sunlight."

Flanner /6/ wrote in context with his year 2100 AHF scenario with continued growth of non-renewable energy consumption at 2%/a (sec. 3.2): *"Although future energy practices are highly uncertain, sources that could sustain such growth while constituting a climate forcing include nuclear fusion …"* . Its realization would stimulate the growth, and even if this would become lower previously, it would become stronger than again.

In /36/ is said that "*nuclear fusion … will be too late as a replacement for CO_2-emitting technologies, and will not meet contemporaneous thermal emissions criteria for a sustainable global environment unless its thermal effects are compensated by addidional geoengineering schemes."*

Some of the latter have been discussed in a subsection *"CCS and Geo-Engineering / Climate Engineering"* of /3/ with regard to the restrained statements of H. Graßl /23/. These are aggravated in /38/ within a section 6.6.2 *"Geo-engineering?".* More recently, the frequently discussed proposal of targeted production of aerosols with in the stratosphere has been critzised again /39/.

In /36/ it is stated that *"dumping thermal energy into the ocean is not a long-term solution".* The latter corresponds to Döpel's statement from 1973 /4/ in his section 5.2 *"Ausnutzung der Wärmekapazität der Ozeane"* (utilization of the heat capacity of the oceans), where he discussed the storage of industrially-generated heat in the water mass of the oceans as a fiction.

6. Conclusion

For a globally sustainable development, the successive decarbonization of the worlds energy system /40/ has absolute priority for the next decades. The widespread acceptance of this demand is not least owing to the IPCC and its increasing focus on greenhouse gases. That

[22] Potsdam Institute for Climate Impact Research (PIK), https://www.pik-potsdam.de/members/john/hjs-director?set_language=en

nuclear fusion cannot replace the fossil energies in time, implicitly also its last report from 2013/2014 has concluded as we have seen above.

Their opponents argue mostly with the huge costs since decades, while the non-sustainable contribution to the anthropogenic heat is mostly overlooked. In any case, projects such as ITER [23] should be stopped in favor of renewable energy payment.

As has been discussed in /3/ under the heading *"Prospects for Energy Production and population Growth"*, the level of economic growth is still used as an indicator of successful policy because it positively affects unemployment, which seems to be crucial for social peace. Thereby, especially in the more developed countries the growth of the economy and of energy production are decoupled. However, increasing energy efficiency is affected by the rebound effect /41/, by which the expected gains from energetically more efficient technologies are decreased, because of behavioral or other systemic responses.

More general, global problems were treated by H. J. Schellnhuber (see footn. 22) in /35, 40/) and recently in an interview about *Climate protection and justice* (2015, in German) /42/. In translation, the focus is on *"unjust world politics, the consumer greed of wealthy countries such as Germany, the drifting apart of rich and poor … ".* With respect to political activities of certain entrepreneurs in the energy business, he said: *"This is not a democracy, it's a kleptocracy".*

In this context, against the prominent author Naomi Klein /43/ *„that a book has written about climate against capitalism, which come - so to speak - from the corner of Marxist or Socialist",* Schellnhuber argued*: "But I don't think that we have enough time to create the optimal social system first and repair then quickly yet climate change."*

It must be mentioned that Robert Döpel came from this corner, too, which can be seen from /3,4/[24]. Regardless of whether the growth ideology is founded capitalistic or communistic, as currently for the world's largest economies United States and China, Döpel's statement from 1973 /4/ remains valid:

"The only way to prevent this threatening temperature rise is a global, gradual transition to a constant energy production."

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[23] In contradiction to the translation of "*Iter*" from Latin (footn. 21), this means that it is seen as a *wrong way* now.

[24] In /4/, on p. 31 the translation of some ideologically relevant sentences from a letter is delivered, which was reprinted in /44 / together with a special section (3.6) under the heading *"Sozialismus?".*

7. Appendix: Carbon dioxide action on global temperature until the end of this millennium from model calculations – for comparison and overlay.

The fateful role of carbon dioxide for the climate will not end with its emissions, as can be seen from Fig. 3. In its upper part (a) the four Representative Concentration Pathways (RCPs) are inserted as new AR5 scenarios, that are described in /5.I/, Box SPM.1 (p. 29). They are identified by their approximate total radiative forcing in year 2100 relative to 1750,

from 2.6 Wm^{-2} for "RCP 2.6" to 8.5 Wm^{-2} for "RCP 8.5".

As is said in the glossary of /5.I/ (p. 1461), they "*include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover".* But the main features of the temperature courses in Fig. 3b are determined by the curves for the long- lived carbon dioxide in Fig. 3a.[25]

Less sophisticated was the corresponding AR4 Figure 10.34 from 2007 /2.I/, that has been given in the preceding version /1/ of this publication. For comparison with our Fig. 1, its main content has been shown in /3/ together with this figure over the same thousand-year time scale. The main features are very similar: The global temperature changes are only small after the end of the emission of carbon dioxide as the most important, long-lived greenhouse gas due to exhaustion of fossil ressources. In contrast to them, e.g. nuclear as other non-renewable ressources are non-exhaustible (Sec. 5), which is reflected by the continously rising curves in Fig. 1.

That the production of anthropogenic heat from non-renewable sources is considered as constant for the calculations to Fig. 3 was mentioned neither in the publication /45/ from the legend (with 34 authors) nor by the lead authors from footnote 27. On the other hand, R. Döpel did not mention the assumed constancy of the influence of greenhouse gases.

To overcome this separatism, as a first step one can add the two types of temperature courses in Figures 1 and 3, in spite of large differences in the underlying assumptions. Starting with a curve from Fig. 3.b, sooner or later a stronger rise will occur corresponding to Fig. 1. Between the two rising regions, a part of the temperature "plateau" from Fig. 3b may occur after the curves have simply added. In every case, a turning point will remain. In the great variety of possible combinations most will come up to a disaster within our millennium if the warning from the end of the preceding section would remain unconsidered.

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[25] In contrast to what happens with long-lived greenhouse gases, a reduction in the production of anthropogenic heat immediately affects the temperature. In that, it corresponds to emission reductions of short-lived species such as sulphate aerosols, leading to almost immediate changes in their atmospheric concentration. Owing to their negative RF contribution, this can result in an intermediate additional warming (Fig. 3c, blue).

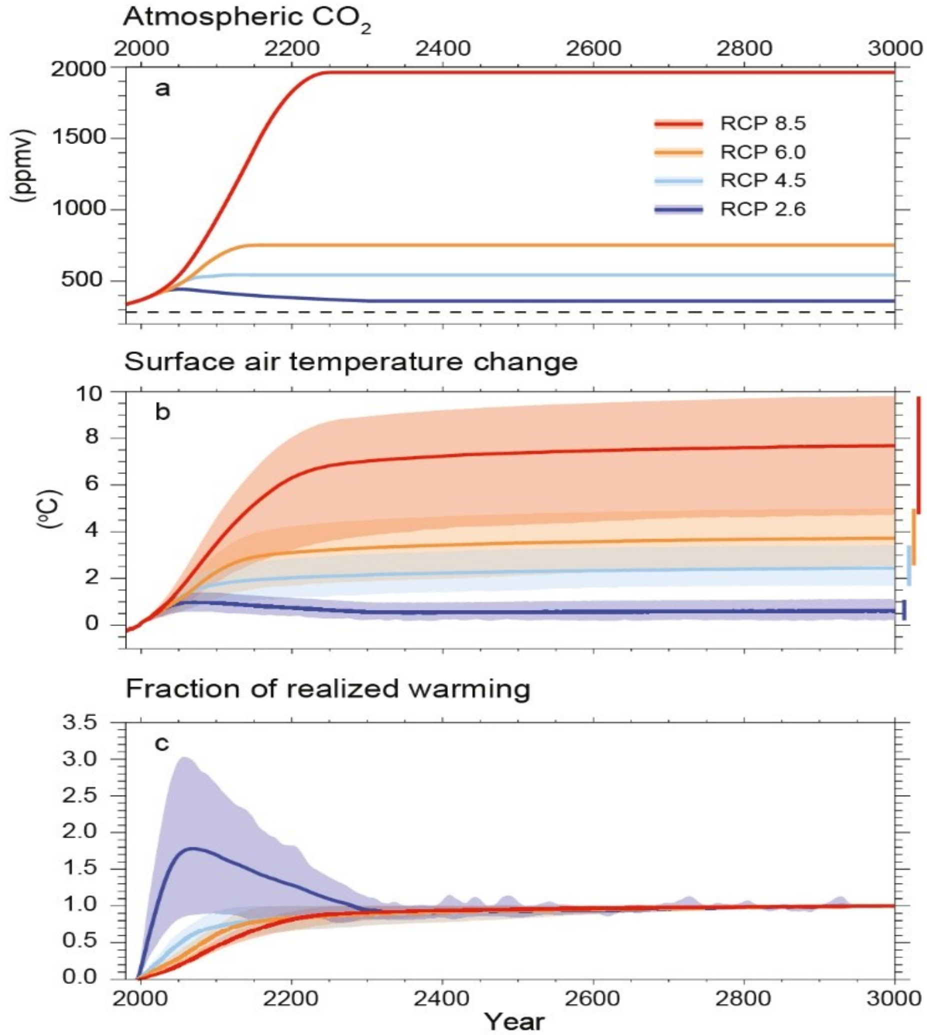

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Fig. 3 is taken from /5.I/ p. 1103, and has to be given with the complete legend [26] : **"Figure 12.43 |** (a) Atmospheric CO2, (b) projected global mean surface temperature change and (c) fraction of realized warming calculated as the ratio of global temperature change at a given time to the change averaged over the 2980–2999 time period, as simulated by Earth System Models of Intermediate Complexity (EMICs) for the 4 RCPs up to 2300 followed by a constant (year 2300 level) radiative forcing up to the year 3000 (Zickfeld et al., 2013). A 10-year smoothing was applied. Shadings and bars denote the minimum to maximum range. The dashed line on (a) indicates the pre-industrial CO2 concentration."

[26] Chapter 12 from which it originates has to be cited as: Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski, T. Johns, G., Krinner, M. Shongwe, C. Tebaldi, A.J. Weaver and M. Wehner, *Long-term Climate Change: Projections, Commitments and Irreversibility.* - See also the answer on the Frequently Asked Question on pp. 1106-1107: FAQ 12.3 | *What Would Happen to Future Climate if We Stopped Emissions Today?*

Another attempt for combination was made by Ahn and Cowern /36, 37/. They added the anthropogenic heat and the radiative forcing (without presentation of appertaining calculations) for their graphs of the resulting global *"Temperature Forcing"* vs. time. Thereby, a parallelism of this new forcing and the temperatures, that are not given explicitly, is assumed. However, there is an inconsistency because different forcing-temperature-relationships must be used for the two items in

RF + AHF = „Temperature Forcing".

In the example of our lower-limit-calculation from AHFs for Fig. 1, these relationships were eq. (6) or (3) with climate sensitivity parameters of 0.41 or $0.27\, K \cdot m^{2} / W$. The latter is attributed to the so-called *"simple response"* in table 3 of /3/. Below this smallest value, more parameters are listed from the carbon dioxide literature . As the *"best estimate"* from the IPPC 2007 report /2.I/ are given $0.8\, K \cdot m^{2} / W$. However, in the 2013 report /5.I/ with respect to the corresponding climate sensitivity is said (within the SPM sec. D.2, footnote 16): *"No best estimate for equilibrium climate sensitivity can now be given because of a lack of agreement on values across assessed lines of evidence and studies."*

Against this background and given the ignoring of the anthropogenic heat influence in /5/, the curves in /36, 37/[27] are a valuable illustration of what could occur. For example, a "*Coal Phase-out"* scenario from /46/ for the RF is combined with two AHF scenarios from Chaisson in Fig.1 of /36/.

For both, between two growth regions an intermediate plateau[28] starts before the midst of our century. For the first scenario with 2% growth in primary energy use (corresponding to the dashed temperature curve for q = 1.02 in our Fig. 1) the plateau lasts for about 80 years. It takes about twice as long for the second, *"more realistic"* mixed scenario ("1% OECD + 5 % Non-OECD", see /3/, p. 50), and thereafter the increase is significant slower. This seems to be too optimistic especially for long times, since it ignores the limits of growth for the renewables (Sec. 3.3). Furthermore, the lower-limit character of the calculations (Sec. 3.2) has not been mentioned.

Of course, more fundamental research about the superposition of the two forcings is strongly needed. It would be helpful with large computer capacity, if e.g. some of the many authors who were involved in the creation of Fig. 3 could extend the calculations to the influence of anthropogenic heat, including the growth limits of the renewables.

Like at the end of the previous section, we can again go back decades for a summarizing utterance related to the preceding considerations: John P. Holdren, who became the US

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[27] From /36/, a very large sensitivity parameter $1.5\, K \cdot m^{2} / W$ can be taken indirectly from a RF of 2.6 W/m^2 that causes a temperature rise of nearly 4°C near the maximum of the RF curve. This is a multiple of the maximum temperature of the bottom curve in Fig. 3b and seems rather improbable.

[28] This lies at a forcing of 2.6 W/m^2, which coincidentally matches the year 2100 value for "RCP 2.6" in Fig. 3. There are similarities between the lowest curve in Fig. 3a and the CO_2 scenario from /46/, with a maximum before the middle of our century in both cases.

presidents advisor as the Director of his *Office of Science and Technology Policy* in 2009, wrote 1971 in a study /11/ cited in the 1st Report to the Club of Rome /10/, that

> *"global thermal pollution is hardly our most immediate environmental threat. It could prove to be the most inexorable, however, if we are fortunate enough to evade all the rest."*

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[29] One exception has been found: An encyclopaedic article within https://en.wikipedia.org/wiki/History_of_climate_change_science

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