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Climate Change – key questions

Klaus Radunsky
Email: KRadunsky@hotmail.com
ORCID iD：https://orcid.org/0000-0002-8650-1046.

Abstract

Last but not least, triggered by the outcome of COP 29, this article tries to answer the following three questions:

a) Can we still meet the goal, identified in the Paris Agreement, to limit global warming to 1.5 degrees C?
b) Could we avoid dangerous climate change – characterized by a 'hot house scenario' - without geoengineering (the deliberate altering of global atmospheric or oceanic conditions) or are we already in a technology trap?
c) If we are already in an emergency situation: what could be possible next steps – also from a process perspective?

This article intends to start a discussion, hopefully informed by persons/scientists, who have the skills and knowledge to provide robust answers in order to inform decisions makers as well as the interested public. However, given the limited expertise of the author, this article does not intend to provide final answers but tries to explain why those questions are relevant and not trivial to be answered.

Keywords: climate change; tipping points; geoengineering;

Introduction

In order to identify what dangerous climate change might be it is helpful to go back to the year 1992. Because in 1992 countries agreed under the Convention on Climate Change on its ultimate objective: to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

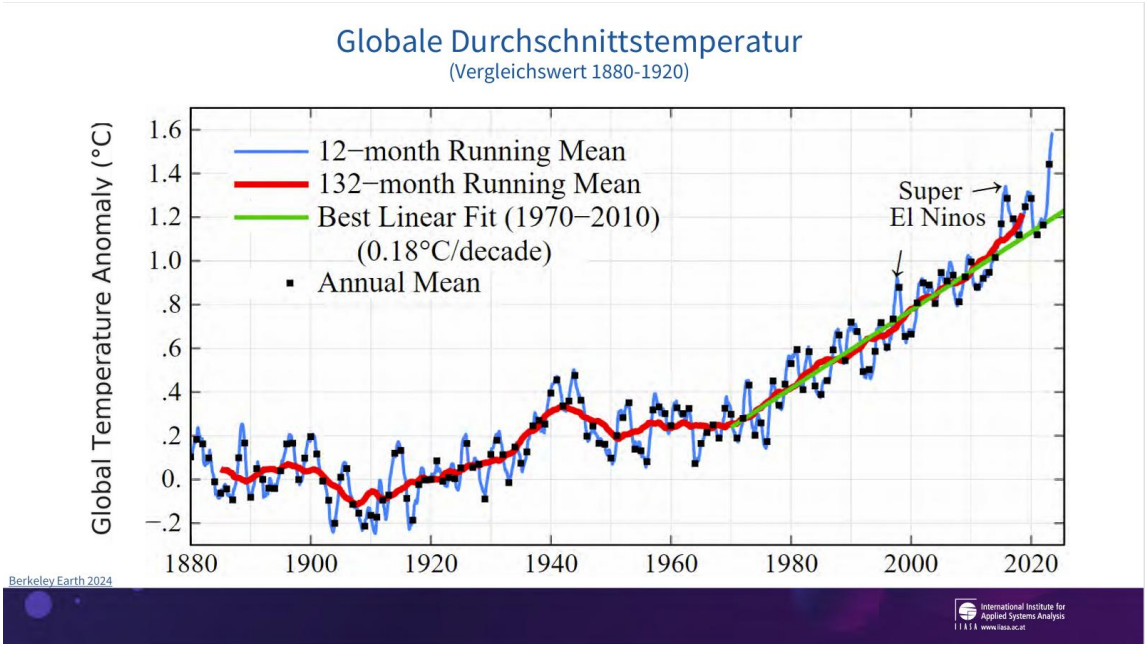
Despite the agreement on related legal instruments such as the Kyoto Protocol and the Paris Agreement concentrations of greenhouse gas concentrations are still increasing and global warming is still increasing. But the international community has not yet actually specified which level of greenhouse gas concentrations in the atmosphere would represent a dangerous anthropogenic interference with the climate system.

Global Warming

According to the recent report by the WMO (1) the global mean surface air temperature from January 2024 - September 2024 was 1.54±0.13°C above the pre-industrial average. Boosted by the El Niño, 2024 is on track to be the warmest year on record (23). Long-term warming, measured over decades reached 1.3°C and thus still remains below 1.5°C.

However, global warming has been accelerating from 0.2°C to about 0.3°C per decade (figure 1).

Figure 1 Global average temperature



This significant increase in temperature in the past 50 years cannot be explained by changes of solar activity and solar irradiance only as those result just in a temperature increase of 0.5°C within a century or 0.05°C within a decade (2).

The assessment of the IPCC in its Synthesis Report of the AR6 is still valid: “Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming” (3).

This global warming emergency has been exacerbated by a rapid decline in anthropogenically-caused atmospheric aerosol loading. Recently implemented International Maritime Organization (IMO) regulations on bunker-fuel sulfur oxide (SOx) have been identified as important contributor to these reduced aerosol loadings and high sea surface temperatures (19) but other factors might also have contributed (32).

The most relevant greenhouse gases reached record observed levels in 2023 (CO_2 420 ppm, CH_4 1934 ppb and N_2O 337 ppb) and real time data indicate that they continued to rise in 2024 (1).

Not only concentrations of GHGs in the atmosphere are still rising but also GHG emissions. According to the Emissions Gap Report of UNEP (4) global greenhouse gas emissions set a new record of 57.1 $GtCO_2e$ in 2023, a 1.3 per cent increase from 2022 levels and under current policies, global 2030 emissions are projected to be 57 $GtCO_2e$ (range: 53–59) – thus no decrease is to be expected in the coming years.

The outcome of COP 29, as reflected by Carbon Brief, with respect to mitigation: Countries failed to reach an agreement on how the outcomes of last year’s “global stocktake”, including a key pledge to transition away from fossil fuels, should be taken forward – instead shunting the decision to COP 30 next year in Brazil (5) does not give hope that there is great willingness among countries to accelerate decarbonization. Only three revised and strengthened National Determined Contributions (NDCs - United Kingdom, Brazil and United Arab Emirates) have been submitted so far – governments are expected to submit their new NDCs (also known as NDCs 3.0) by early 2025, with upgraded targets for 2030 and new targets for 2035.

A failure to increase ambition in new National Determined Contributions and start delivering immediately what has been already submitted would put the world on course for a temperature increase of 2.6-3.1°C over the course of this century. This would bring debilitating impacts to people, planet and economies (4).

However, it remains technically possible to get still on a 1.5°C pathway, with solar, wind and forests holding real promise for sweeping and fast emissions cuts. To deliver on this potential, sufficiently strong NDCs would need to be backed urgently by a whole-of-government approach, measures that maximize socioeconomic and environmental co-benefits, enhanced international collaboration that includes reform of the global financial architecture, strong private sector action and a minimum six-fold increase in mitigation investment. G20 nations, particularly the largest-emitting members, would need to do the heavy lifting (4).

Given this significant need for additional investments to speed up transformation as indicated above, the current economic and political crises (need to control inflation, growing public support for right wing Parties and leaders, geopolitical crises), such rapid decline in greenhouse gas (GHG) emissions required to still meet the 1.5°C goal of the Paris Agreement seems however quite unlikely in the near future.

Risk of dangerous climate change

Given this current situation it seems important to recognize what the most recent report of the IPCC, its Sixth Assessment Report (AR6), and even more recent scientific assessments can tell us about climate change risks.

In the AR6 Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC (3)) key risks have been identified based on the magnitude of adverse consequences (pervasiveness of the consequences, degree of change, irreversibility of consequences, potential for impact thresholds or tipping points, potential for cascading effects beyond system boundaries); likelihood of adverse consequences; temporal characteristics of the risk; and ability to respond to the risk, e.g., by adaptation.

According to the Global Tipping Points Report 2023 (6) harmful tipping points in the natural world pose some of the gravest threats faced by humanity. Their triggering will severely damage our planet’s life-support systems and threaten the stability of our societies. The effects will cascade through globalised social and economic systems, and could exceed the ability of some countries to adapt. The threat posed by the climate and ecological crisis is far more severe than is commonly understood and is of a magnitude never before faced by humanity.

The Global Tipping Points Report 2023 identified five major tipping systems that are already at risk of crossing tipping points at the present level of global warming: the Greenland and

West Antarctic ice sheets, warm-water coral reefs, North Atlantic Subpolar Gyre circulation, and permafrost regions.

The Planetary Health Check Report 2024 (7) has been prepared in order to inform about the "Planetary Health" by monitoring and safeguarding Earth's stability, resilience, and life-support functions. The Planetary Boundaries (PB) framework analyses and monitors the nine PB processes and systems that scientifically are proven to regulate the health of our planet. Each of these processes, such as Climate Change or Ocean Acidification, is currently quantified by one or two different control variables. The 2024 Planetary Health Check report reveals that six out of nine PB processes have breached the safe PB levels, with all six showing trends of increasing pressure in all control variables, suggesting further boundary transgression in the near future.

One of these six PB processes that have breached safe PB levels is climate change because atmospheric CO_2 levels are at a 15-million-year high, and global radiative forcing continues to rise, with a persistent warming trend that has accelerated since the late 20th century. Global mean temperatures are now higher than at any point in time since human civilizations emerged on Earth (10.000 years ago).

Thus, the Earth is now entering a dangerous new era marked by increasing symptoms of PB transgressions, such as more frequent extreme weather events, wildfires, reduced plant productivity, and water scarcity. These challenges are compounded by a still-growing global population that must navigate unprecedented difficulties. Beyond these immediate concerns, a more profound threat lies in the gradual weakening of Earth system resilience. As we approach — and potentially cross — critical tipping points, these slow changes may not result in abrupt shifts but could lead to irreversible trends, such as accelerated sea-level rise and self-reinforcing pathways that move us further from the stable, Holocene-like conditions crucial for human life.

In October 2024 about 44 leading climate scientists from 15 countries sent an open letter to the Nordic Council of Ministers (8). The key message of this open letter reads: ”We, the undersigned, are scientists working in the field of climate research and feel it is urgent to draw the attention of the Nordic Council of Ministers to the serious risk of a major ocean circulation change in the Atlantic. A string of scientific studies in the past few years suggests that this risk has so far been greatly underestimated. Such an ocean circulation change would have devastating and irreversible impacts especially for Nordic countries, but also for other parts of the world.” Those scientists addressed the risk of the collapse of the Atlantic

meridional overturning circulation (AMOC), which has already become significantly weaker in the recent past due to melting of the Greenland Ice shield which is driven by global warming. Based upon more recent studies, the climate scientists identified that those risks have been underestimated in the AR6 of the IPCC.

Extreme heat waves and flash floods are becoming increasingly common in Europe, which used to enjoy mild weather conditions. The escalating extreme weather in Europe in 2024, from storms and hail to floods and heatwaves, is a warning sign of the growing impact of climate change. Thus, experts have called for closer international efforts to build resilient infrastructure and reduce greenhouse gas emissions. (20)

According to the scientific director of the Russian Hydrometeorological Center, over the past 25 years the number of dangerous weather phenomena (hurricane winds, heavy rains, snowfalls that lead to collapse) has doubled in Russia. Particularly dangerous are the processes associated with desertification: an increase in the frequency of droughts and a decrease in the amount of precipitation (21).

An article by Reuters “COP 29: What is the latest science on climate change” (22) mentioned i.a. the Amazon alarm: “Brazil's Amazon is in the grips of its worst and most widespread drought since records began in 1950. River levels sank to all-time lows this year, while fires ravaged the rainforest. This adds concern to scientific findings earlier this year that between 10% and 47% of the Amazon will face combined stresses of heat and drought from climate change, as well as other threats, by 2050. This change in weather conditions could push the Amazon past a tipping point, with the jungle no longer able to produce enough moisture to quench its own trees, at which point the ecosystem could transition to degraded forests or sandy savannas.”

And such risks for forests are not limited to Russia and the Amazon. Globally, forests appear to be struggling. A July study found that forests overall in 2023 failed to absorb as much carbon dioxide from the atmosphere as in the past, due largely to the Amazon drought and wildfires in Canada. This weak absorption of carbon by forests means a record amount of CO_2 entered the atmosphere.

An inconvenient truth

Given the above scientific findings and given the huge risks associated already with the current level of global warming and the severe impacts that might evolve if the level of

current warming is reached for decades it seems necessary to lower the maximum level of global warming from 1.5ºC to 1.0ºC. Such lower level has already been suggested by several experts, among them top climate scientist Johan Rockström who informed that global warming above 1°C is already causing significant harm to humans (31).

Climate scenarios

Climate scenarios as defined by the IPCC AR6 are a plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions.

The Network for Greening the Financial System (NGFS) Workstream on Scenario Design and Analysis developed a set of scenarios (9) which has been published in November 2024 and thus reflect better the current situation.

The NGFS scenarios have been created to provide a common starting point for analysing the impact of climate risks on the economy and financial system. They map out different futures, depending on how climate change (physical risk), transition policies, technological developments and changes in preferences (transition risk) evolve.

The NGFS scenarios explore a range of plausible outcomes but are not forecasts. While the NGFS scenarios are constantly improved, the uncertainty and limitations of climate and economic modelling remain high. For instance, tipping points are not represented in the NGFS scenarios. Thus, the scenarios usually underestimate global warming because crossing tipping points results in most cases in faster global warming.

One main result is that limiting the temperature increase to 1.5 °C above pre-industrial levels in an orderly fashion is still within reach but it requires substantially more intensive efforts than delineated in previous vintages. While economic impacts differ significantly across countries, regions and economic sectors, almost all countries will benefit from keeping global warming levels close to the 1.5 °C threshold. Early and coordinated policy action will yield the highest long-run returns. If action is delayed, the scale of the adjustment grows disproportionately.

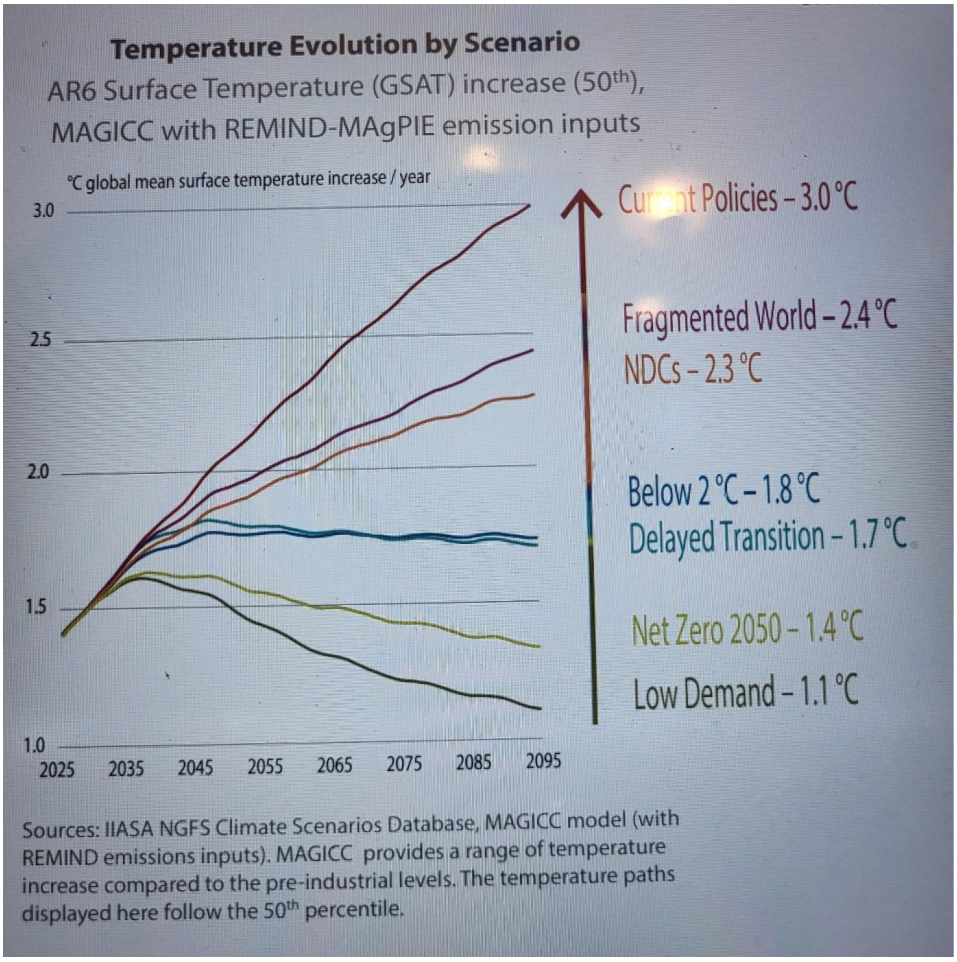
Another main result is that substantial economic transformation affecting all sectors of the economy is required to achieve global net zero CO_2 emissions by 2050. Slow progress in

implementing climate policies so far necessitates a more ambitious approach going forward. It also means higher emissions in the near term and a more disruptive transition than previously anticipated fostered by a higher (shadow) carbon price.

Another main result is that in all scenarios, the impact of physical risk rapidly outweighs the impact of transition efforts. The expected economic impact of unabated climate change has significantly increased. Due to the implementation of the new damage function (compared to the AR6), the projected physical risk impact has quadrupled by 2050 in some scenarios. However, these strong negative impacts on GDP could be mitigated by timely transition efforts.

This scenario analysis by NGFS (9) clarifies that a scenario based upon NDCs or current policies results in a Hothouse World. And overshooting the 1.5°C goal by 0.1 to 0.2°C is unavoidable, even under the most stringent scenarios (see figure 2). In a Hothouse Earth scenario, human greenhouse gas emissions activate mechanisms in Earth's climate that eventually push the global climate over a threshold into continued, self-perpetuating warming, independent of human emissions (9).

Figure 2 Global average temperature increase above pre-industrial level by NGFS scenario



In order to limit the risks of climate change and avoid a Hothouse Earth scenario, immediate policy reaction would be required, resulting in fast technology change and medium to high use of carbon dioxide removal, both with only medium regional policy variation. The stringent scenarios require negative global CO_2 emissions from around 2050 onwards which requires a carbon price between 500 and 700 USD per t CO_2 per year according to the NGFS and deploying large-scale direct air capture combined with permanent carbon storage.

Only scenarios that assume a global cooperation allow to gain control on global warming – the sooner meaningful action can be agreed the smaller will be the future warming. Time is not on our side any more – it has to be assumed that each additional 0.1°C warming results in at least twice as much economic impacts of climate change as the last increase of 0.1°C before (10). Thus, by 2034, worldwide economic impacts of climate change have to be expected to be significant higher than in 2024.

A fragmented world would not be in a position to stop global warming to avoid a Hothouse Earth scenario. A mass extinction of species, which occurred the last time about 65 million years ago, and a great loss of land suitable for permanent living of people would be the consequence.

Possible next steps

This section identifies activities that might allow to avoid a Hothouse Earth scenario.

COP 29 (November 2024) delivered very little, if the goal is to manage the current emergency situation with respect to climate change risks.

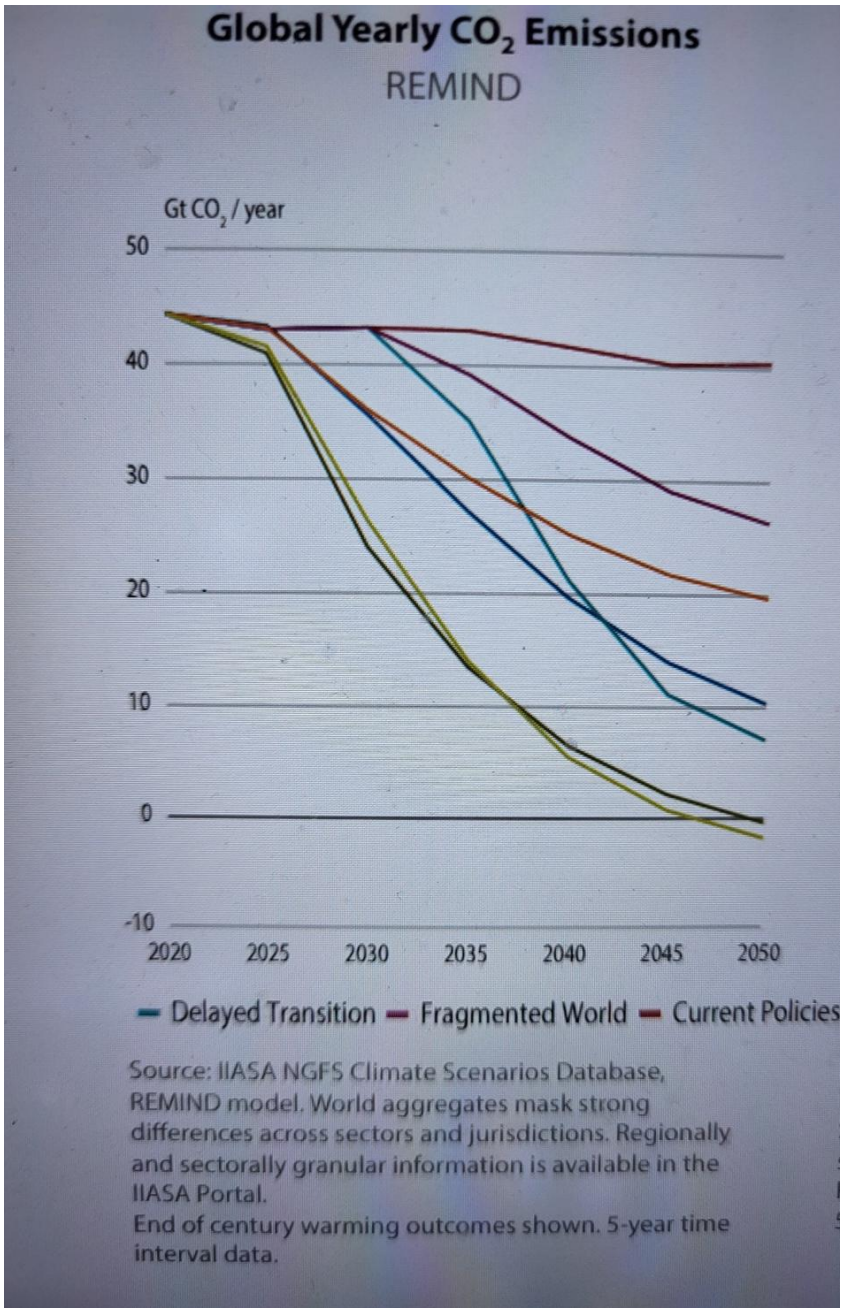
The Baku finance goal – 300 bio USD by 2030 – falls short compared to the requirements which have been estimated to be 1300 bio, and the finalisation of the Art.6 rule will not change a lot on the current NDCs which would need to be strengthened considerably in order to achieve net zero carbon emissions by 2050 – a prerequisite for successful managing the increase in climate change risks.

The COP Presidency had set the right priorities: enhancing ambition and enabling action. However, negotiations were highly confrontational in many key negotiation streams, monetary pledges were much below average, and NDCs and ambition were very weak, as already described above.

Thus COP 29 confirmed the view expressed already in the Global Tipping Points Report 2023 (6) that “currently, there is no adequate global governance at the scale of the threats posed by negative tipping points” and that “the world is on a disastrous trajectory”.

The NGFS scenario “delayed transition” assumes that it will require under the current governance system, which consists mainly of the IPCC and the UNFCCC, about 20 years from now to move the world into the right direction (see figures 2 and 3). It is quite likely that within the decades until global net zero GHG emissions will be achieved, several tipping points will have been crossed already and that the temperature increase will be even higher than indicated in the figures 2 and 3 due to positive feedback mechanisms.

Figure 3 Global yearly CO_2 emissions



Global warming will continue until net global GHG emissions have been achieved. The following activities are helpful to meet this goal and to control climate change risks: GHG emissions reductions, e.g. by phasing out the use of fossil fuels and by substituting those by renewables; use of alternatives to high GHG emitting processes, materials, practices and services; counterbalancing of residual GHG emissions through appropriate high-quality removals and storage; working towards a state in which removals exceed GHG emissions.

The International Workshop Agreement IWA 42 (11) provides some guidance for organizations on the first four actions identified above. ISO 14068-1 (12) specifies also requirements for achieving and demonstrating carbon neutrality for goods and services.

Globally net negative emissions are required in order to address overshooting of a still safe global warming level and will reduce the concentration of CO_2 in the atmosphere to a safe level. This level might be less than the level corresponding to a warming of 1.5°C given the uncertainties of the temperature level of tipping points, e.g. AMOC.

In addition to these mitigation efforts adaptation to a global warming of about 1.7°C (the likely range of overshooting) is necessary in order to avoid as much as possible loss and damage due to extreme weather events.

The International Standard ISO 14093 (Mechanism for financing local adaptation to climate change —Performance-based climate resilience grants — Requirements and guidelines (13)), offers an approach and a methodology for a country-based mechanism to channel climate finance to subnational authorities. Such action is intended to support climate change adaptation and to increase local resilience in a cost-effective manner.

It becomes evident – see the open letter of scientists (8) that not only the level of global warming in the next 100 years is relevant in order to avoid dangerous climate change but also the level of overshooting which means the level of warming in the coming decades. This implies that policy decisions should not only be based on a metrix such as Global Warming Potential 100 but on a metrix which allows to control global warming in 10 and 20 and 30 years as well.

Therefore, activities such as the decision of the IPCC to prepare a Special Report on short lived climate forcers is very relevant. Short lived climate forcers are chemically reactive compounds with short (relative to CO_2) atmospheric lifetimes (from hours to about two decades). They contribute significantly to global warming and the reduction of their concentration in the atmosphere results in much more rapid reduction of global warming compared to mitigation of CO_2. Over time scales of 10 to 20 years, the global temperature

response to a year's worth of current emissions of SLCFs is at least as large as that due to a year's worth of CO_2 emissions. This Special Report is planned to be released at the end of 2027 (24).

Additional mitigation actions, resulting in quick cooling, or at least a slowing down of further warming have been suggested related to radiative forcing management. With comprehensive climate accounting, SCS Global Services' Heat Reduction Initiative claims to target all sources of global warming, including methane, nitrous oxide (N_2O), black carbon, and hydrofluorocarbons (HFCs) and other non-emission factors such as albedo (Earth's reflectivity) to slow global warming faster (14). This initiative excludes SRM explicitly.

Geoengineering

It has to be noted that as climate change impacts intensify, the debate over what safe, effective national and international geoengineering policies should look like has intensified among academics, regulatory and advisory bodies and researchers.

A Swiss-led proposal to the UN Environment Assembly (UNEA-6; 26 February – 1 March 2024) to establish an expert group on solar radiation management (SRM) proved divisive and was eventually withdrawn (27).

A Stratospheric Controlled Perturbation Experiment (SCoPEx), a scientific experiment to advance understanding of stratospheric aerosols that could be relevant to solar geoengineering, was cancelled in March 2024 (28).

Launching reflective aerosols into the atmosphere above the poles would require expansion of the world's most northerly and southerly airports (29).

In October 2024, the Climate Overshoot Commission published the policy paper "Reducing the Health Risks of Climate Overshoot" (15). This policy paper identifies the following five key policy recommendations, including one recommendation related to geoengineering: (a) Significantly increase global climate finance to meet the urgent needs of health systems and fund adaptation efforts to deal with climate overshoot; (b) Enhance global governance and multilateral systems to tackle health challenges exacerbated by climate overshoot, focusing on supporting and fulfilling financial pledges; (c) Set fossil fuel phase-out and carbon removal as key objectives to protect public health; (d) Adopt a comprehensive, systems-based approach to effectively adapt and decarbonize health systems, addressing every aspect of healthcare, from supply chains to training health workers, while prioritizing the quality of care and

individual outcomes; (e) Carefully explore solar radiation modification (SRM) research, governance, and public health risks, and any potential benefits.

Scientists continue trying to find out if geoengineering can help cool off a dangerously warming planet without triggering harmful effects.

Some scientists warn, geoengineering is too risky and want field research to be stopped (25). Two risks associated with SRM – and in particular stratospheric aerosol injection (SAI) – relate to the risk of so-called moral hazard (lack of incentive to reduce GHG emissions against risk where one is protected from its consequences thanks to SAI). The second risk associated with SAI is the so-called termination risk. Depending on the amount of warming masked, SAI has a distinctly high latent risk due to termination shock. A temperature rise of 6 degrees in the space of centuries would be an order of magnitude faster than the warming experienced during the Great Permian Dying (33).

Others say research is urgently needed so decision-makers can understand geoengineering options and risks, so as to make informed choices. For now, few definitive road signs exist to guide policymaking.

During COP 29 the Degrees Initiative organized a side event on Solar radiative management (SRM), one of the considered geoengineering options (16). During this event, speakers highlighted the need to build capacity in the Global South in solar geoengineering, which aims to limit global temperature increases by reflecting sunlight back into space; that SRM's inclusion in policy discussions raises significant risks and uncertainties; that an open and inclusive dialogue on governance and research issues surrounding SRM is required; that the Global South needs to be empowered to actively participate in global discussions on solar geoengineering; that when SRM is applied prudently and in conjunction with net-zero objectives, solar geoengineering could mitigate risks like sea-level rise or intense storms, but careless deployment could take attention away from mitigation efforts, overcool the planet, or disrupt regional weather patterns, the event highlighted.

Speakers also mentioned the need for an ethical framework to guide SRM research and decision making; inclusion of SRM in successive Intergovernmental Panel on Climate Change (IPCC) assessments; and growing civil society interest in SRM.

In October 2024, the American Geophysical Union (AGU), in collaboration with a global panel of experts, released the Ethical Framework Principles for Climate Intervention Research—an essential and urgent resource to guide climate intervention measures that may be needed in addition to emissions reduction. The Ethical Framework builds on similar

initiatives, including the Oxford Principles (2009), the Asilomar recommendations (2010), the Tollgate Principles (2018), and the draft resolution on geoengineering and its governance presented at the United Nations Environment Assembly in 2019 (17, 18).

Notes from a workshop on mitigating the effects of climate change through the global geoengineering strategy of solar radiation modification (September 2024, organized by Resources for the Future and the Harvard Solar Geoengineering Research Program at the Salata Institute for Climate and Sustainability) try to inject reality into debates about Solar Radiation Modification (SRM) (26).

It seems important to have a reasonably good understanding of risks to be in a position to compare the risks of stratospheric aerosol injection (e.g. unequal cooling, rapid temperature rise if being stopped suddenly, potential damage to the stratospheric ozone layer, disagreement on governance resulting in geopolitical and security tensions) and the growing risks of a rapidly warming planet.

The key question is: how strong do we need to be pushed by nature in order to respond to the increasing climate change risks in a much more meaningful manner, compared to current practice.

The agreement at COP 29 in Baku on an overall climate financing target to reach “at least $1.3 trillion by 2035” is a very important step (30). Although it remains to be seen whether the international community, including also the private sector and developing countries that are in a position to provide additional finance, will be willing to live up to this goal. It can be expected that Loss and damage as well as carbon dioxide removal will require such huge amount of money for decades – until we managed to reduce GHG levels in the atmosphere to a safe level. If we are successful to reduce the costs of direct air capture and removal of carbon to 100 USD/t CO_2 and if we build the infrastructure to remove 10 Gt CO_2 per year this will require the amount of 1 trillion USD and will take a decade for the removal of 100 Gt CO_2 from the atmosphere. Therefore, it is so important to make use of all cheaper option as fast as possible in order to limit the burden for future generations.

Demonstrated willingness to pay year by year such amount of money would be a prerequisite to deploy SRM and SAI in particular. Because natural removal processes would work an order of a magnitude slower – and only few species would survive such temperature change as expected under a Hothouse Earth scenario. The willingness to pay might depend on the ratio between the social cost of carbon and the cost of Direct Air Capture and permanent storage of

carbon; currently the ratio is about ~ 1/3 but it can be expected that sooner or later this ratio will become larger than 1.

Conclusions

The world is unfortunately on track to a Hothouse Earth Scenario. Pushing the world on a transformative trajectory preventing dangerous climate change impacts should become the core goal of policies at all levels.

Actions should include i.a. enhanced investments in research addressing all possible options to control the increasing climate change risks, and implement the ethical framework for climate intervention; mandate the IPCC to prepare a Special Report, to provide the basis for a policy discussion on governance including a comparative risk assessment of climate change impacts versus the potential impacts of climate intervention, e.g. by stratospheric aerosol injection; strengthen international co-operation to speed up mitigation and adaptation in all countries – including agreement on measures of enforcement (e.g. by cross-border tax adjustments in case of unequal mitigation goals); provide incentives and foster private investments to speed up and upscale deployment of mitigation and adaptation action worldwide; move financial resources from consumption and production to management and reduction of climate change risks; improve communication of the public, including NGOs on the risks of climate change and the options to reduce those; accelerate the global transition to net-zero emissions by 2050 by innovative strategies and collaborative partnerships by use of voluntary market mechanisms with high environmental integrity; develop information material for all levels of education to properly inform about climate change risks now and in the future as well as about the options to reduce those.

References

[1] WMO - State of the Climate 2024 – Update for COP 29 https://wmo.int/publication-series/state-of-climate-2024-update-cop29

[2] Periodicities in Solar Activity, Solar Radiation and Their Links with Terrestrial Environment Valentina V. Zharkova, Irina Vasilieva, Simon J. Shepherd, Elena Popova Natural Science, 2023, Vol. 15, (No. 3), pp: 111-147; https://www.scirp.org/pdf/ns_2023033010033932.pdf

[3] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647. https://www.ipcc.ch/report/sixth-assessment-report-cycle/

[4] UNEP Emissions Gap Report 2024: No more hot air … please! https://www.unep.org/resources/emissions-gap-report-2024

[5] Carbon Brief: COP29: Key outcomes agreed at the UN climate talks in Baku https://www.carbonbrief.org/cop29-key-outcomes-agreed-at-the-un-climate-talks-in-baku/

[6] T. M. Lenton, L. Laybourn, D.I. Armstrong McKay, S. Loriani, J.F. Abrams, S.J. Lade, J.F. Donges, M. Milkoreit, S.R. Smith, E. Bailey, T. Powell, L. Fesenfeld, C. Zimm, C.A. Boulton, J.E. Buxton, J.G. Dyke, A. Ghadiali (2023), Global Tipping Points Report 2023: 'Summary Report' in [T. M. Lenton, D.I. Armstrong, McKay, S. Loriani, J.F. Abrams, S.J. Lade, J.F. Donges, M. Milkoreit, T. Powell, S.R. Smith, C. Zimm, J.E. Buxton, L. Laybourn, A. Ghadiali, J.G. Dyke (eds), 2023, The Global Tipping Points Report 2023.] University of Exeter, Exeter, UK. https://report-2023.global-tipping-points.org/summary-report/narrative-summary/

[7] L. Caesar*, B. Sakschewski*, L. S. Andersen, T. Beringer, J. Braun, D. Dennis, D. Gerten, A. Heilemann, J. Kaiser, N.H. Kitzmann, S. Loriani, W. Lucht, J. Ludescher, M. Martin, S. Mathesius, A. Paolucci, S. te Wierik, J. Rockström, 2024, Planetary Health Check Report 2024. Potsdam Institute for Climate Impact Research, Potsdam, Germany. https://www.stockholmresilience.org/publications/publications/2024-10-27-planetary-health-check-report-2024.html

[8] https://en.vedur.is/media/ads_in_header/AMOC-letter_Final.pdf

[9] Network for Greening the Financial System Workstream on Scenario Design and Analysis - NGFS long-term scenarios for central banks and supervisors November 2024 https://www.ngfs.net/sites/default/files/medias/documents/ngfs_scenarios_main_presentation.pdf

[10] Hitze, Dürre, Überschwemmungen – 2024 als Weckruf: IIASA-Generaldirektor Professor Dr. Hans Joachim Schellnhuber warnt beim Nachhaltigkeitsfrühstück der Hagelversicherung vor dramatischen Entwicklungen und fordert proaktive Maßnahmen beim Klima- und Bodenschutz; Wien, 5. November 2024

[11] ISO IWA 42:2022(en) Net zero guidelines

[12] ISO 14068-1 Climate change management — Transition to net zero Part 1: Carbon neutrality

[13] ISO 14093:2022 Mechanism for financing local adaptation to climate change — Performance-based climate resilience grants — Requirements and guidelines

[14] SCS Global Services https://www.heatreduction.com/

[15] Climate Overshoot Commission Policy Paper Reducing the Health Risks of Climate Overshoot https://www.overshootcommission.org/_files/ugd/0c3b70_1ac33b2c4ea844dea6d93324ce9d8a90.pdf

[16] Solar Radiation Modification: A Conversation on Governance and Research, 11 November 2024 | Baku, Azerbaijan https://enb.iisd.org/events/solar-radiation-modification-cop29

[17] https://www.agu.org/learn-about-agu/about-agu/ethics/ethical-framework-for-climate-intervention

[18] https://agu.mediavalet.com/portals/ethicalframework

[19] Oxford Open Climate Change, 2024, 4(1), kgae008 https://doi.org/10.1093/oxfclm/kgae008 July 2024

[20] Xinhua, 5 October 2024 https://english.news.cn/20241005/dc3c455c36f947489c22291aaf5b7b9a/c.html

[21] Ураганы и засухи в России происходят в два раза чаще - в чем причина РИА Новости (Russia), 14 November 2024 https://crimea.ria.ru/20241114/uragany-i-zasukhi-v-rossii-proiskhodyat-v-dva-raza-chasche---v-chem-prichina-1141858845.html

[22] Gloria Dickie, Reuters, 12 November 2024 https://www.reuters.com/sustainability/climate-energy/cop29-what-is-latest-science-climate-change-2024-11-12/#:~:text=The%20last%20global%20scientific%20consensus,are%20unfolding%20faster%20than%20expected.

[23] https://climate.copernicus.eu/copernicus-second-warmest-november-globally-confirms-expectation-2024-warmest-year

[24] https://www.ipcc.ch/site/assets/uploads/2024/06/006_SB60_IPCC_WGI_TFI.pdf

[25] https://www.climatechangenews.com/2024/12/09/eu-should-push-for-global-deal-not-to-deploy-solar-geoengineering-advisors-say/

[26] Joseph E. Aldy, Milan Elkerbout, Tyler Felgenhauer, and William Pizer; https://www.resources.org/common-resources/injecting-reality-into-debates-about-solar-radiation-modification/?utm_source=substack&utm_medium=email

[27] https://legal-planet.org/2024/03/08/the-global-conversation-about-solar-geoengineering-just-changed/?utm_source=substack&utm_medium=email

[28] Jinnah, Sikina, Louise Bedsworth, Shuchi Talati, Michael B. Gerrard, Michael Kleeman, Robert, Lempert, Katharine Mach, Leonard Nurse, Hosea Olayiwola Patrick, and Masahiro Sugiyama. 2024. Final Report of the SCoPEx Advisory Committee. 18 March 2024. SCoPEX Advisory Committee. Available at: https://scopexac.com/finalreport

[29] https://www.harvardmagazine.com/2024/04/climate-tipping-elements?utm_source=substack&utm_medium=email

[30] https://www.carbonbrief.org/cop29-key-outcomes-agreed-at-the-un-climate-talks-in-baku/

[31] https://www.eco-business.com/news/15c-for-planet-1c-for-people-scientists-step-up-climate-warning/

[32] Scientists struggle to explain record surge in global heat (2024, December 16) retrieved16 December 2024 from https://phys.org/news/2024-12-scientists-struggle-surge-global.html

[33] https://www.geoengineeringmonitor.org/wp-content/uploads/2021/04/stratospheric-aerosol-injection.pdf