# Transcript Keynote

## Professor Johan Rockström, Berlin Aviation Summit, 4 June 2024

### Scale and speed

The scientific conclusion is today unequivocal and clear, on a global transformation at a record pace can direct the world away from unacceptable global environmental impacts on people across the world, and potentially unmanageable conditions for current and future generations on Earth.

The only "currency" that counts today is "speed and scale", to return the world within the safe operating space of Planetary Boundaries.

Here is a summary of the latest scientific data and assessments of rising Earth risks.

### 1.2°C-1.48°C-1.5°C

We have reached a global mean surface temperature (GMST) rise of 1.2°C (WMO, 2024). This is the ten year moving average, and the reference in relation to the Paris Agreement, where all the world's countries have agreed to limit warming to 1.5°C of GMST. 1.2°C is the warmest temperature on Earth over the past 100,000 years (IPCC AR6, 2021), and this heat is starting to cause major social and economic impacts across the world.

In 2023, due to a human reinforced El Niño, we experienced a so far record high, never before experienced temperature of 1.48°C. WMO in June 2024, showed that the GMST over the past 12 months have been > 1.5°C (WMO, 2024). This means that we for the first time, have experienced a "1.5°C world". And the costs are massive. Just in 2023, the invoices set back by the Planet, through droughts, floods, heatwaves, fires, reinforced storms, accumulate to 250 billion USD for natural disasters worldwide (Munich Re, 2024).

### Double digit impacts on the global economy

Recent economic analyses (Kotz et al., 2024), shows that we, already today, are committed to a loss of income of 19% of the global economy by 2050, corresponding to 38 trillion USD. The social cost of carbon (SCC), the estimate of the damage caused by climate change today to people, amounts to a mean estimate of 185 USD/ton CO2 (Rennert et al., 2022). This is to be compared to the world's highest market price on carbon of 80-100 USD/ton CO2 in the EU ETS.

An additional, very worrying trend, is that the rate of global warming is accelerating. From 1970-2008, GMST rose by 0.18°C/decade. From 2010 onwards, the rate has jumped up to 0.3°C/decade (Forster et al., 2024). Science does not have the explanation for this, but it is a worrying sign of the instability of the Earth system. This worry is accentuated by the current observations in Earth's most important stabilizing system - the Ocean.

### Deeply worrying Ocean trends

The ocean functions as Earth's prime provider of resilience. 90% of the heat caused by human GHG emissions is not in the atmosphere, it is absorbed in the Ocean. 25% of carbon dioxide is sequestered in the ocean. These are Earth's largest dampening (cooling factors). Over the past 50 years, with rising energy imbalance due to global GHG emissions, ocean temperatures have been rising by about 0.6°C over the last four decades and about 0.9°C since the pre-industrial level. (Copernicus, 2023) This is a worrying indicator - of marine systems increasingly subject to stress, but well understood and reflected in global climate models. Then suddenly, something happens in 2023. Sea Surface Temperature (SST) jumps off the charts. The oceans warming suddenly jumps almost 0.3°C in just a year (Copernicus, 2023). And then, in 2024, the trend just continues, even further away from historic trends. What is happening? The honest (scientific) answer, is we do not know. Climate models have not predicted anything like this, and there are no clear explanations, yet. Could it be that the ocean is starting to show signs of instability? We do not know. What we do know, is that this should be taken as a warning sign.

## Earth Resilience

One reason the observations in the ocean are so worrying, is that we see similar signs in other systems on Earth that buffer (dampen) the impacts of global warming. Permafrost systems in Siberia are rapidly thawing, releasing methane and carbon; Polar Ice sheets and inland glaciers are melting fast, causing shifts in reflectivity of incoming solar radiation (shift in Albedo towards darker surface colors) absorbing more heat from the Sun; large forest systems, like the Brazilian part of the Amazon is shift from carbon sink to carbon source, i.e., instead of contributing to cool the planet, is part of warming it.

All these are signs of a planet under stress. A planet that is losing resilience.

## Moving rapidly towards Tipping Points

The big risk when losing resilience is that tipping points are crossed. Scientifically we have today mapped 16 climate tipping element systems, confirmed in the IPCC (IPCC AR6 WG1 Table 4.10, 2021). These tipping elements are large biophysical systems on Earth that contribute to regulate the state of the climate system, and they have evidence of multiple stable states - push them too far and they will cross physical thresholds (when feedback dynamics that govern their functioning change direction), and the system will irreversibly (unstoppably) shift towards a new state. The "drama" is that all tipping element systems are configured (in the Holocene - the state of the Planet since we left the last Ice Age 18000 years ago) in a way that they dampen/reduce warming caused by stress. If tipping points are crossed, feedbacks shift from dampening/cooling to amplifying/warming. Take one example, the Greenland Ice sheet. In its stable Holocene state, it reflects back some 90% of incoming solar radiation back to Space (thanks to is white surface). In a melted state, at a given point, the darker "liquid" surface, will absorb more heat than it reflects. A tipping point is crossed, and the Ice Sheet goes into a mode of unstoppable "self-melting".

Science has now mapped the 16 climate tipping elements, and even been able to assess the GMST when they are likely to cross their physical tipping points. The following tipping elements are likely to cross tipping points already at 1.5°C of GMST:
- The Greenland Ice Sheet (GIS),
- The West Antarctic Ice Sheet (WAIS),
- Abrupt thawing of Permafrost,
- Loss of all Tropical Coral Reef systems,
- Collapse of the Labrador Current.

Just the melting of the Greenland Ice Sheet alone holds a potential of 7.4 meters sea-level rise (NSIDC, 2023)[1]. It would not flood the world in a tsunami, the moment the tipping point is crossed, but the rate of melting would increase, and above all, the melting would be unstoppable. We would be handing over, to all future generations and less and less livable planet.

This is why, science can be very clear today. 1.5°C is not a goal or target. It is a physical limit. We should do everything we can to hold this climate planetary boundary.

## Pathway to a manageable future?

### We are rapidly running out of global carbon budget

The latest assessment (June 2024) shows that the remaining global carbon budget to have a chance of holding the 1.5°C limit has rapidly decline from ≈ 500 $GtCO_2$ in the IPCC AR6 (budget by year 2020), to a remaining budget of only 200 $GtCO_2$ today (MCC-Berlin, Carbon Clock). The reason for this is that the world is not making progress (despite all legally binding commitments from the COP/UNFCCC process). Global emissions continue rising (albeit "only" at ≈ 1 %/yr), when they need to be cut by > 7%/yr. This means we continue to emit approximately 40 $GtCO_2$/yr from burning oil, coal and gas, which gives us only 200/40 = 5 years at current rate of emissions, until the budget is consumed (and we lose the chance of holding 1.5°C). According to the International Energy Agency (IEA), emissions were rising about 1.1% in 2023 (IEA, 2024).

For an orderly phase out of fossil-fuels, within the remaining budget, is what translates to the scientific pathways of cutting global emissions by 50% by 2030, and continue cutting emissions at least by half each decade, to reach a net-zero world economy no later than 2050 (Rockström et al, 2017).

This is the absolute minimum required.

### Window still open but only after Overshoot

[1] The ice sheet of west Antarctica would push up the oceans by five metres if lost completely. (Naughten et al., 2023)

Still, even if we keep within the remaining global carbon budget, we are inevitably approaching overshoot.

This means that even at best (we phase out fossil-fuels by 2050, we halt degradation of nature, we phase out non-CO2 gases, and we do not cross any tipping points), we will inevitably breach 1.5°C, and have a 3-4 decades long period of overshoot (exceeding 1.5°C with ≈ 0.1-0.3°C) before potentially landing back at 1.5°C of GMST by the end of this century (year 2100) (Warszawski et al, 2021). This is what the only realistic IPCC scenarios show. The best we can accomplish, is 1.5°C with overshoot. The reason for this is that we have already loaded so much energy/heat into the Earth system, that even if we stopped all emissions today, we are already committed to warming exceeding 1.5°C:

What does this imply?
Three key insights emerge:
1) We know with 100 % certainty that this means rising frequency and strength of extreme events. So, the message to the world is this - "buckle up" because we are inevitably facing 30-40 years of rising climate damages to societies across the world. It will - even at best - get worse before it gets better.
2) We will be exceeding the likely threshold when tipping elements like all coral reef systems, the great Ice sheets (GIS/WAIS) and permafrost thawing, shift state from "good" to "bad". Will these tipping elements cope with a period of overshoot? We do not know. It will be a very risky period. Science is required to assess tipping point risks during overshoot - the question being - how long overshoot can e.g., the GIS buffer, without permanently crossing a tipping point?
3) What is it that takes Earth back to 1.5°C after overshoot? What the climate models show is that once GHG emissions are turned off, temperatures will gradually decline, as carbon is absorbed in the biosphere on land and in the ocean. Is this likely to happen? Can we count on Earth resilience - the health of the planet - to continue this "cooling" behaviour? The simply answer is, we do not know. What we do know though, is that our only chance to increase the potential of the Earth system to keep up this buffering service to humanity, is to return to the safe operating space of all Planetary Boundaries.

## Why come back 2100? Planetary Boundaries

This becomes the key message to humanity. The only way to solve the climate crisis - to come back to 1.5°C by the end of the century after overshoot, is to (i) decarbonize the global economy in record pace, and (ii) return back with all the planetary boundaries that provide Earth's resilience, its capacity buffer (dampen) stress, shock and warming.

Of the nine scientifically established planetary boundary processes (that together regulate the stability, resilience and life-support on Earth), six have now been assessed as breached (Richardson et al., 2023). We are not only breaching the climate boundary, we are also breaching the boundaries of Land use change, Freshwater use, Biodiversity loss, Overloading of nutrients (N and P), and over loading of Novel Entities (human created chemical pollutants). In summary, this means that in the midst of the climate crisis, we are undermining the capacity of the living biosphere to buffer the strain caused by the GHG driven global energy imbalance.

This also means, that for any sector in society, be it aviation, ground transport, food industry, retail and tech, all must align business models and value chains within scientifically defined boundaries that cover the entire Earth system. It is not enough to focus only on fossil-fuel phase out, even if the focus is "climate only". For aviation, this e.g., means that bio-jet fuels, a potential "green" substitute for conventional jet-fuels, need to be accounted against freshwater use, biodiversity loss, use of biomass and land use change (not only its positive impacts on reducing CO2 emissions).

## Requires Transformation!! Safe operating space

We have reached a transformative moment. Linear change is no longer an option. As mentioned in the beginning of this short summary, speed and scale are the only currencies that count today. And, shifts have to be systemic and occur across the global economy at record pace. This requires sectors, with mature markets and institutions operating in the global economy - such as aviation - to collaborate in pre-competitive arrangements that set global "rules of the game", such as a global price on carbon (of > 100 USD/ton $CO_2$), phase out date(s) for conventional fuels, investments in R&D for innovation pathways towards new alternative - planetary boundary aligned fuels, etc.

Given the pace and scale of change required, the only way of succeeding is to ensure that the sustainable "offer" is more attractive in terms of prosperity and equity. Interestingly, data shows that this is possible. "Green" solutions are not only good for the planet, they are increasingly competitive (without subsidies), more technologically advanced and thus "modern" and attractive, and have well established benefits for health, security, and social stability. Making the path to a safe landing within Planetary Boundaries, I believe to be the most important narrative required to unleash the innovations, leadership and civil engagement required to tip the scales towards global sustainability.

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