POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

The Planetary Boundaries Framework

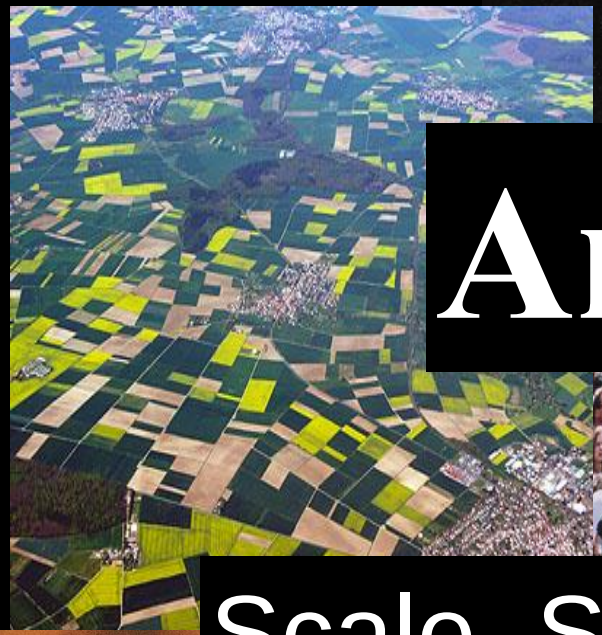
Prof. Dr. Johan Rockström
Director PIK
Professor Earth System Science, University of Potsdam

Member of Leibniz Association

Webinar,
11 June 2020

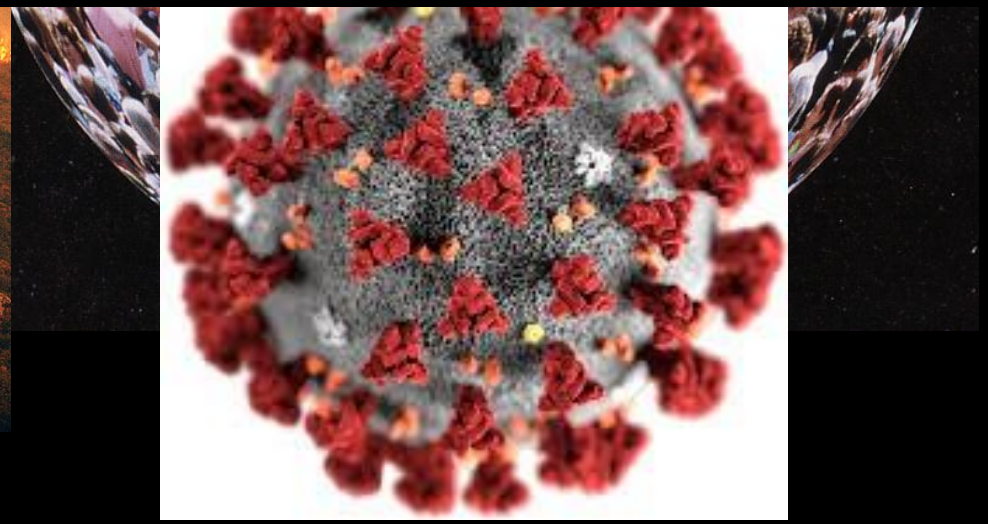
Universität Potsdam
Institut für Umweltwissenschaften und Geographie

A biosphere shaped by humans



Anthropocene

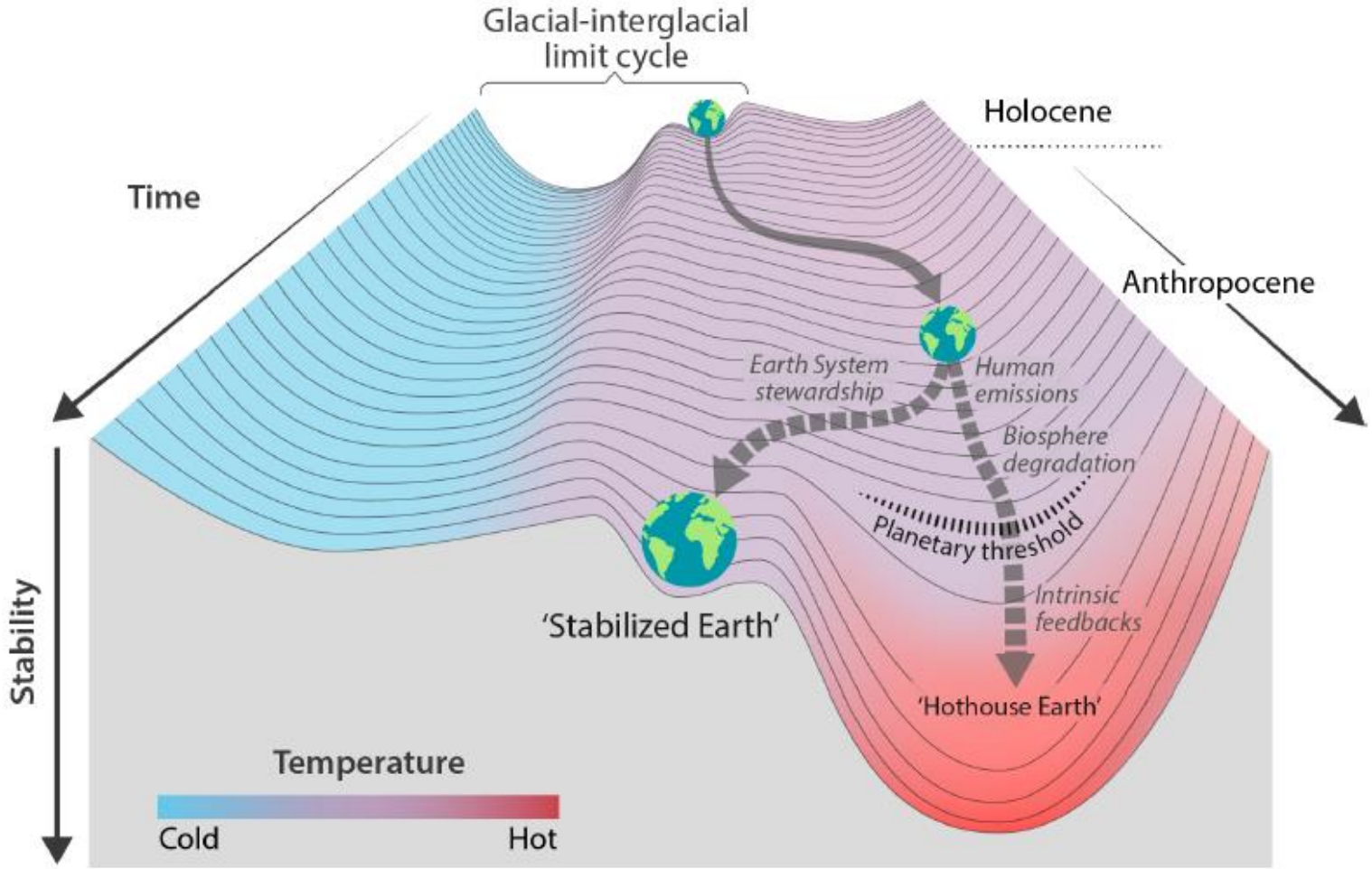
Scale, Speed, Inter-connections



Trajectories of the Earth System in the Anthropocene

Will Steffen[a,b]*, Johan Rockström[a], Katherine Richardson[c], Timothy M. Lenton[d], Carl Folke[a,e], Diana Liverman[f], Colin P. Summerhayes[g], Anthony D. Barnosky[h], Sarah E. Cornell[a], Michel Crucifix[i,j], Jonathan F. Donges[a,k], Ingo Fetzer[a], Steven J. Lade[a,b], Marten Scheffer[l], Ricarda Winkelmann[k,m], Hans Joachim Schellnhuber[a,k,m]*

Proceedings of the National Academy of Sciences of the United States of America, 2018



Stability landscape showing the pathway of the Earth System out of the Holocene

Climate Crisis

Health Crisis

Ecosystem Crisis

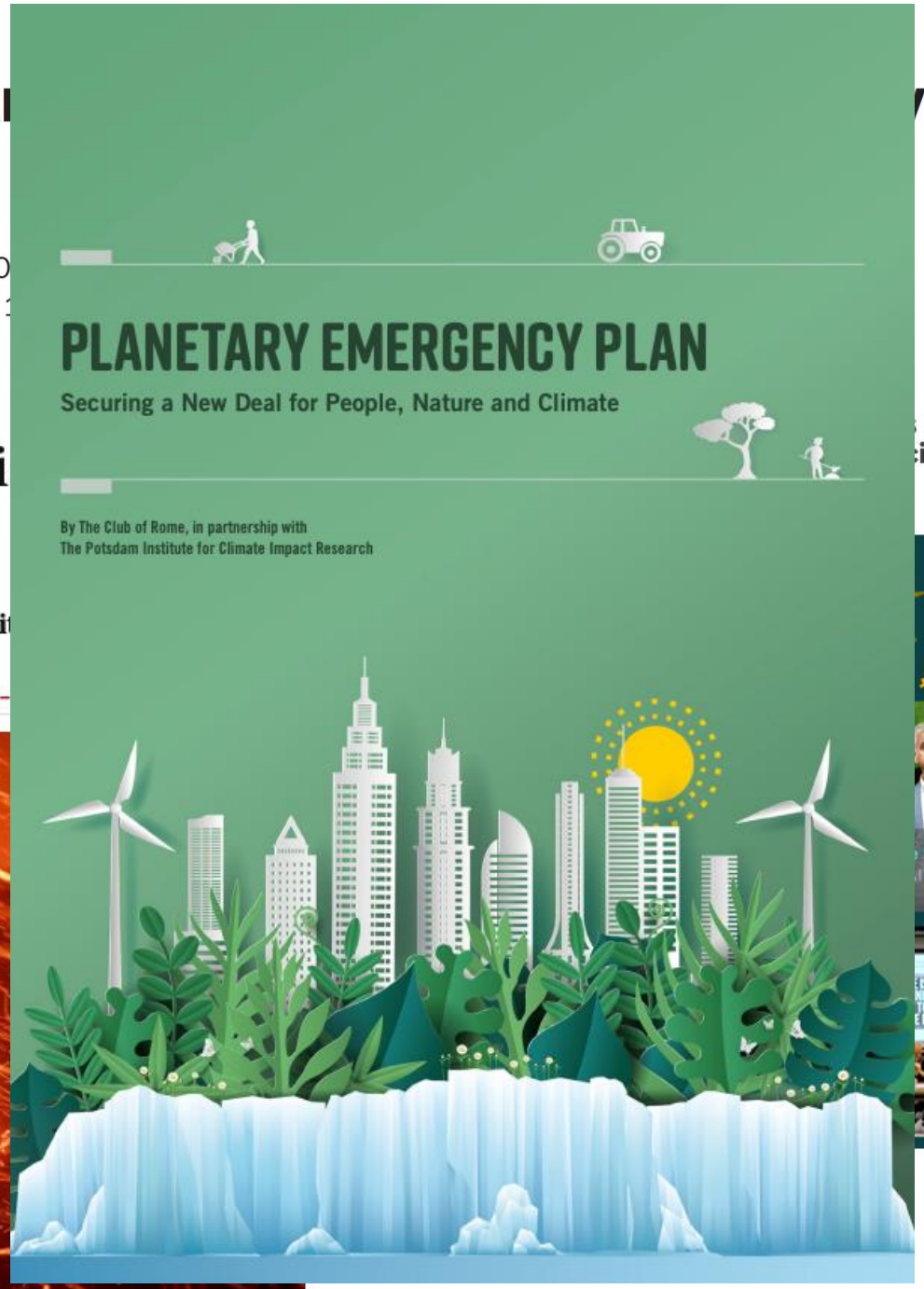
World Scientists' War

WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THO
AND 11,258 SCIENTIST SIGNATORIES FROM 1

Climate crisis: 11,000 scienti
'untold suffering'

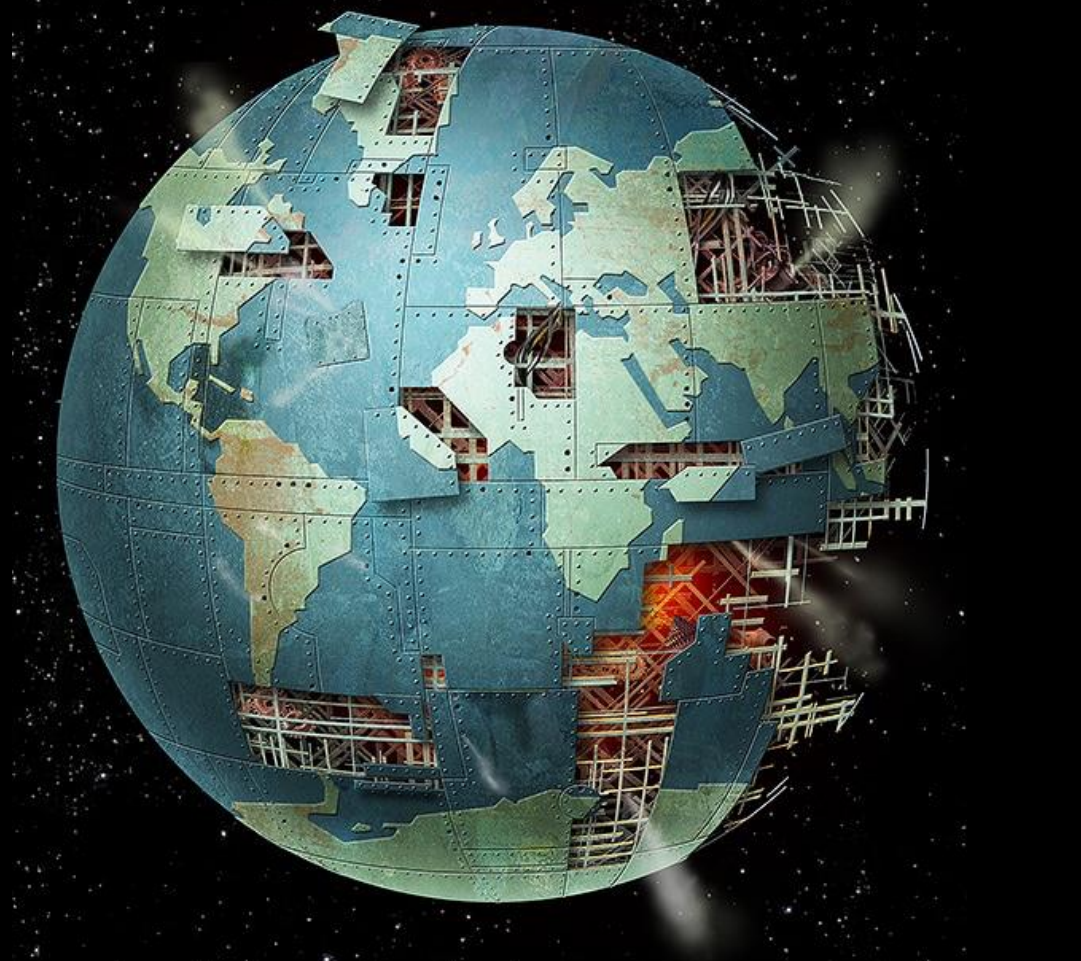
**Statement sets out 'vital signs' as indicators of magni
climate emergency**

Most countries' climate plans 'totally inadequate' –



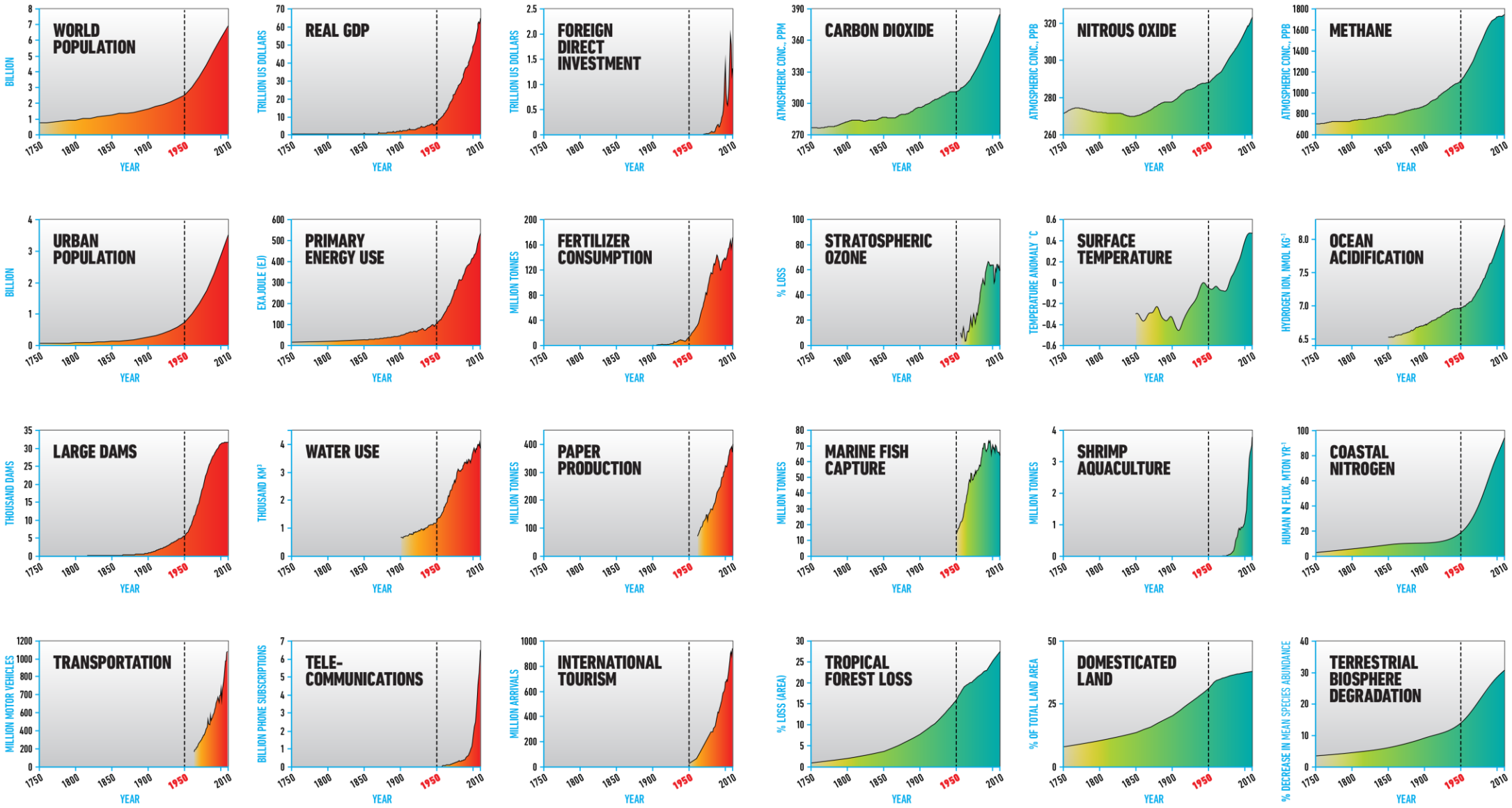
in 1,180 jurisdictions and local
citizens

Welcome to the



Anthropocene

The Great Acceleration

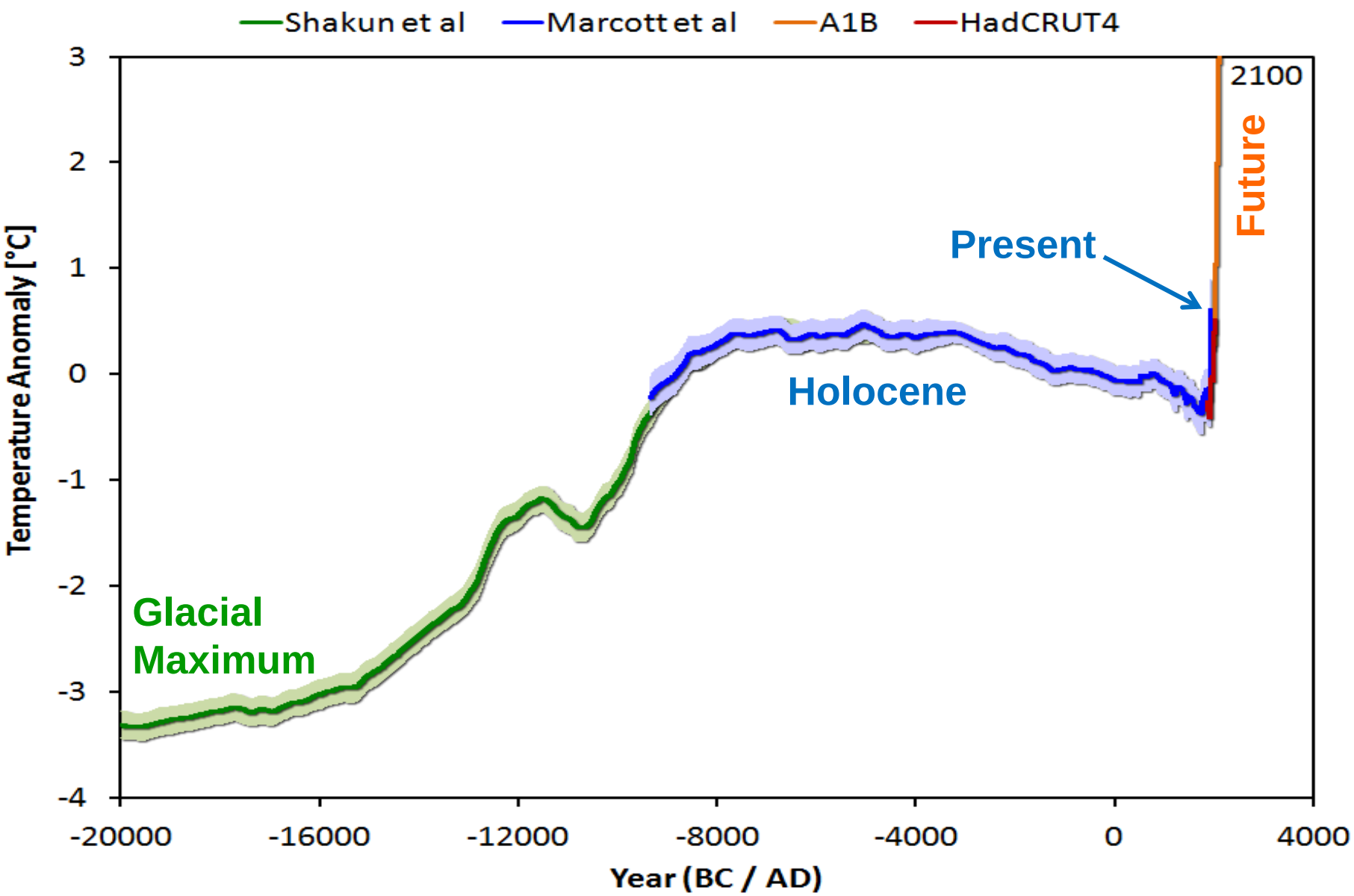


Steffen, Broadgate, Deutsch, Gaffney, Ludwig *Anthr. Review 2015.* Image: Globaia

Are We Leaving the

Garden of Eden?

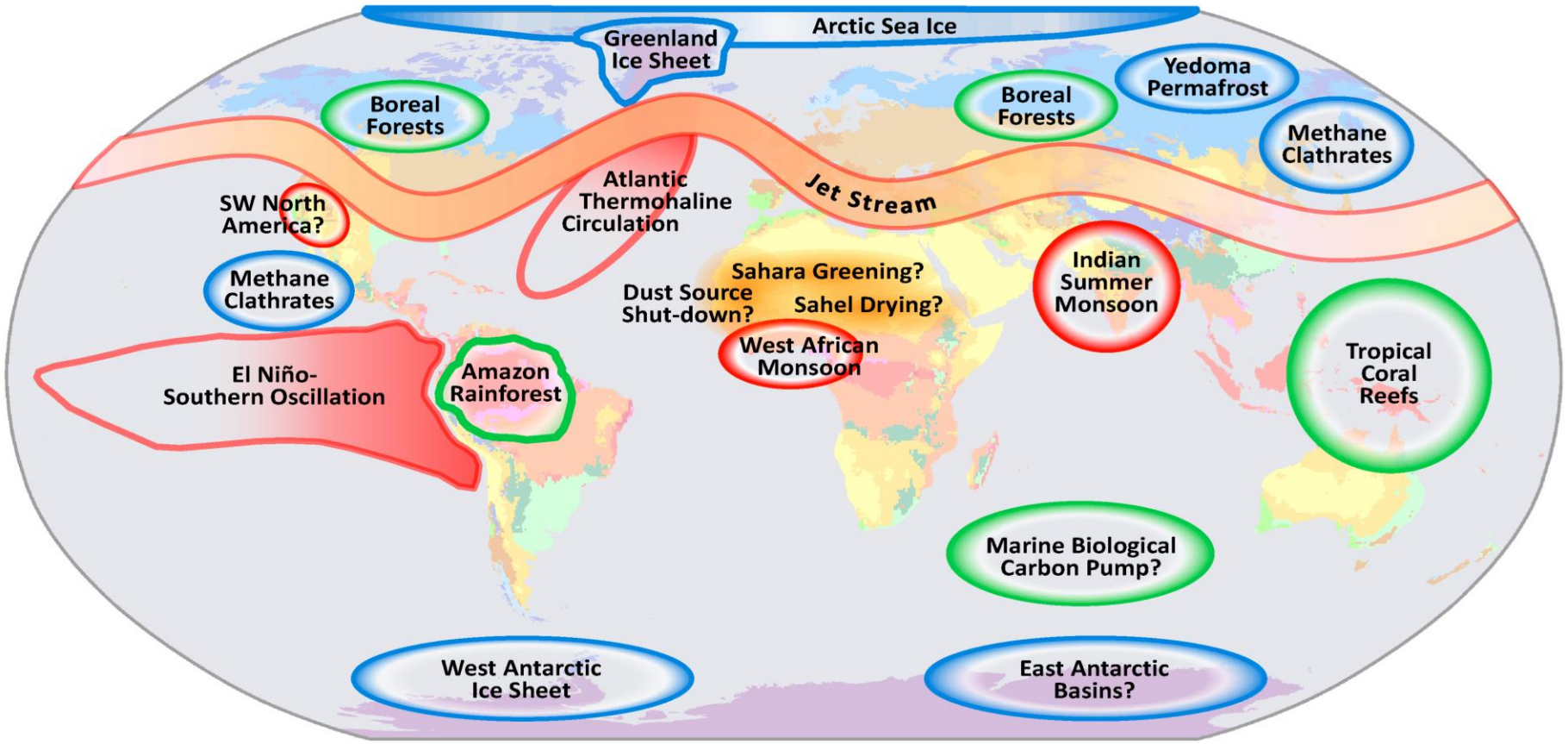
Global Temperature since the Last Ice Age



Tipping Points

are Real

Looming Risks: Tipping Elements in the Earth System



Cryosphere Entities

Circulation Patterns

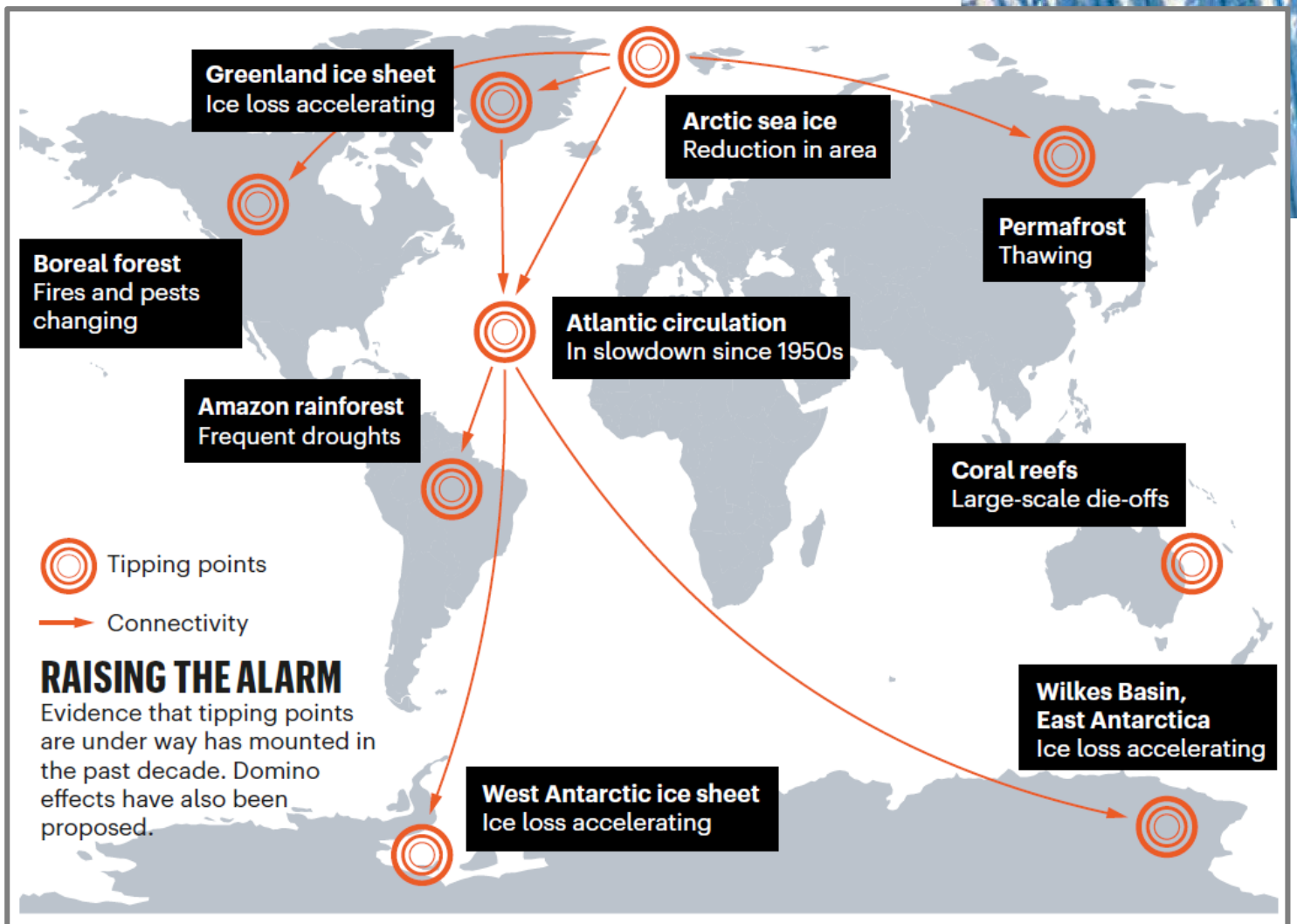
Biosphere Components

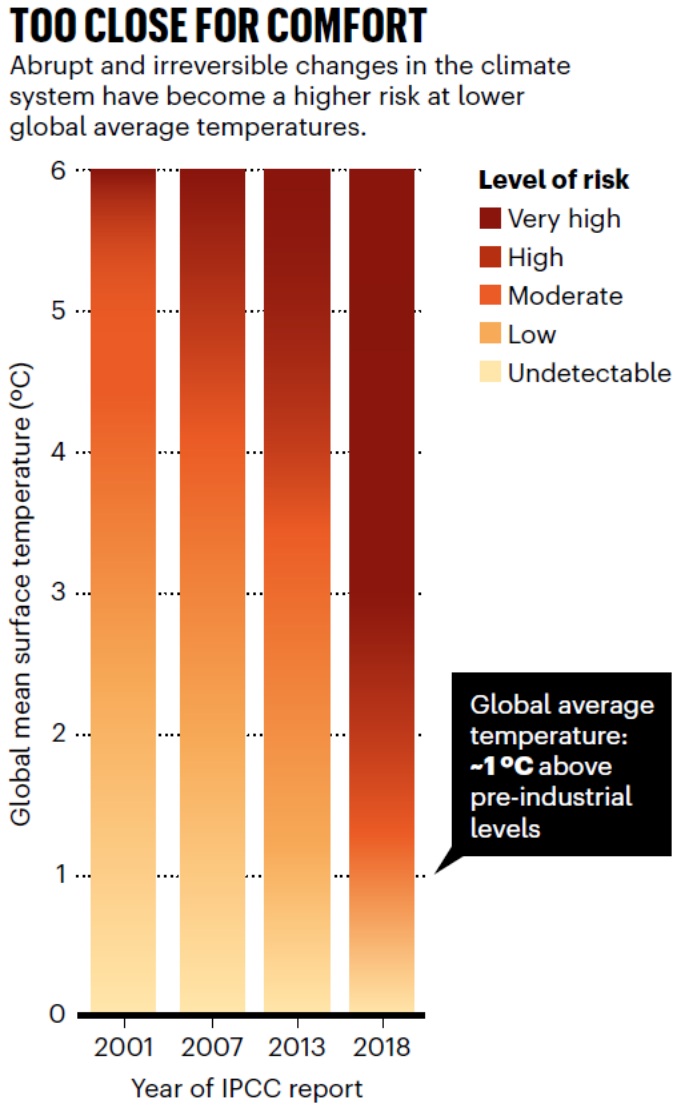
Köppen Climate Classification

Ar Am Aw As BS BW Cr Cs Cw Do Dc Eo Ec FT FI

Climate tipping points — too risky to bet against

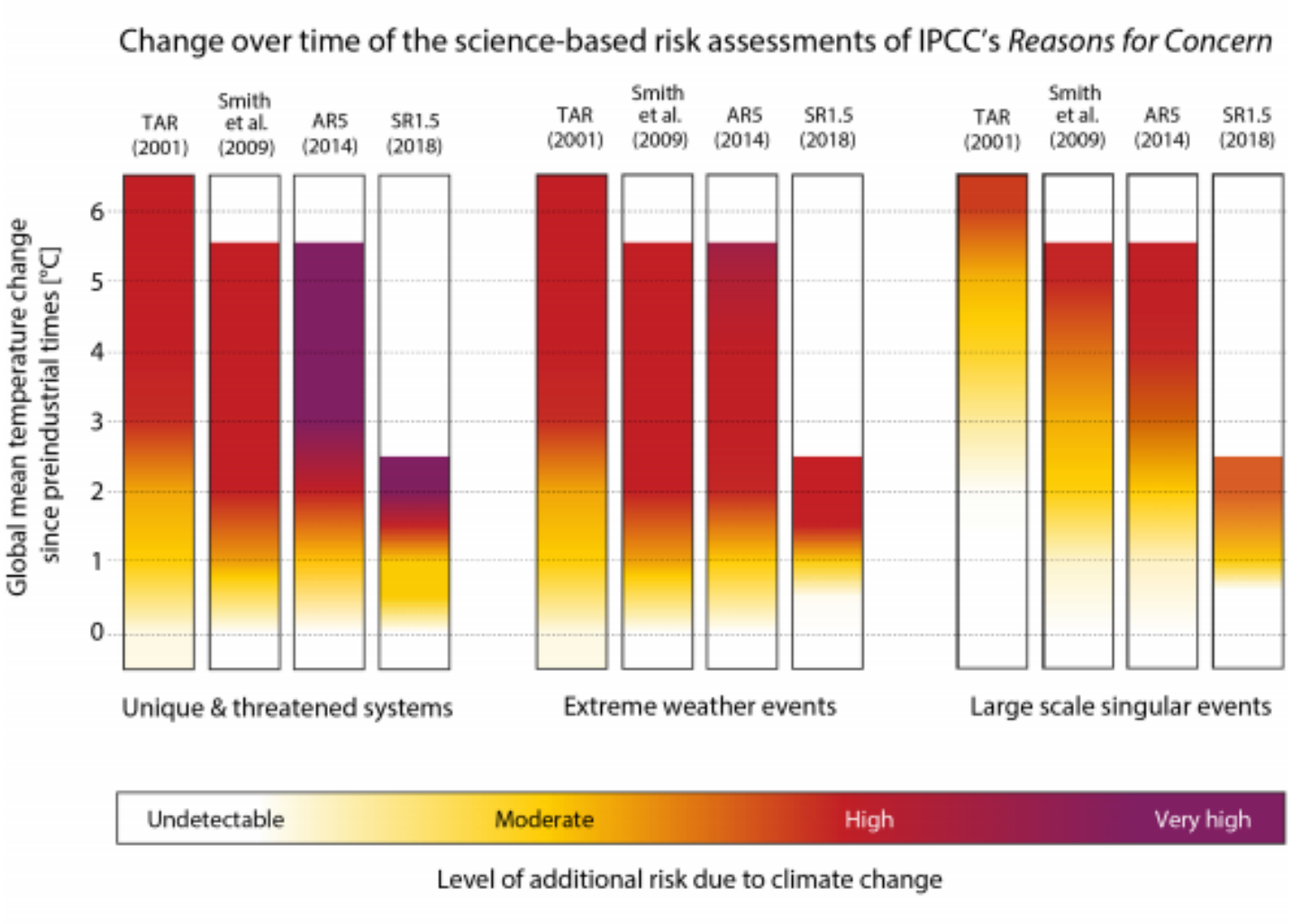
Timothy M. Lenton, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen & Hans Joachim Schellnhuber





Nature, 28 November, 2019


United In Science
High-level synthesis report of latest climate science information by global partner organizations convened by the Science Advisory Group of the UN Climate Action Summit 2019
futureearth
ipcc
UN environment


Change over time of the science-based risk assessments of IPCC's *Reasons for Concern*
TAR (2001)
Smith et al. (2009)
AR5 (2014)
SR1.5 (2018)
Global mean temperature change since preindustrial times [°C]
0
1
2
3
4
5
6
Unique & threatened systems
Extreme weather events
Large scale singular events
Undetectable
Moderate
High
Very high
Level of additional risk due to climate change

Two Questions Guide the Planetary Boundaries Framework:

1. Which are the biophysical systems and processes that regulate the state of the Earth System?

2. What are the quantitative boundaries for each of these systems/processes that define a safe operating space of a stable Earth System?

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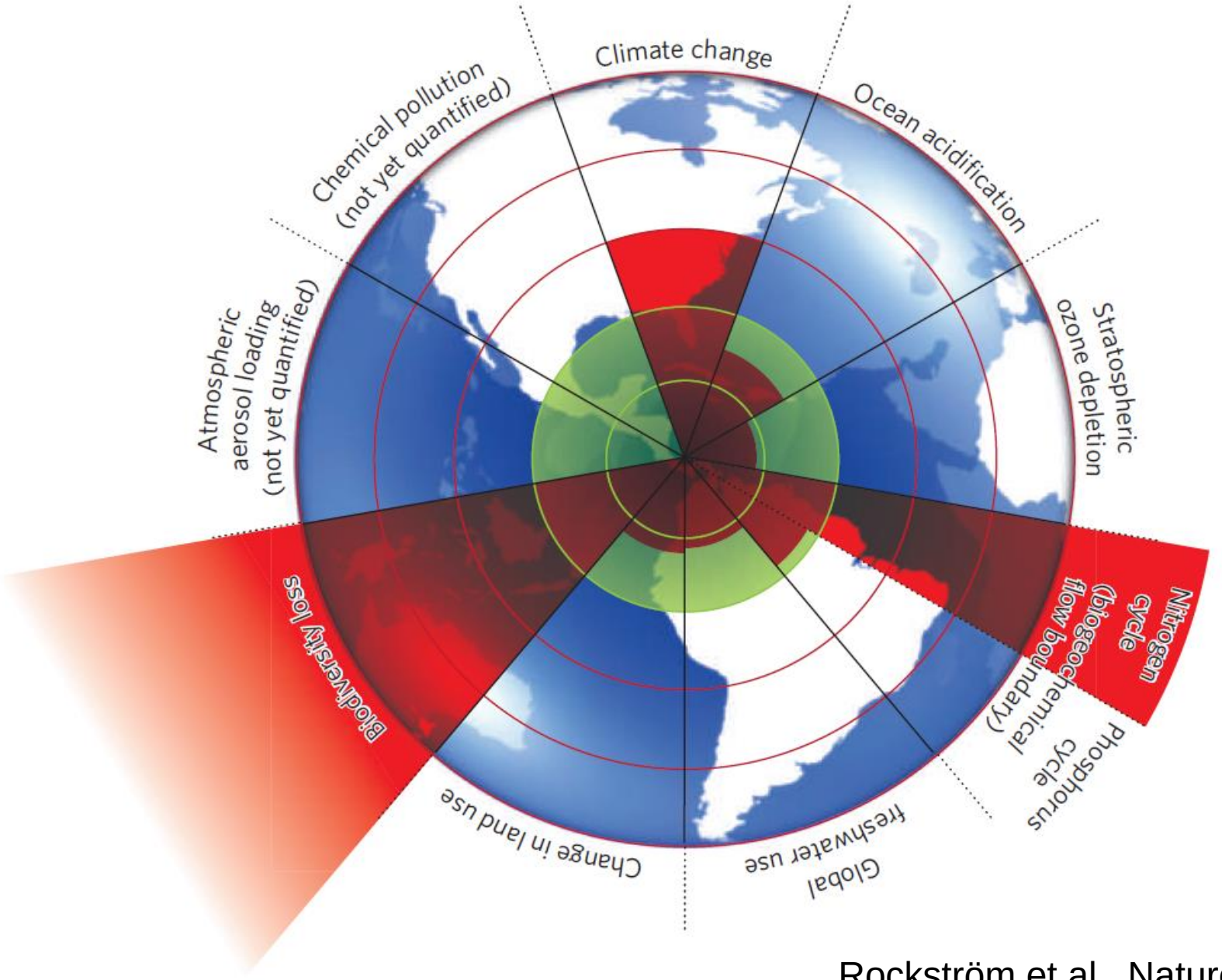
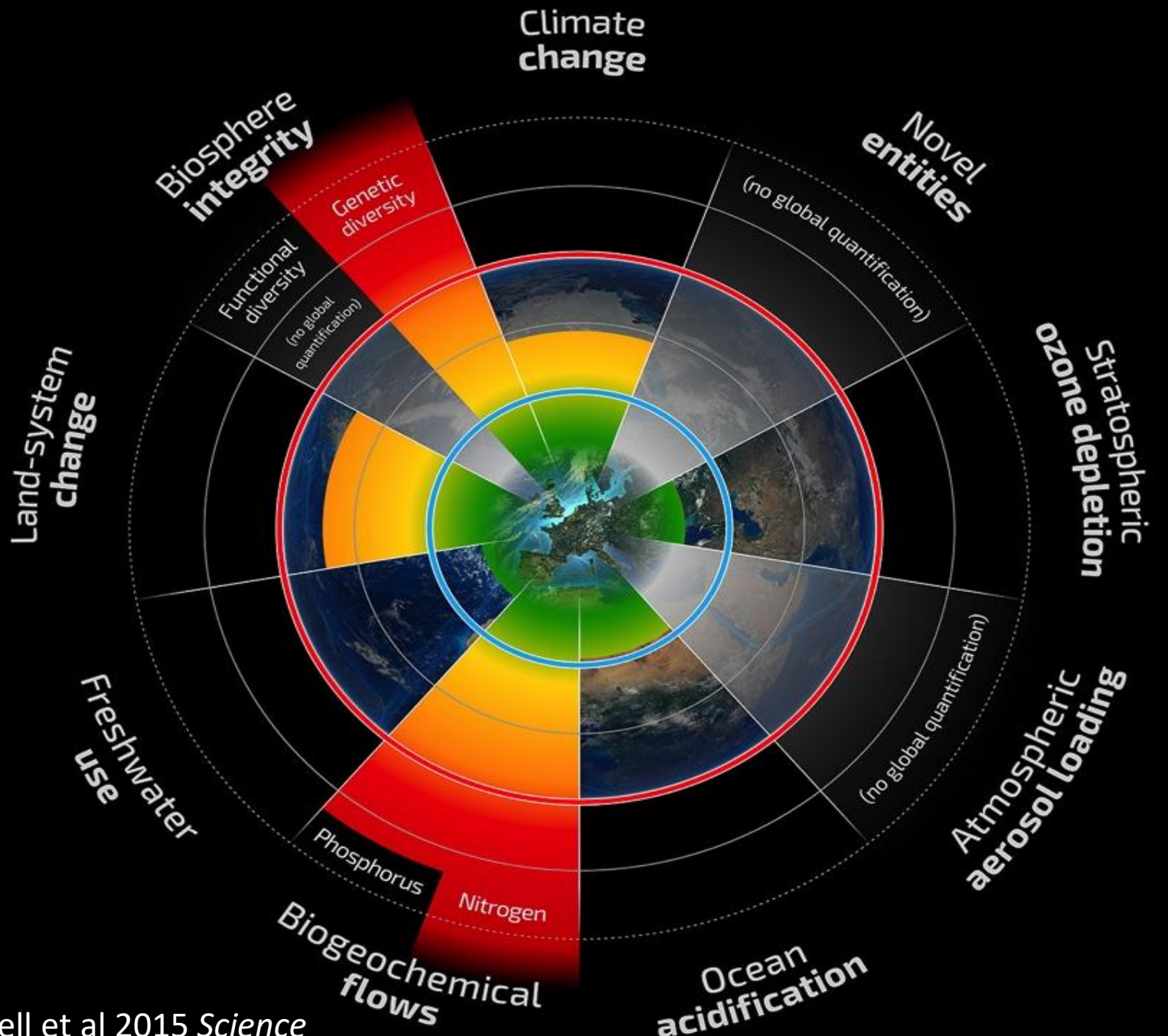
Planetary Boundaries 2009

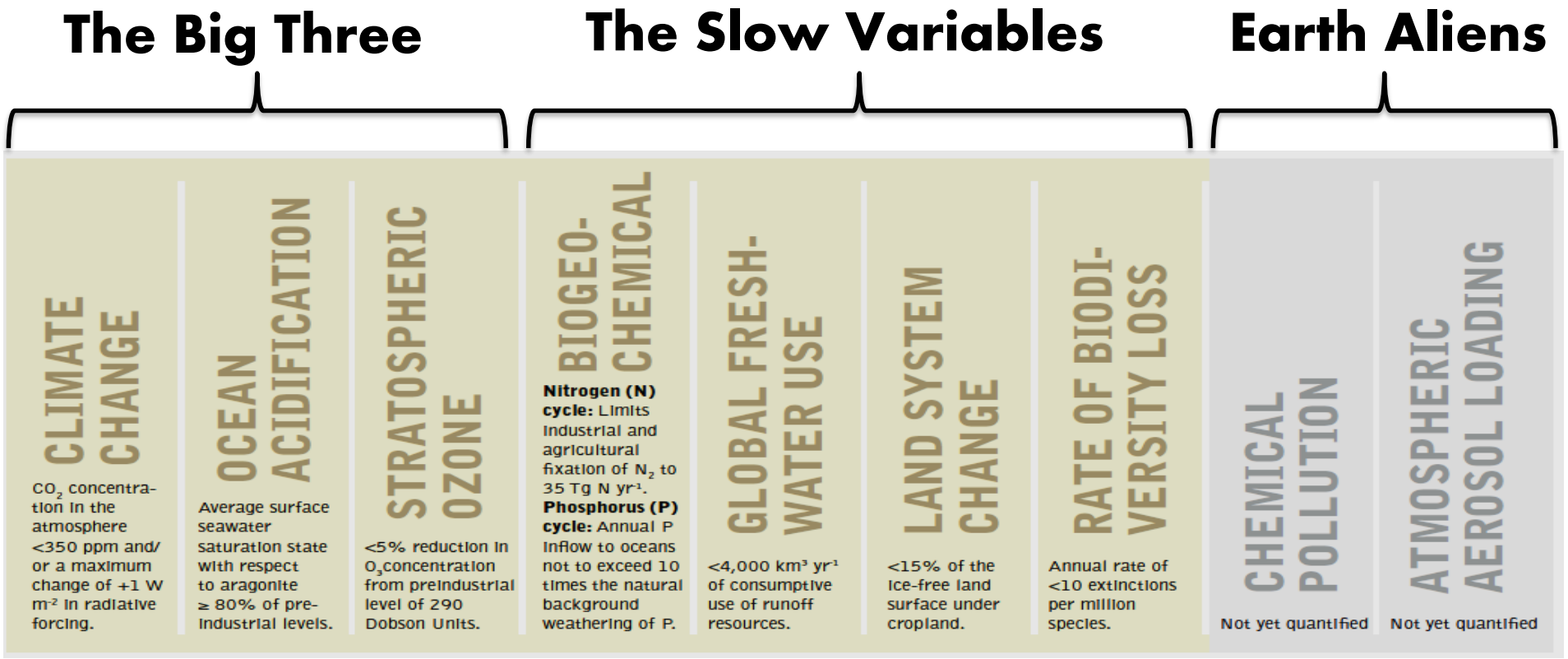


Rockström et al., Nature 2009

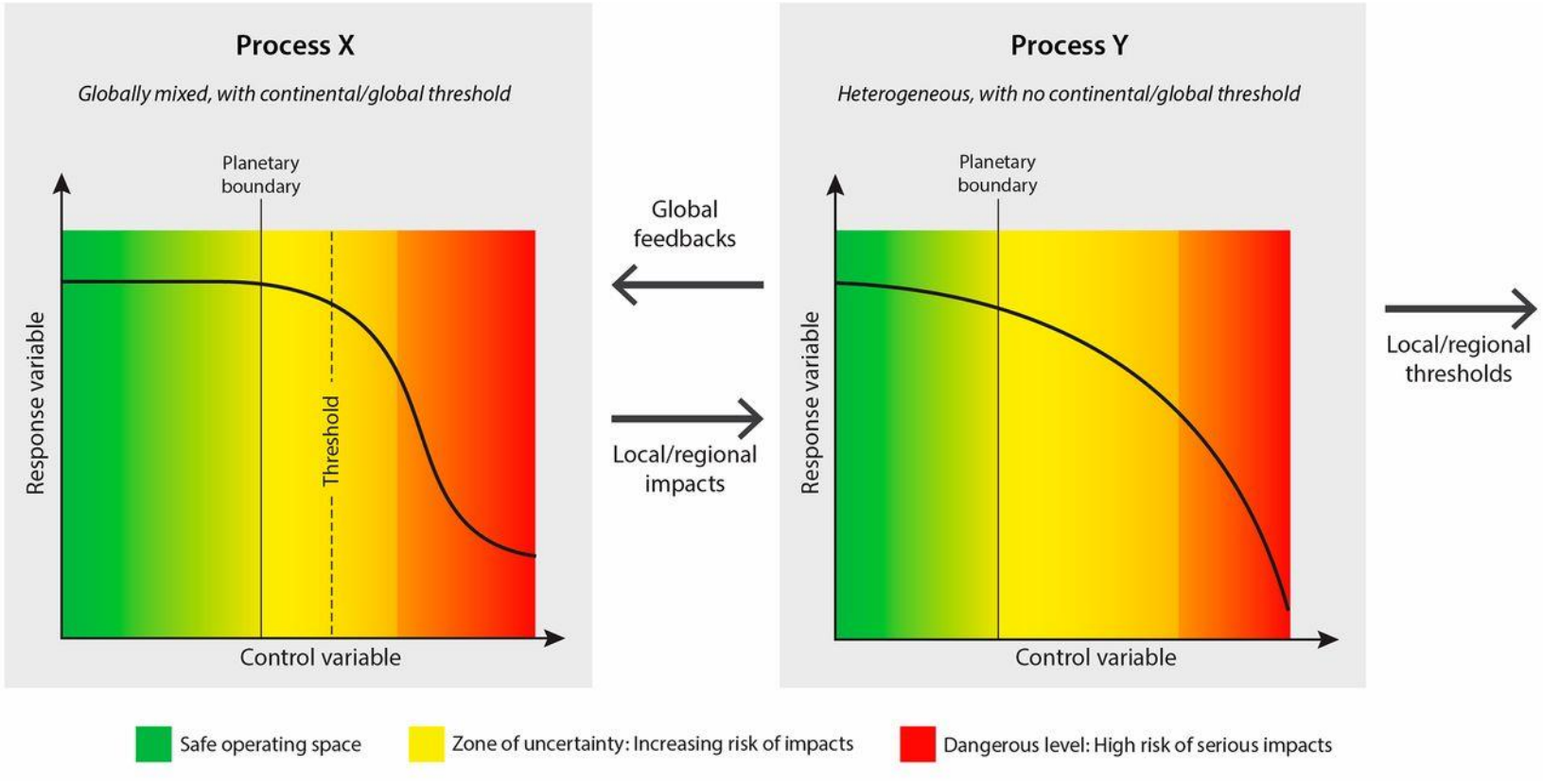


Steffen, Rockström, Cornell et al 2015 *Science*
Image: Globaia

Definition of Planetary Boundaries 1.0

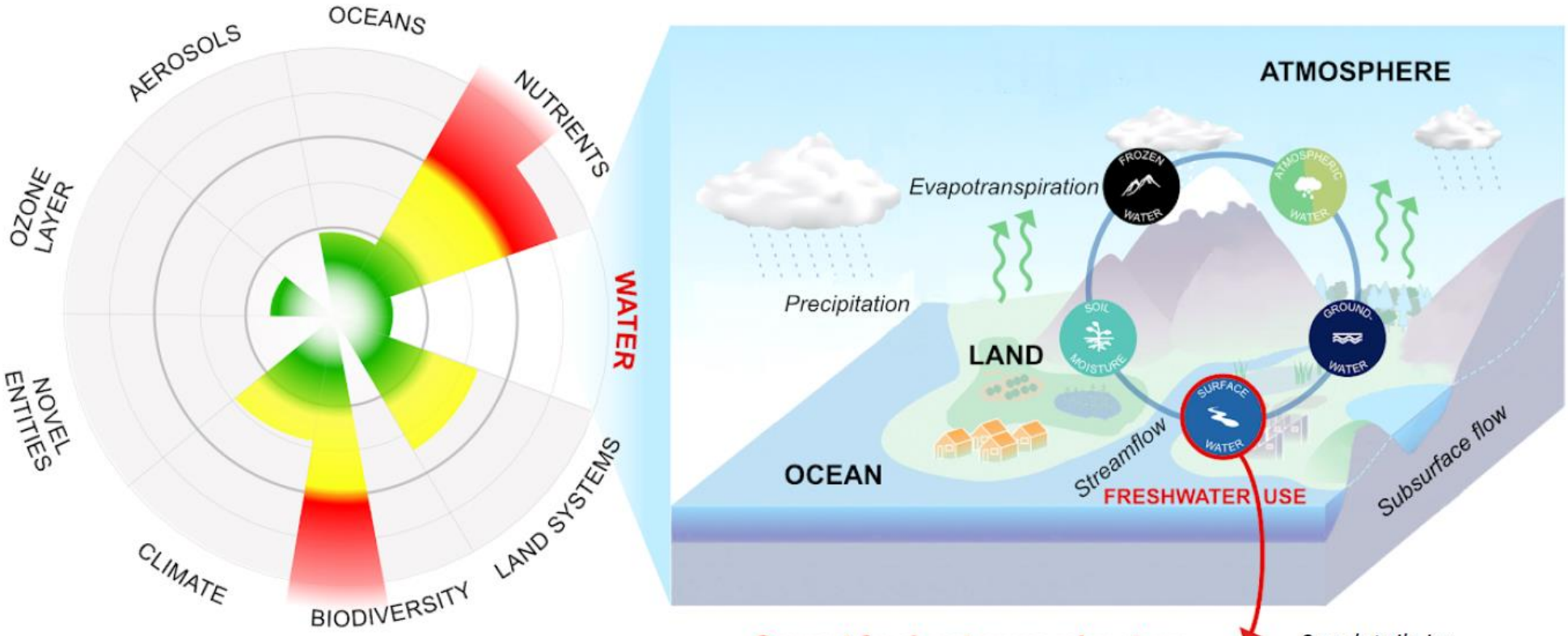


The Concept of Planetary Boundaries



Steffen et al, Science 2015

The Water Planetary Boundary and Related Earth System Components and Functions



Current freshwater use planetary boundary only considers streamflow impacts on aquatic biodiversity.

See details in:
Rockström et al., (2009), E&S
Gerten et al., (2013),
Steffen et al., (2015), Science

Freshwater use is one of the current planetary boundaries, yet affecting only a small component of the hydrosphere, which includes numerous stores of water. Since we focus on the near-surface hydrosphere, we consider land (part of the lithosphere) and ocean (part of the hydrosphere) as important related Earth System components.

Gleeson et al., (2020), One Earth

Planetary Boundaries:
A New Scientific Agenda

futureearth
research for global sustainability

Planetary Boundaries Research Network PB. net

SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

Ein transdisziplinäres Beispiel am PIK:

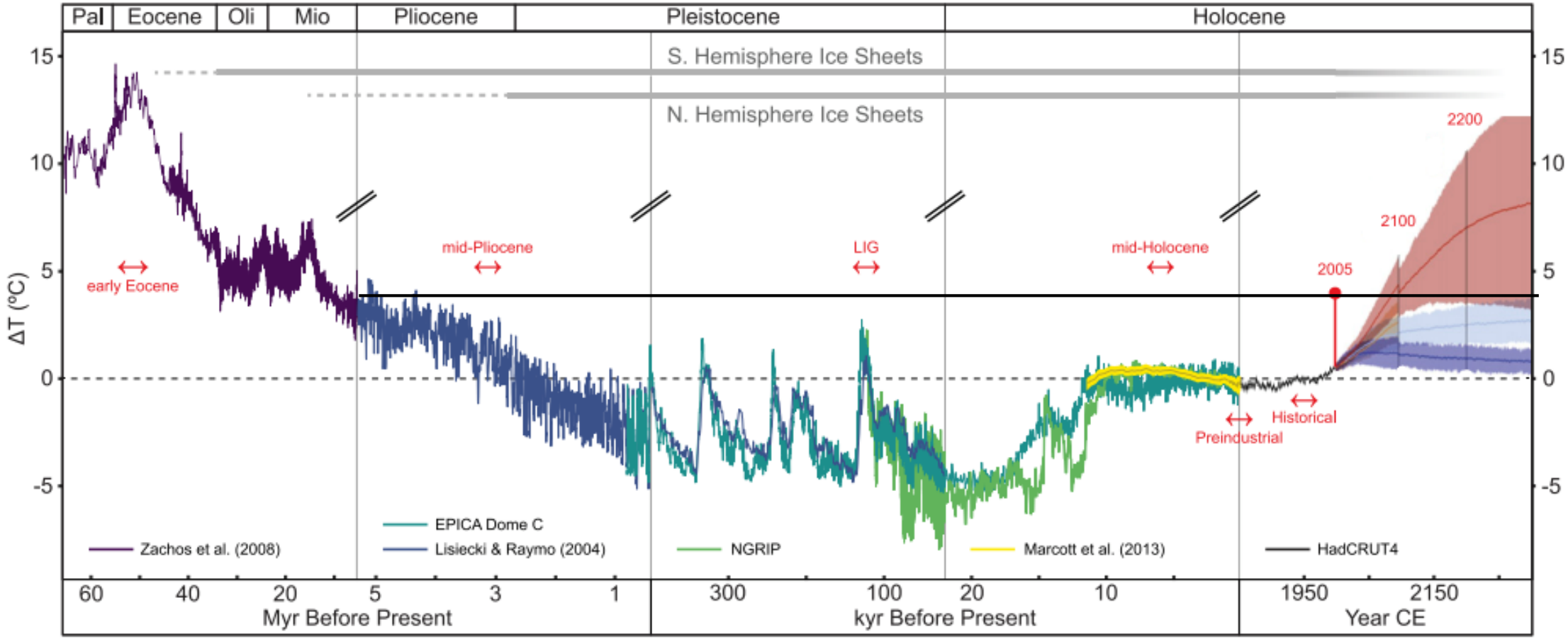
copan coevolutionary pathways

Anthropocene new Geological Epoch

But

NOT (yet) a new State

Are We Heading Towards a Pliocene or Even Miocene Future...?



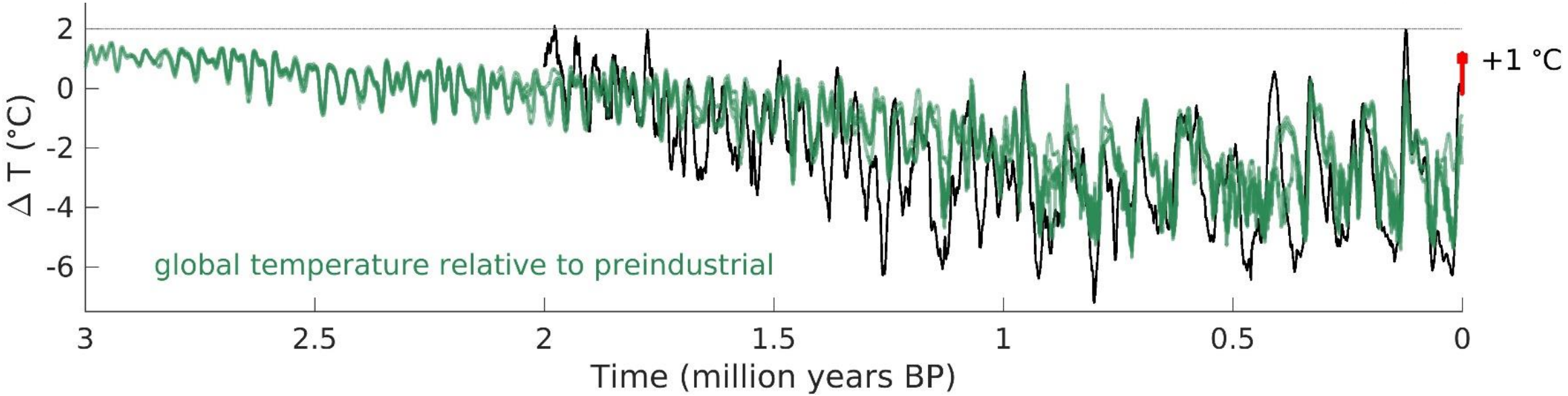
PNAS

Pliocene and Eocene provide best analogs for near-future climates

K. D. Burke[a,1], J. W. Williams[b], M. A. Chandler[c,d], A. M. Haywood[e], D. J. Lunt[f], and B. L. Otto-Bliesner[g]

December 26, 2018

We have never exceeded 2 C in the last Three Million Years



Results of model simulations: Observations shown in black, model results in colour.

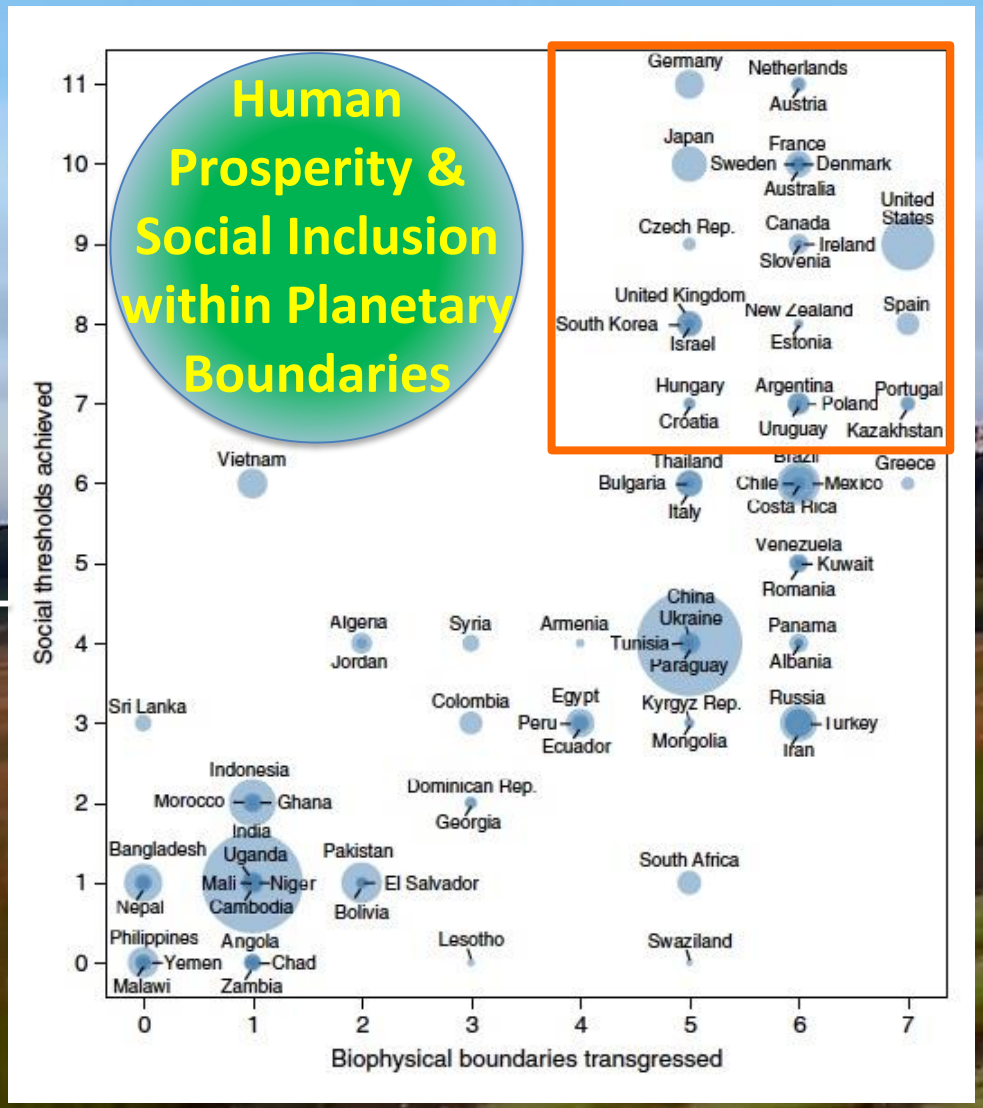
Willeit et al., Science Advances 2019

Introducing a new definition of Sustainable Development

Prosperity and Equity within Planetary Boundaries

A good life for all within planetary boundaries

Life Satisfaction
Healthy Life Expectancy
Nutrition
Sanitation
Income
Access to Energy
Education
Social Support
Democratic quality
Equality
Employment



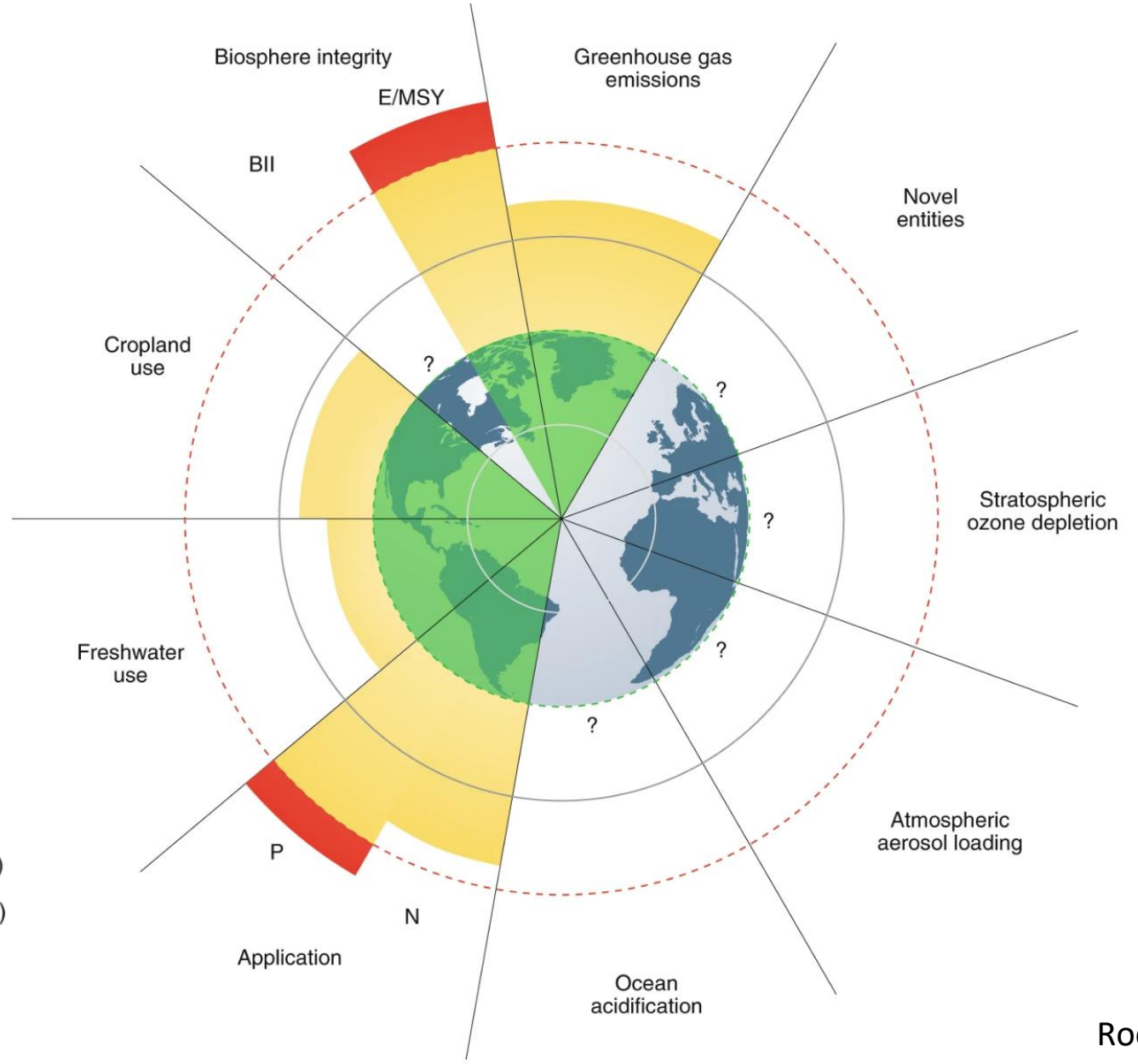
Climate Change
Phosphorus
Nitrogen
Blue water use
Land system change
Ecological Footprint
Material flow

O'Neill, D., et al. (2018). A good life for all within planetary boundaries.
Nature Sustainability, 1, pp. 88-95.

Conceptual Framework EAT-Lancet Commission

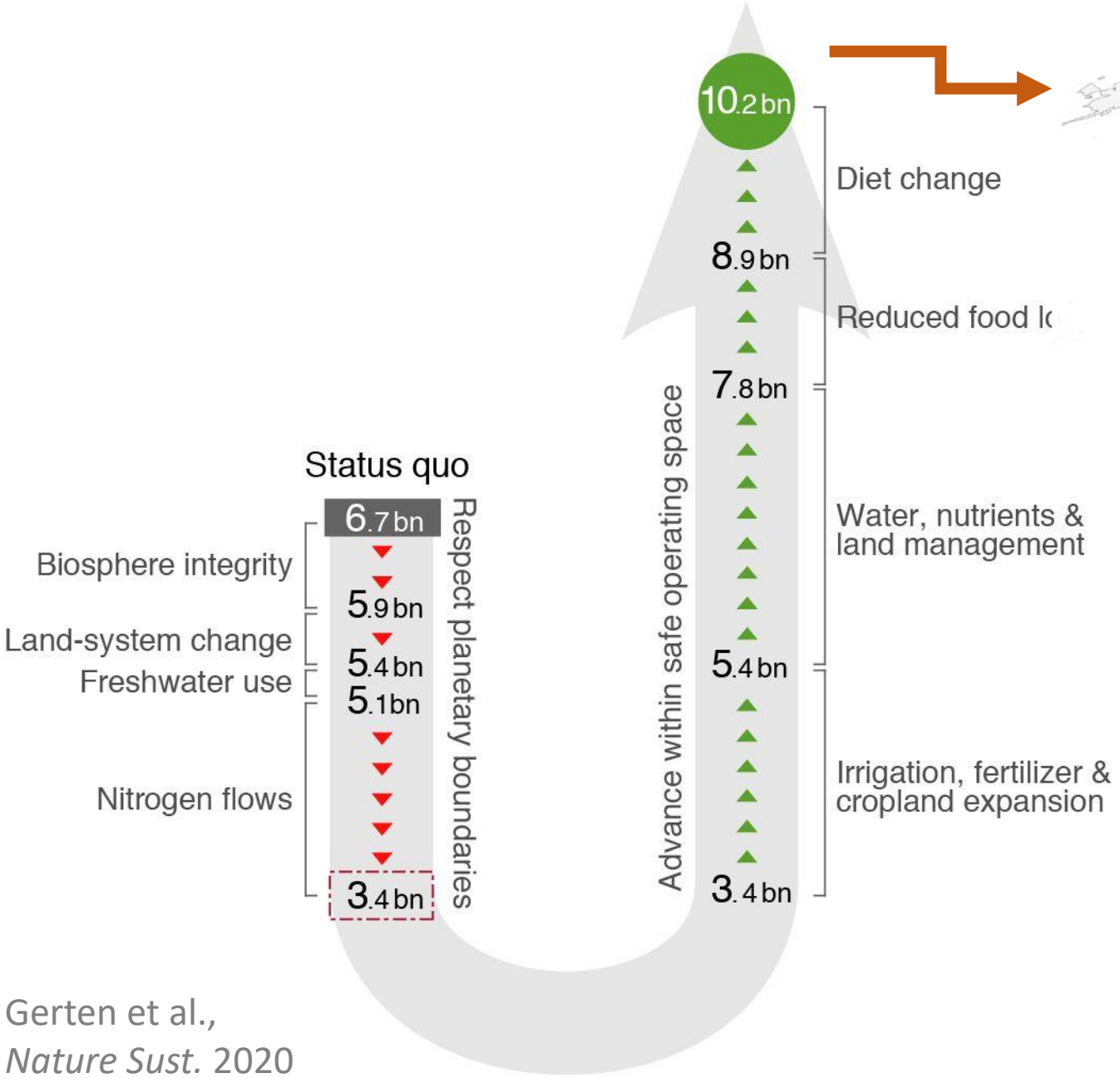
PIK

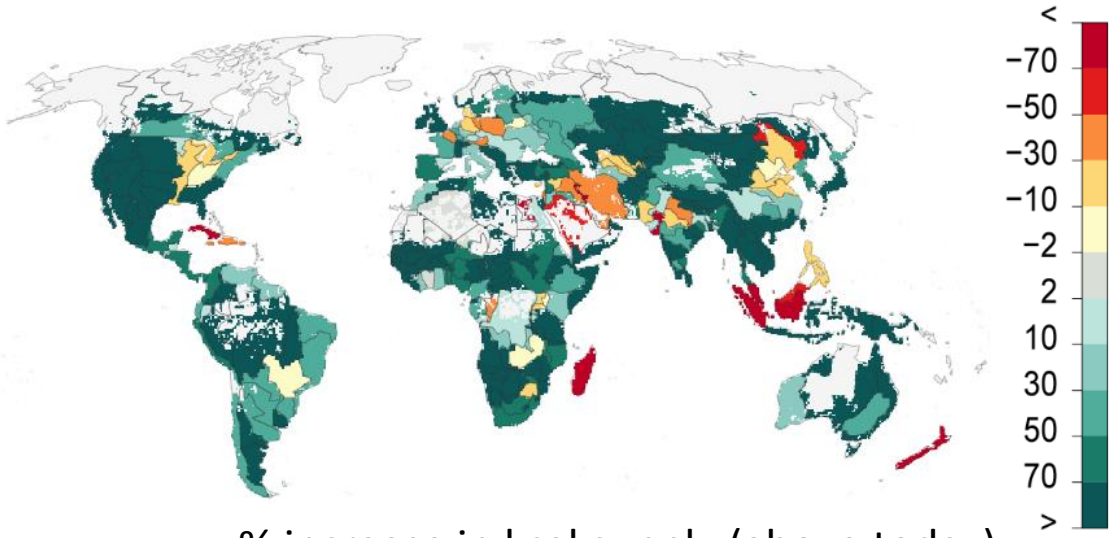
THE FOOD SYSTEM TRANSGRESSES PLANETARY BOUNDARIES



Rockström et al., Nature Food, 2020

Feeding 10 bn people within planetary boundaries is possible





- Half of current food production depends on planetary boundary transgressions
- An u-turn towards sustainable food production and consumption would enable enough food for ~10 bn people – within the boundaries
- However this requires radical co-transformations across sectors

Gerten et al., *Nature Sust.* 2020

THE CARBON LAW

EMBARGOED UNTIL 2:00 PM US ET THURSDAY, 23 MARCH 2017

POLICY FORUM

The road to global decarbonization must involve renewable energy, as from these wind turbines in Germany, and improved transportation technologies.

CLIMATE POLICY

A roadmap for rapid decarbonization

Emissions inevitably approach zero with a "carbon law"

By **Johan Rockström,[1] Owen Gaffney,[1,2] Joeri Rogelj,[3,4] Malte Meinshausen,[5,6] Nebojsa Nakicenovic,[4] Hans Joachim Schellnhuber[1,5]**

Although the Paris Agreement's goals (*1*) are aligned with science (*2*) and can, in principle, be technically and economically achieved (*3*), alarming inconsistencies remain between science-based targets and national commitments. Despite progress during the 2016 Marrakech climate negotiations, long-term goals can be trumped by political short-termism. Following the Agreement, which became international law earlier than expected, several countries published mid-century decarbonization strategies, with more due soon. Model-based decarbonization assessments (*4*) and scenarios often struggle to capture transformative change and the dynamics associated with it: disruption, innovation, and nonlinear change in human behavior. For example, in just 2 years, China's coal use swung from 3.7% growth in 2013 to a decline of 3.7% in 2015 (*5*). To harness these dynamics and to calibrate for short-term realpolitik, we propose framing the decarbonization challenge in terms of a global decadal roadmap based on a simple heuristic—a "carbon law"—of halving gross anthropogenic carbon-dioxide (CO_2) emissions every decade. Complemented by immediately instigated, scalable carbon removal and efforts to ramp down land-use CO_2 emissions, this can lead to net-zero emissions around mid-century, a path necessary to limit warming to well below 2°C.

The Paris goal translates into a finite planetary carbon budget: a 50% chance of limiting warming to 1.5°C by 2100 and a >66% probability of meeting the 2°C target imply that global CO_2 emissions peak no later than 2020, and gross emissions decline from ~40 gigatons (metric) of carbon dioxide ($GtCO_2$)/year in 2020, to ~24 by 2030, ~14 by 2040, and ~5 by 2050 (*3*) (see the figure, top). Risks could be further reduced by moderately increasing ambition to halve emissions every decade (see the figure, bottom right). Following such a global carbon law means at least limiting cumulative total CO_2 emissions from 2017 until the end of the century to ~700 $GtCO_2$, which allows for a small but essential contingency (~125 $GtCO_2$ less compared with total CO_2 emissions in the pathway in the figure, top) for risks of biosphere carbon feedbacks (*6*) or delay in ramping up CO_2-removal technologies.

A carbon law applies to all sectors and countries at all scales and encourages bold action in the short term. It means, for example, doubling of zero-carbon shares in the energy system every 5 to 7 years, a rate consistent with the trajectory of the past decade (see the figure, bottom left). All sectors (e.g., agriculture, construction, finance, manufacturing, transport) need comparable transformation pathways. In addition, in the absence of viable alternatives, the world must aim at rapidly scaling up CO_2 removal by technical means from zero to at least 0.5 $GtCO_2$/year by 2030, 2.5 by 2040, and 5 by 2050. CO_2 emissions from land-use must decrease along a nonlinear trajectory from 4 $GtCO_2$/year in 2010, to 2 by 2030, 1 by 2040, and 0 by 2050 (see the figure, bottom right). The endgame is for cumulative CO_2 emissions since 2017 to be brought back from around 700 $GtCO_2$ to below 200 $GtCO_2$ by the end of the century (see the figure, top) and atmospheric CO_2 concentrations to return to 380 ppm by 2100 (currently at 400 ppm).

Roadmaps are planning instruments, linking shorter-term targets to longer-term goals. They help align actors and organizations to instigate technological and institutional breakthroughs to meet a collective challenge. An explicit carbon roadmap for halving anthropogenic emissions every decade, codesigned by and for all industry sectors, could help promote disruptive, nonlinear technological advances toward a zero-emissions world. The key to such a carbon law will be a dual strategy that pushes renewables and other zero-emissions technologies up the creation and dissemination trajectory, while simultaneously pulling fossil-based value propositions from the market. Thus, the transformation unfolds at a pace governed by novel schemes rather than by inertia imposed by incumbent technologies (see the figure, bottom left).

We sketch out a broad decadal decarbonization narrative in four dimensions—innovation, institutions, infrastructures, and investment—to provide evidence of feasibility and depth of transformation for economies to stay on a carbon-law trajectory. The narrative provides no guarantees but identifies crucial steps, grounded in published scenarios combined with expert judgment. Each step has two parts: actions for rapid near-term emissions reductions, and actions for systemic and long-term impact, creating the basis for the next steps. Such a narrative, specifically designed with decadal targets and incentives, could provide key elements for national and international climate strategies.

2017–2020: NO-BRAINERS

Annual emissions from fossil fuels must start falling by 2020. Well-proven (and ideally income-neutral) policy instruments such as carbon tax schemes, cap-and-trade

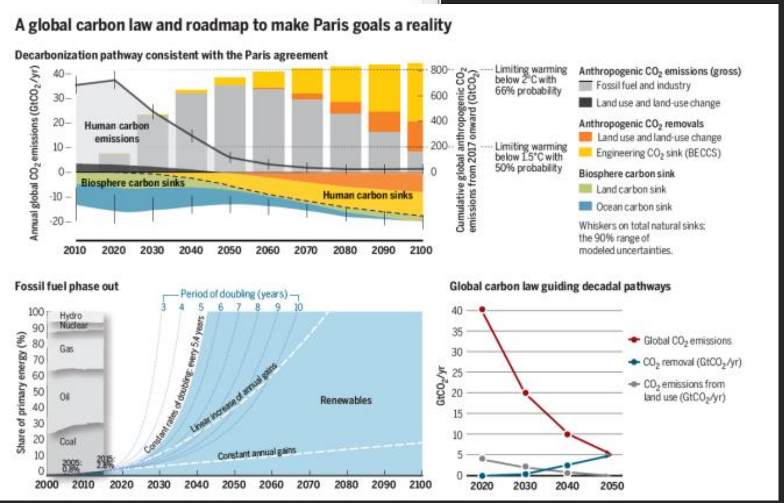
[1]Stockholm Resilience Centre, Stockholm University, 114 18 Stockholm, Sweden. [2]Future Earth, The Royal Swedish Academy of Sciences, 104 05 Stockholm, Sweden. [3]International Institute for Applied Systems Analysis, 2361 Laxenburg, Austria. [4]ETH Zurich, 8092 Zurich, Switzerland. [5]Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany. [6]Australian-German Climate and Energy College, School of Earth Sciences, University of Melbourne, Victoria 3010, Australia. Email: johan.rockstrom@su.se

PHOTO: GFC COLLECTION / ALAMY STOCK PHOTO

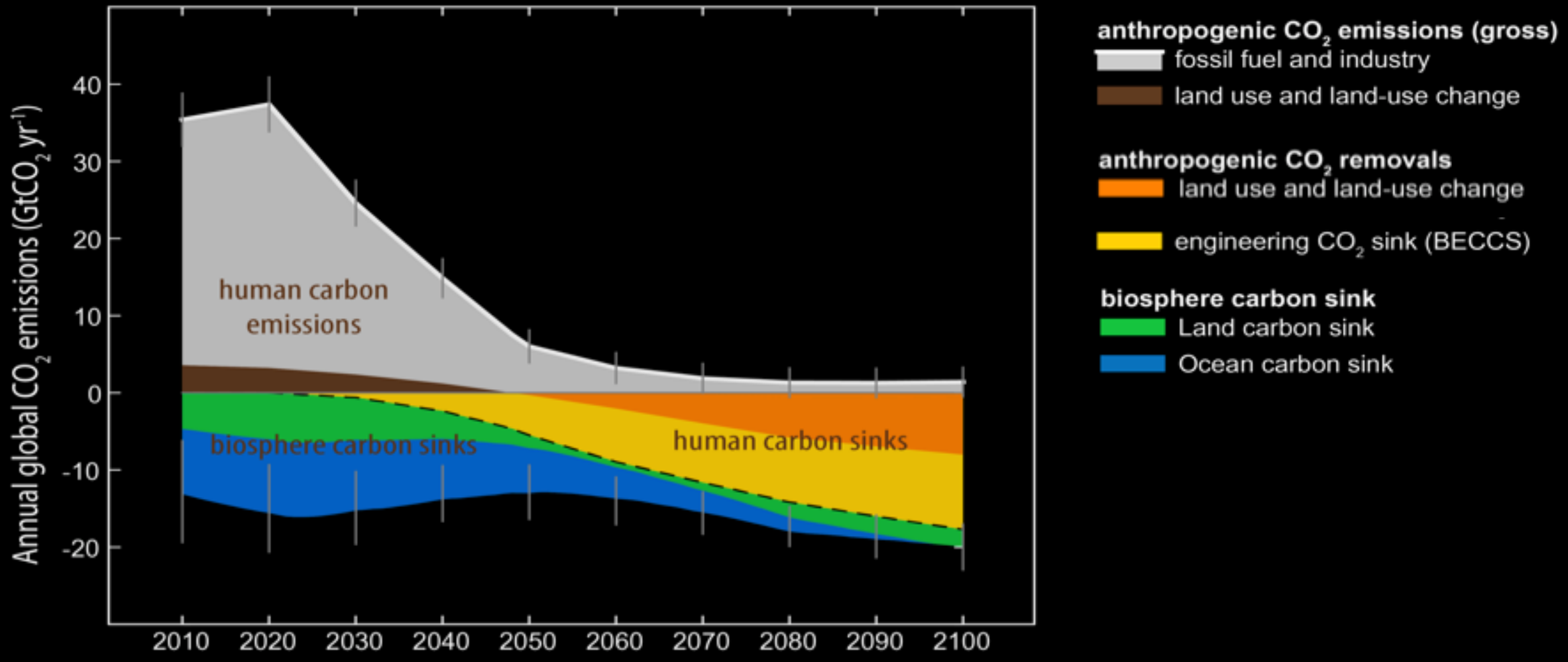
SCIENCE sciencemag.org

24 MARCH 2017 • VOL 355 ISSUE 6331 1269

0324PolicyForum.indd 1269 3/20/17 12:10 PM



A Roadmap for Rapid Decarbonization



Rockström, Gaffney, Rogelj, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017

nature sustainability

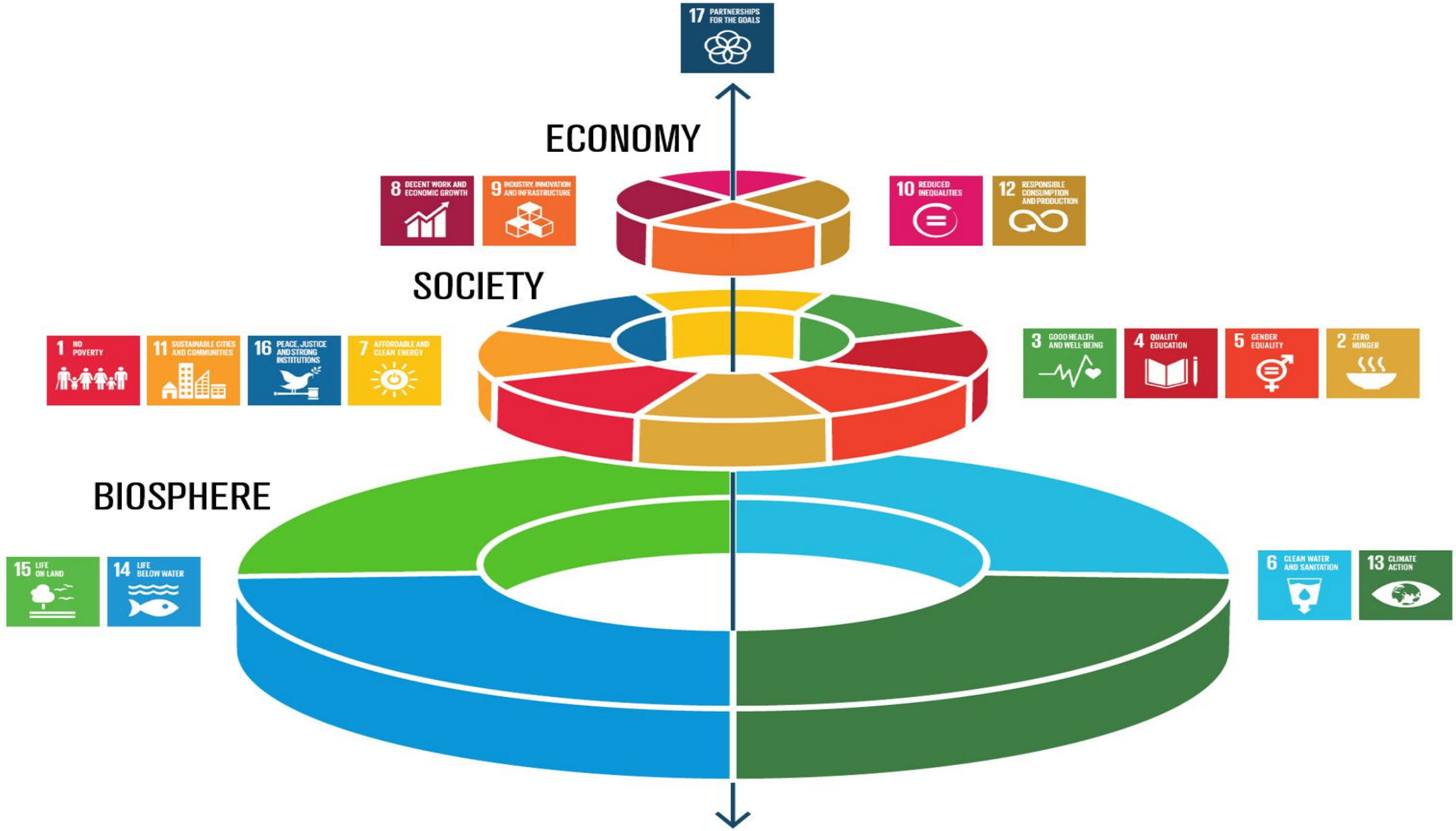
PERSPECTIVE

https://doi.org/10.1038/s41893-019-0352-9

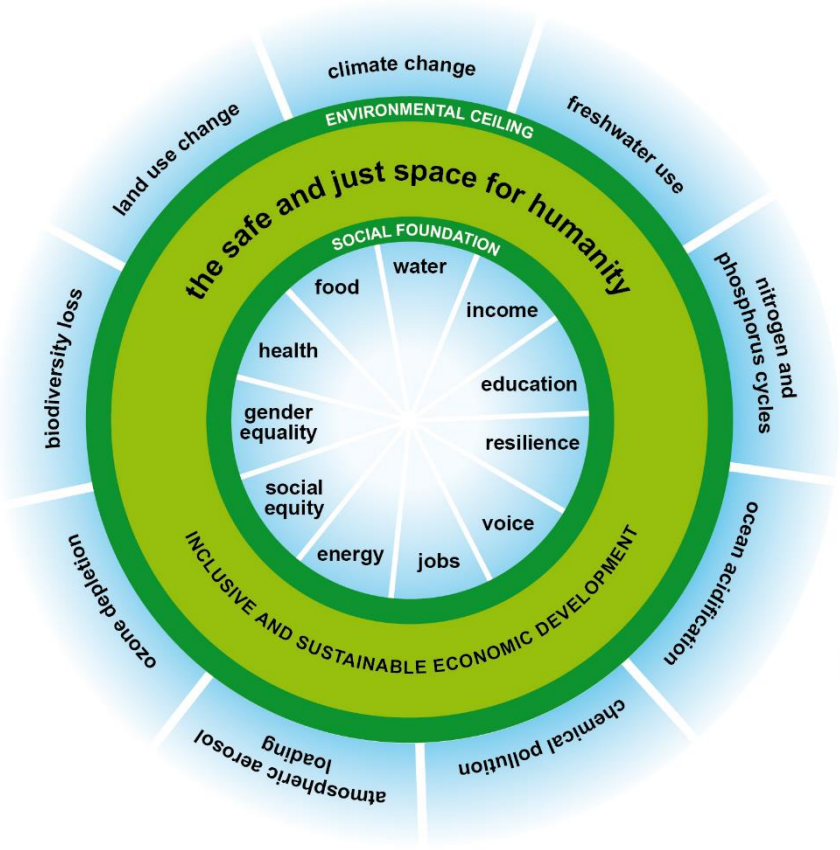
Six Transformations to achieve the Sustainable Development Goals

Jeffrey D. Sachs[1], Guido Schmidt-Traub[2*], Mariana Mazzucato[3], Dirk Messner[4], Nebojsa Nakicenovic[5] and Johan Rockström[6]

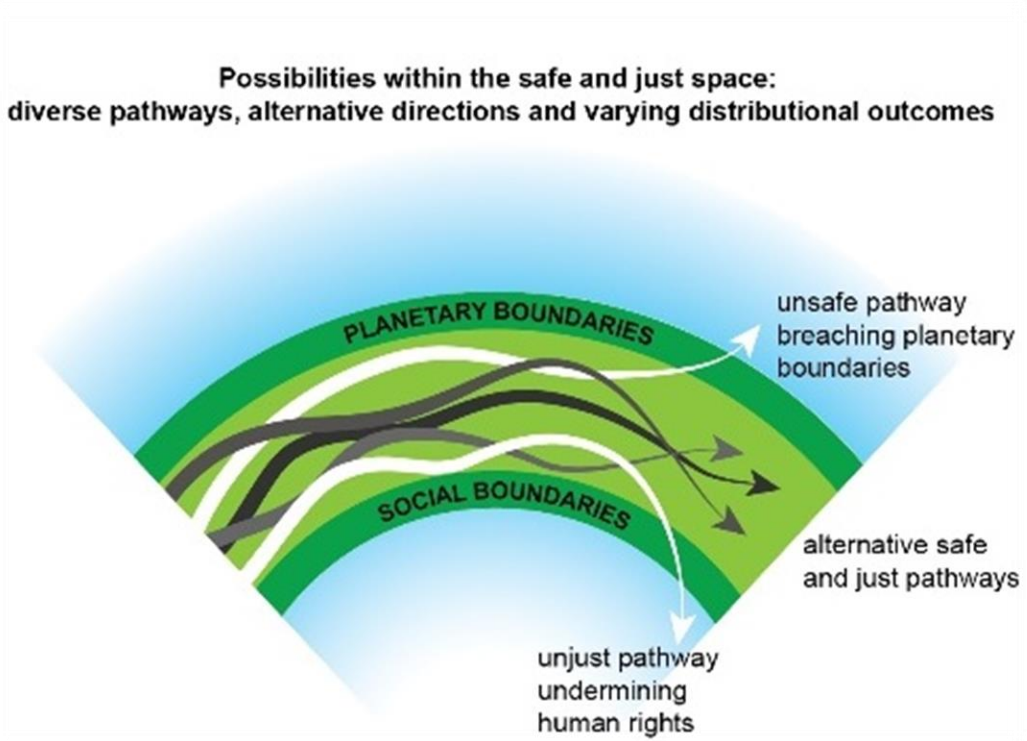

SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS


17 PARTNERSHIPS FOR THE GOALS
ECONOMY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
SOCIETY
1 NO POVERTY
11 SUSTAINABLE CITIES AND COMMUNITIES
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
7 AFFORDABLE AND CLEAN ENERGY
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
2 ZERO HUNGER
BIOSPHERE
15 LIFE ON LAND
14 LIFE BELOW WATER
6 CLEAN WATER AND SANITATION
13 CLIMATE ACTION

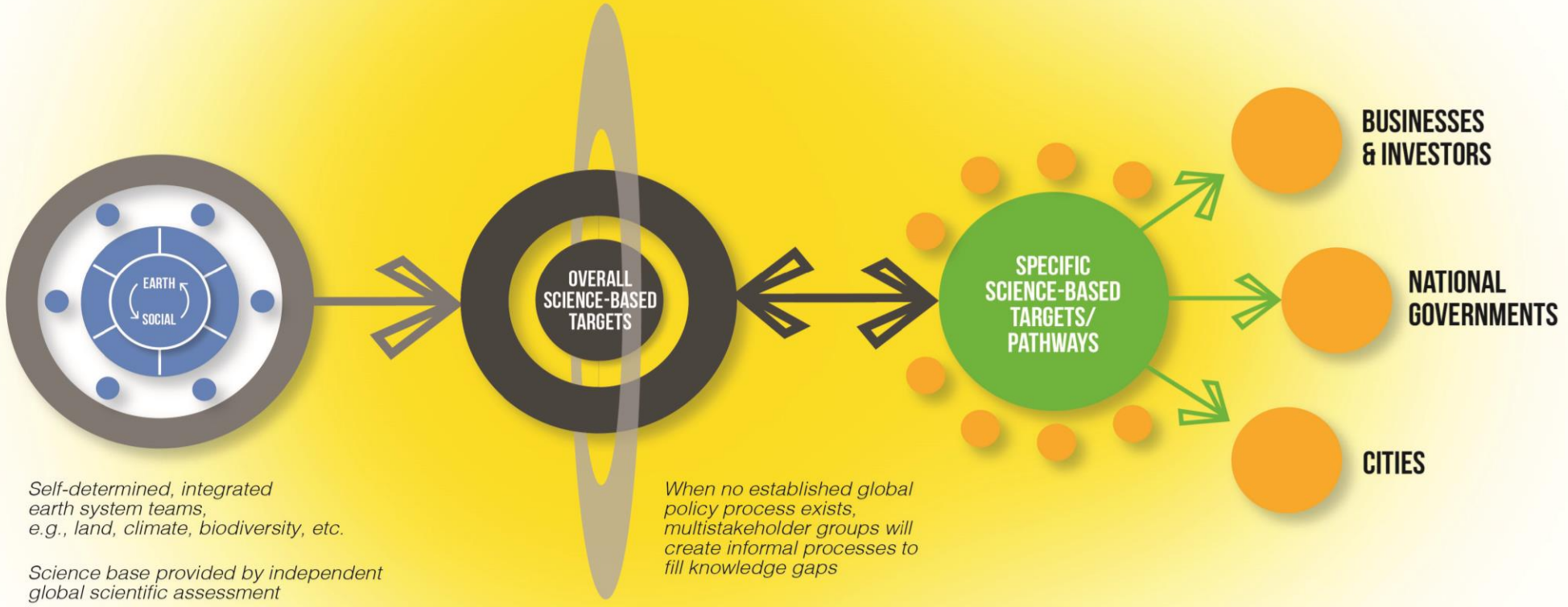
Planetary Boundaries and Social Justice



Raworth 2012, nach Rockström et al., Nature 2009



Leach, Raworth and Rockström, WSSR 2012



EARTH COMMISSION

IDENTIFY METRICS, ASSESS RISK, & DEFINE RANGES

GLOBAL POLICY PROCESSES

(FORMAL & INFORMAL)

ASSESS, OPERATIONALIZE, & COORDINATE PROCESS

SCIENCE-BASED TARGETS INITIATIVE +

TRANSLATE, DEVELOP METHODS, CREATE DATA ARCHITECTURE, PROMOTE, ENGAGE, & MOBILIZE

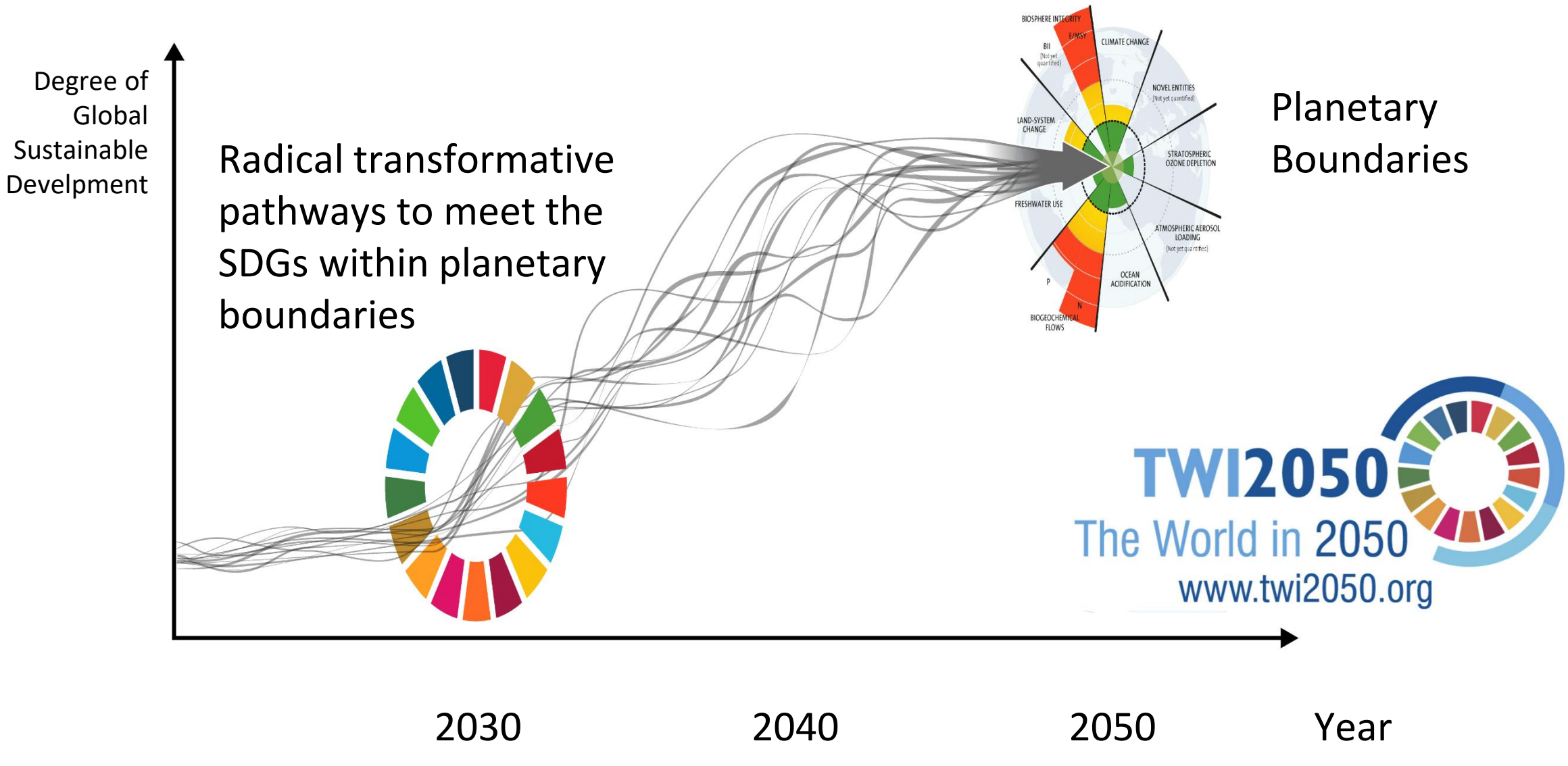
SCIENCE

CIVIL SOCIETY, THINK TANKS, ACADEMICS, & CONSULTANTS

STAKEHOLDERS & IMPLEMENTERS

INTEGRATION & FACILITATION

The World In 2050



A Safe Operating Space for Humanity

POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Thank You!

Member of Leibniz Association