

World Development within a Resilient and Stable Earth system Only Path to the SDGs

Impacts World 2017
PIK, Potsdam
11th October 2017

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Executive Director, Stockholm Resilience Centre
Professor of Environmental Science, Stockholm University

Photo: Yann Arthus-Bertrand

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship



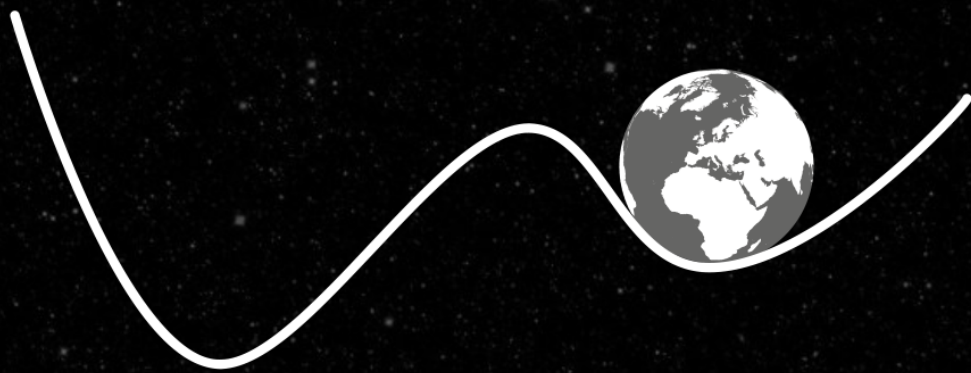
Stockholm
University



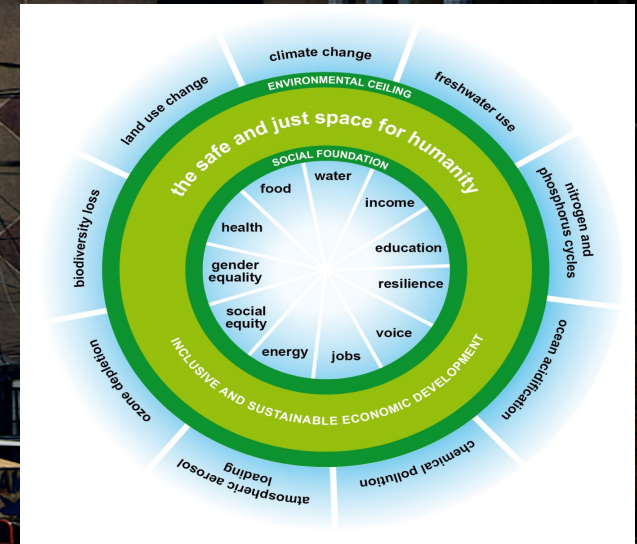
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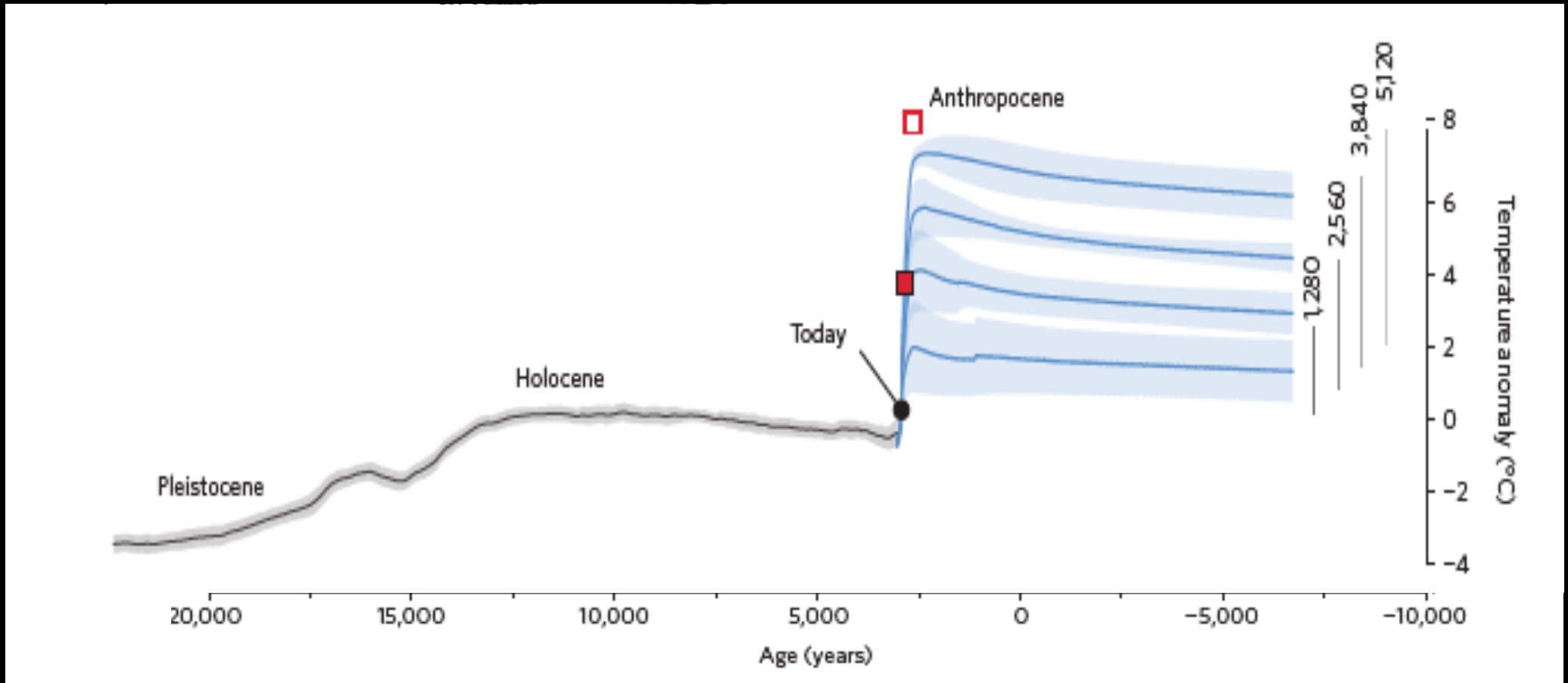
Equity and Justice in an Increasingly Turbulent World



A return to the Holocene equilibrium?

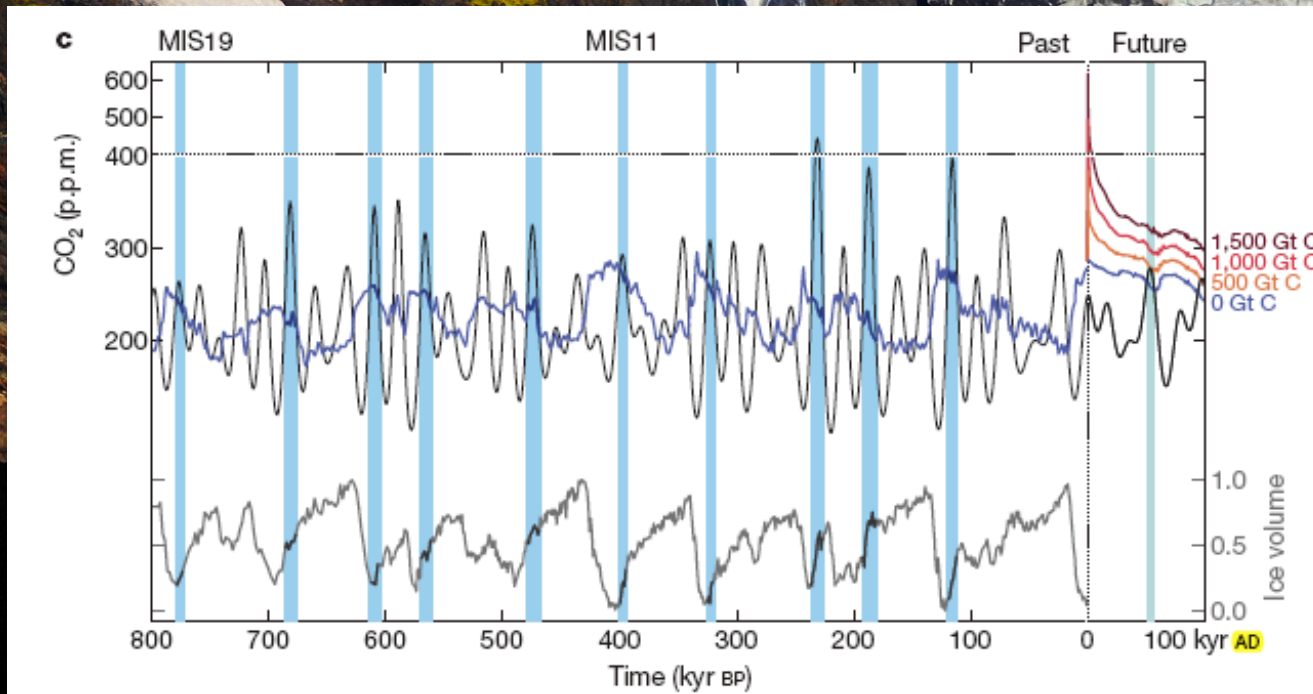
The door is likely closed...

Source: Clark et al. (2016). Consequences of Twenty-first Century Policy for Multi-millennial climate and sea level change. *Nature Climate Change*



An oscillation to a new ice age? The door is likely closed...

Source: Ganopolski et al. (2016). Critical Insolation- CO₂ relation for diagnosing past & future glacial inception. *Nature*



The background of the slide is a composite image of Earth from space. The left side shows the blue and white horizon of the planet, while the right side is a dark, textured surface, possibly representing the night side or a different layer of the atmosphere. Overlaid on this is a complex, glowing blue network of lines and nodes, resembling a global communication or data network. The text is centered over this network.

Anthropocene

+

Holocene

+

Earth Tipping points

=

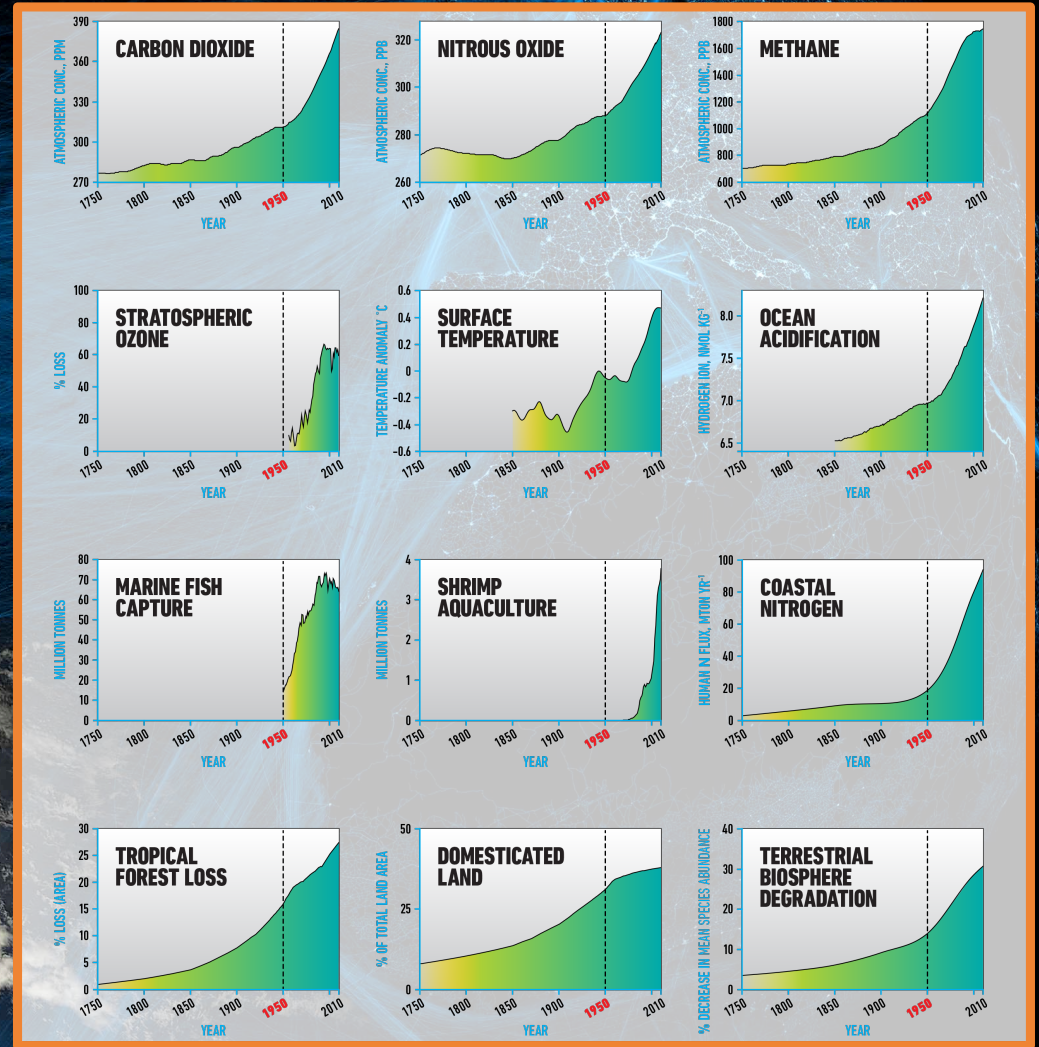
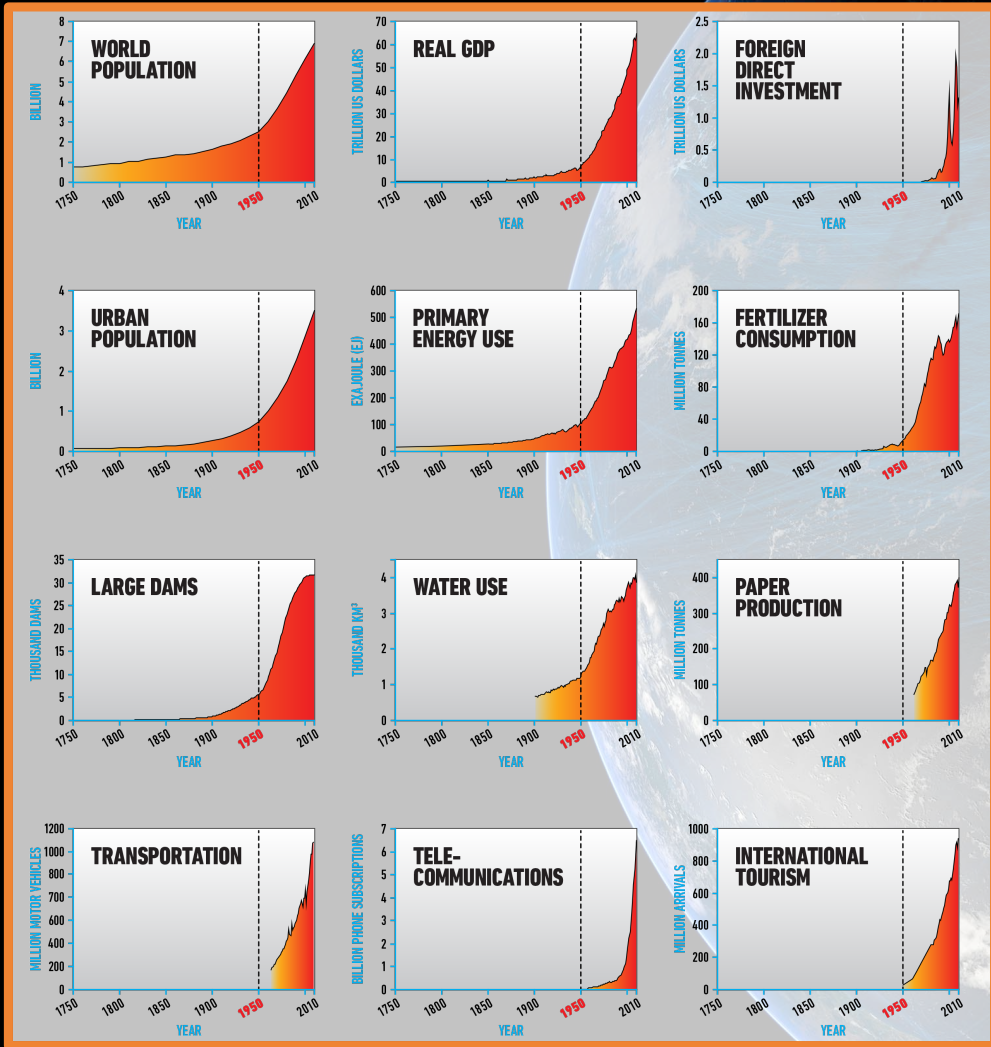
World within Stable & Resilient Earth



In **50 years we tipped** from 10,000 years Holocene
to the Anthropocene

What we do next 50 years will **determine next 10,000 years**

GREAT ACCELERATION 1950 TO PRESENT



SMALL WORLD ON LARGE PLANET

Externalities

Incremental, linear change

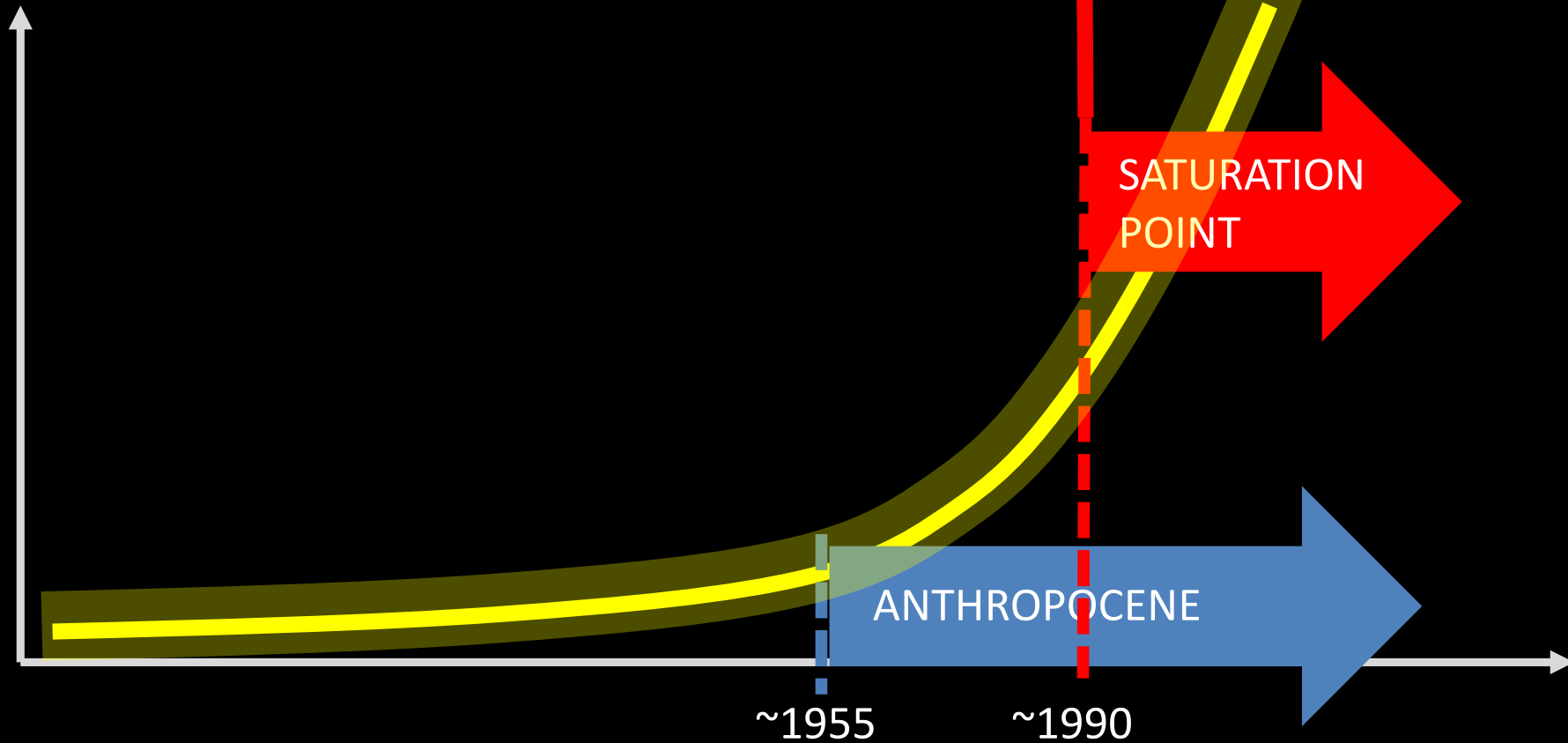
Earth resilience high

BIG WORLD ON SMALL PLANET

Internalities

Non-linear, Regime shifts

Earth resilience low



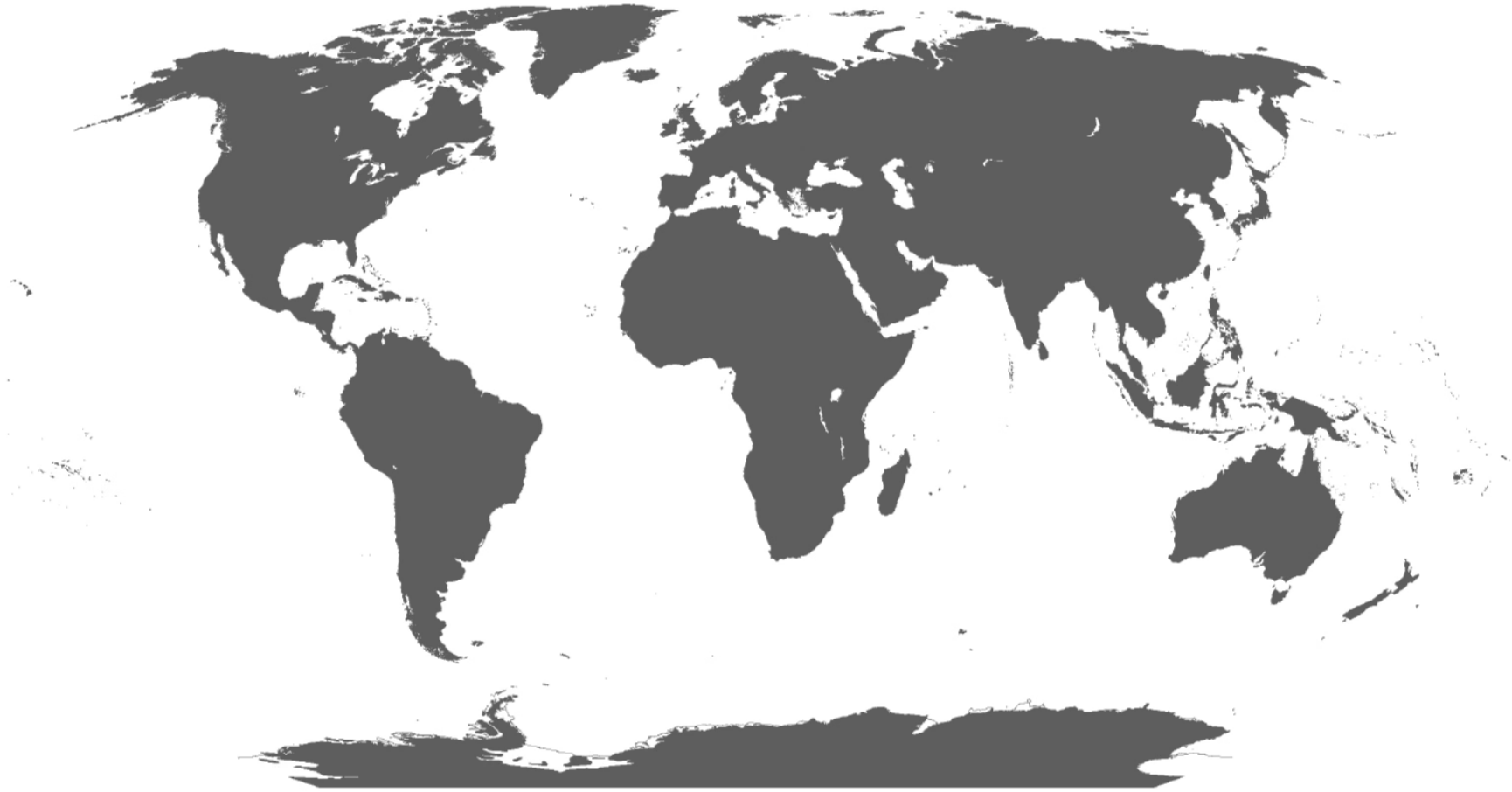
From a **small world** on a large planet...



To a **large world** on a small planet...

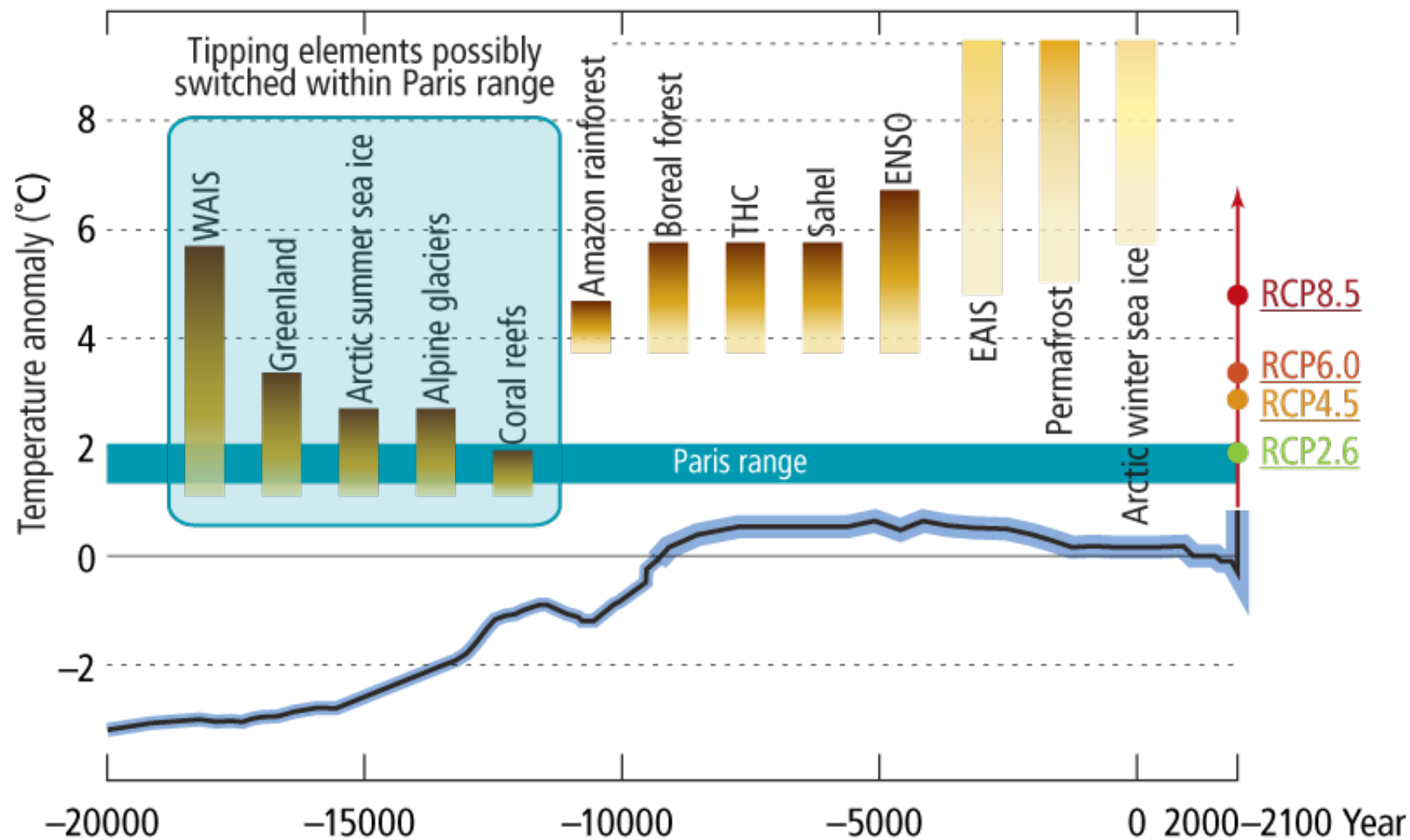


Global Tipping Points



Tipping Points & the Paris Agreement

Sources: Adapted from Schellnhuber et al. (2016). Nature Climate Change



A photograph of an Arctic landscape featuring a vast expanse of white sea ice under a clear blue sky. A bright sun is positioned in the upper right quadrant, creating a prominent starburst effect. The ice in the foreground is broken into smaller, irregular chunks, with some water visible between them. The overall scene is bright and clear, suggesting a sunny day in a high-latitude region.

A 5°C Arctic in a 2°C World

CHALLENGES AND RECOMMENDATIONS FOR IMMEDIATE ACTION
FROM THE JULY 21-22, 2016 WORKSHOP

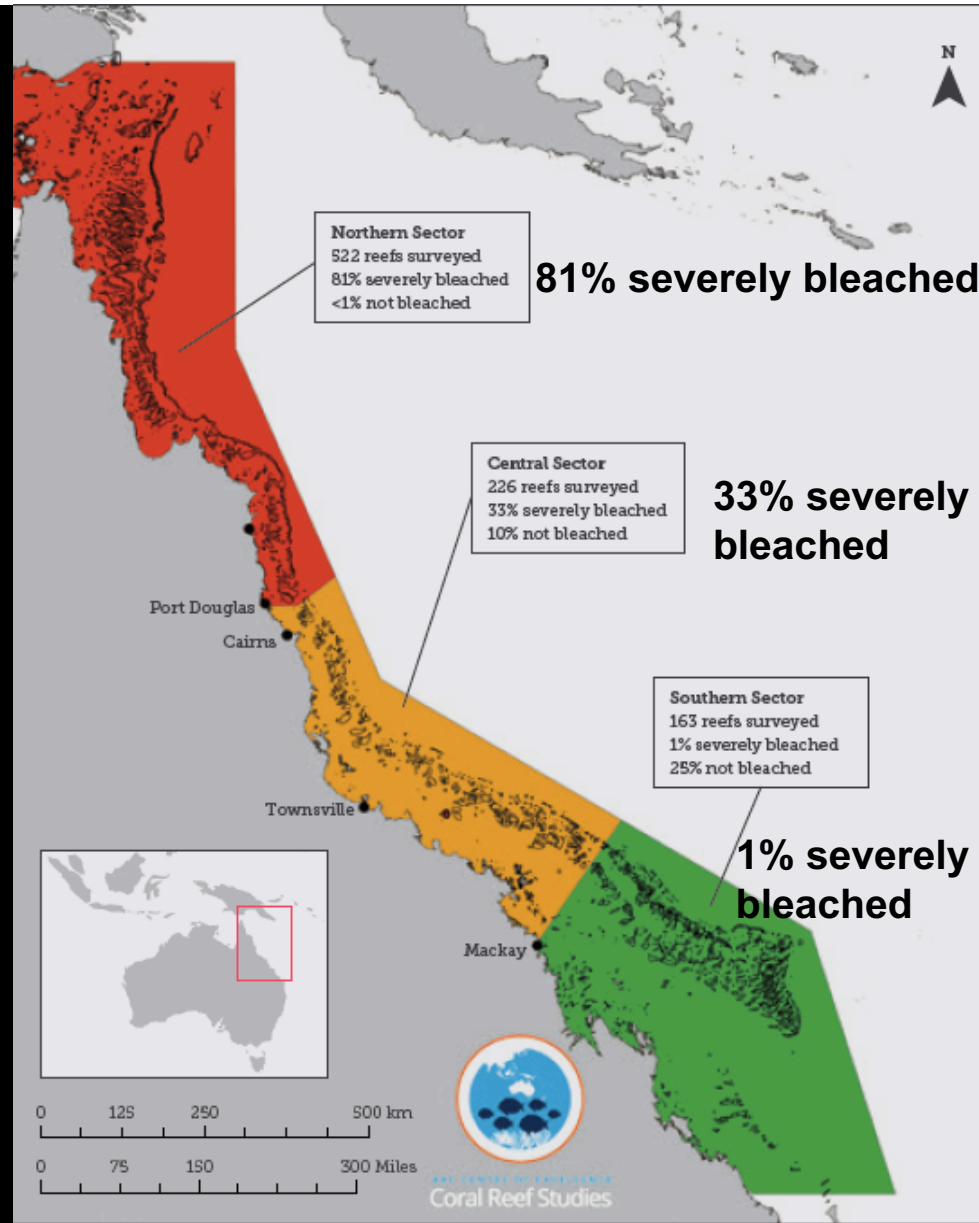
Briefing Paper for Arctic Science Ministerial

September 20, 2016

AUTHORS

Peter Schlosser
Stephanie Pfirman
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Margaret Williams
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Phil Duffy
Hajo Eicken;
Mojib Latif
Maribeth Murray
Doug Wallace

Great Barrier Reef Bleaching 2016

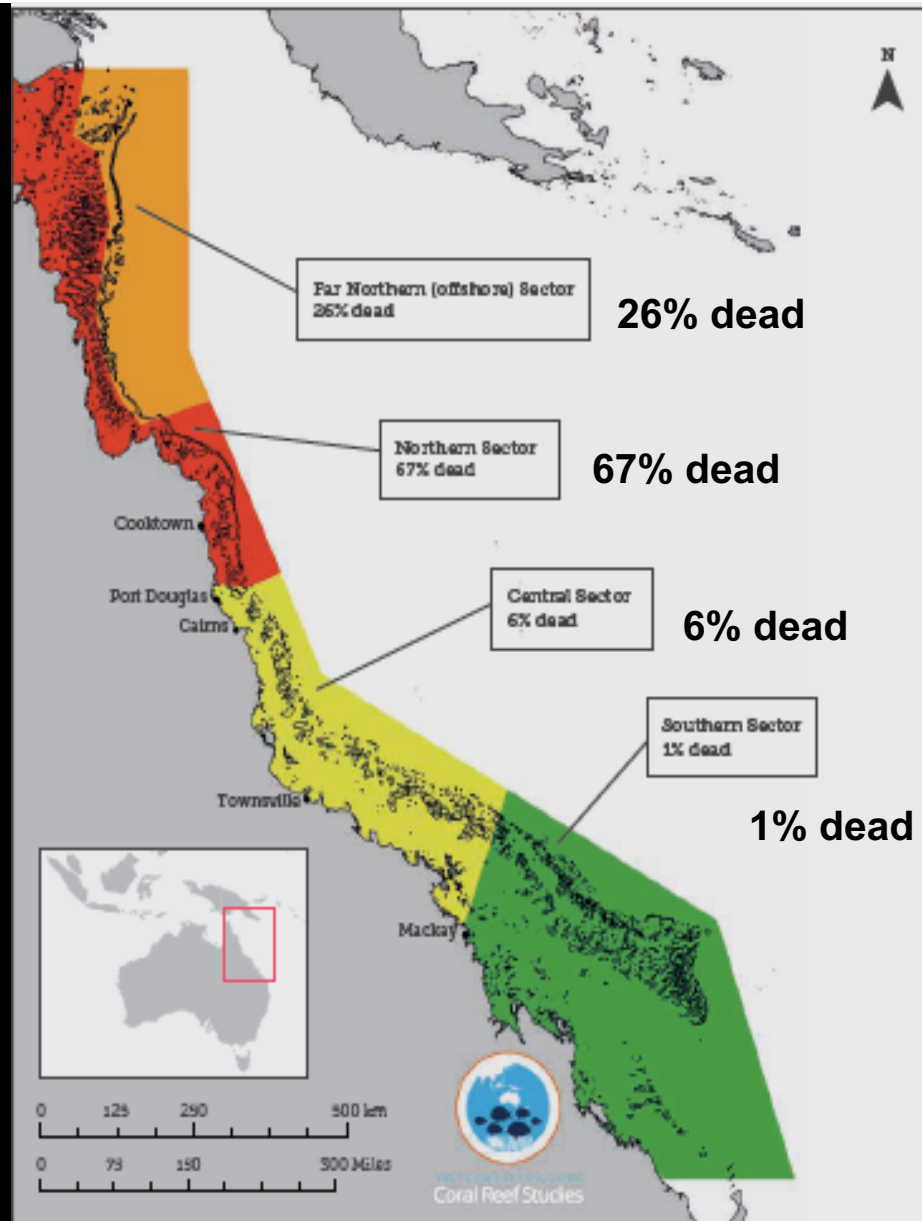


Longest global coral bleaching ever, affecting 36 % of all coral reefs around the world

> 90 % reefs GBR were bleached

Source: ARC Centre of Excellence for Coral Reef Studies

Great Barrier Reef Bleaching 2017



Another mass bleaching event

Central section most severely affected

No chance for Northern section to recover

Source: ARC Centre of Excellence for Coral Reef Studies

Risk of a **tipping point** in the Amazon rainforest

Source: Lewis et al. (2011), Science

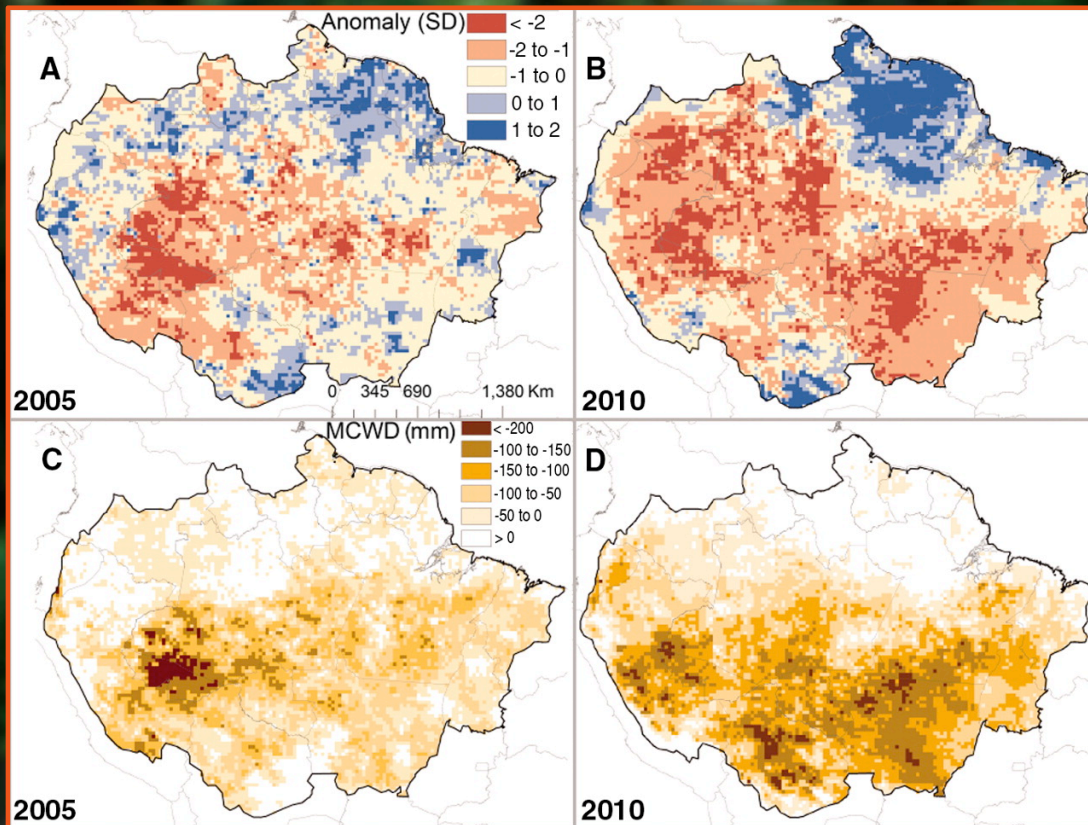


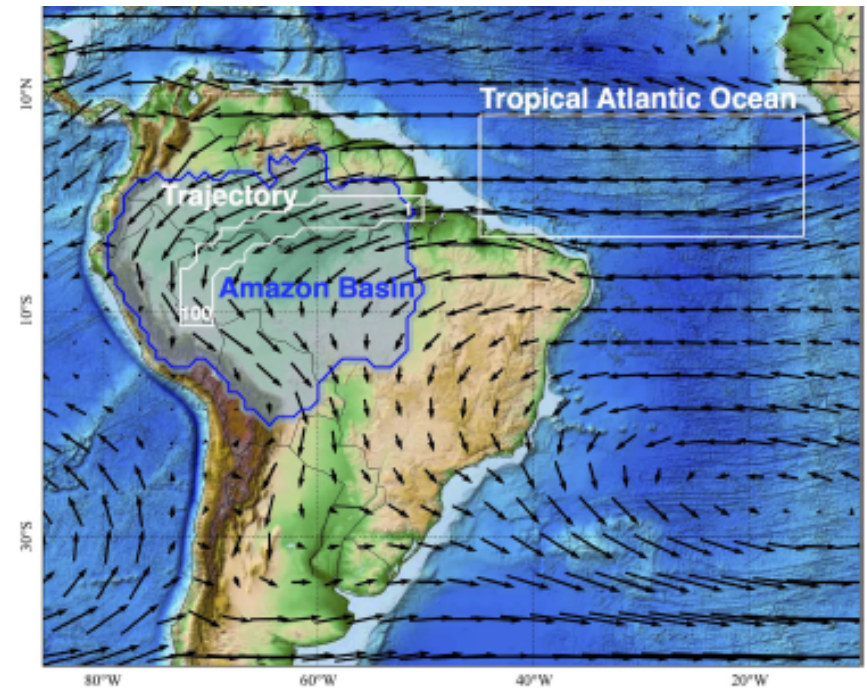
Fig 1. (A and B) Satellite-derived standardized anomalies for dry-season rainfall for the two most extensive droughts of the 21st Century in Amazonia. (C and D) The difference in the 12 months (October to September) MCWD from the decadal mean (excluding 2005 and 2010), a measure of drought intensity that correlates with tree mortality. (A) and (C) show the 2005 drought; (B) and (D) show the 2010 drought.

OPEN

A deforestation-induced tipping point for the South American monsoon system

Received: 05 August 2016
Accepted: 21 December 2016

Niklas Boers^{1,2}, Norbert Marwan², Henrique M. J. Barbosa³ & Jürgen Kurths^{2,4,5,6}



ARTICLE

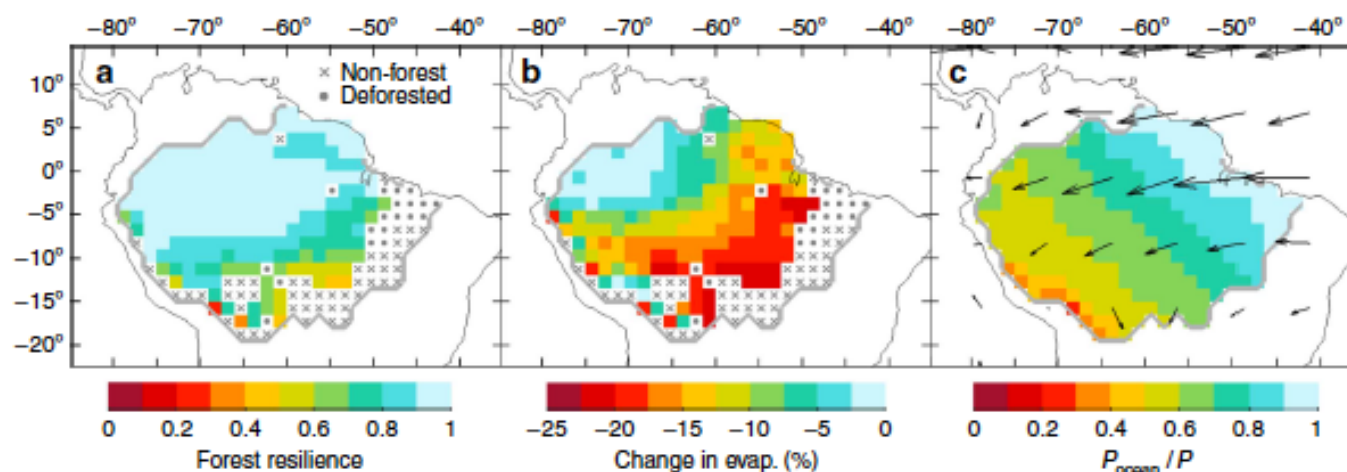
Received 9 Mar 2016 | Accepted 24 Jan 2017 | Published 13 Mar 2017

DOI: 10.1038/ncomms14681

OPEN

Self-amplified Amazon forest loss due to vegetation-atmosphere feedbacks

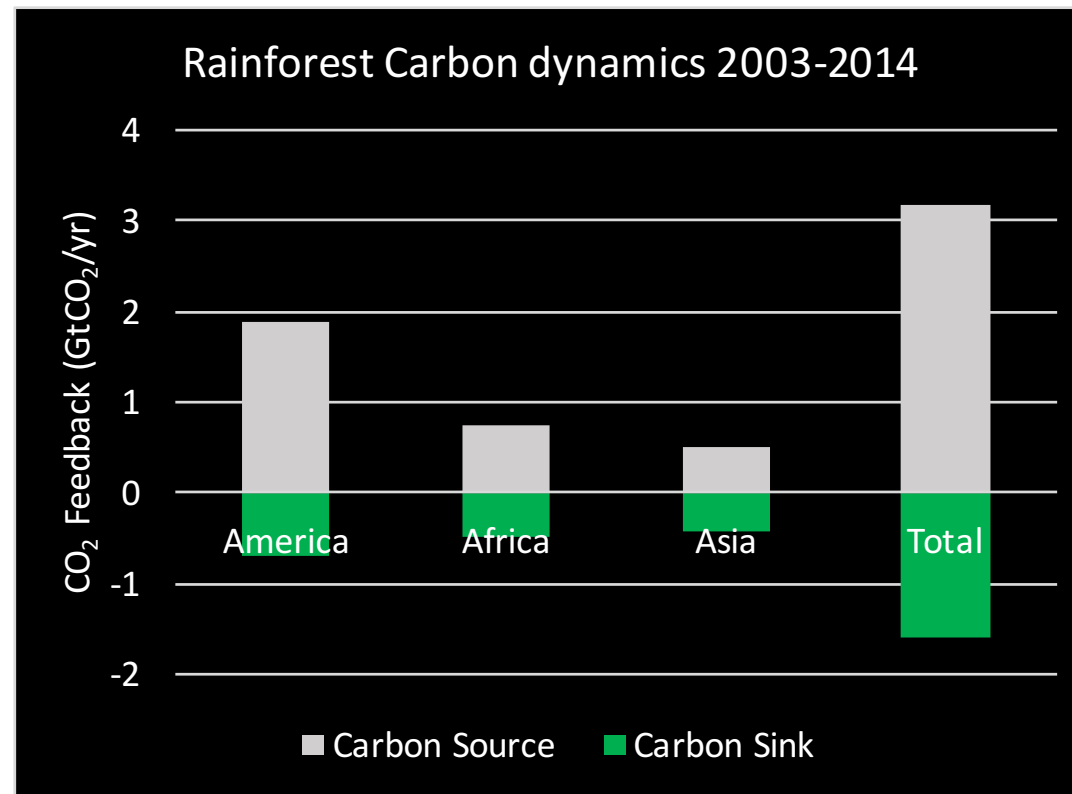
Delphine Clara Zemp^{1,2,†}, Carl-Friedrich Schleussner^{2,3}, Henrique M. J. Barbosa⁴, Marina Hirota^{5,6}, Vincent Montade⁷, Gilvan Sampaio⁸, Arie Staal⁹, Lan Wang-Erlandsson^{10,11} & Anja Rammig^{2,12}



Cite as: A. Baccini *et al.*, *Science*
10.1126/science.aam5962 (2017).

Tropical forests are a net carbon source based on aboveground measurements of gain and loss

A. Baccini,^{1*} W. Walker,¹ L. Carvalho,² M. Farina,¹ D. Sulla-Menashe,² R. A. Houghton¹



Anthropocene

+

Holocene

+

Tipping Points

=

Planetary Boundaries

FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.



SUMMARY
 • New approach proposed for defining preconditions for human development
 • Crossing certain biophysical thresholds could have disastrous consequences for humanity
 • Three of nine interlinked planetary boundaries have already been overstepped

Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years.¹ This stability has allowed human civilizations to flourish. However, human activities now pose a new threat. Since the Industrial Revolution, a new era has arisen, the Anthropocene, in which human actions have become the major driver of global environmental change.² This could see the Earth system's stability eroded, with the potential for catastrophic events that are detrimental to human well-being. To avoid such a fate, we must identify and maintain the conditions that are essential for a safe and sustainable future. We propose a framework for at least several thousands of years.

Industrialized forms of agriculture, human activities have reached a level that could damage the systems that keep Earth habitable and, in some cases, threaten environmental stability, leading to a state less conducive to human development. Without pressure to change, the Holocene is expected to continue for at least several thousands of years.

Planetary boundaries

To meet the challenge of maintaining the Holocene state, we propose a framework based on 'planetary boundaries'. These boundaries define the safe operating space for humanity with respect to the Earth's biophysical subsystems or processes. Although Earth's complex systems sometimes respond smoothly to change, there are limits to this rate. Many subsystems of Earth react in a nonlinear way, with small levels of variability sending around the edges into a new state, often with deleterious or potentially even catastrophic consequences for humanity.³

Most of these thresholds, although hard to cross, then represent subsystems such as a critical state or subsystem — for example, land use, such as carbon dioxide concentration. We all process and generate waste, and actions that undermine the system will also be crossed. Processes and associated thresholds which, if crossed, could generate unacceptable environmental change. We have found nine such processes, and associated thresholds, that are necessary to define planetary boundaries, and that have the potential to be transgressed. These are: climate change, ocean acidification, stratospheric ozone depletion, land use change, freshwater use, global biodiversity loss, atmospheric aerosol loading, chemical pollution, and nitrogen cycle. The inner green shaded ring represents the current operating space for the planetary system. The red wedges represent an estimate of the current position for each variable. The boundaries in these systems (out of biophysical boundaries, climate change and human interference with the nitrogen cycle), have already been exceeded.

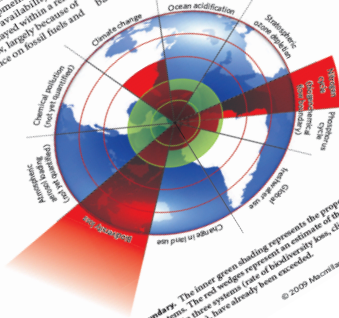


Figure 1 | Beyond the boundary. The inner green shaded ring represents the current operating space for the planetary system. The red wedges represent an estimate of the current position for each variable. The boundaries in these systems (out of biophysical boundaries, climate change and human interference with the nitrogen cycle), have already been exceeded.

RESEARCH

RESEARCH ARTICLE

SUSTAINABILITY

Planetary boundaries: Guiding human development on a changing planet

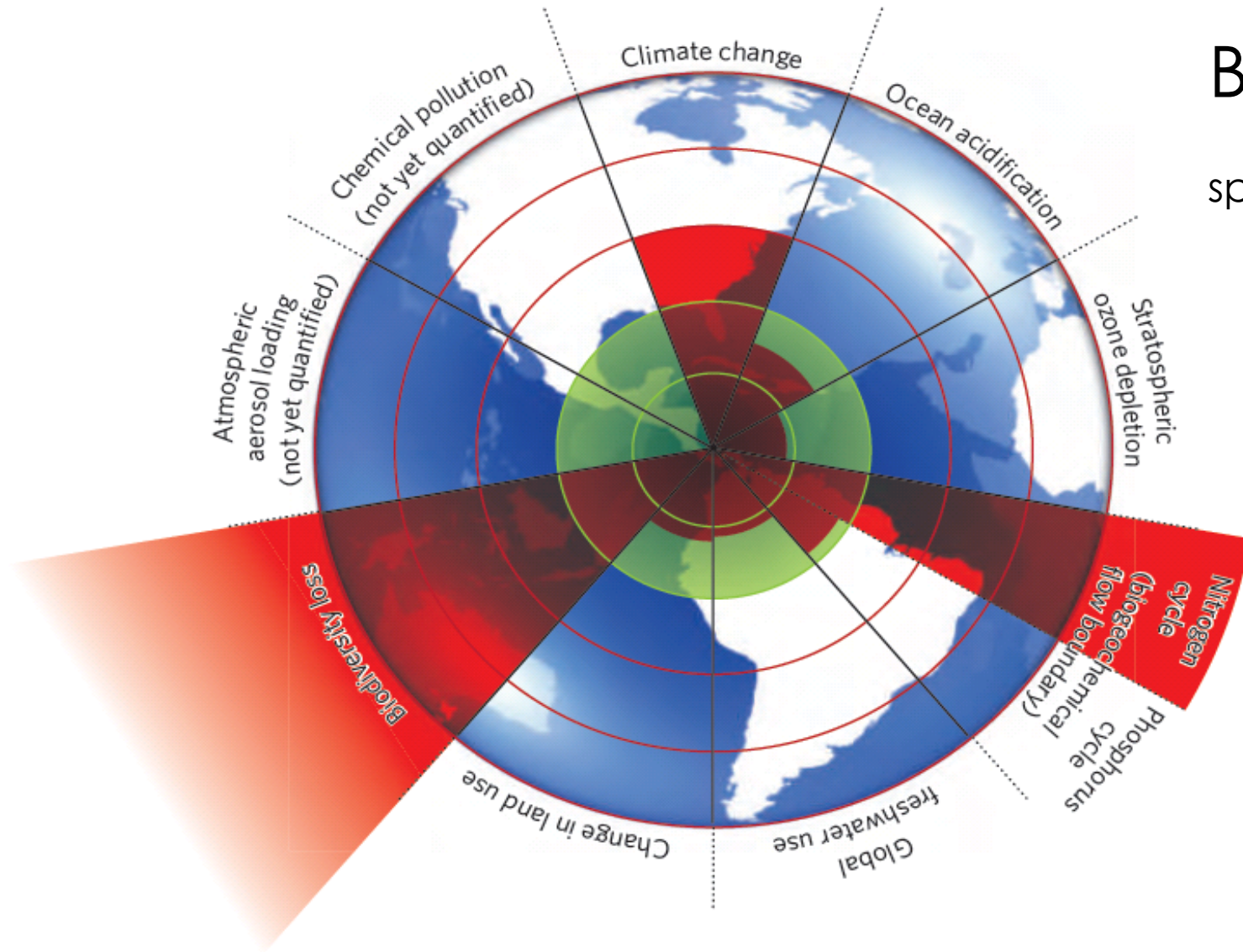
Will Steffen,^{1,2*} Katherine Richardson,³ Johan Rockström,¹ Sarah E. Cornell,¹ Ingo Fetzer,¹ Elena M. Bennett,⁴ Reinette Biggs,^{1,5} Stephen R. Carpenter,⁶ Wim de Vries,^{7,8} Cynthia A. de Wit,⁹ Carl Folke,^{1,10} Dieter Gerten,¹¹ Jens Heinke,^{11,12,13} Georgina M. Mace,¹⁴ Linn M. Persson,¹⁵ Veerabhadran Ramanathan,^{16,17} Belinda Reyers,^{1,18} Sverker Sorlin¹⁹

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Planetary Boundaries

A safe operating space for humanity

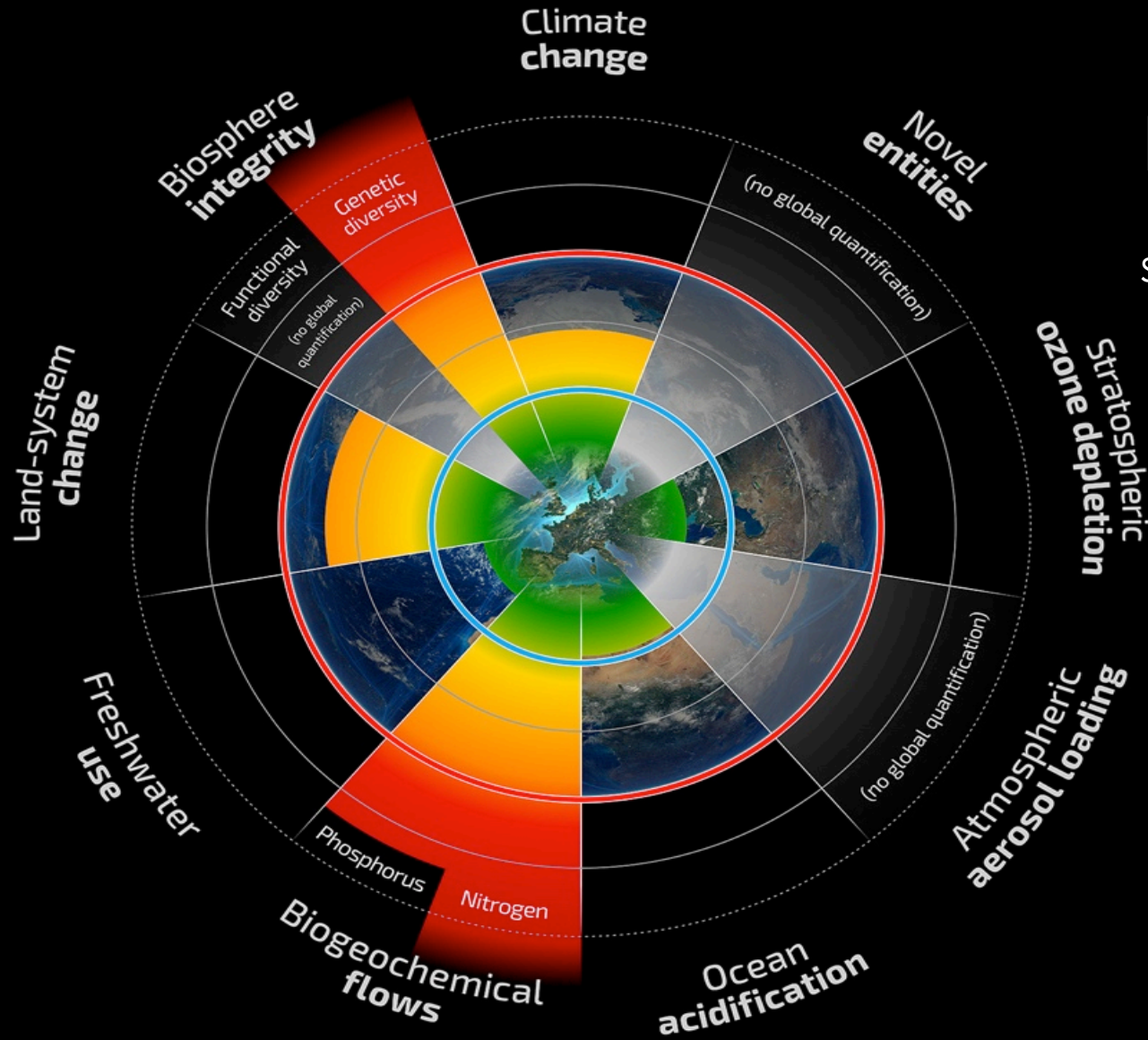
2009 1st Analysis



Planetary Boundaries

A safe operating space for humanity

2015 Update





Pictet - Environmental Megatrend Selection

Pictet Asset Management

February 2015
Geneva



Pictet Asset Management | For professional investors only | Pictet - Environmental Megatrend Selection

Definition of the opportunity set

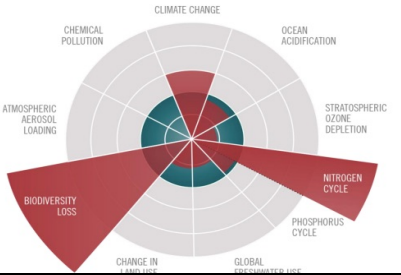


THE B TEAM

- > Demand on environmental resources exceeds the natural regeneration rate
- > A novel and rigorous framework presented in *Nature* in 2009 selected by our team
- > Nine key environmental dimensions, each with its own 'threshold'
- > "Safe operating space" defined as the area within thresholds

Companies within the safe operating space are more likely to benefit from environmental trends

The nine planetary boundaries and the safe operating space



Agile organizations... sustainability shifts

Planetary Boundaries – Policy Operationalization



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

Ministry of Infrastructure and the Environment



Supported by:



Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

Planetary Boundaries – Intergovernmental focus



European Environment Agency



Living well, within
the limits of our planet
7th Environment Action Programme



RESEARCH
PROGRAM ON
Water, Land and
Ecosystems





The Global Commons in the Anthropocene – Biomes,
Biogeochemical cycles and Biodiversity

Image: NASA

A photograph showing several fishermen in a body of water, pulling a large, reddish-brown fishing net. The net is overflowing with fish, creating a large splash of white water. The fishermen are wearing various hats and work clothes. The background is a calm, light-colored body of water.

World Transformations to Global Sustainable Development

Towards transformation – Four priority areas

Source: Rockström et al. (2016). Global Commons in the Anthropocene: World Development on a Stable and Resilient Planet. IIASA & SRC



1

Global energy system transformation

2

Transformation towards sustainable cities & urbanisation

3

Transformation towards a healthy & sustainable food system

4

A transformation to a circular economy paradigm



The Carbon Law – A Moore's law for climate stability

The Carbon Law

Opinion | OP-ED CONTRIBUTOR

Why the World Economy Has to Be Carbon Free by 2050

By JOHAN ROCKSTROM MARCH 23, 2017

The New York Times



In front of the financial district of Pudong amid heavy smog in Shanghai in 2015. Aly Song/Reuters



CLIMATE POLICY

A roadmap for rapid decarbonization

Emissions inevitably approach zero with a "carbon law"

By Johan Rockström,¹ Owen Gaffney,² Joeri Rogelj,³ Malte Meinshausen,⁴ Nebojsa Nakicenovic,⁵ Hans Joachim Schellnhuber⁶

Although the Paris Agreement's goals (2) are aligned with science (2) and one, in principle, is technically and economically achievable (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 responsibility, 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 (CO₂) emissions every decade. Complemented by immediately instigated, scalable carbon removal and efforts to ramp down land-use CO₂ emissions, this... zero emissions...

...pose 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 (CO₂) emissions every decade. Complemented by immediately instigated, scalable carbon removal and efforts to ramp down land-use CO₂ emissions, this... zero emissions...

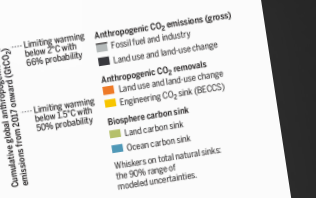
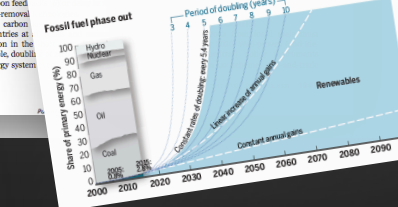
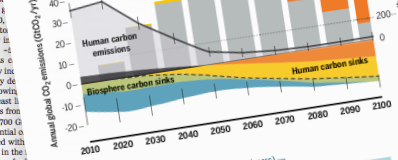
SCIENCE | science.com

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

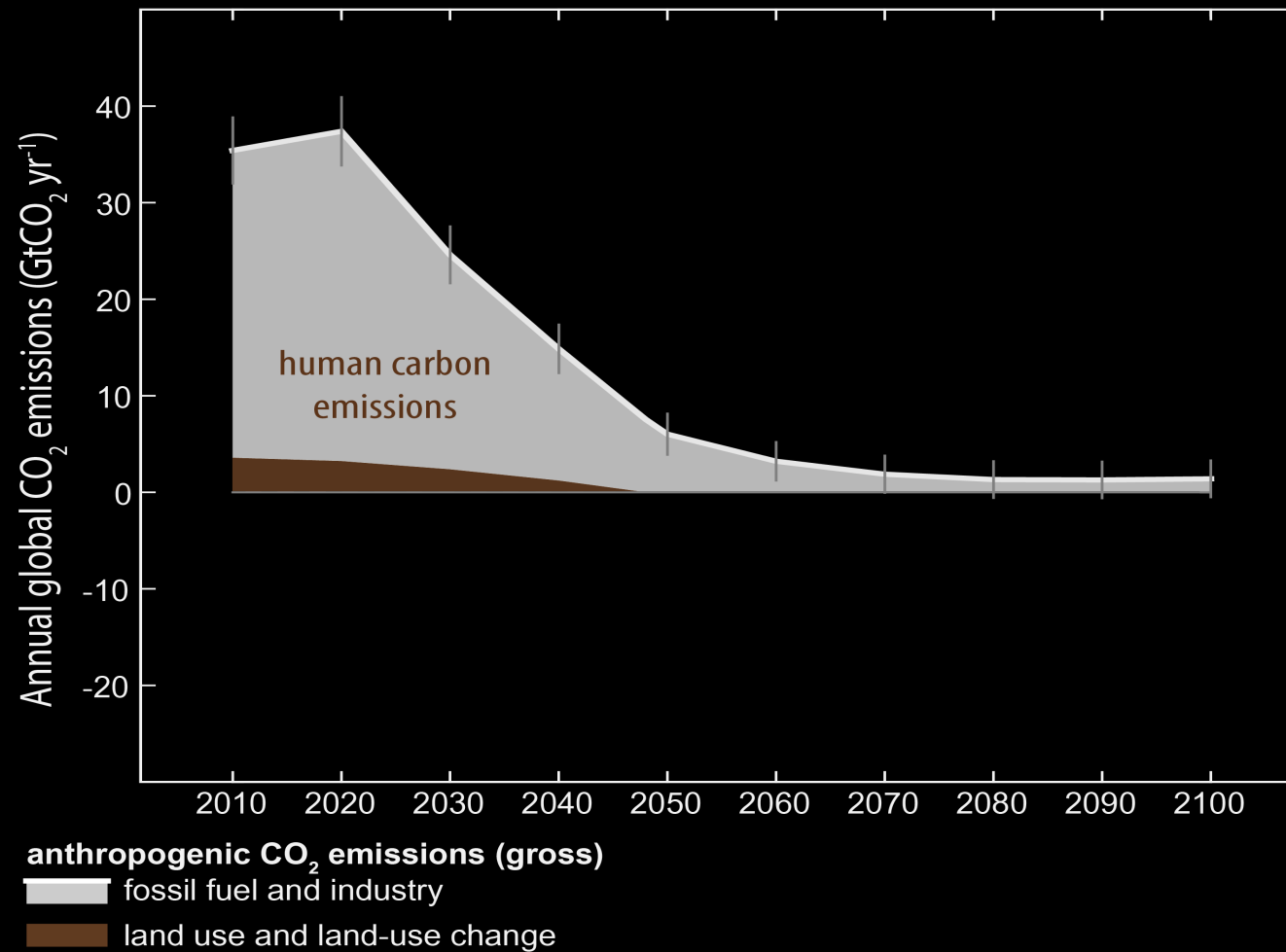
...sistent with the trajectory of the past decade (see the figure, bottom left). All sectors (e.g., agriculture, construction, finance, manufacturing, transport) need comparable transformation pathways. In addition, in the absence of viable alternatives, the world must aim at rapidly scaling up CO₂ removal by technical means from zero to at least 0.5 GtCO₂/year by 2030, 2.5 by 2040, and 8 by 2050. CO₂ emissions from land-use must decrease along a nonlinear trajectory from 4 GtCO₂/year in 2010, to 2 by 2030, 1 by 2040, and 0 by 2050 (see the figure, bottom right). The endgame is for cumulative CO₂ emissions since 2017 to be brought back from around 700 GtCO₂ to below 200 GtCO₂ by the end of the century (see the figure, top) and atmospheric CO₂ concentrations to return to 380 ppm by 2100 (currently at 400 ppm).

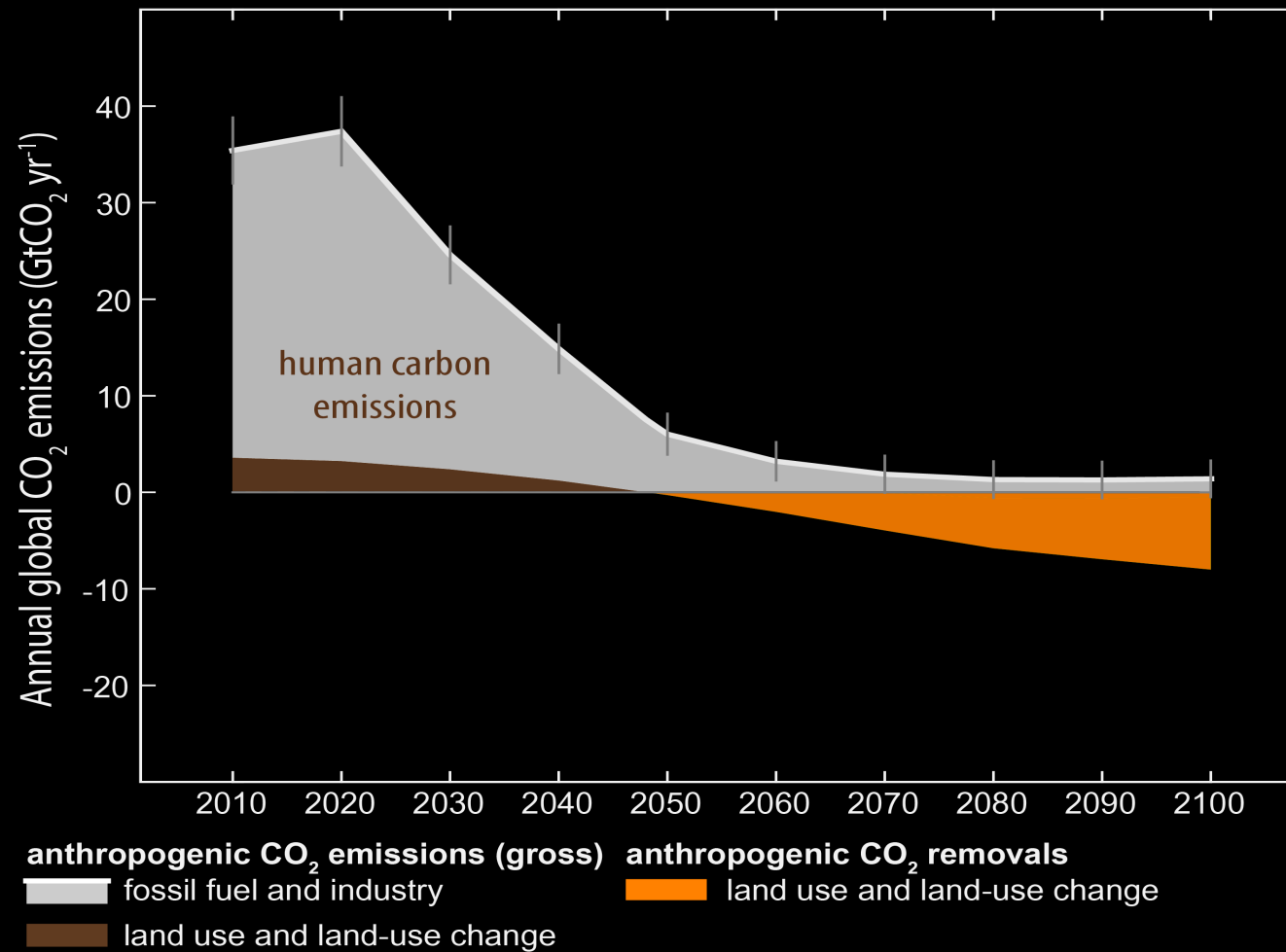
Roadmaps are planning instruments, linking shorter-term targets to longer-term goals. They help align actors and organizations to investigate technological and institutional breakthroughs to meet a collective challenge. An explicit carbon roadmap for halving anthropogenic emissions every decade, codified by and for all industry sectors, could help promote disruptive, nonlinear technological advances toward a zero-emissions world. A key to such a carbon...

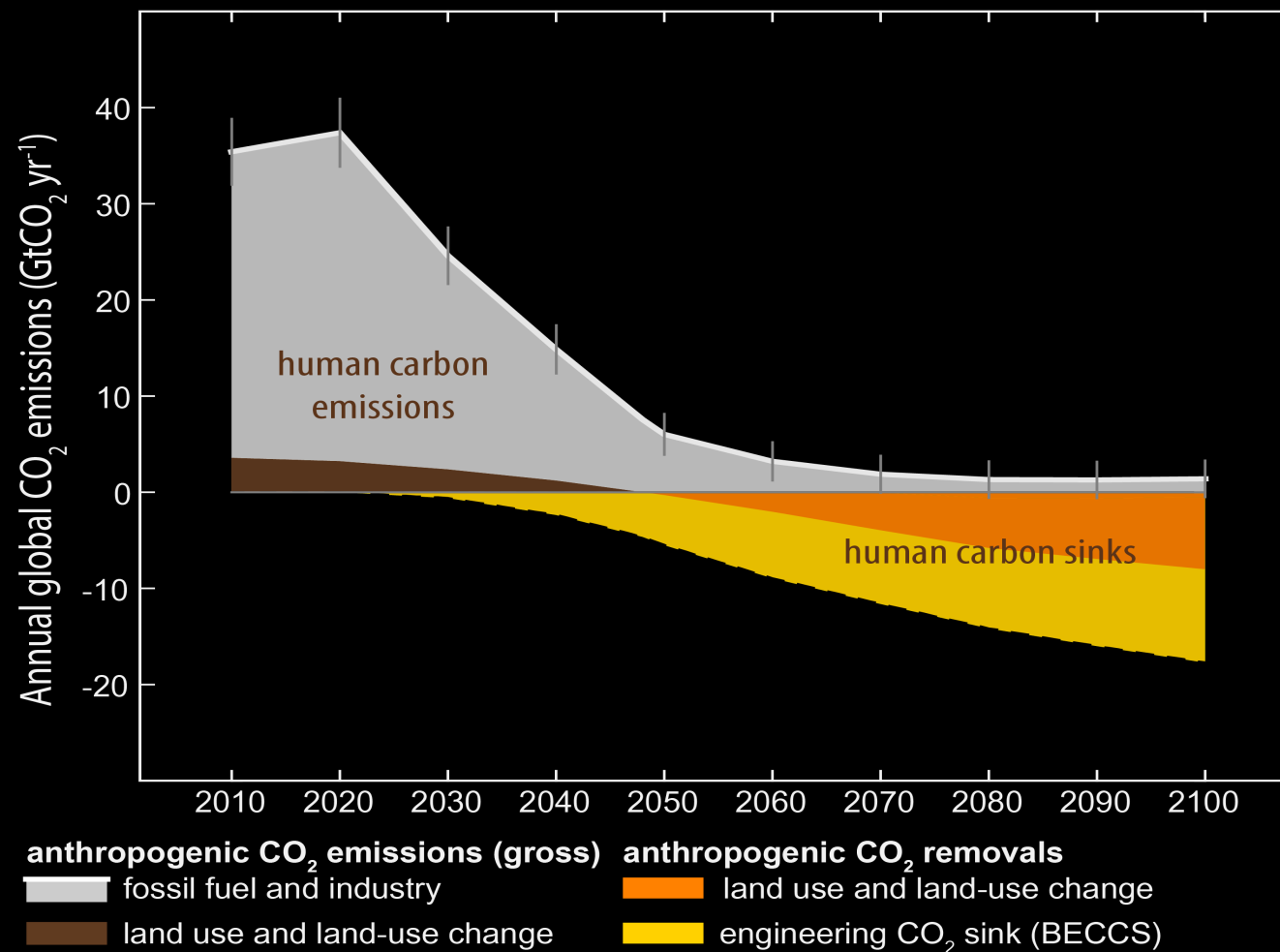
Global carbon law and roadmap to make Paris goals a reality



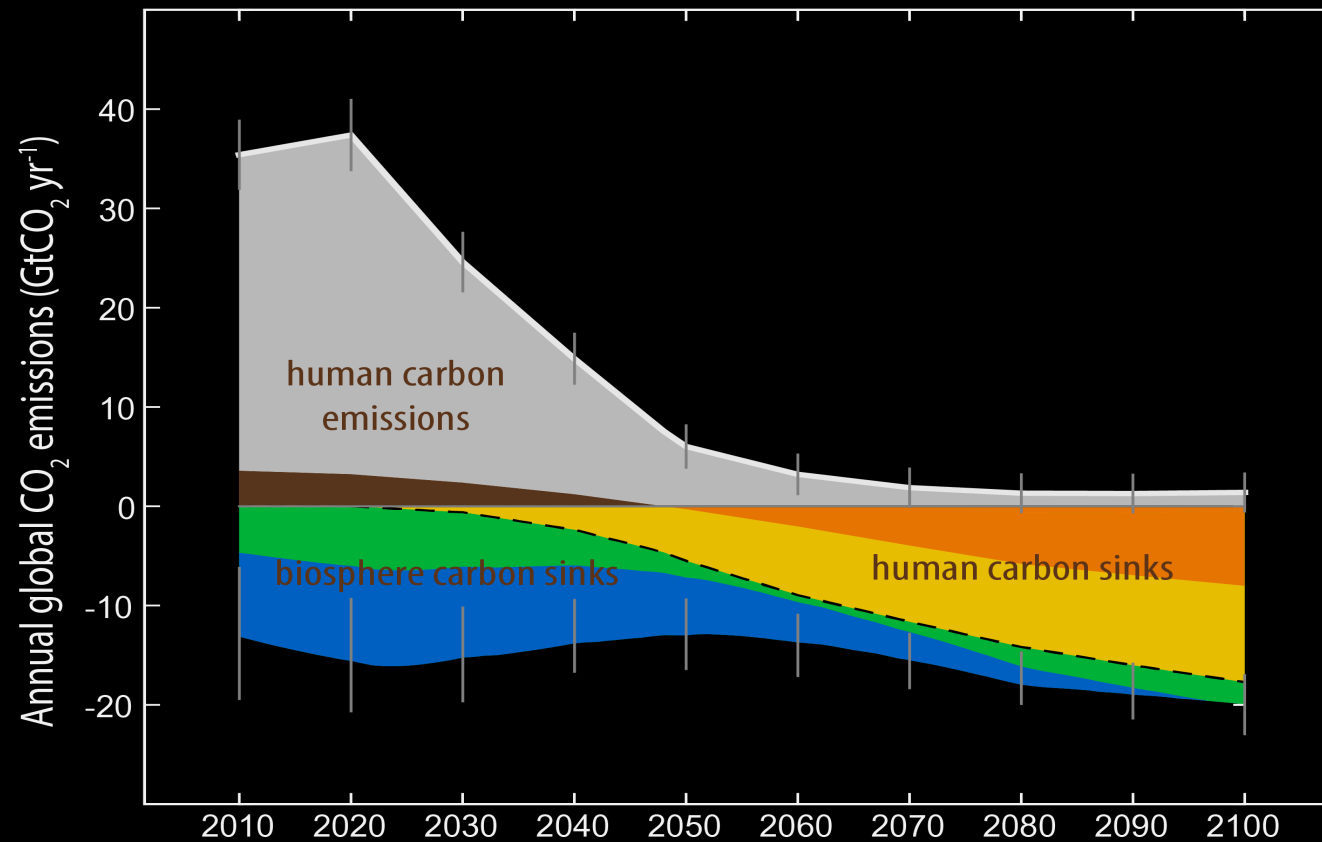
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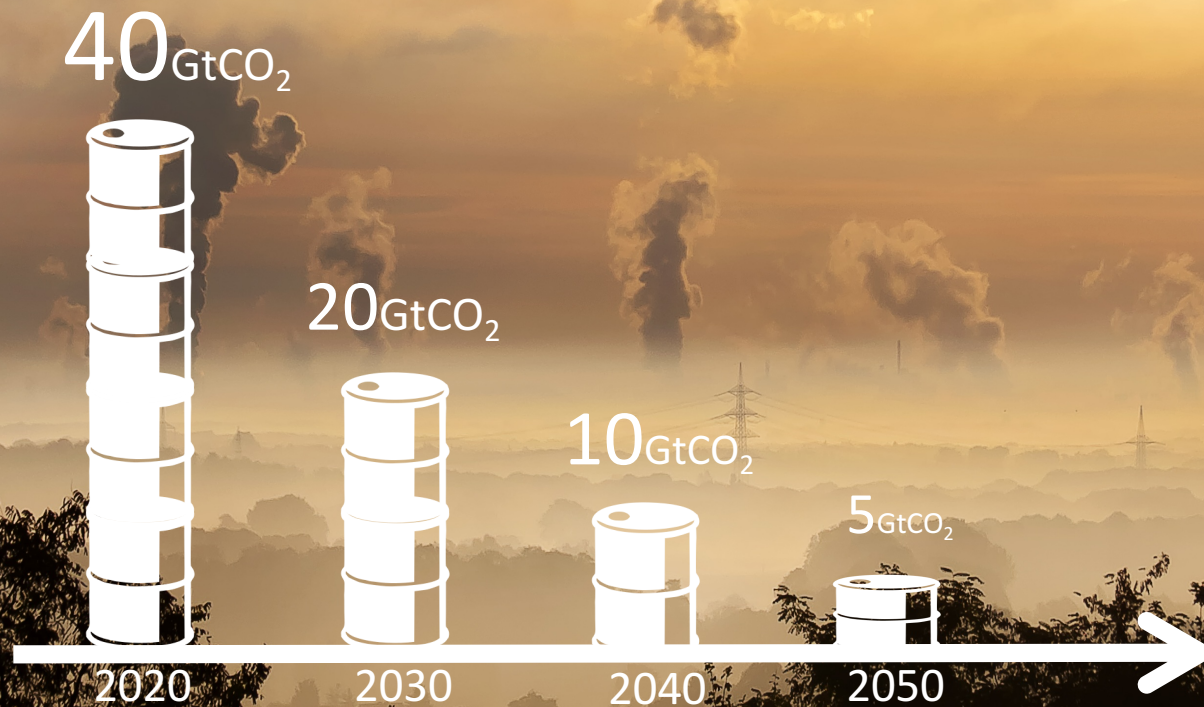


Rockström, Gaffney, Joeri, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017



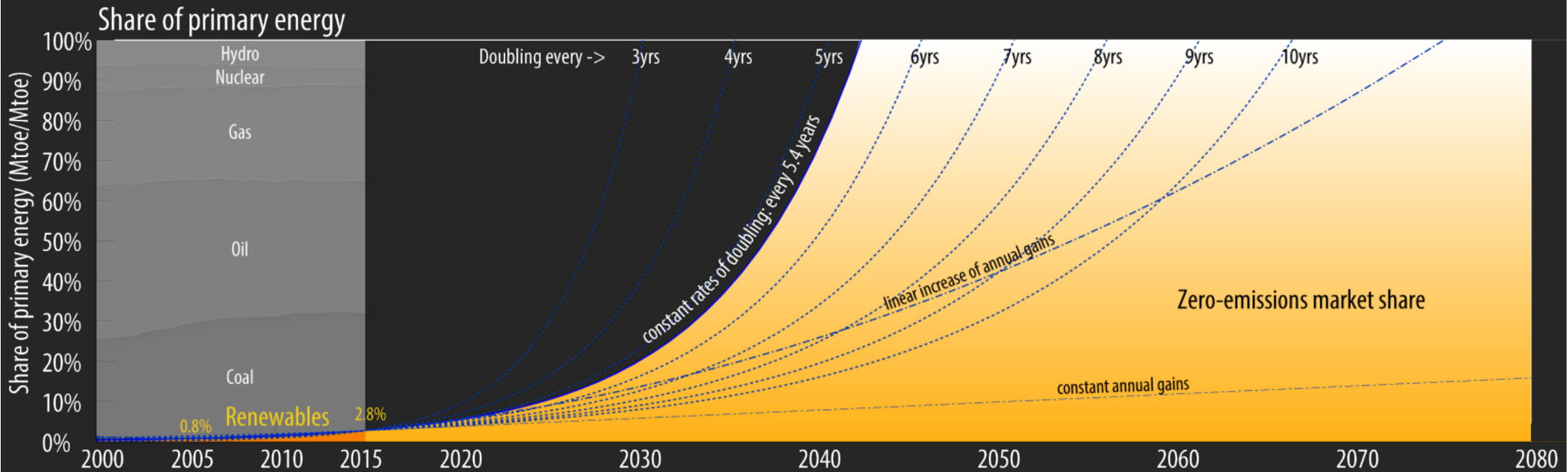
anthropogenic CO₂ emissions (gross)	anthropogenic CO₂ removals	biosphere carbon sink
<ul style="list-style-type: none"> █ fossil fuel and industry █ land use and land-use change 	<ul style="list-style-type: none"> █ land use and land-use change █ engineering CO₂ sink (BECCS) 	<ul style="list-style-type: none"> █ Land carbon sink █ Ocean carbon sink

A Global Carbon Law Halving Emissions Every Decade



We are already on the right trajectory

Renewables: Share of primary energy



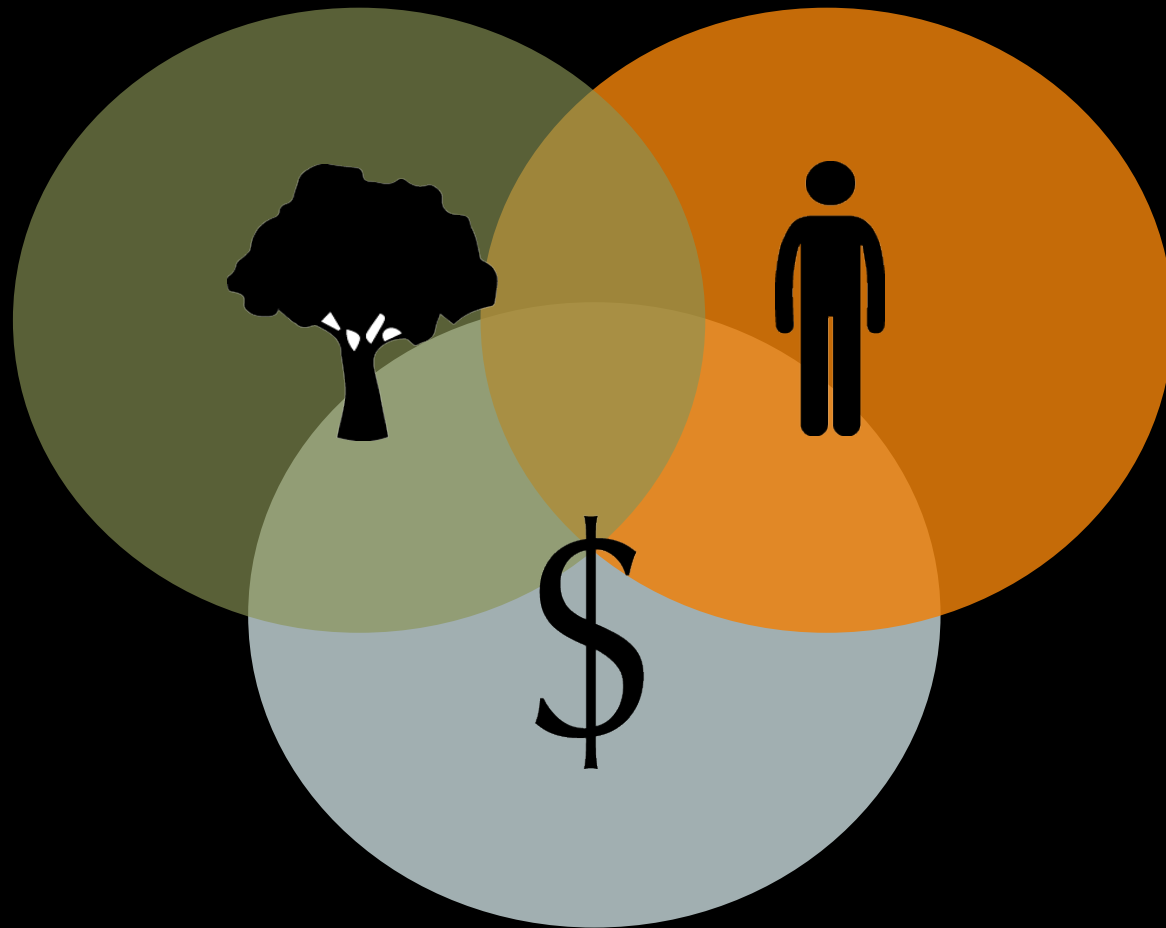


Planetary Stewardship

THE GLOBAL GOALS
For Sustainable Development



Photo: Trollbäck and





SUSTAINABLE DEVELOPMENT GOALS

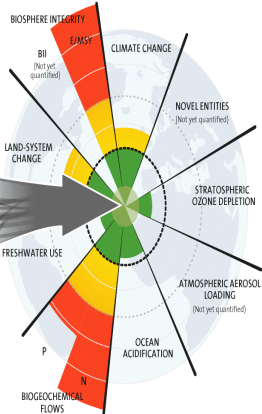
1 NO POVERTY 	2 ZERO HUNGER 	3 GOOD HEALTH AND WELL-BEING 	4 QUALITY EDUCATION 	5 GENDER EQUALITY 	6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY 	8 DECENT WORK AND ECONOMIC GROWTH 	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE 	10 REDUCED INEQUALITIES 	11 SUSTAINABLE CITIES AND COMMUNITIES 	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

The World In 2050

Degree of
Global
Sustainable
Development

Radical transformative
pathways to meet the
SDGs within planetary
boundaries

Planetary
Boundaries

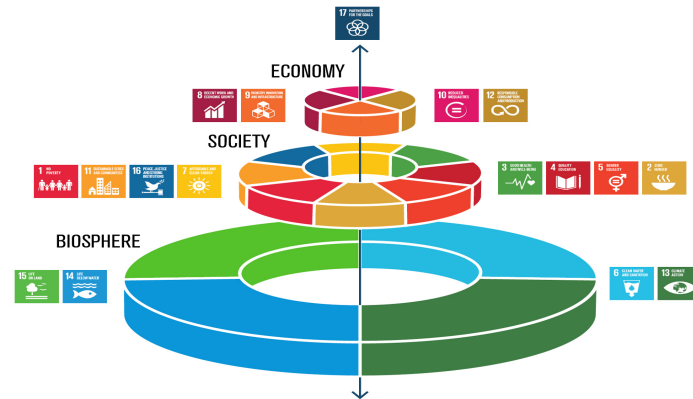
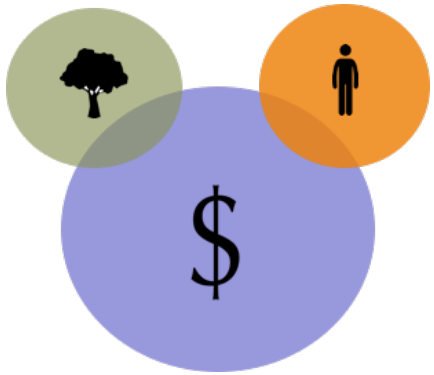


TWI2050
The World in 2050
www.twi2050.org

A smaller version of the SDG wheel graphic is integrated into the TWI2050 logo.

2030 2040 2050 Year





World
Development
within
Stable &
Resilient
Earth System



Thank you!
www.stockholmresilience.su.se

Photo: O.Henriksson/Azote

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Sustainability Science for Biosphere Stewardship

