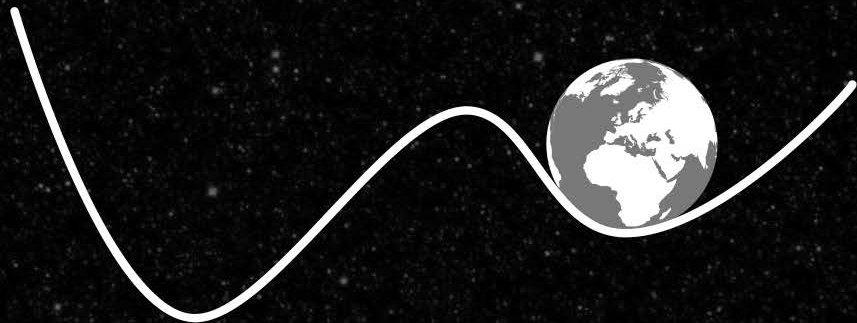


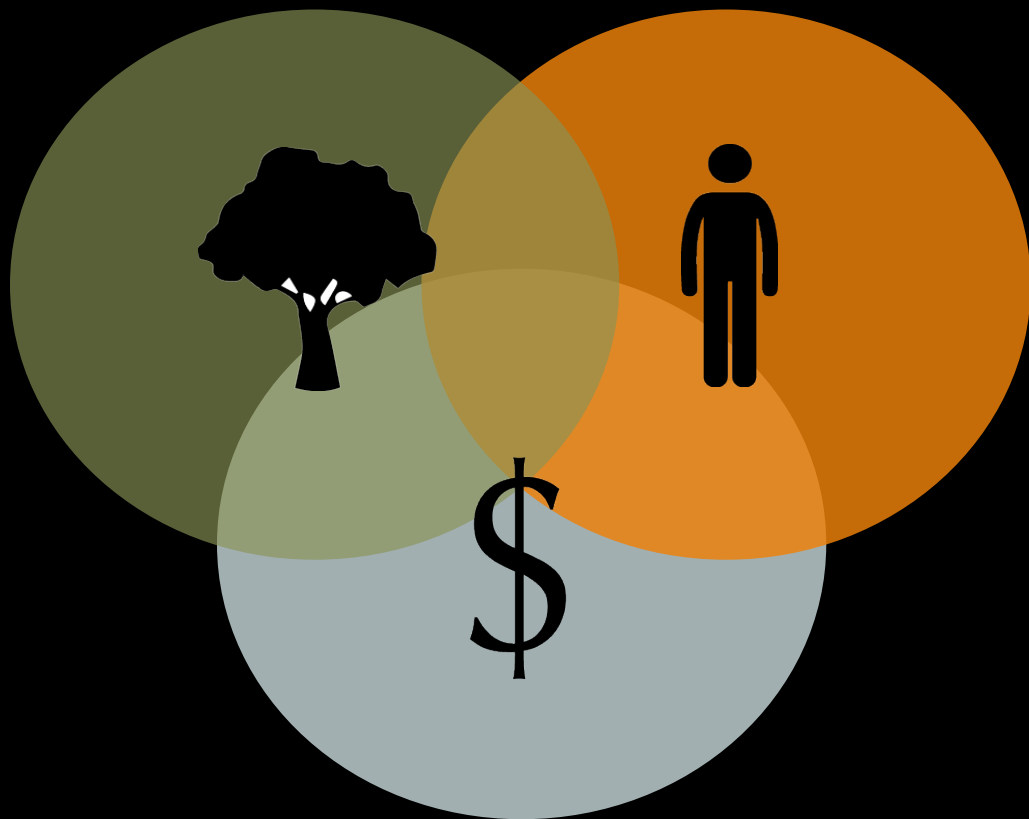
World Development within Planetary Boundaries

Roland Clift Lecture Series
University of Surrey
2nd November 2017

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

Photo: Yann Arthus-Bertrand

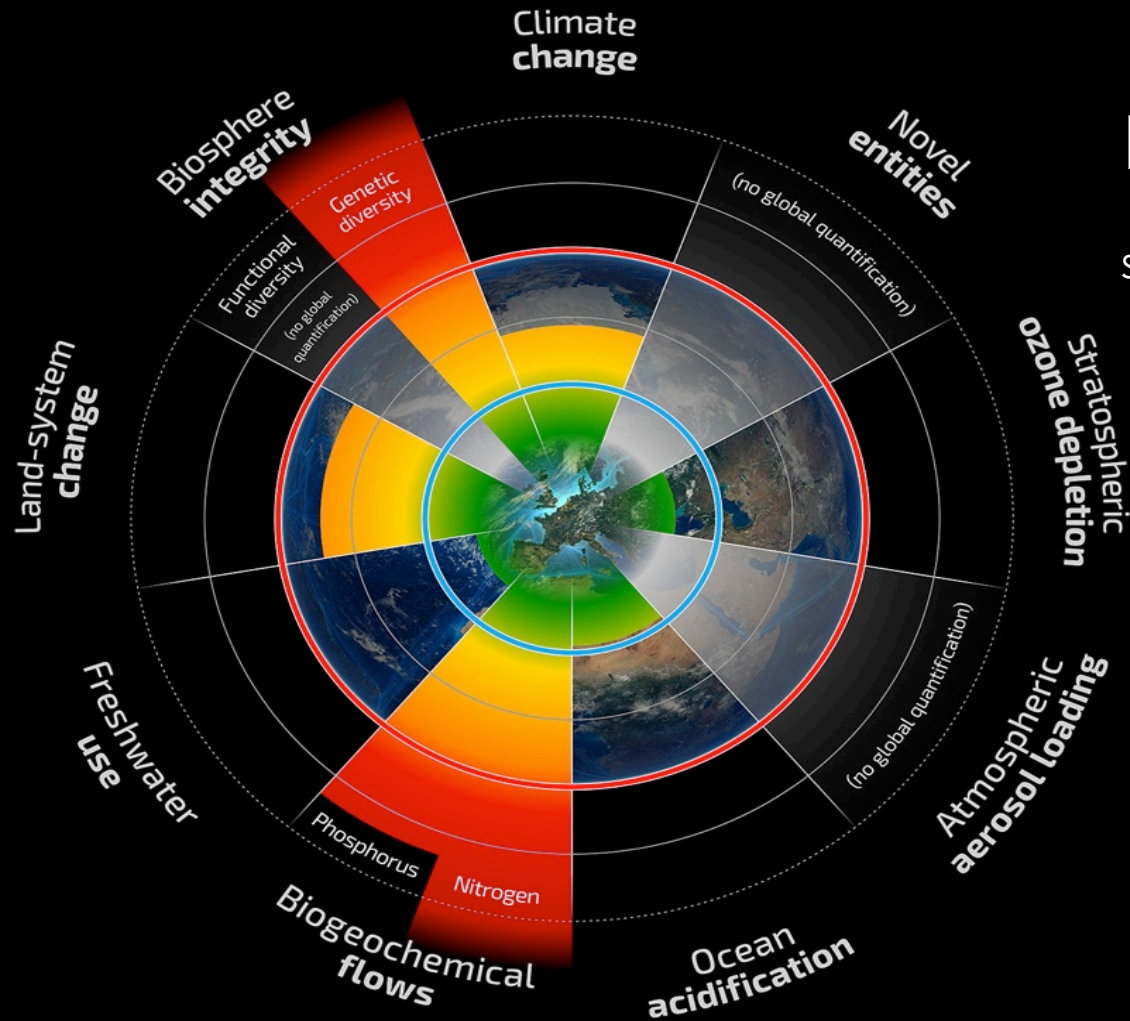




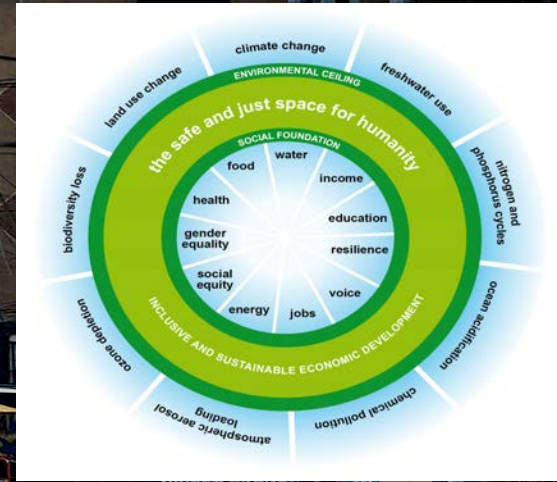
Planetary Boundaries

A safe operating space for humanity

2015 Update



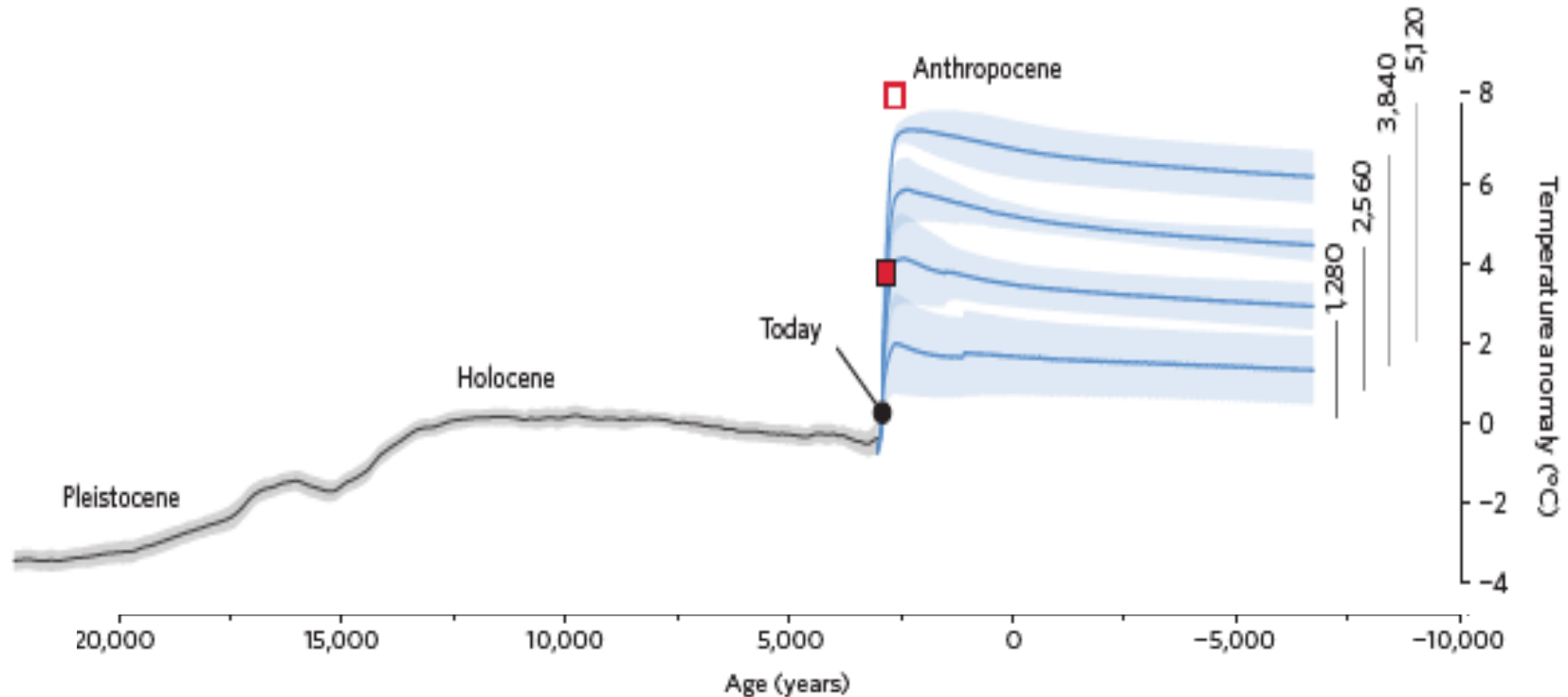
Equity and Justice in an Increasingly Turbulent World



A return to the Holocene equilibrium?

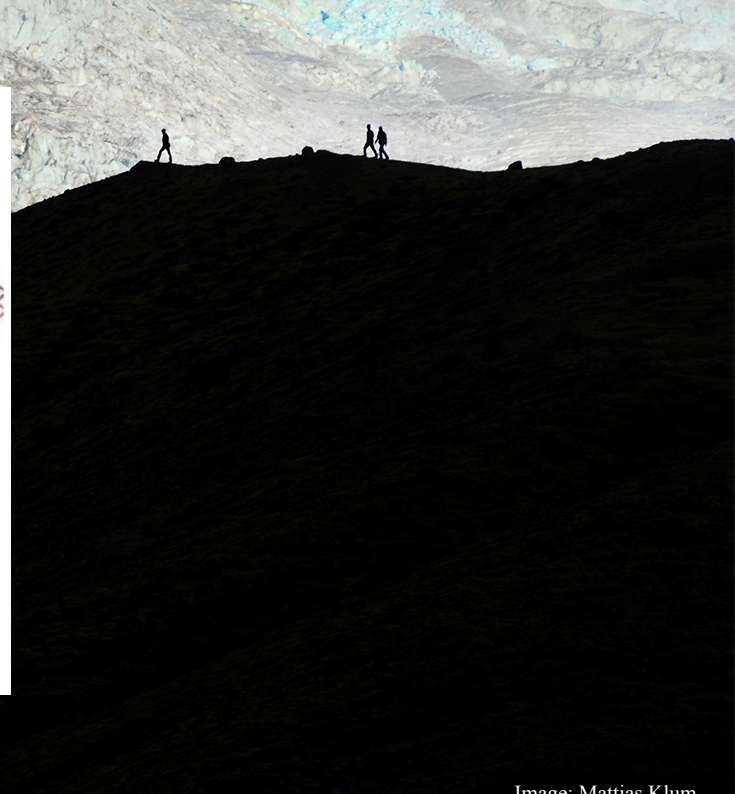
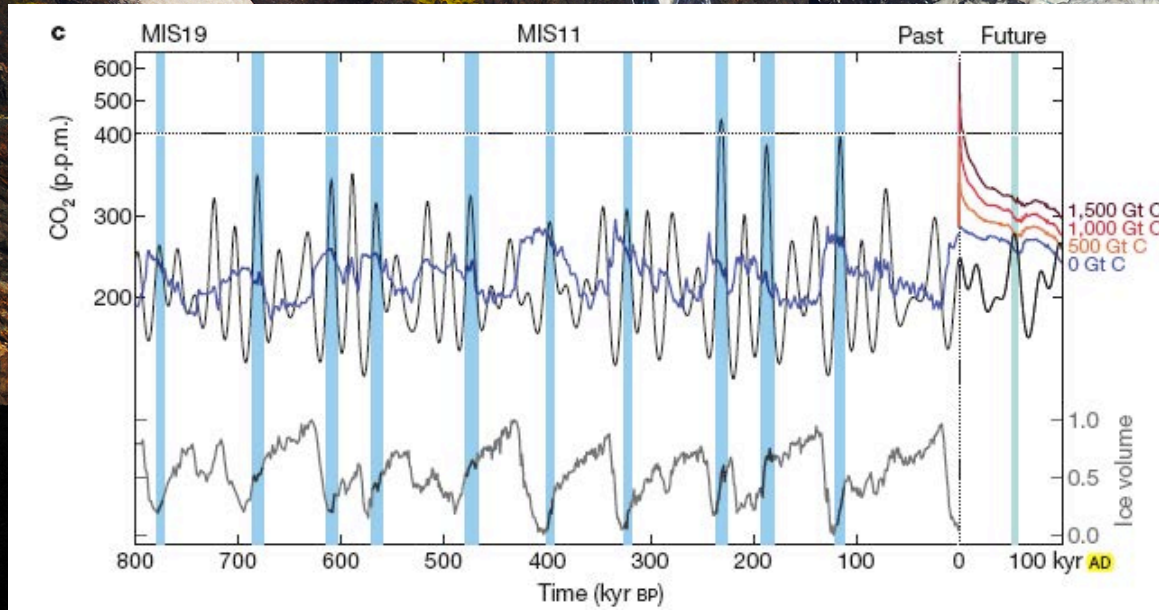
The door is likely closed...

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

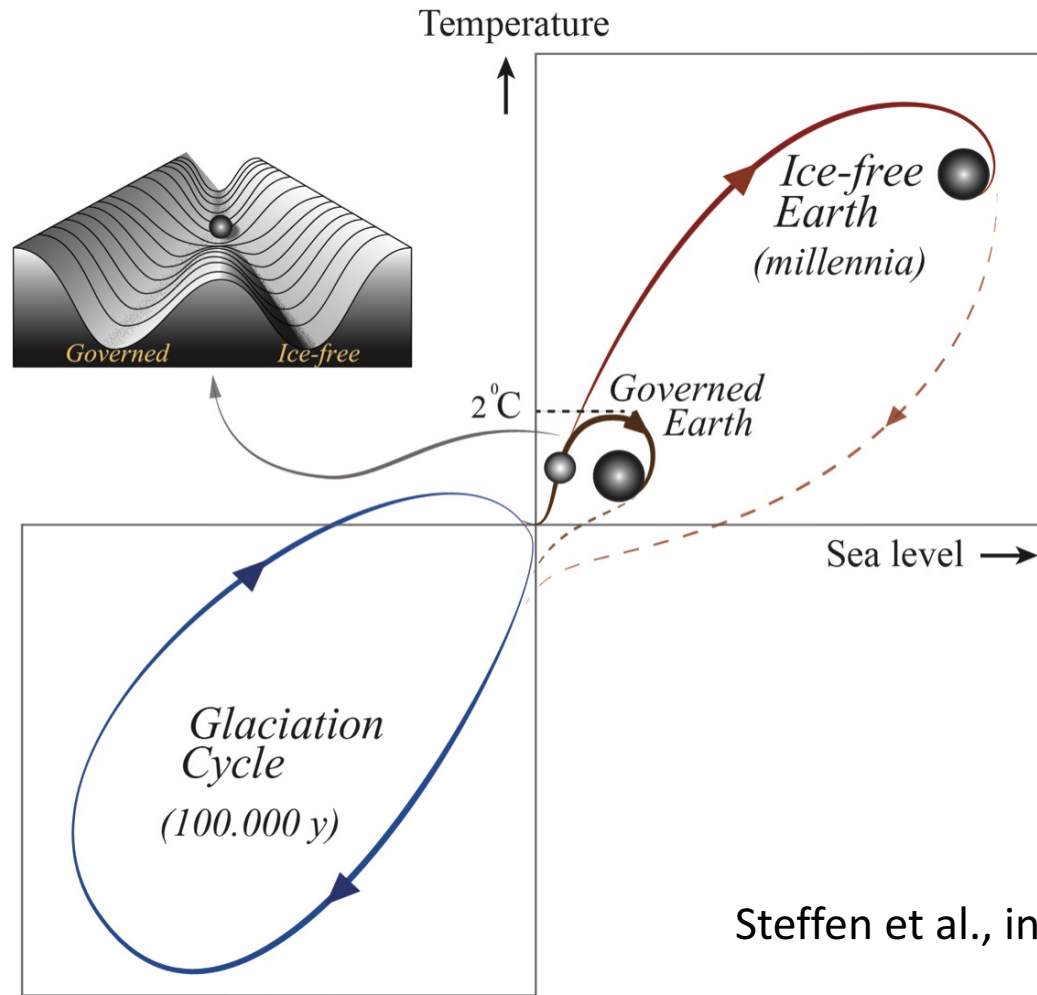


An oscillation to a new ice age? The door is likely closed...

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



Risk of Tipping the Earth System away from Manageable Inter-glacial?




Steffen et al., in prep

The background of the slide is a composite image of Earth from space, showing the curvature of the planet and the dark, cratered surface of the Moon in the upper right. Overlaid on this is a complex, glowing blue network of lines that resemble a global communication or data network, with many lines converging and diverging across the globe.

Anthropocene
+
Holocene
+
Earth Tipping points
=

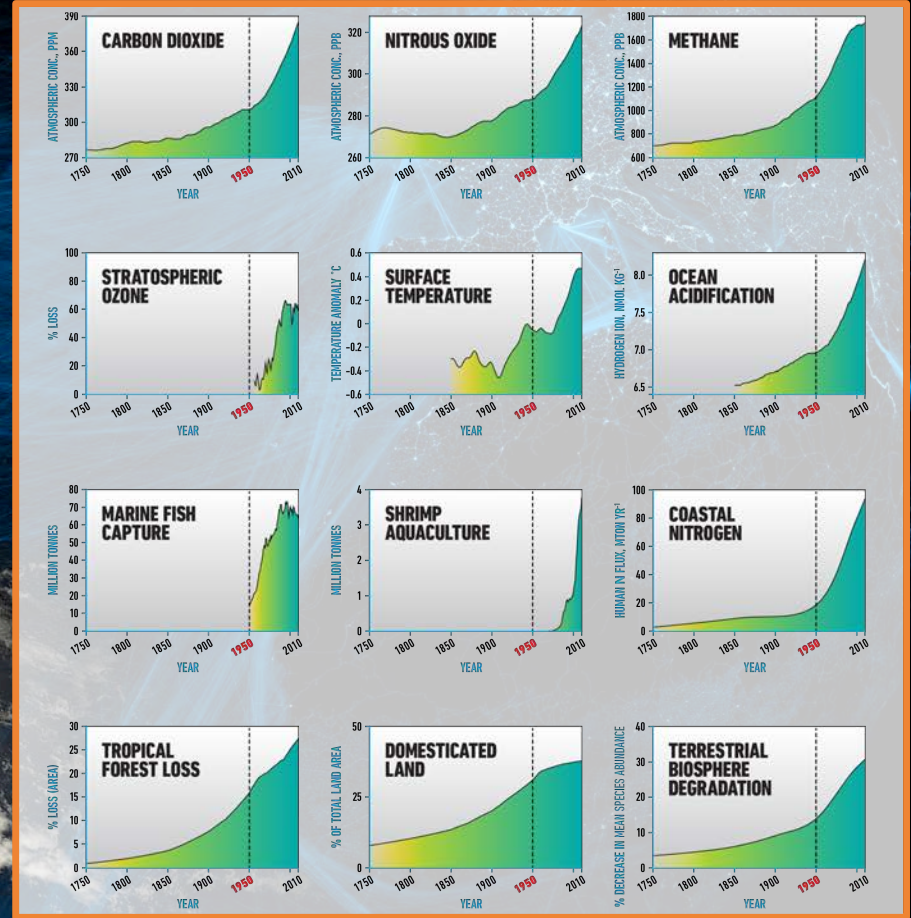
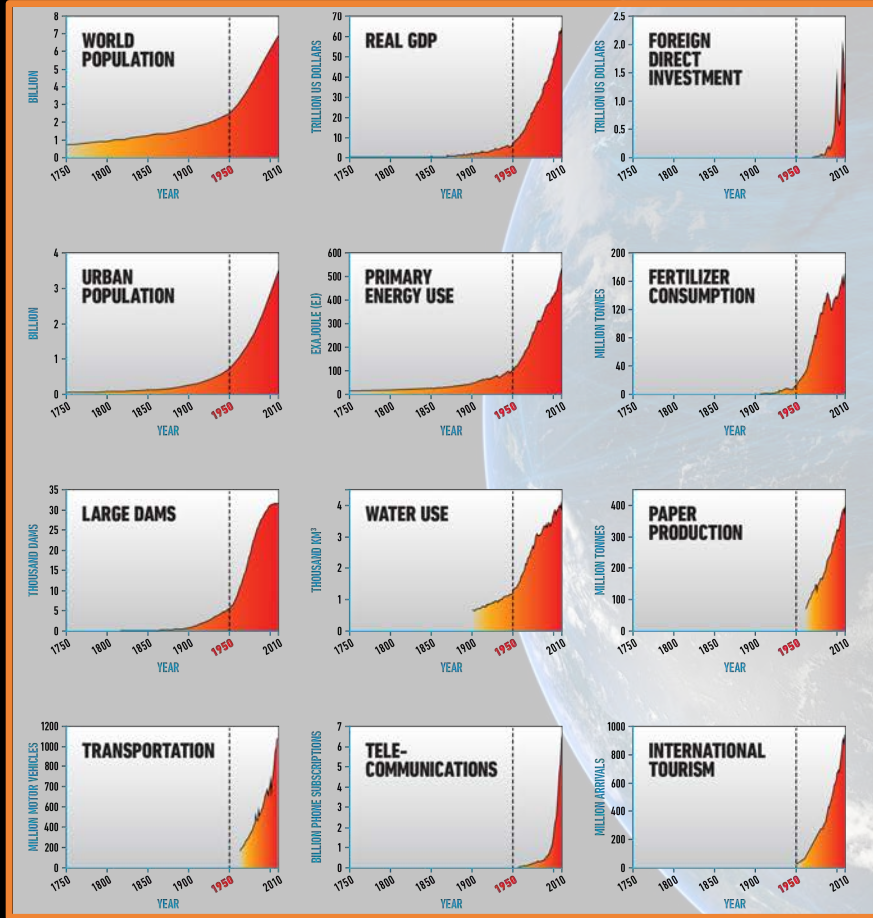
World within Stable & Resilient Earth



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

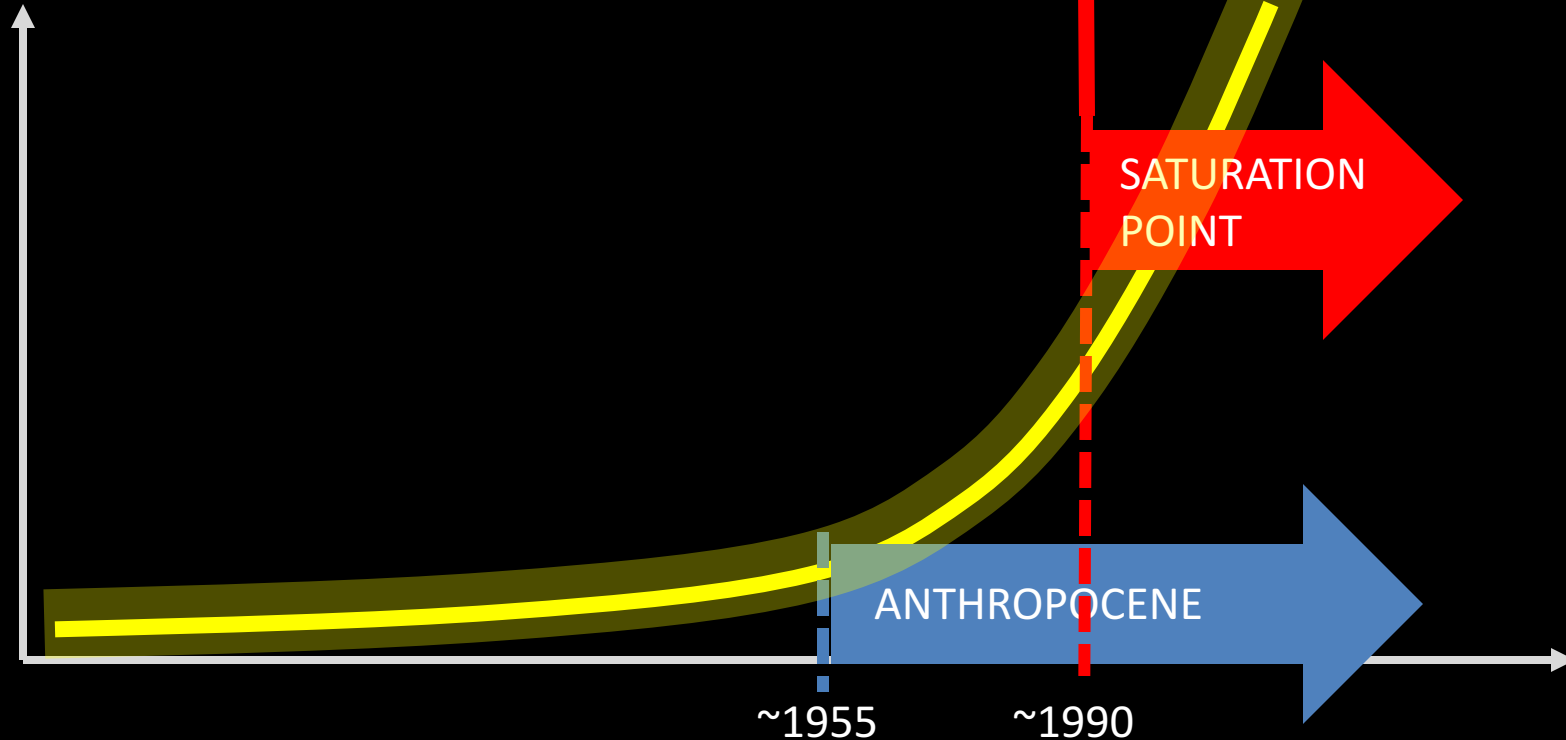
Earth resilience high

BIG WORLD ON SMALL PLANET

Internalities

Non-linear, Regime shifts

Earth resilience low



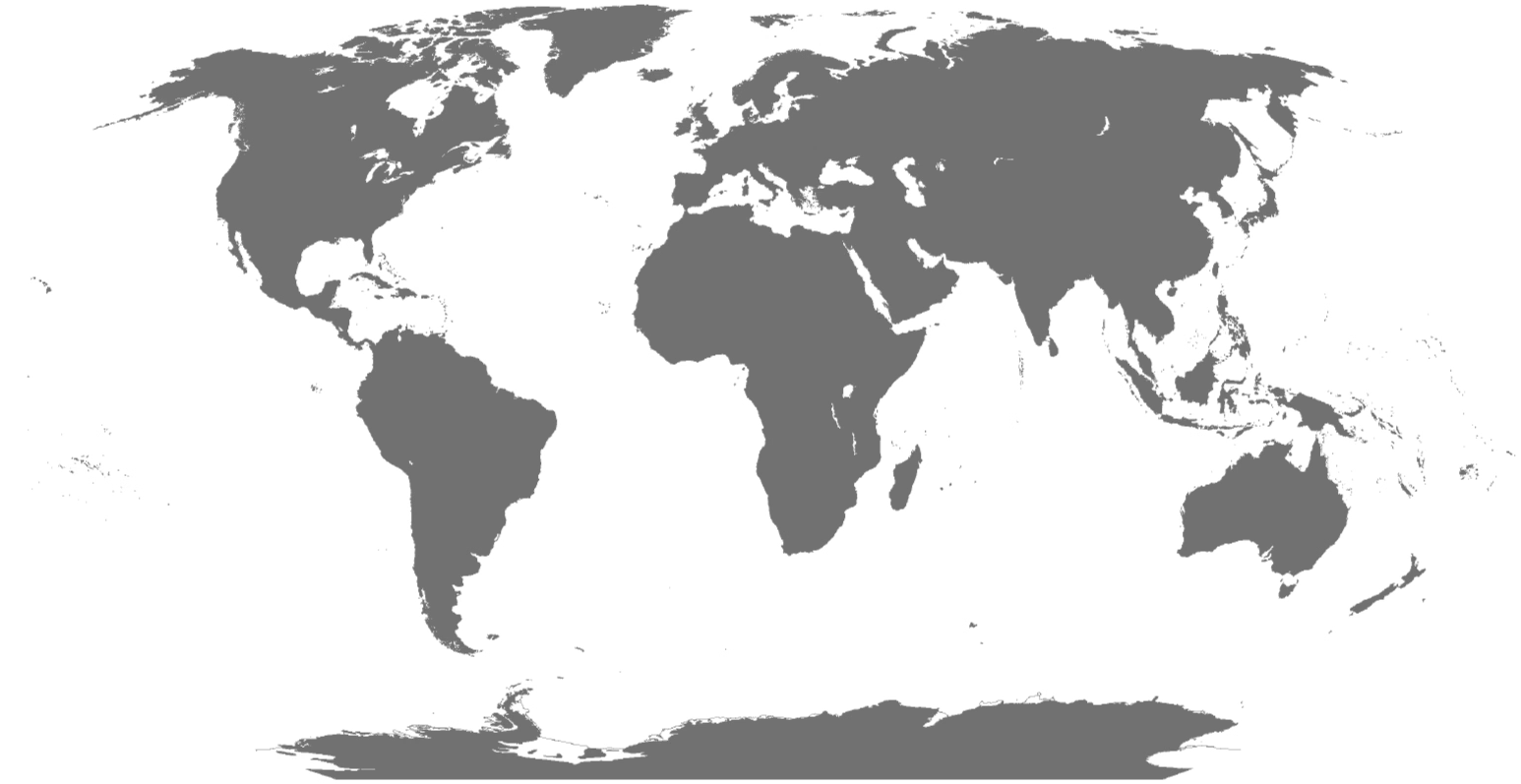
From a **small world** on a large planet...



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

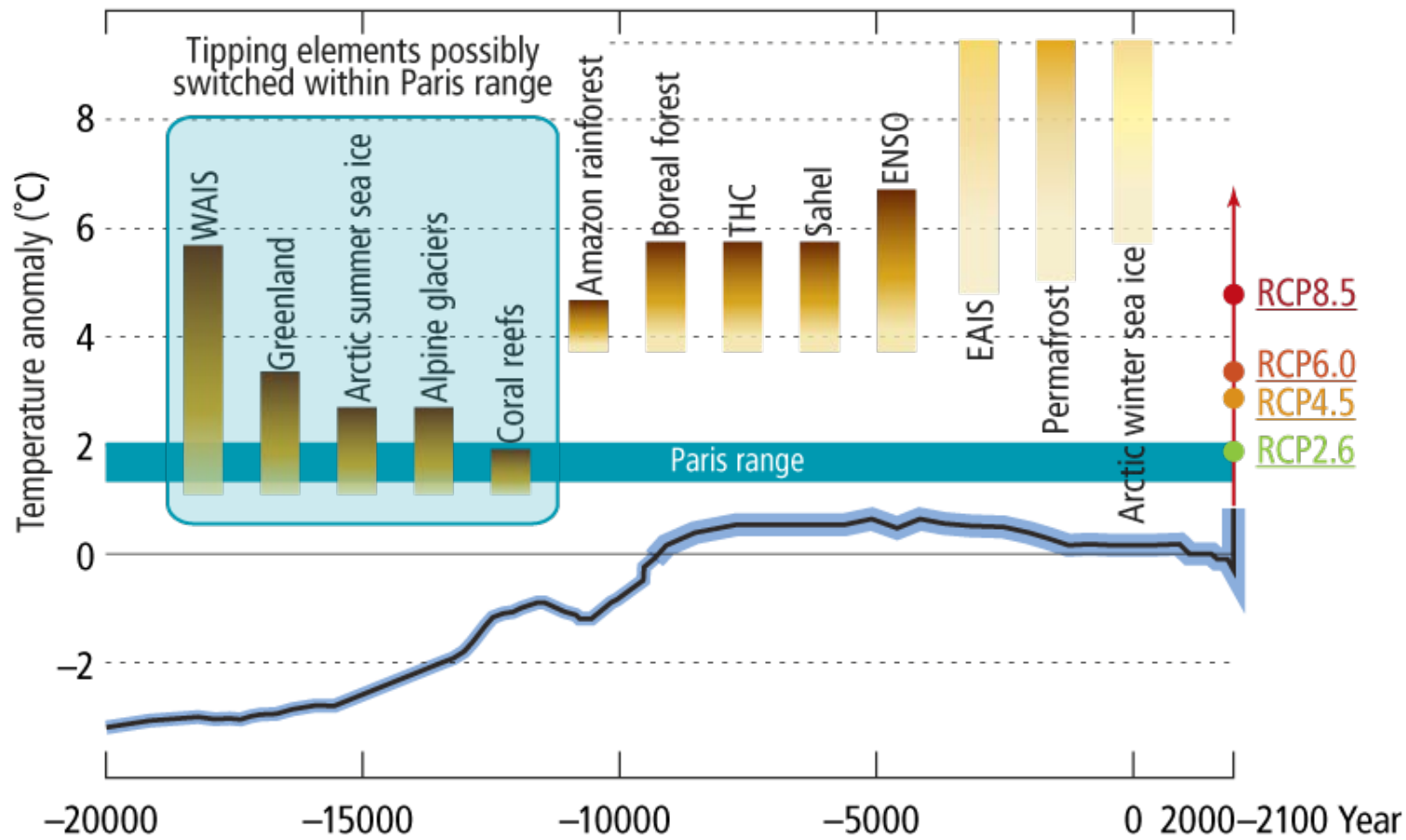


Global Tipping Points



Tipping Points & the Paris Agreement

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



A photograph of an Arctic landscape featuring a large, textured ice formation in the foreground and a bright sun with prominent rays in a clear blue sky.

A 5°C Arctic in a 2°C World

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

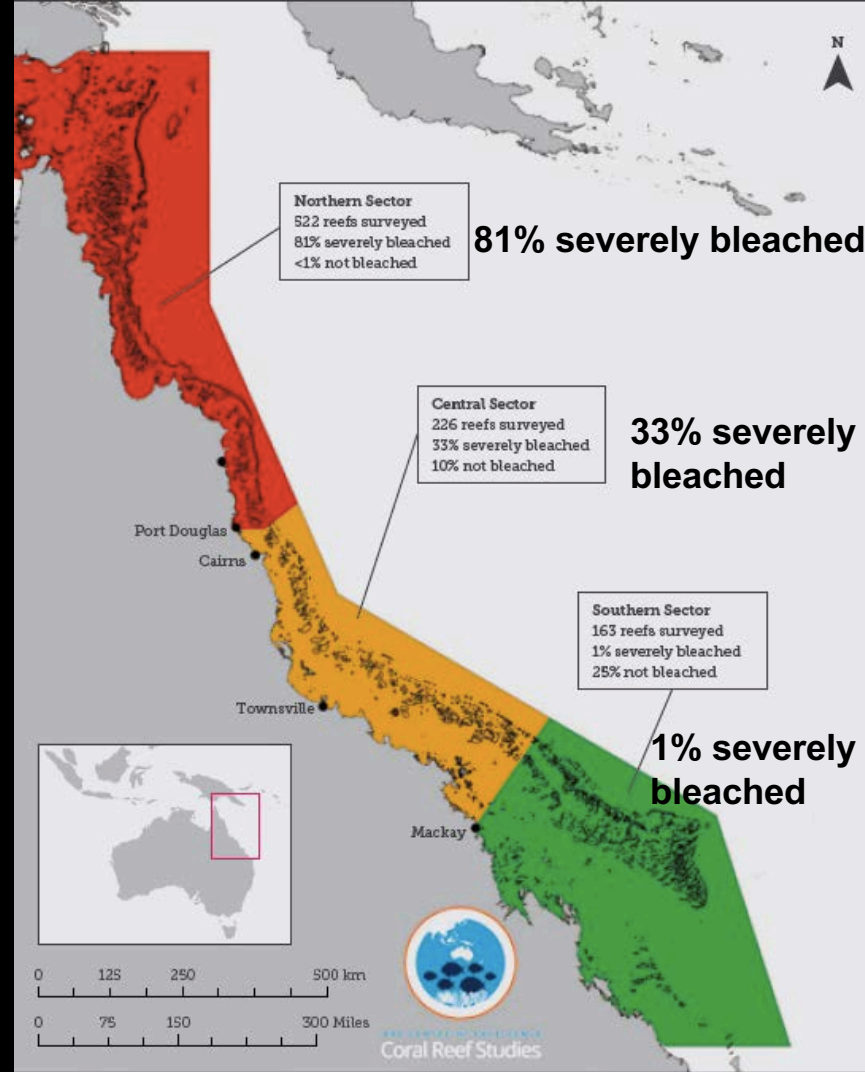
Briefing Paper for Arctic Science Ministerial

September 20, 2016

AUTHORS

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

Great Barrier Reef Bleaching 2016

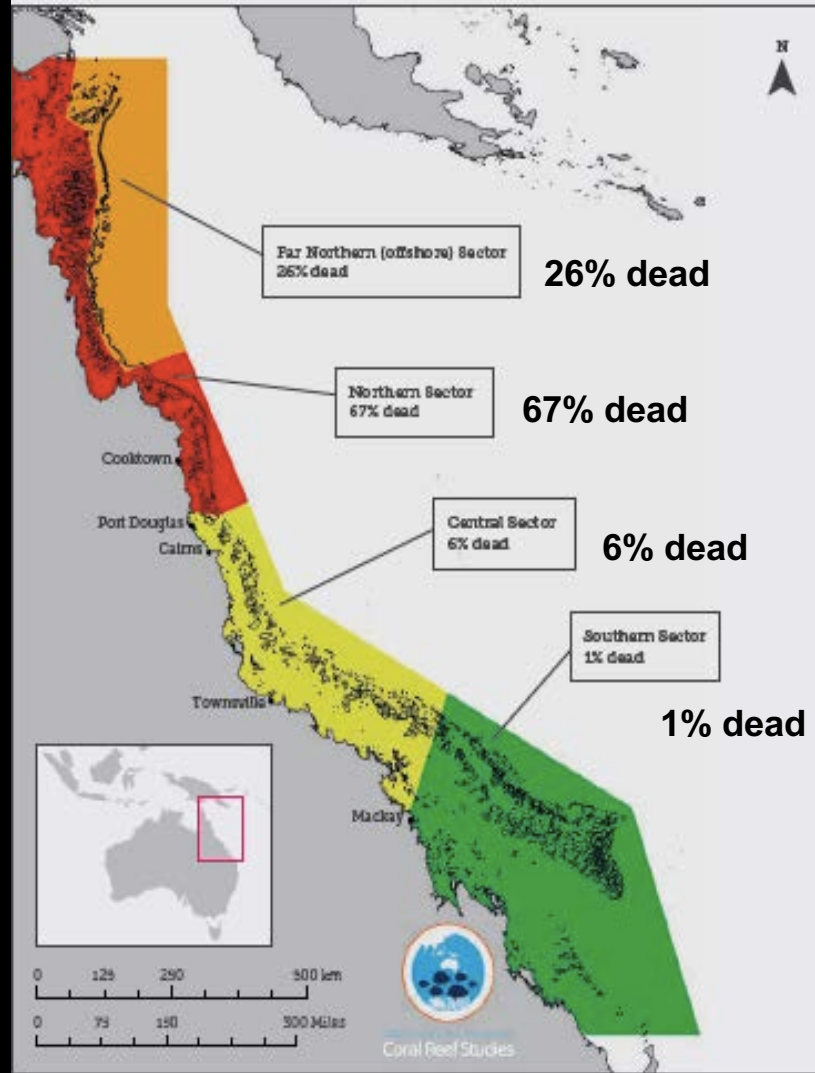


Longest global coral bleaching ever, affecting 36 % of all coral reefs around the world

> 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

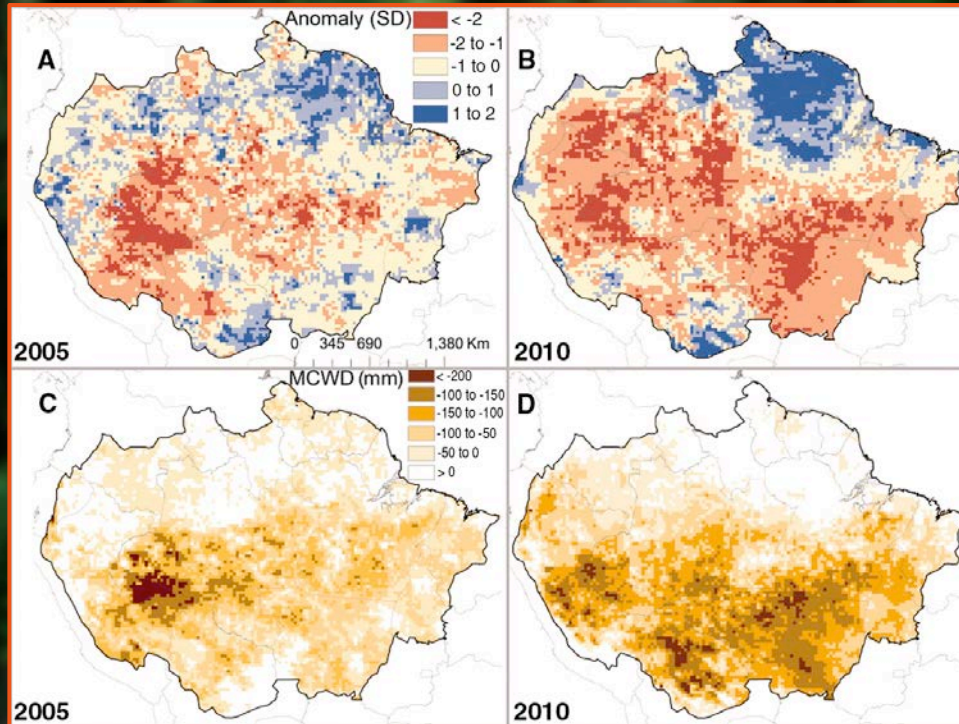


Fig 1. (A and B) Satellite-derived standardized anomalies for dry-season rainfall for the two most extensive droughts of the 21st Century in Amazonia. (C and D) The difference in the 12 months (October to September) MCWD from the decadal mean (excluding 2005 and 2010), a measure of drought intensity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

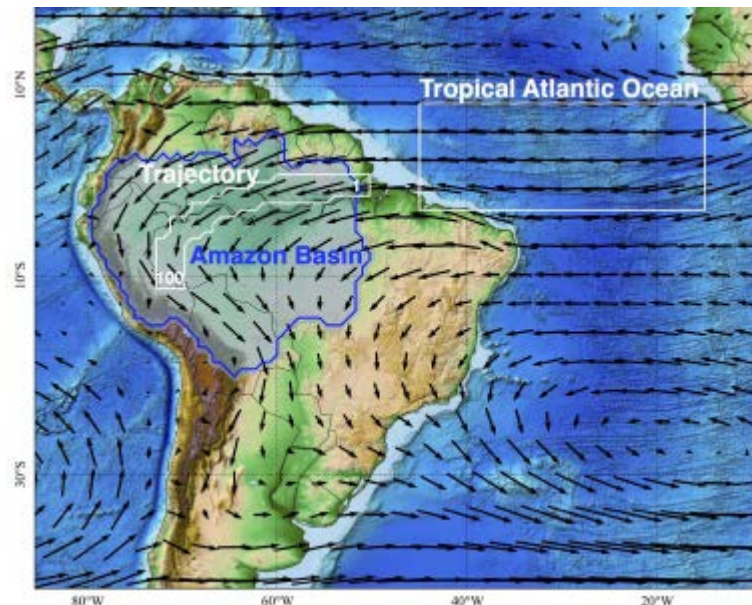
OPEN

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

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

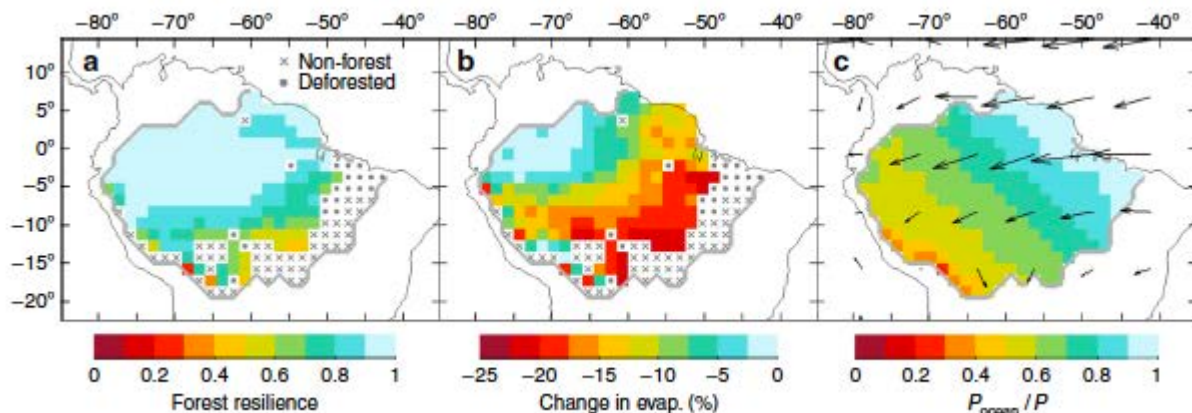
Received: 05 August 2016

Accepted: 21 December 2016



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

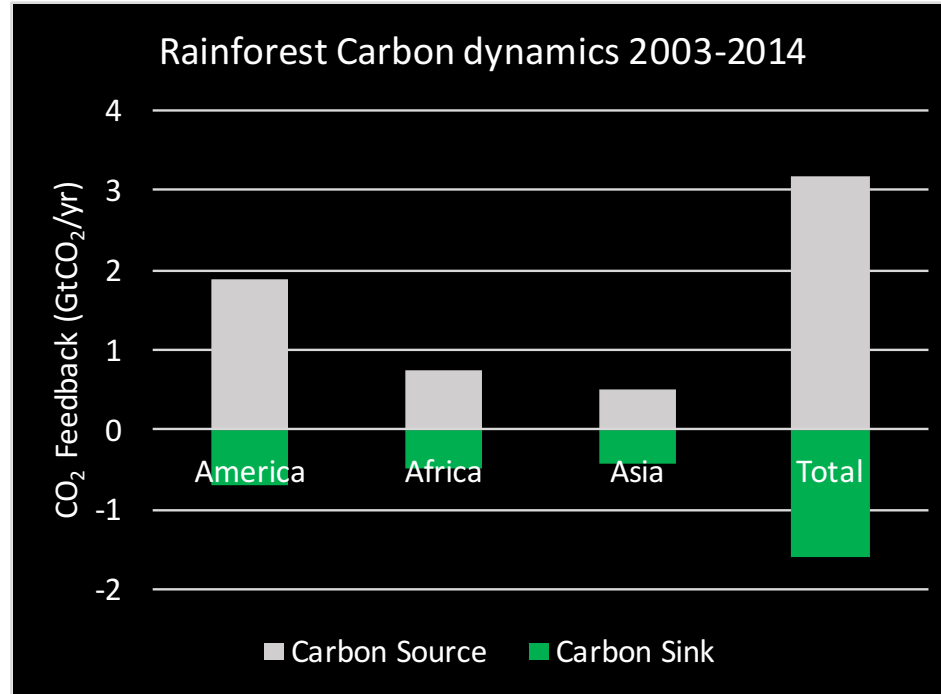
Delphine Clara Zemp^{1,2,†}, Carl-Friedrich Schleussner^{2,3}, Henrique M. J. Barbosa⁴, Marina Hirota^{5,6}, Vincent Montade⁷, Gilvan Sampaio⁸, Arie Staal⁹, Lan Wang-Erlandsson^{10,11} & Anja Rammig^{2,12}



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,³ 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 thresholds for human development
- Crossing certain biophysical thresholds could have disastrous consequences for humanity
- Three of nine interlinked planetary boundaries could have already been transgressed

Industrialized forces of agriculture, human activities have reached a level that could damage the systems that sustain life on the planet. The rate of environmental change is accelerating, leading to a 'new geological age' in which human actions have become the dominant driver of global environmental change. This could see human activities push the Earth system into a less stable state, with the potential for irreversible changes to the climate, biodiversity and other planetary boundaries that are fundamental to the stability of the Earth system. To ensure the challenge of maintaining the planet's habitability, we propose a framework based on 'planetary boundaries'.

Planetary boundaries

To meet the challenge of maintaining the planet's habitability, we propose a framework based on 'planetary boundaries'.

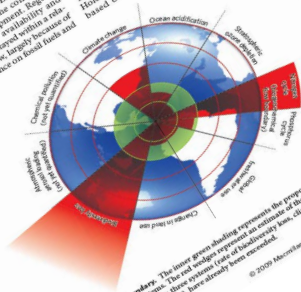


Figure 1 | Beyond the boundaries. The inner green shading represents the proposed safe operating space for the nine planetary boundaries. The red and yellow shading represents activities that are likely to transgress the boundaries. The boundaries are: climate change, ocean acidification, land use change, freshwater use, biogeochemical flows, biodiversity loss, air quality, ozone depletion, and nuclear waste. The diagram also shows the current position of each boundary, with some segments indicating that the boundary has been transgressed (red) and others indicating it has not (green).

RESEARCH

RESEARCH ARTICLE

SUSTAINABILITY

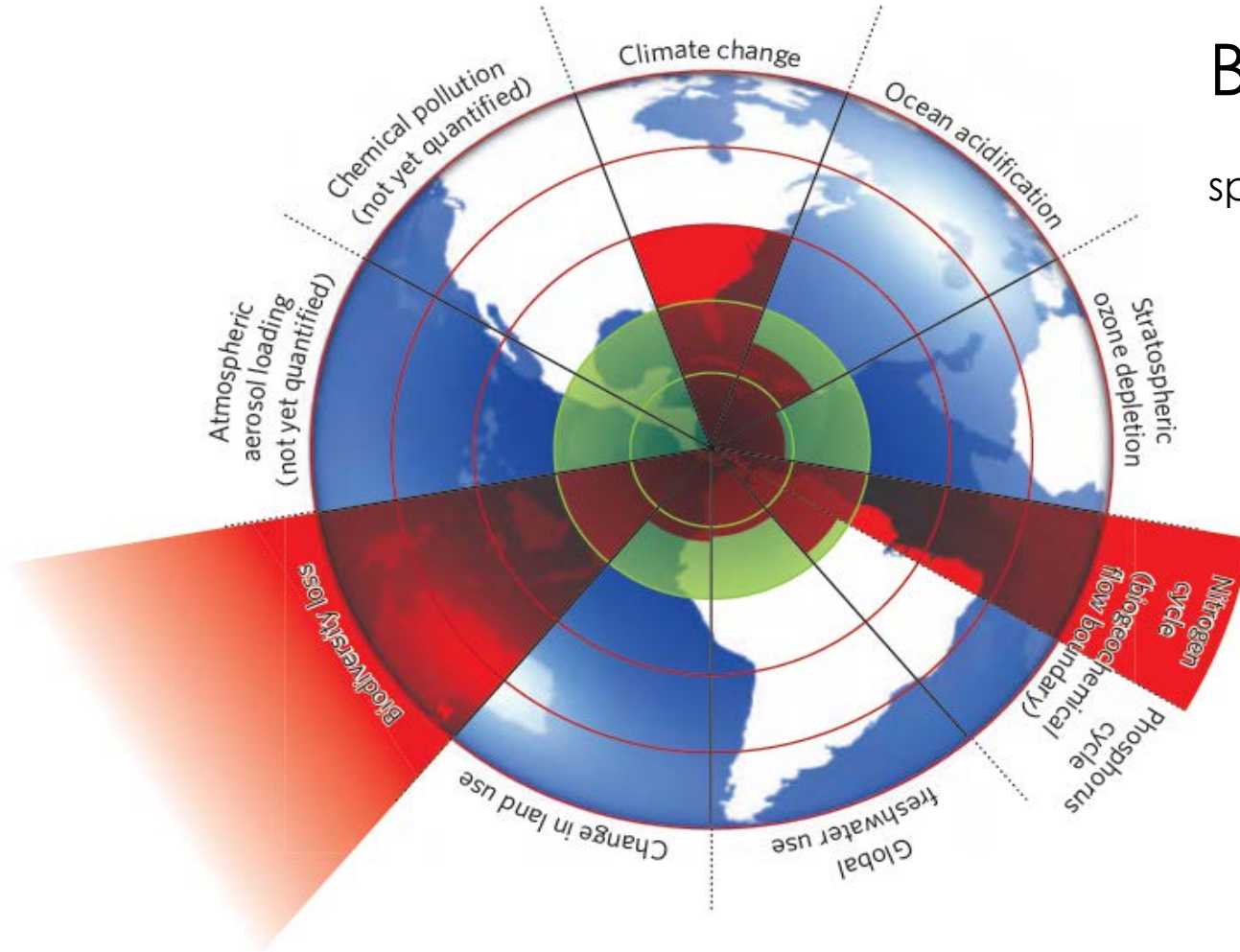
Planetary boundaries: Guiding human development on a changing planet

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 Sörlin¹⁹

Planetary Boundaries

A safe operating space for humanity

2009 1st Analysis



Defining Planetary Boundaries 1.0

"The Big Three"

CLIMATE CHANGE

CO₂ concentration in the atmosphere <350 ppm and/or a maximum change of +1 W m⁻² in radiative forcing.

OCEAN ACIDIFICATION

Average surface seawater saturation state with respect to aragonite ≥ 80% of pre-Industrial levels.

STRATOSPHERIC OZONE

<5% reduction in O₃ concentration from pre-Industrial level of 290 Dobson Units.

"The Slow Variables"

BIOGEO-CHEMICAL

Nitrogen (N) cycle: Limits Industrial and agricultural fixation of N₂ to 35 Tg N yr⁻¹.
Phosphorus (P) cycle: Annual P Inflow to oceans not to exceed 10 times the natural background weathering of P.

GLOBAL FRESH-WATER USE

<4,000 km³ yr⁻¹ of consumptive use of runoff resources.

LAND SYSTEM CHANGE

<15% of the ice-free land surface under cropland.

RATE OF BIODIVERSITY LOSS

Annual rate of <10 extinctions per million species.

"Earth Aliens"

CHEMICAL POLLUTION

Not yet quantified

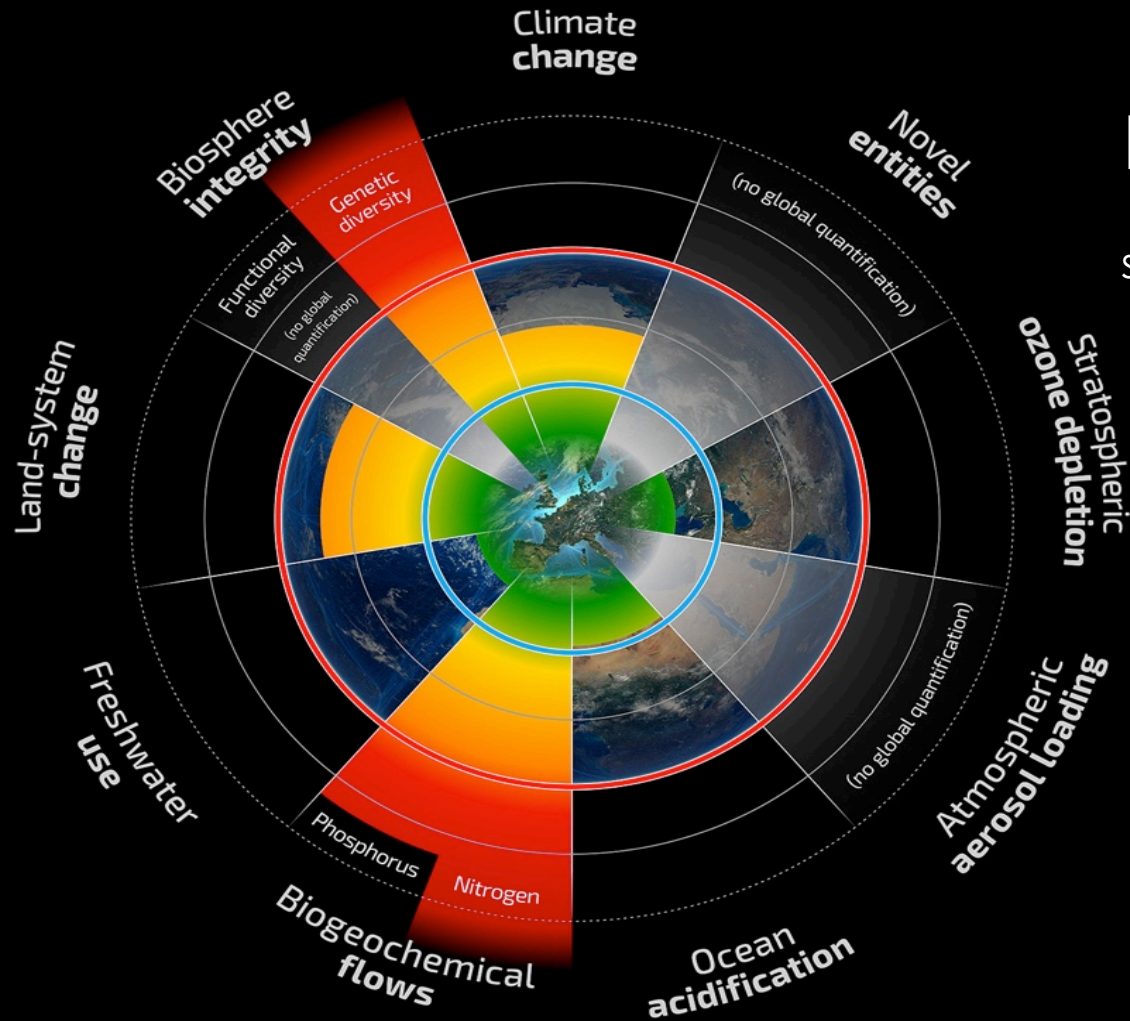
ATMOSPHERIC AEROSOL LOADING

Not yet quantified

Planetary Boundaries

A safe operating space for humanity

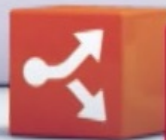
2015 Update





Action2020

led by the WBCSD



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

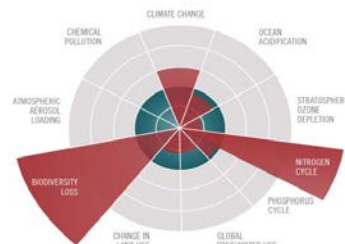


THE B TEAM

- › 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



Ympäristöministeriö
Miljöministeriet
Ministry of the Environment



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Office for the Environment FOEN

**Ministry of Infrastructure and the
Environment**



SWEDISH ENVIRONMENTAL
PROTECTION AGENCY

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

A photograph showing several fishermen in a body of water, pulling a large, reddish-brown fishing net. The net is filled with many small, silvery fish, creating a large splash of white water. The fishermen are wearing various hats and work clothes. The background is a calm body of water under a clear sky.

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



POLICY FORUM

CLIMATE POLICY

A roadmap for rapid decarbonization

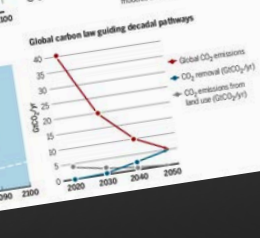
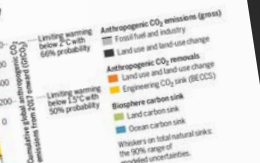
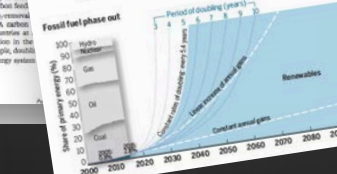
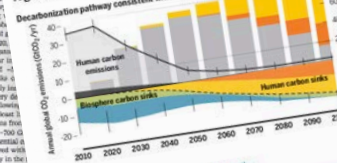
Emissions inevitably approach zero with a "carbon law"

By Johan Rockström, Owen Gaffney,^{1,2} Joeri Rogelj,^{3,4} Niklas Höhne,^{5,6} Niklas Höhne,^{5,6} and Stefan H. Schneider⁷

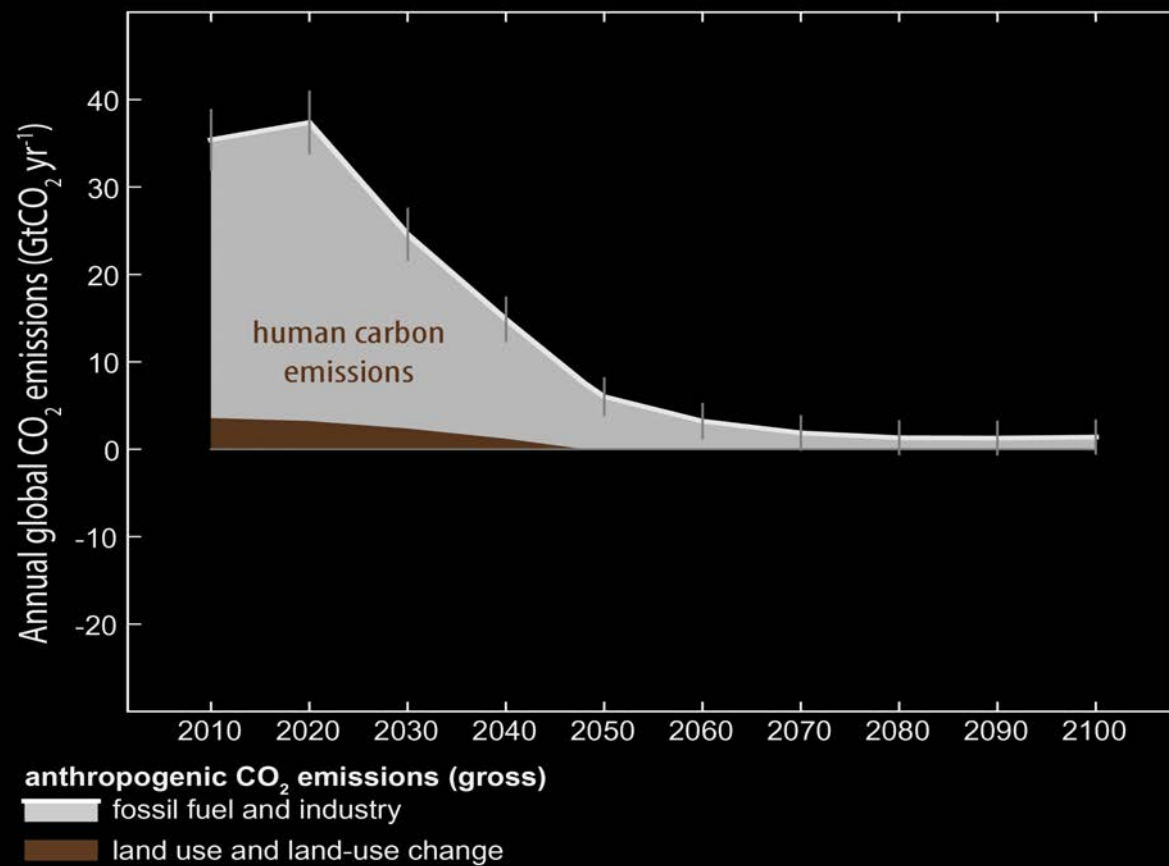
Although the Paris Agreement's goal is aligned with science (2) and, in principle, is technically and economically achievable (3), attaining this goal requires a transition from current business-as-usual emissions to net-zero emissions by 2050. Progress during the 2016 Marrakesh climate negotiations, long-term goals can be trusted by political decision-makers. 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 massive efforts through to capture transformation change and the transition associated with it (disruption, innovation, and nonlinear change in human behavior). For example, in just 3 years, China's coal use peaked 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 maladaptation, we propose framing the decarbonization challenge in terms of a global decarbonization law based on a simple heuristic—a "carbon law"—of halving gross anthropogenic carbon-dioxide (CO₂) emissions every decade. Compelled by increasingly stringent, reliable carbon removal and efforts to ramp down net-zero CO₂ emissions, this law provides a clear, simple, and actionable framework for policy-making.

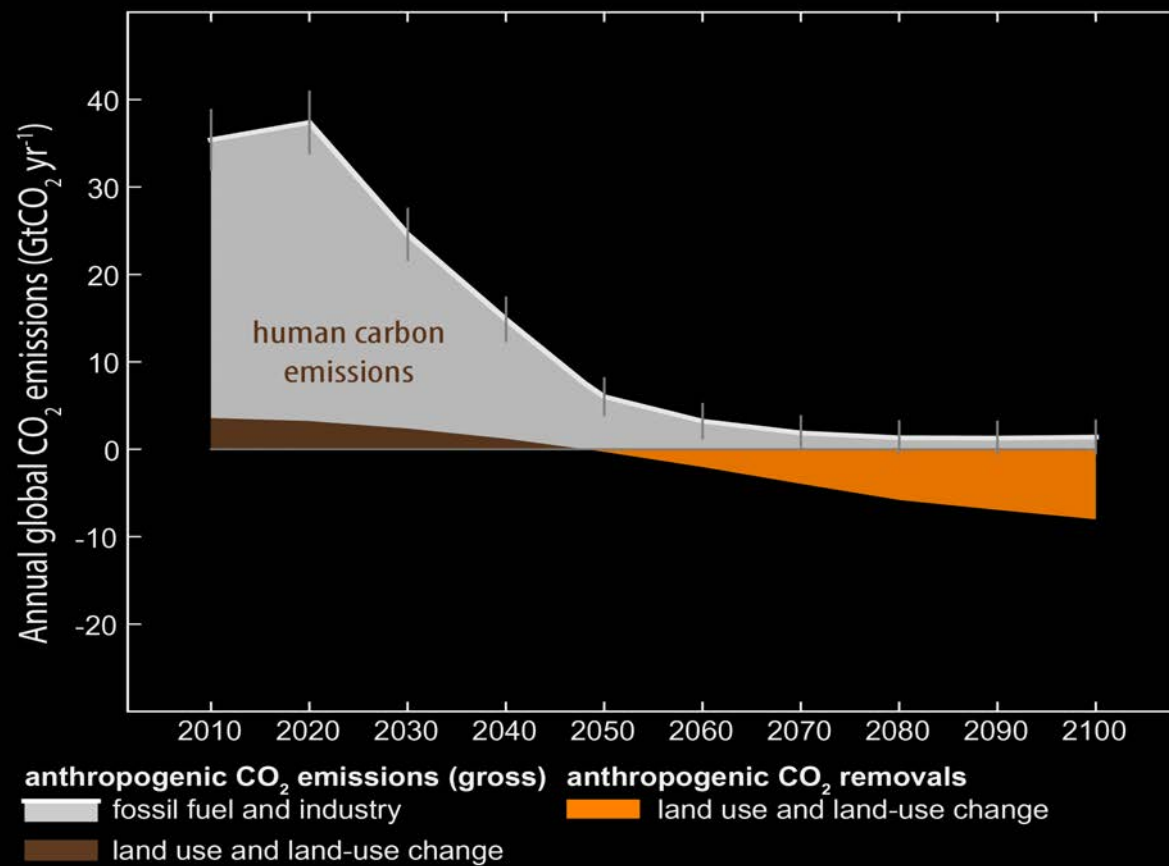
Decarbonization pathways consistent with the Paris agreement

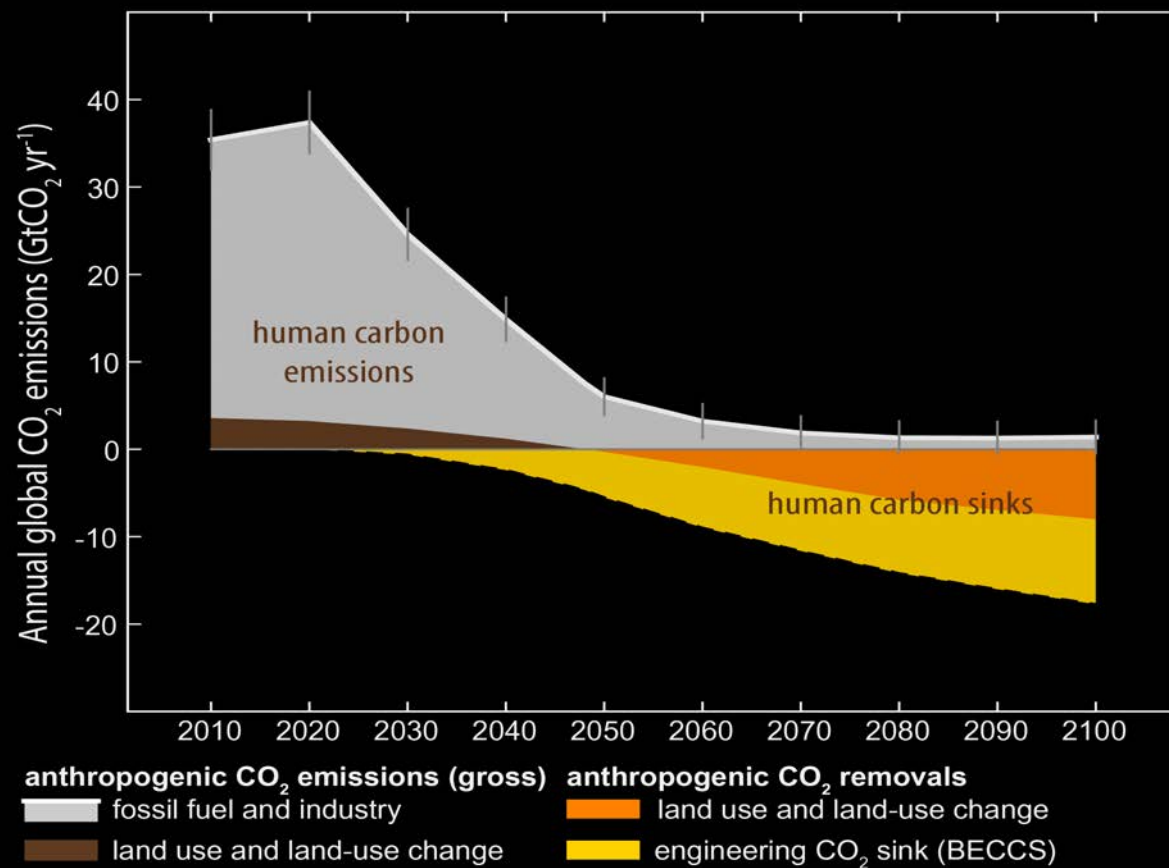
A global carbon law and roadmap to make Paris goals a reality

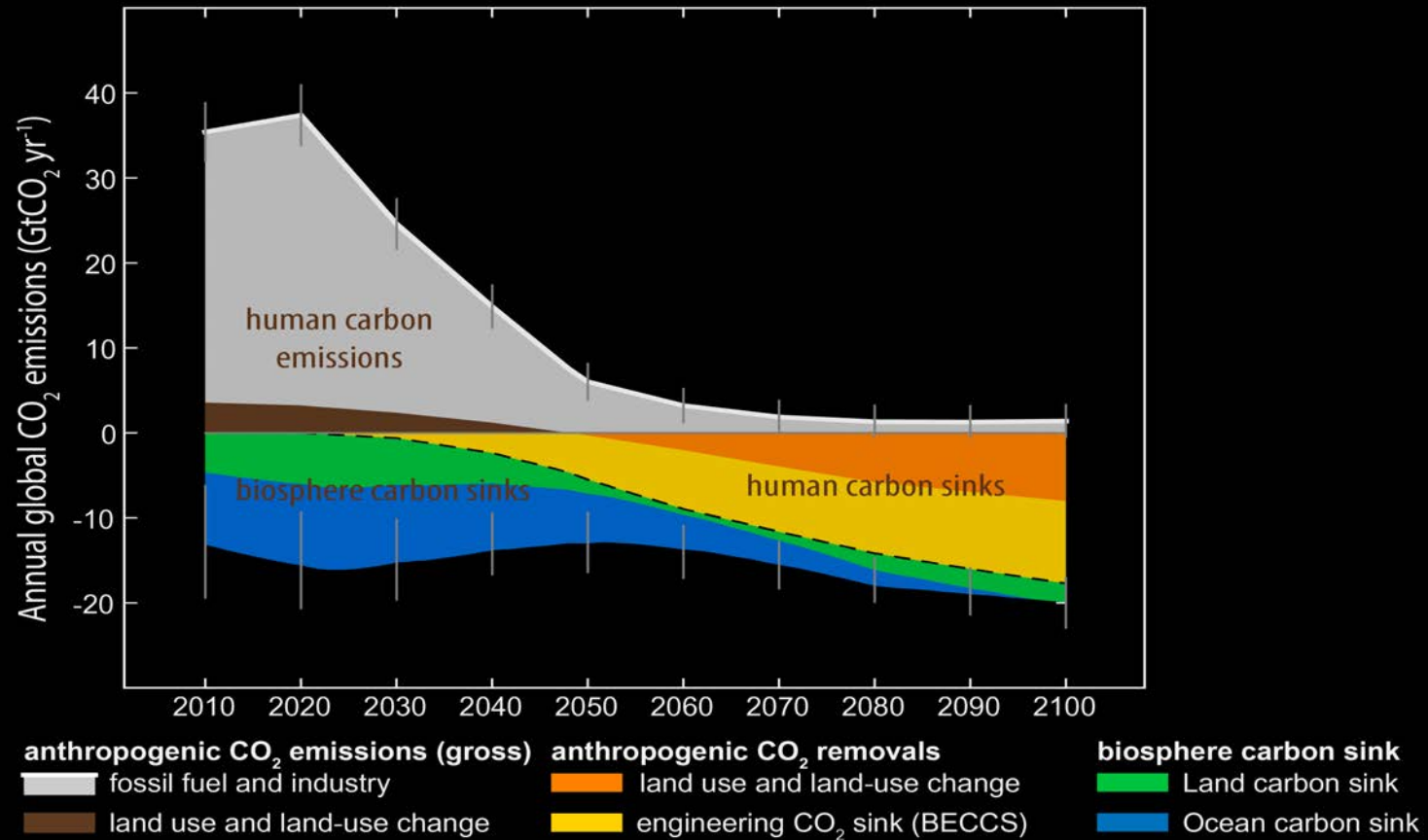


SOURCE: rockström.org



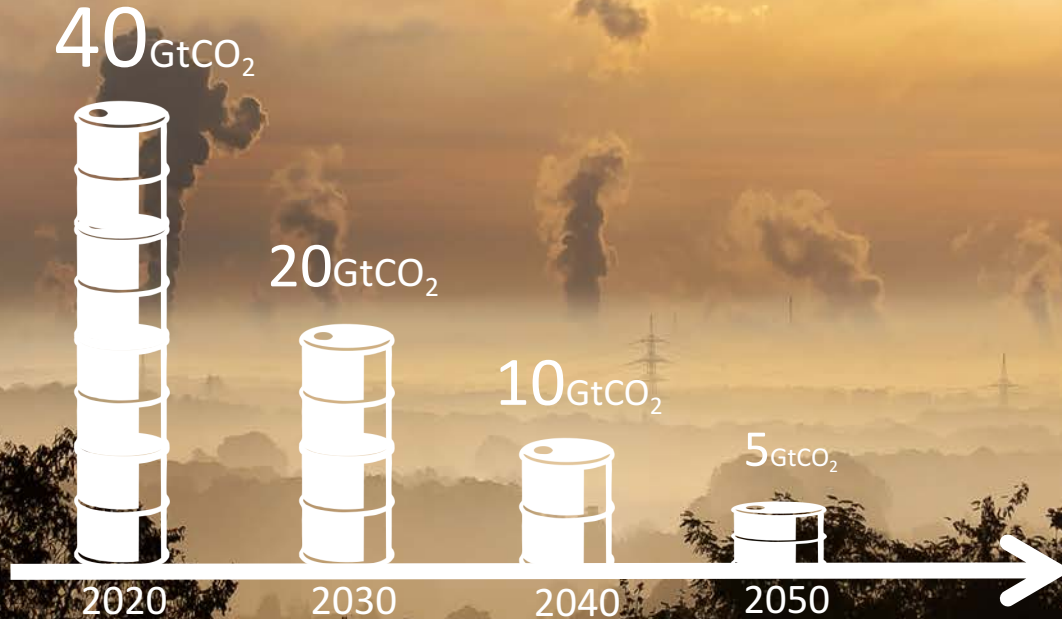






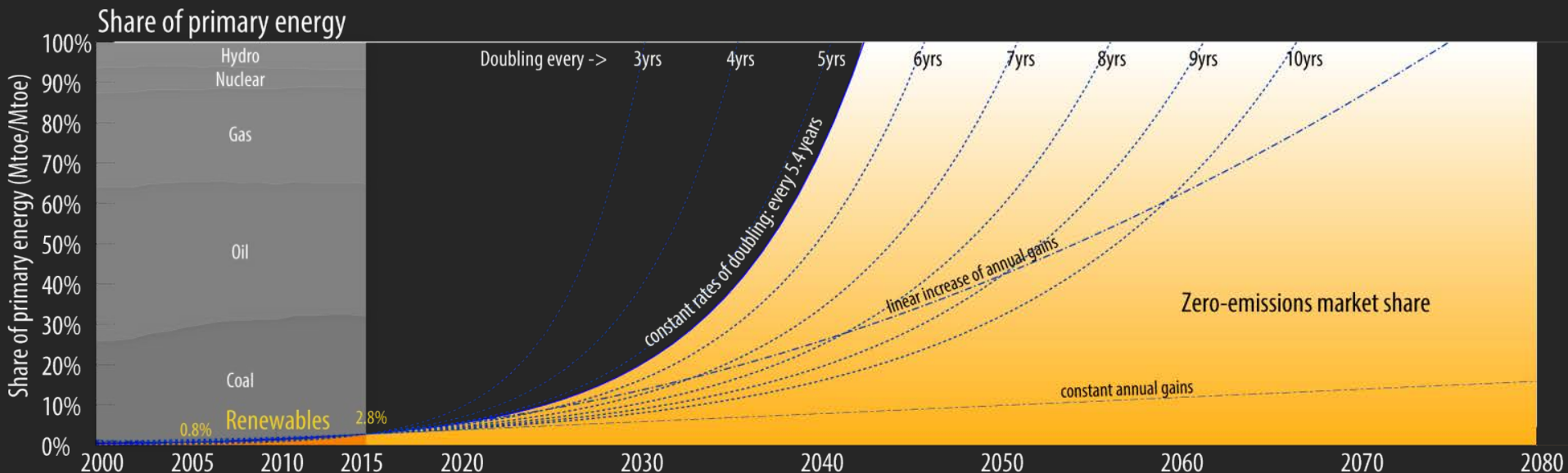
A Global Carbon Law

Halving Emissions Every Decade



We are already on the right trajectory

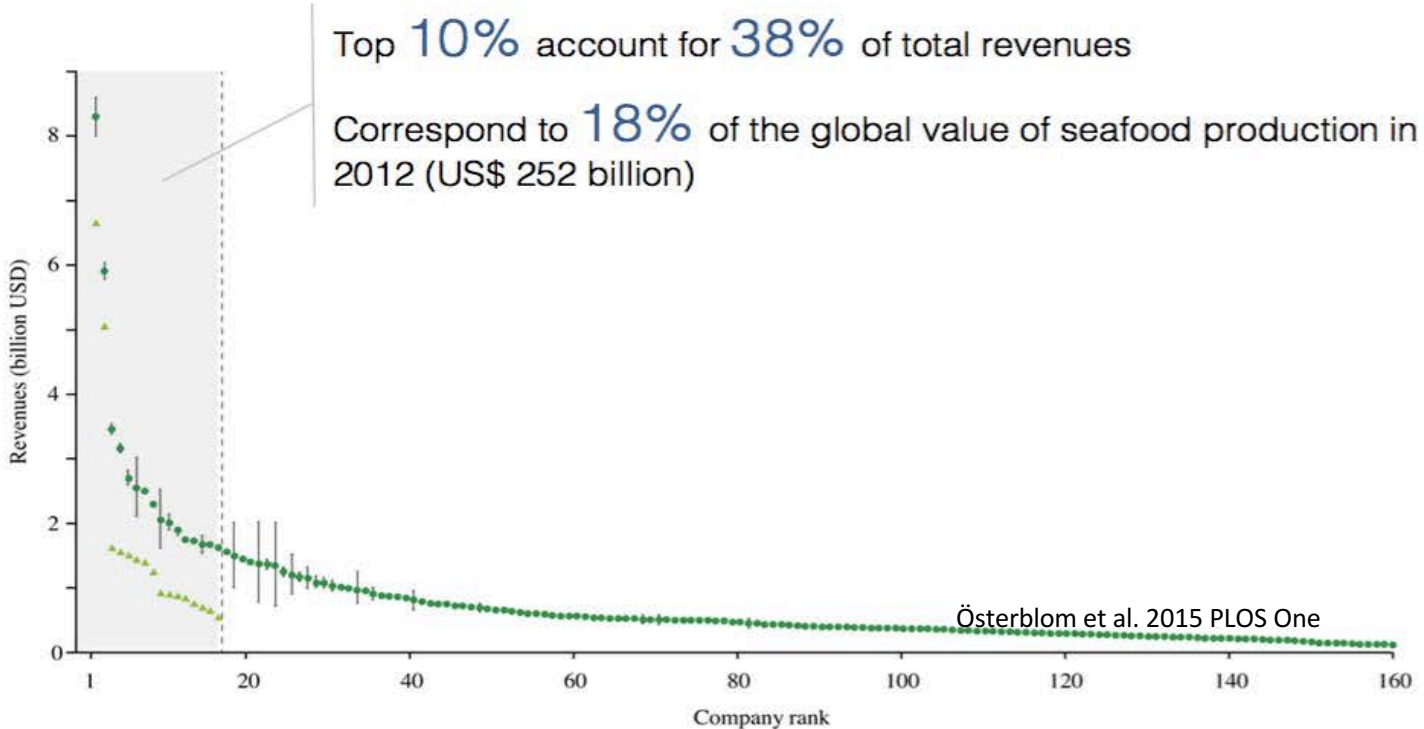
Renewables: Share of primary energy



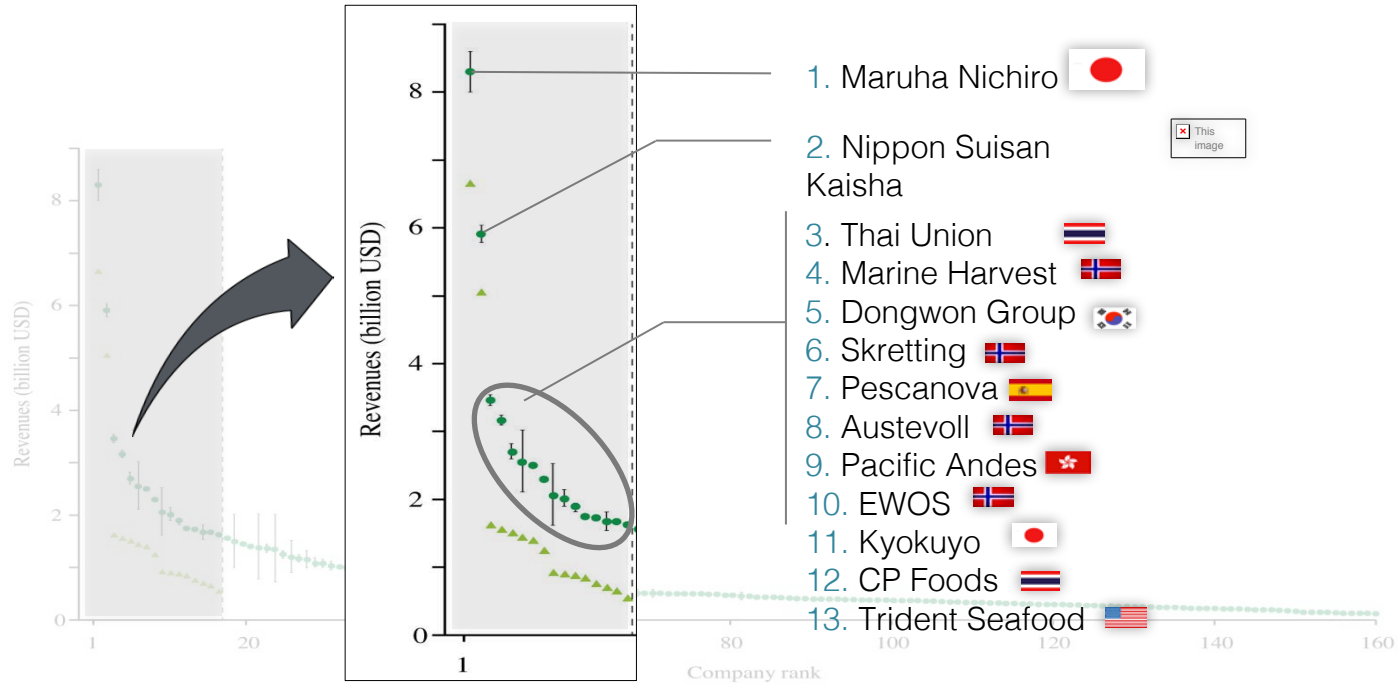


Ocean Stewardship

Concentration in the seafood industry



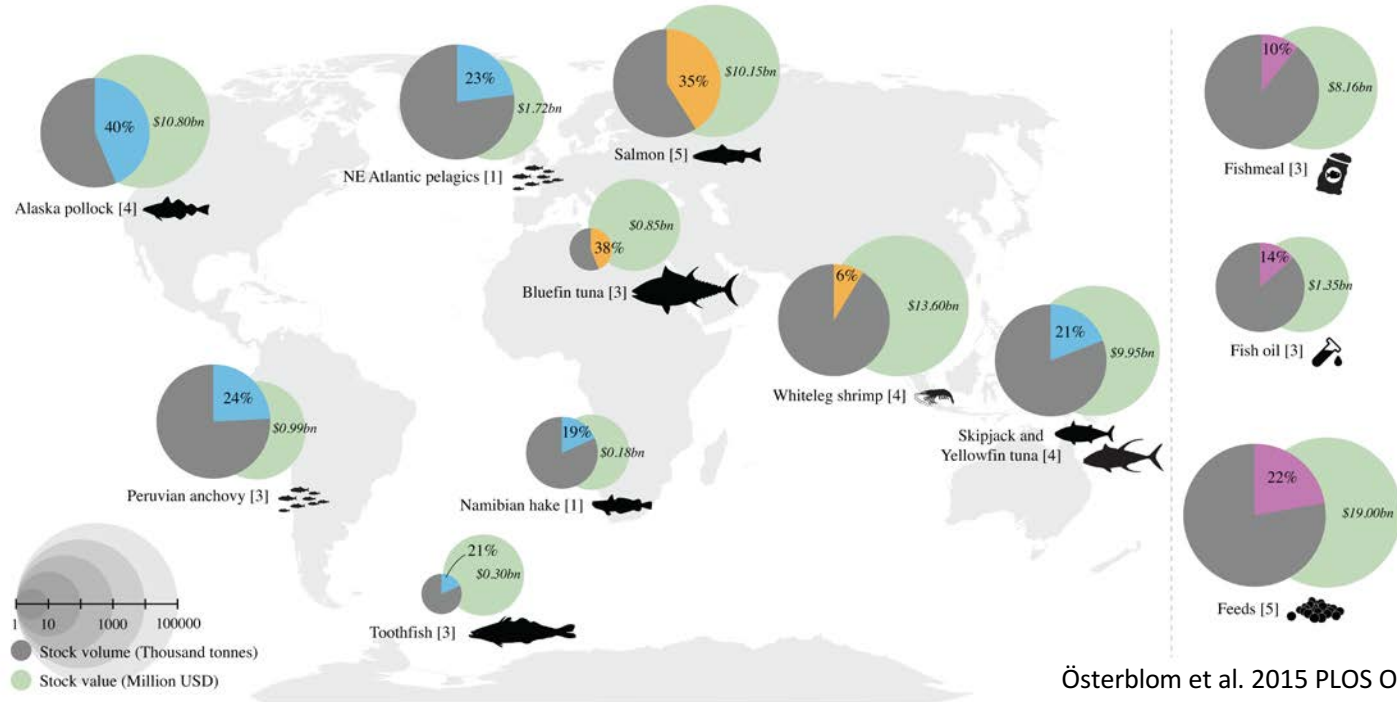
Who are the “keystone” actors?



How much do they produce?

Catch 11-16% of global marine catch

Control 19-40% of several of the world's largest or most valuable capture fisheries



A large blue and red ship hull is the central focus, with a white crane positioned on a platform above it. The scene is set in a shipyard with various industrial structures and equipment visible in the background.

These 'Keystone' companies...

... **dominate** global production revenues and volumes

... **control** globally relevant segments of seafood production

... **connect** ecosystems globally through subsidiaries

... **influence** global governance processes and institutions

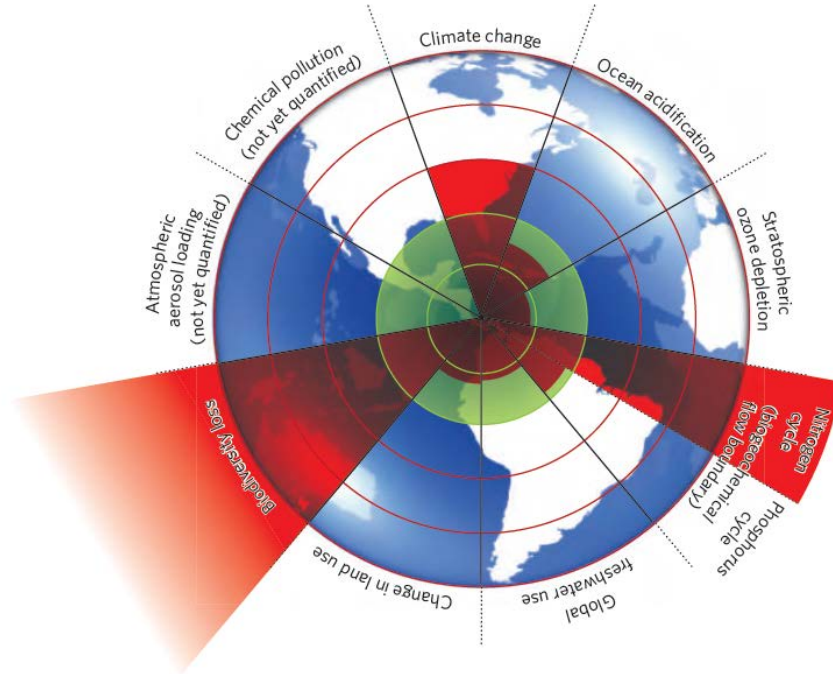
THE
**STOCKHOLM
DIALOGUE**

PROGRAM

Advancing the Seafood Business for Ocean Stewardship Initiative

Monday 15th May

Macro-economic implications of world development within Planetary Boundaries?

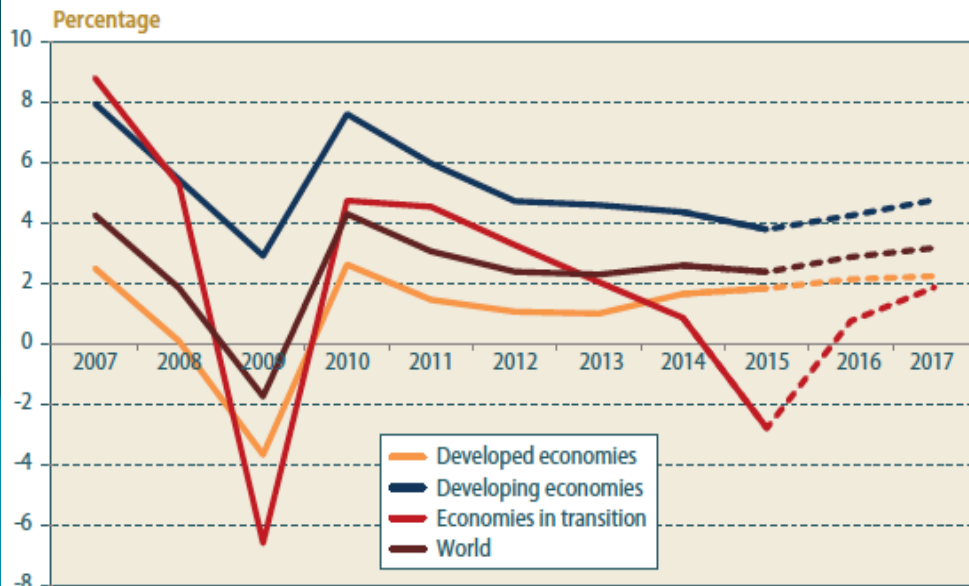


Report by the Commission on the Measurement of Economic Performance and Social Progress

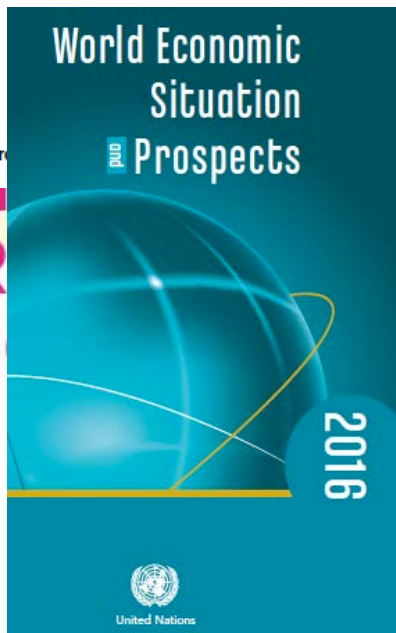
The Dilemma of Growth

Figure I.1

Growth of world gross product and gross domestic product by country grouping,
2007–2017



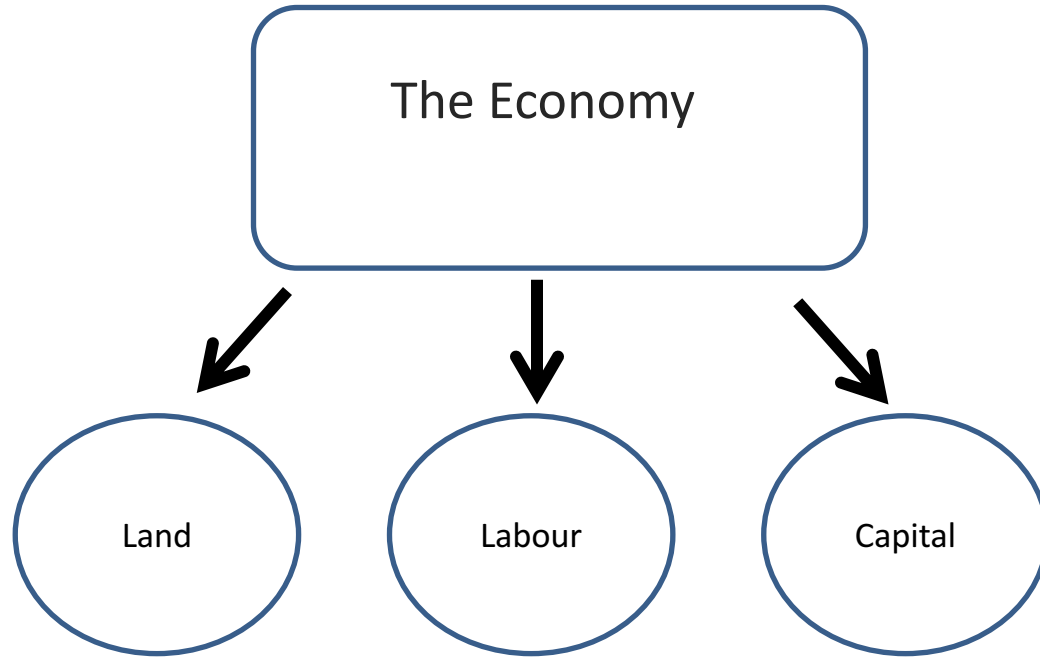
Source: UN/DESA.
Note: Data for 2015 are
estimated; data for 2016 and
2017 are forecast.

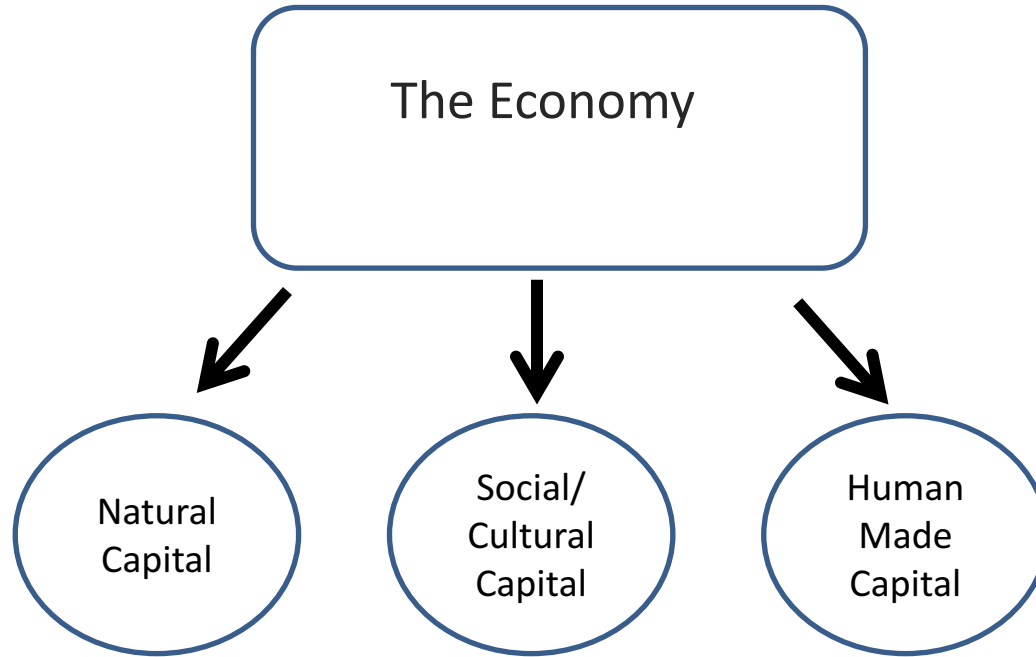


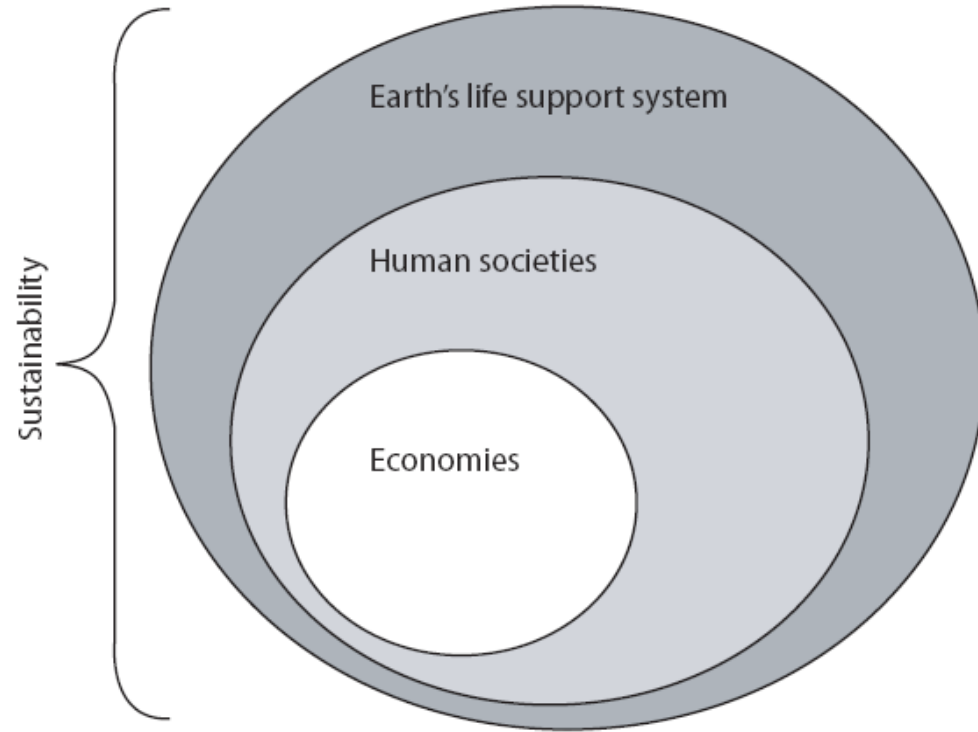
GDP per capita, PPP (current international \$)

Note: The World Happiness Index is a subjective measure with values ranging from 0 ("completely dissatisfied") to 10 ("completely satisfied").

Source: Author's own compilation based on data from the World Happiness Report 2016. Online at: <http://worldhappiness.report/ed/2016/>; World Bank, World Development Indicators. Online at: <http://data.worldbank.org/products/wdi>.



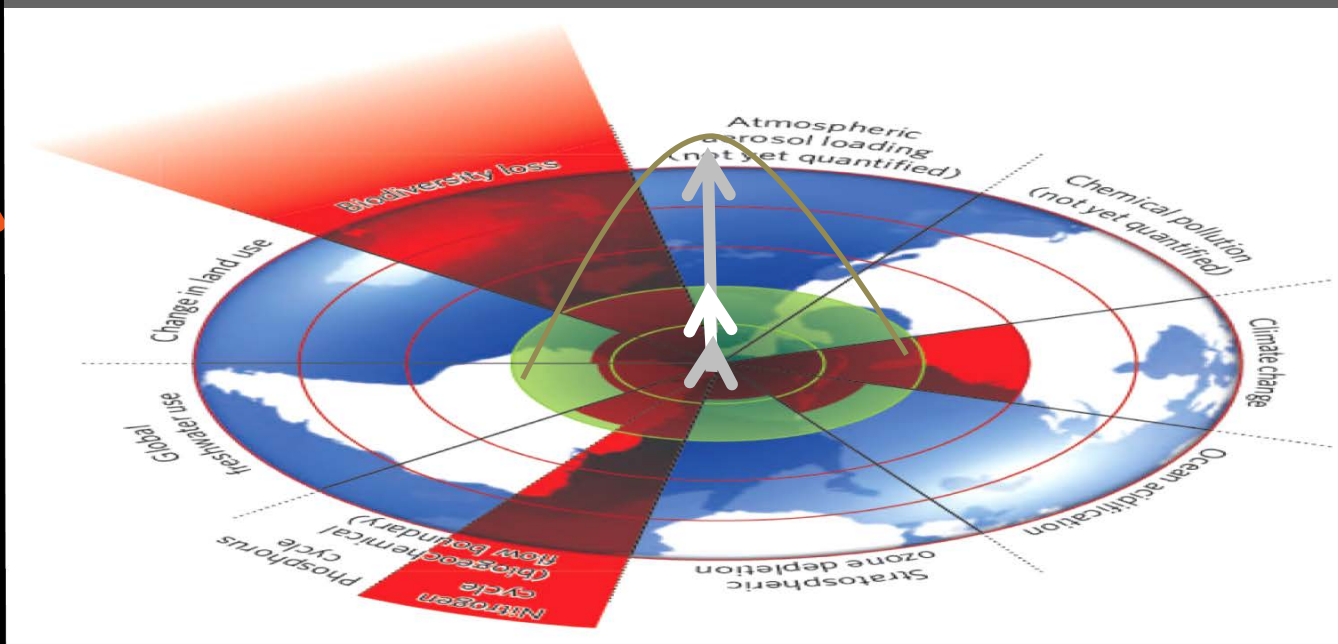




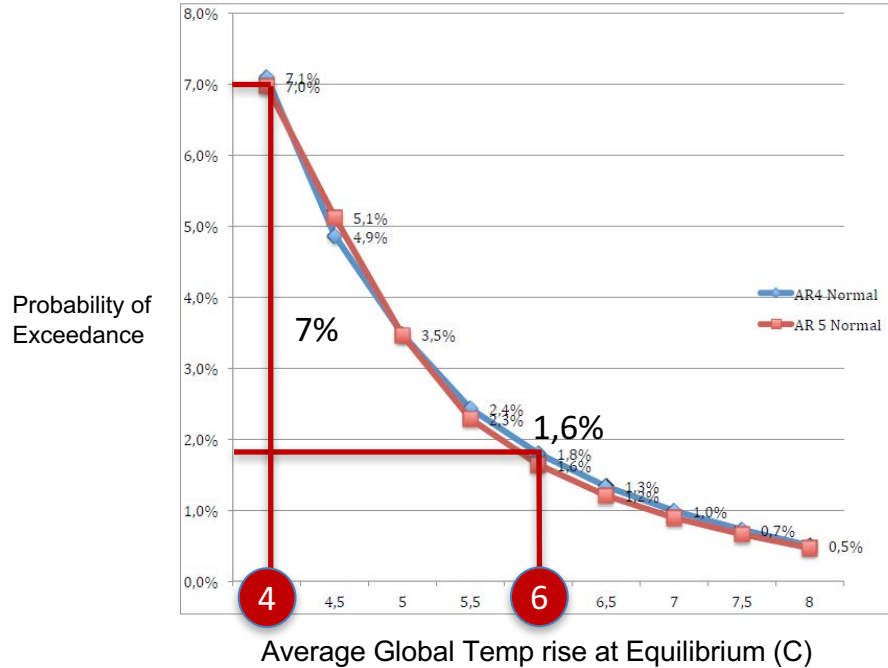
A Planetary Soufflé

Human Prosperity within Planetary Boundaries

Economic
Development



Risks related to agreed global goal of 450 ppm



Global Challenges Foundation



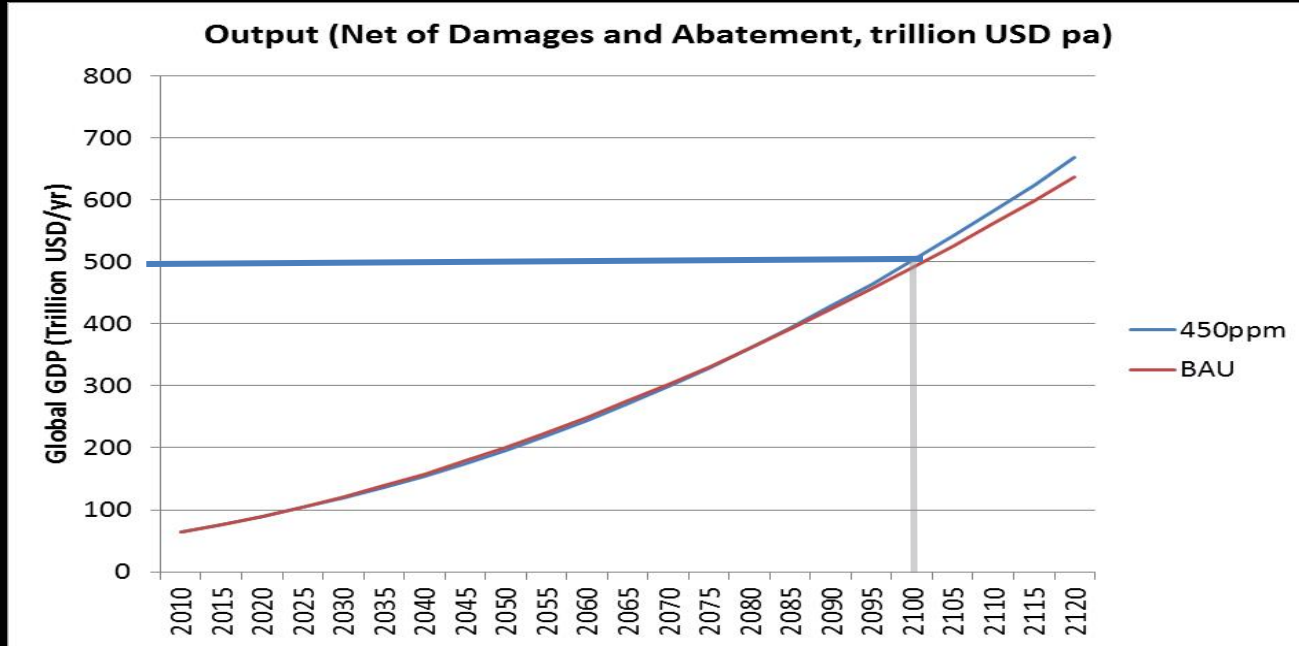
GLOBAL
RISK AND OPPORTUNITY
INDICATOR

Global Climate Risk

Understanding
the
unacceptable

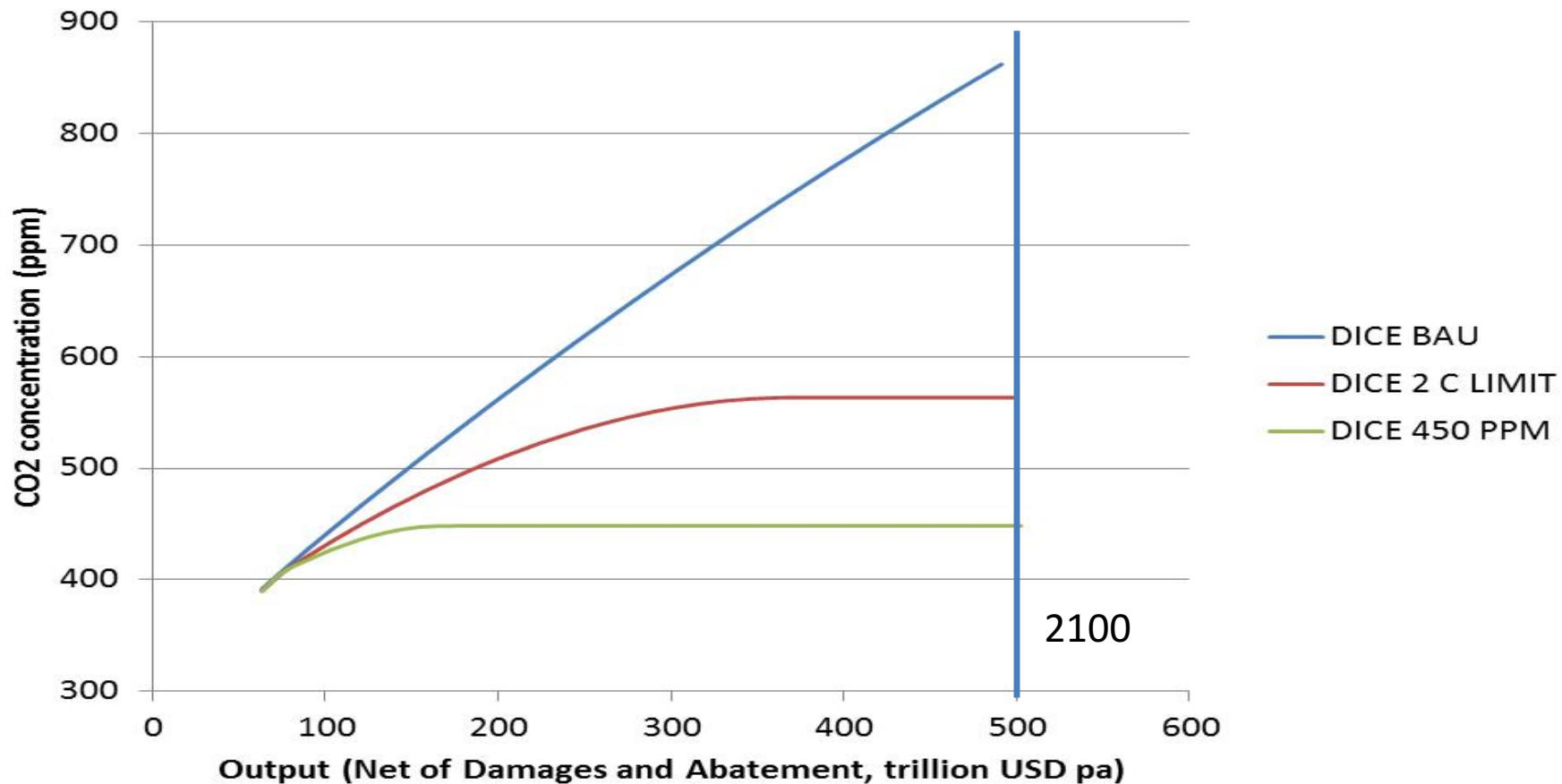


Economic Growth and Climate Change – the conventional macro-economic approach

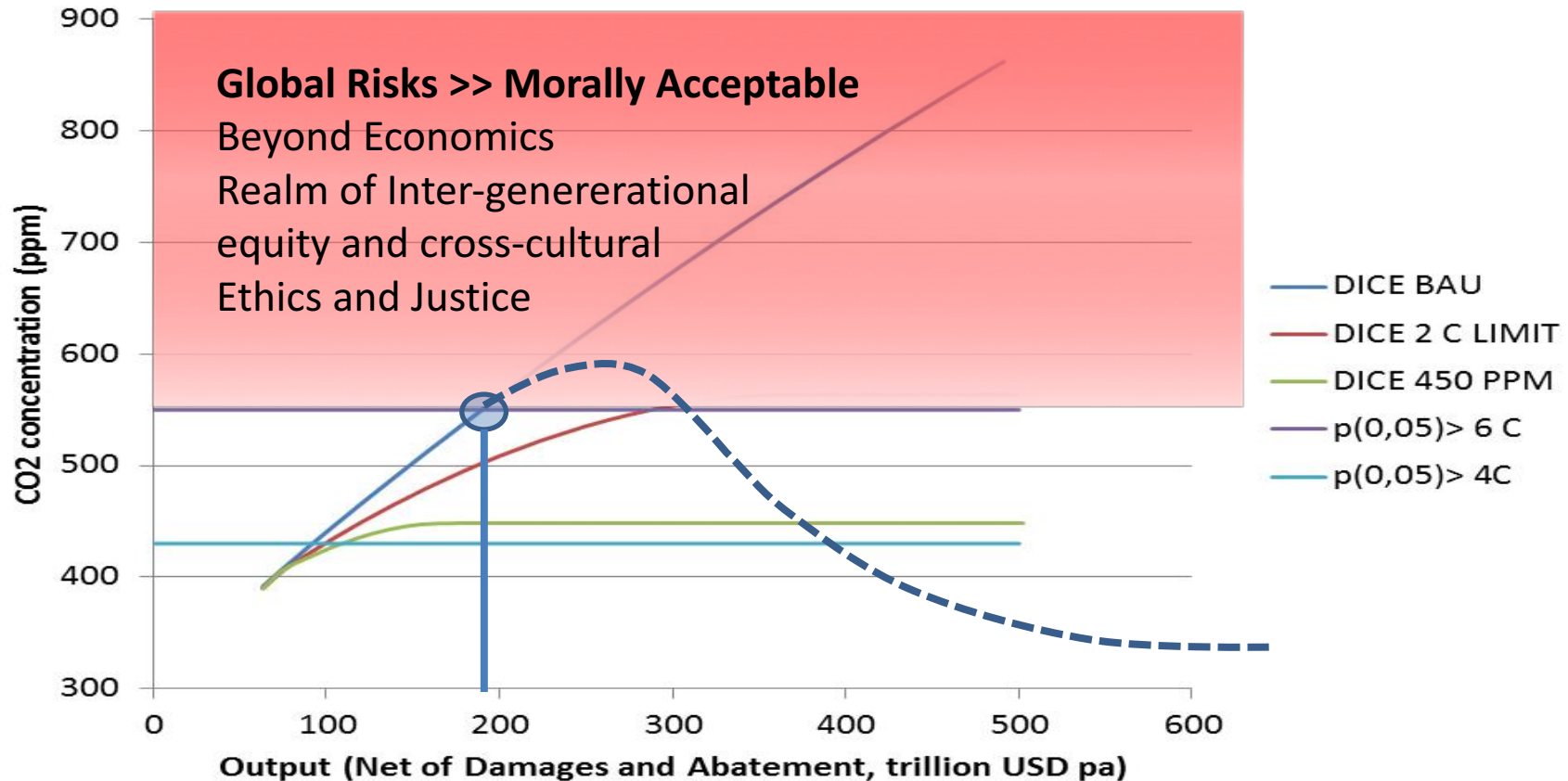


(Applying DICE, 2014)

CO2 emissions versus Global Economic Growth 2010-2100



CO2 emissions versus Global Economic Growth 2010-2100



Planetary Stewardship

THE GLOBAL GOALS
For Sustainable Development



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



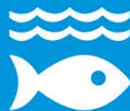
12 RESPONSIBLE CONSUMPTION AND PRODUCTION



13 CLIMATE ACTION



14 LIFE BELOW WATER



15 LIFE ON LAND



16 PEACE, JUSTICE AND STRONG INSTITUTIONS

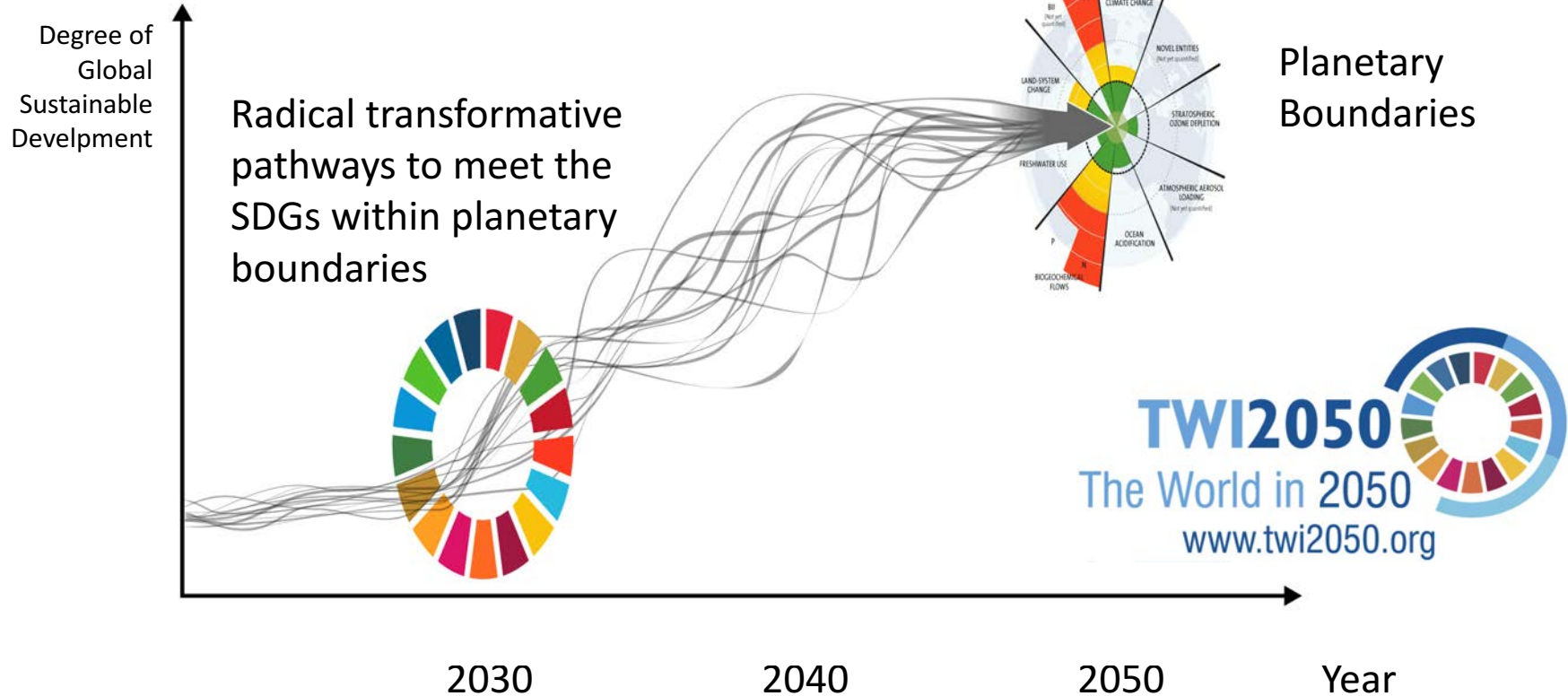


17 PARTNERSHIPS FOR THE GOALS

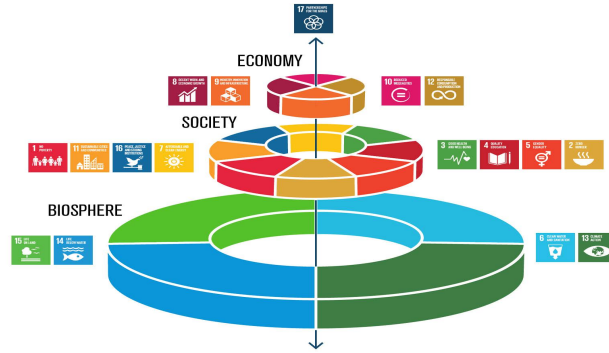
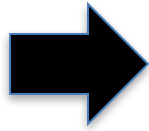
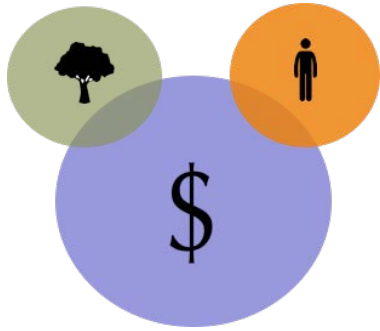


SUSTAINABLE
DEVELOPMENT
GOALS

The World In 2050







=

World
Development
within
Stable &
Resilient
Earth System



Thank you!

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