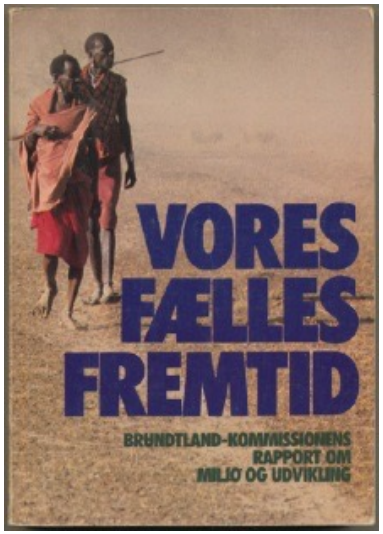
We humans are part of an ecosystem!

Katherine Richardson Professor
Leader, Sustainablity Science Centre

KØBENHAVNS UNIVERSITET



Brundtland Rapport, Our Common future (1987), gave society a new definition of sustainablity:

3 components:

-economic
-environmental
-social

In 1987, environmental and social components could not be defined..

"intergenerational equity"

"Pillars" of Sustainability

Sustainable Development:

Environmental Component: *Demand for the Earth's resources within the supply*

Social Component: *A "just" distribution (sharing) of the Earth's resources*

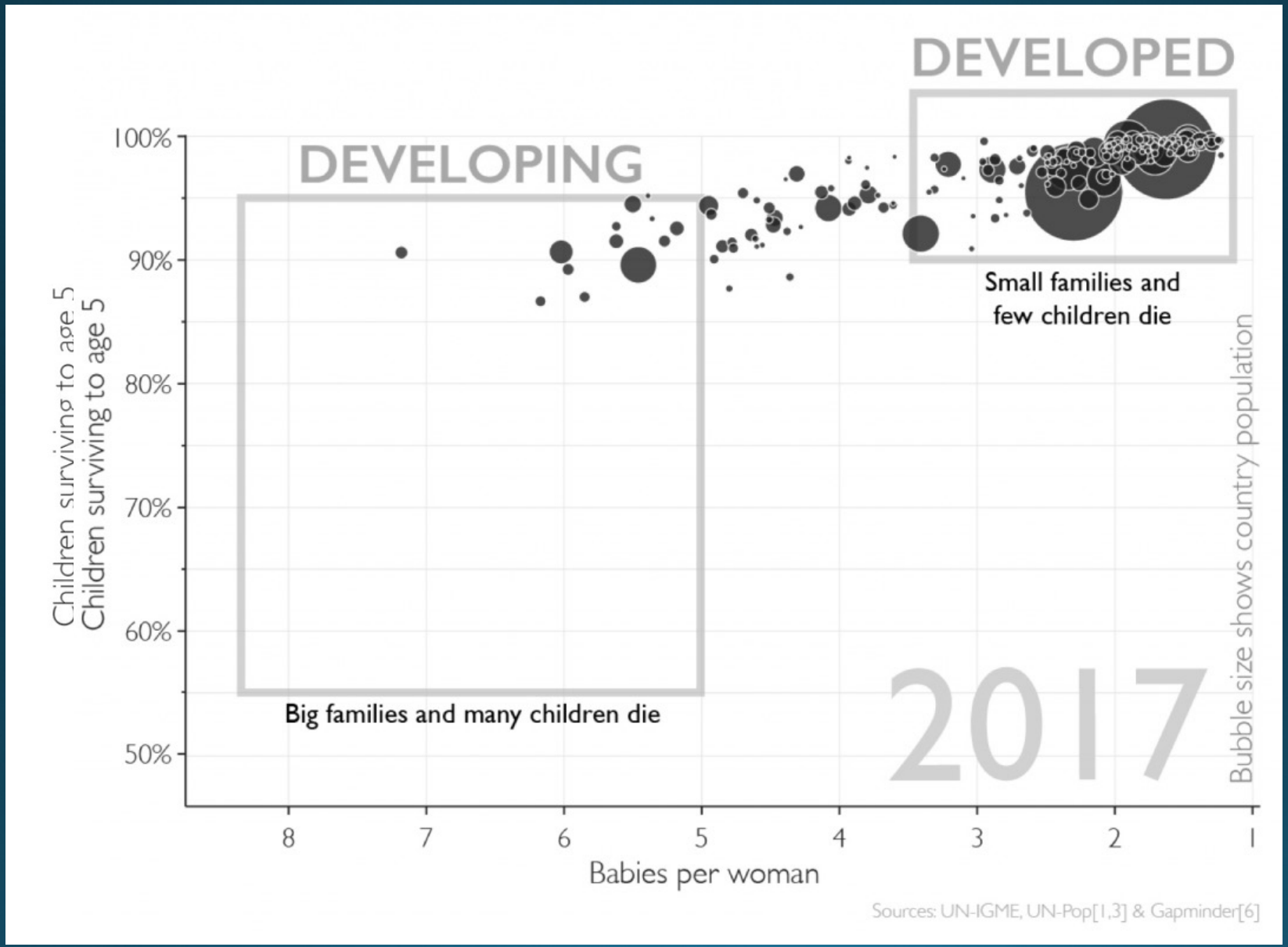
Sustainable development = "need to have"…

THE FUTURE IS NOW

SCIENCE FOR ACHIEVING SUSTAINABLE DEVELOPMENT

GLOBAL SUSTAINABLE DEVELOPMENT REPORT 2019

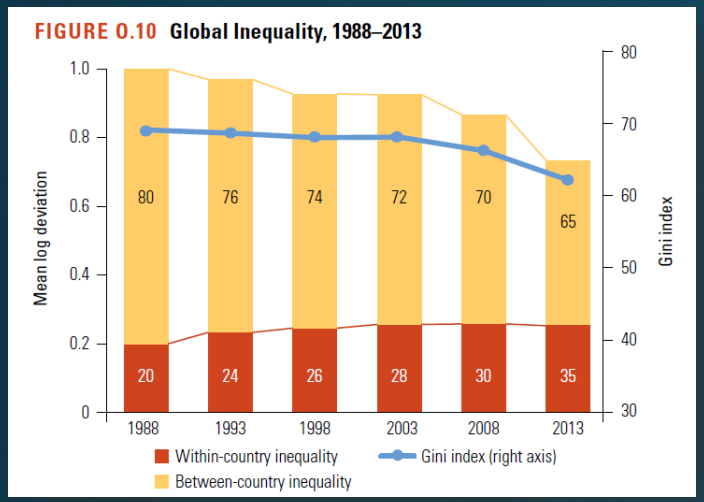
A Success Story?



Rosling, 2018. Factfulness

Den succes kommer med "externaliteter"

Raising inequalities



World Bank, 2016

Biodiversity loss

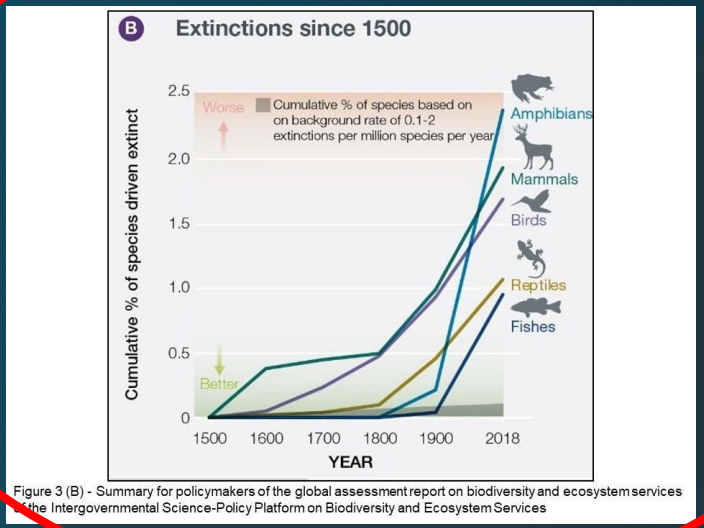
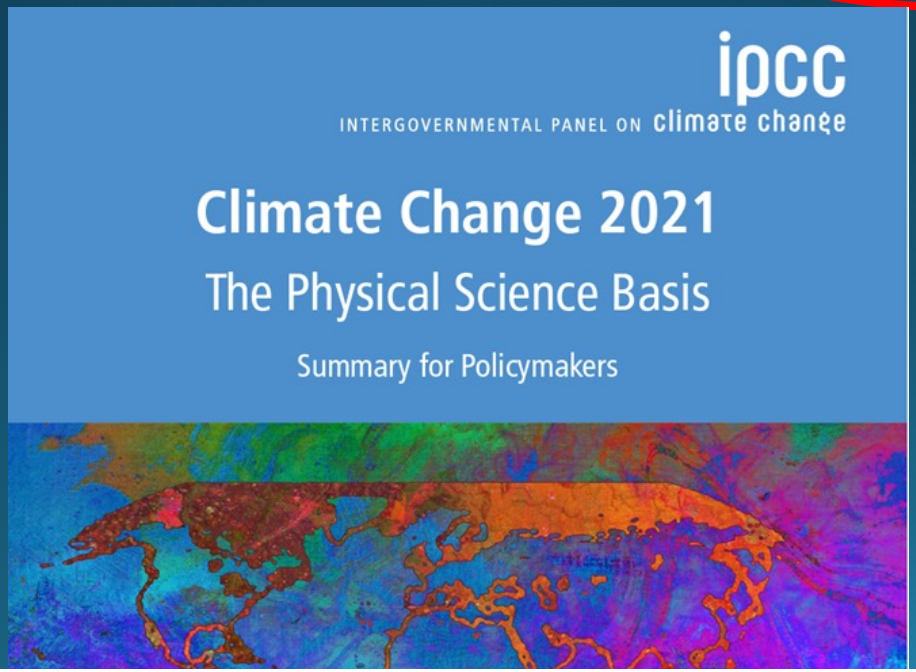


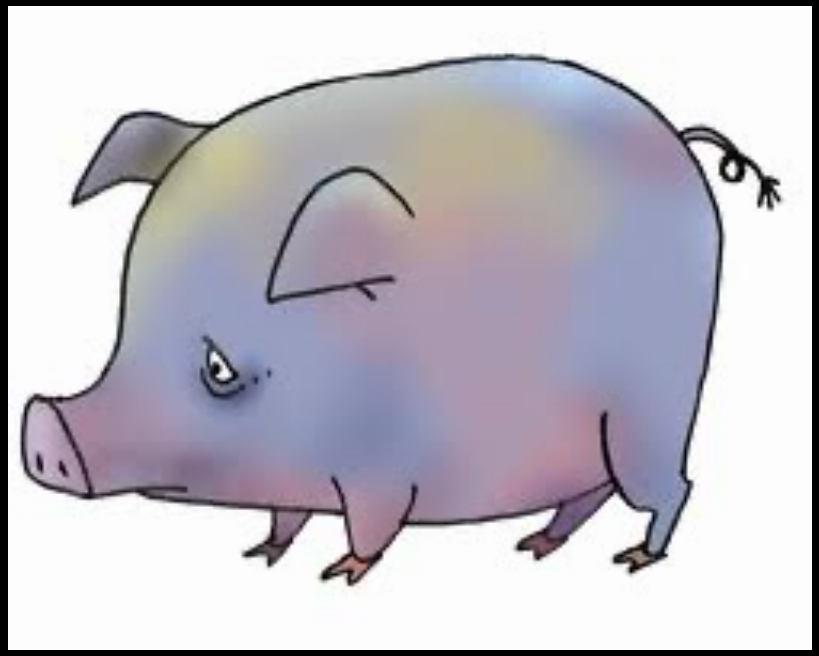
Figure 3 (B) - Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPBES, 2019

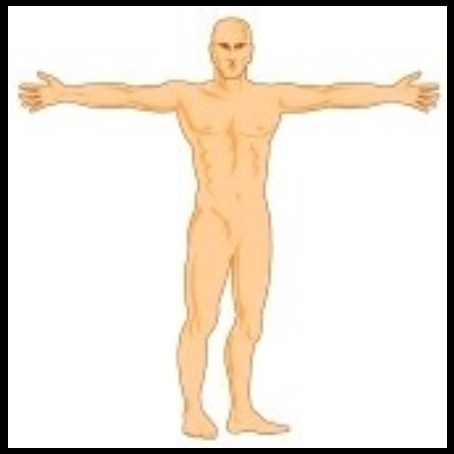
Climate change



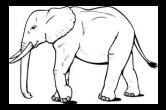
Terrestrial vertebrate biomass



Domesticated animals
ca 65%



Humans
ca 32%



Vertebrate
wildlife
< 3%

Smil 2002

What makes this planet unique is the fact that there is life!

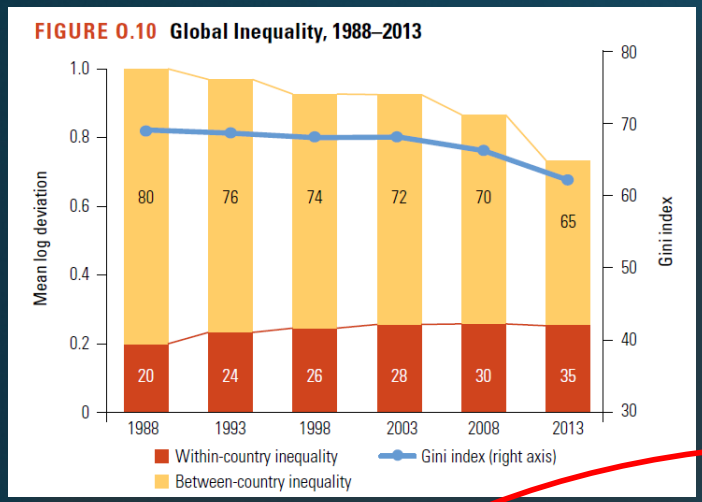
Climate and Biodiversity can be used as proxies for the Earth's resources!

Conditions on Earth are a product of the ***interaction*** between the "biosphere" (all living organisms) and physical-geochemical processes

The biodiversity crisis is at least as important as the climate crisis!

Den succes kommer med "externaliteter"

Raising inequalities



World Bank, 2016

Biodiversity loss

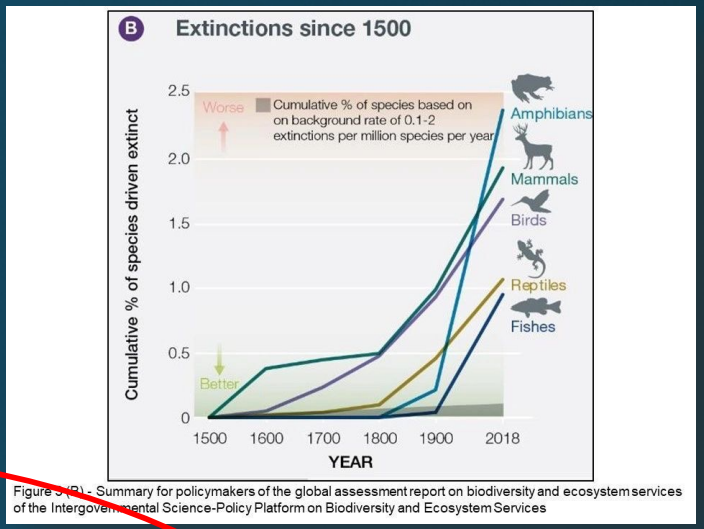
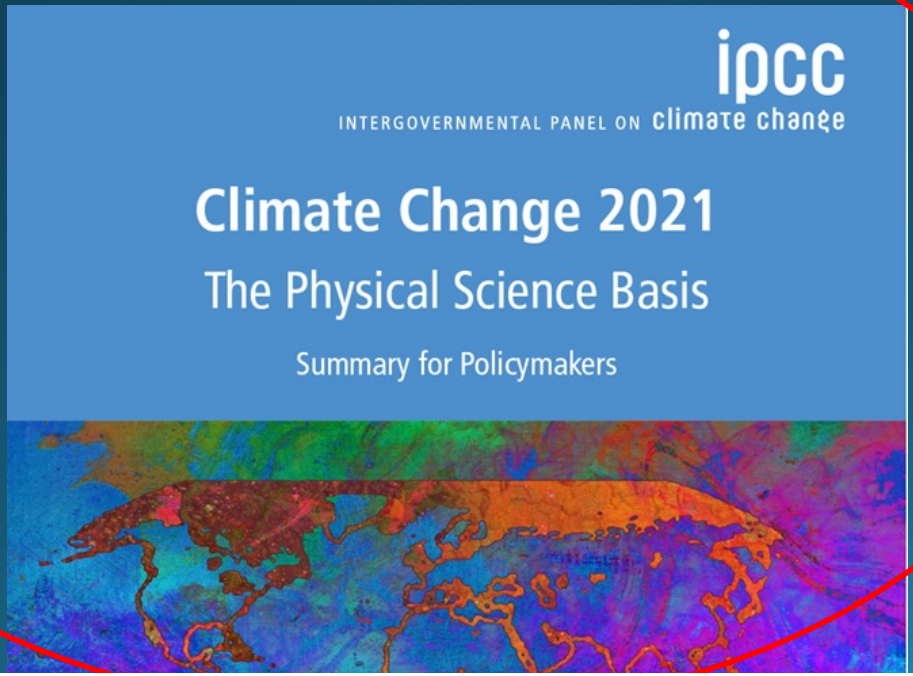
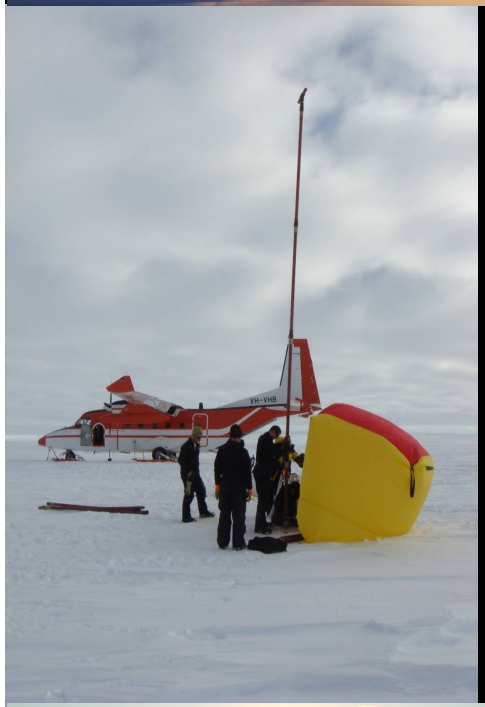


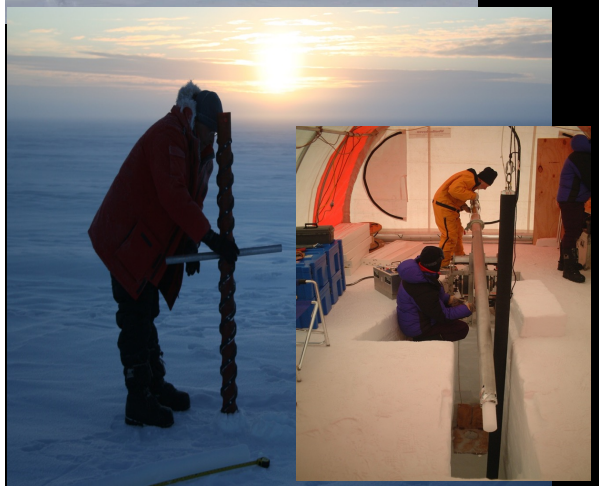
Figure SPM.1 - Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPBES, 2019

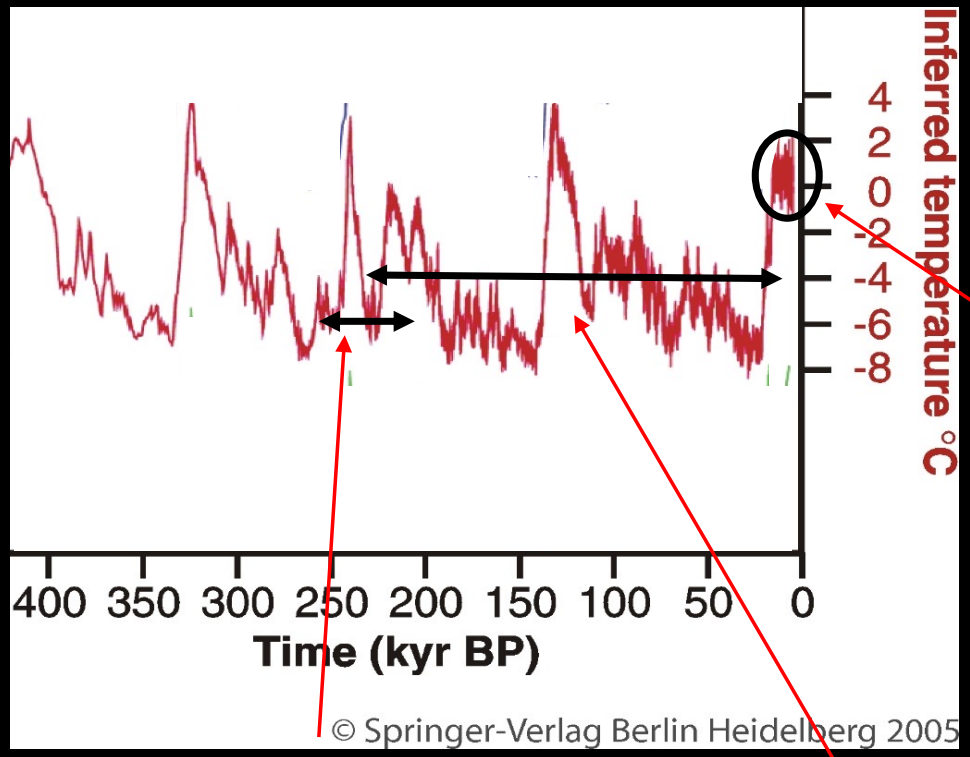
Climate change







Human Development
and
the Earth System



Beginning of agriculture

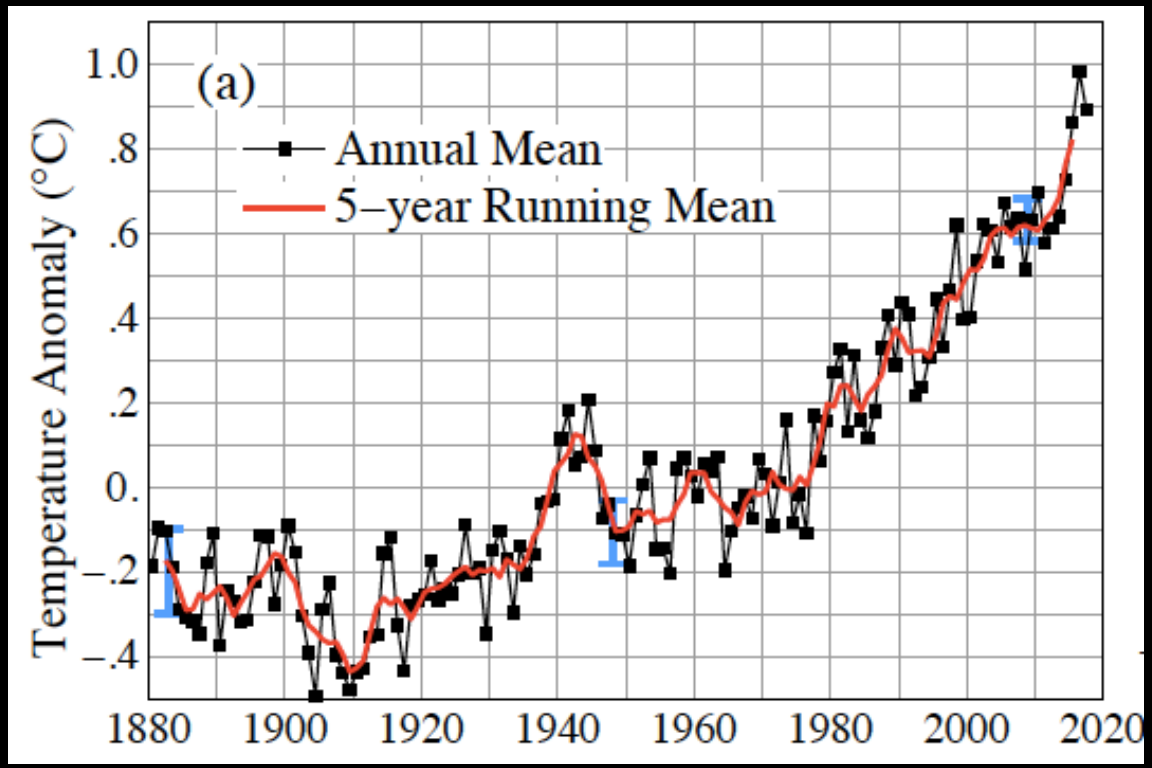
Evolution of fully modern humans in Africa

Hunter-gatherer societies only

Adapted from Steffen et al. 2004; ice core data from Petit et al. 1999

Climate Change 2018

Global Average Temperature Anomaly, 1880-2017



Baseline is 1951-1980

NASA 2018

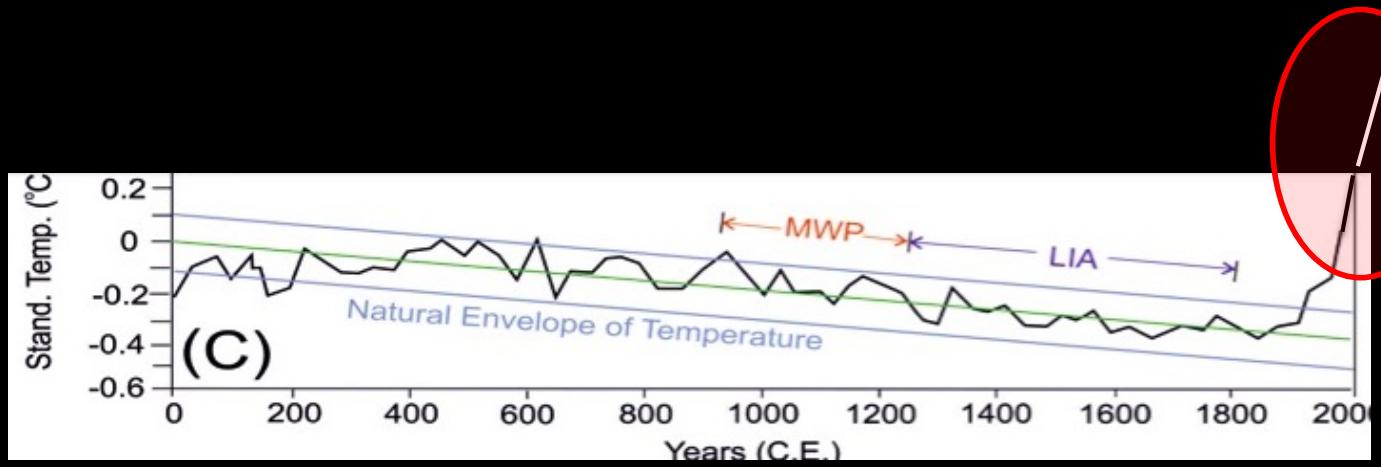
Climate Change:

An Earth System Perspective

Temperature rise:

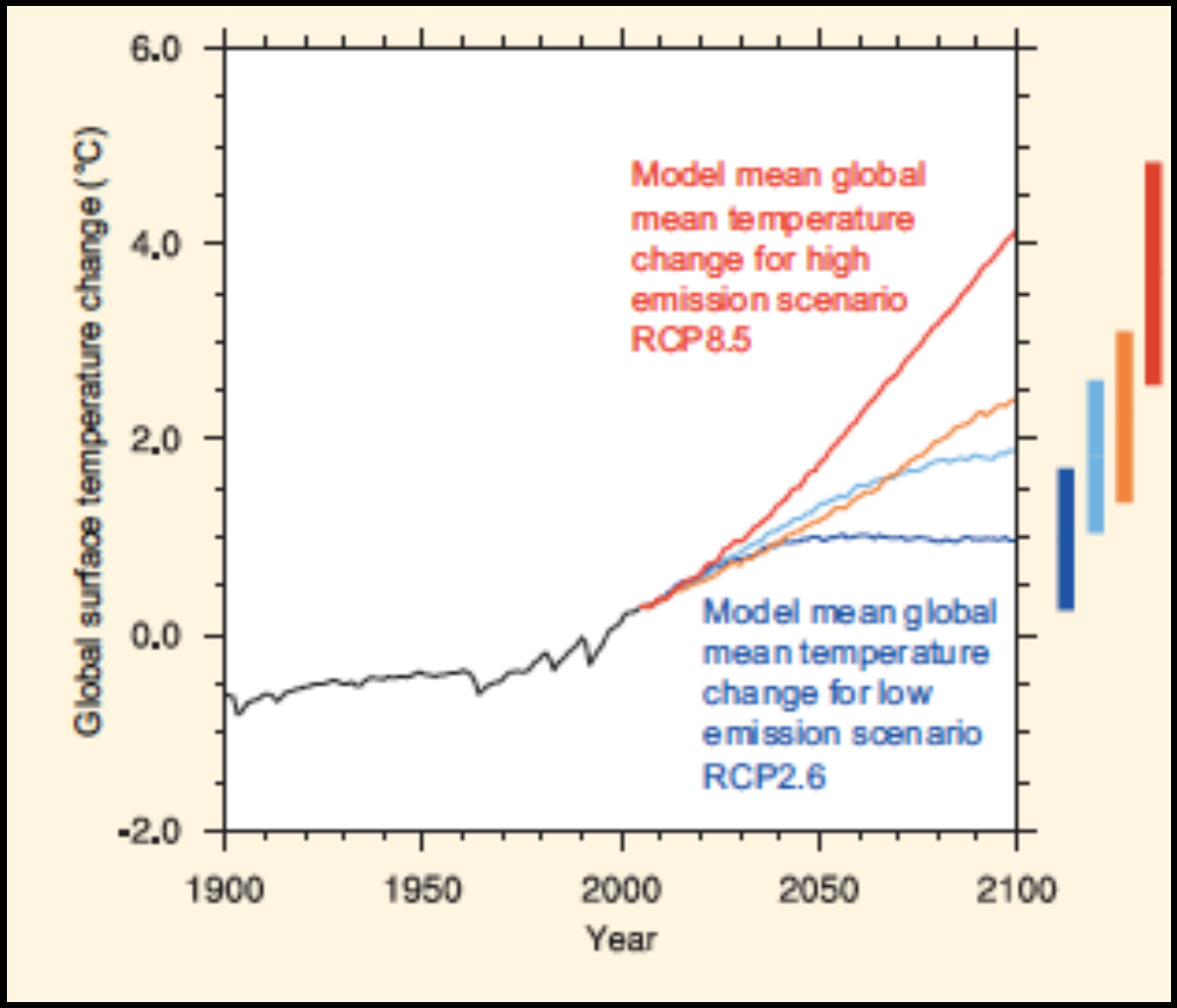
Beyond the envelope of natural variability!

Human influence



Summerhayes 2015

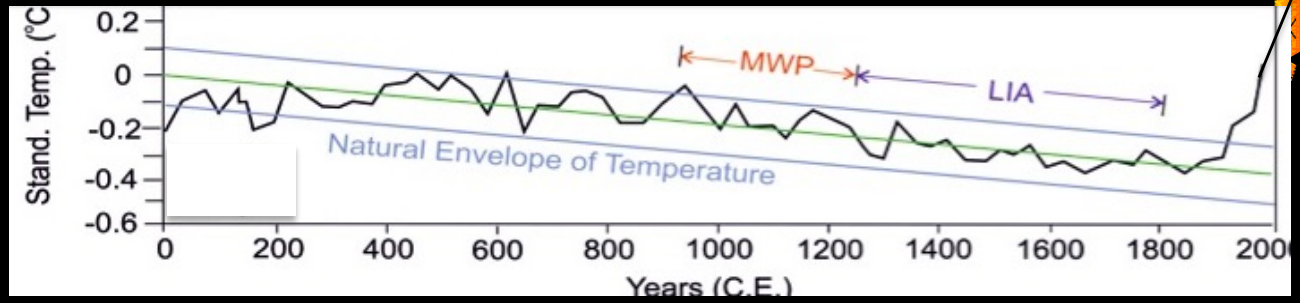
IPCC temperature projections

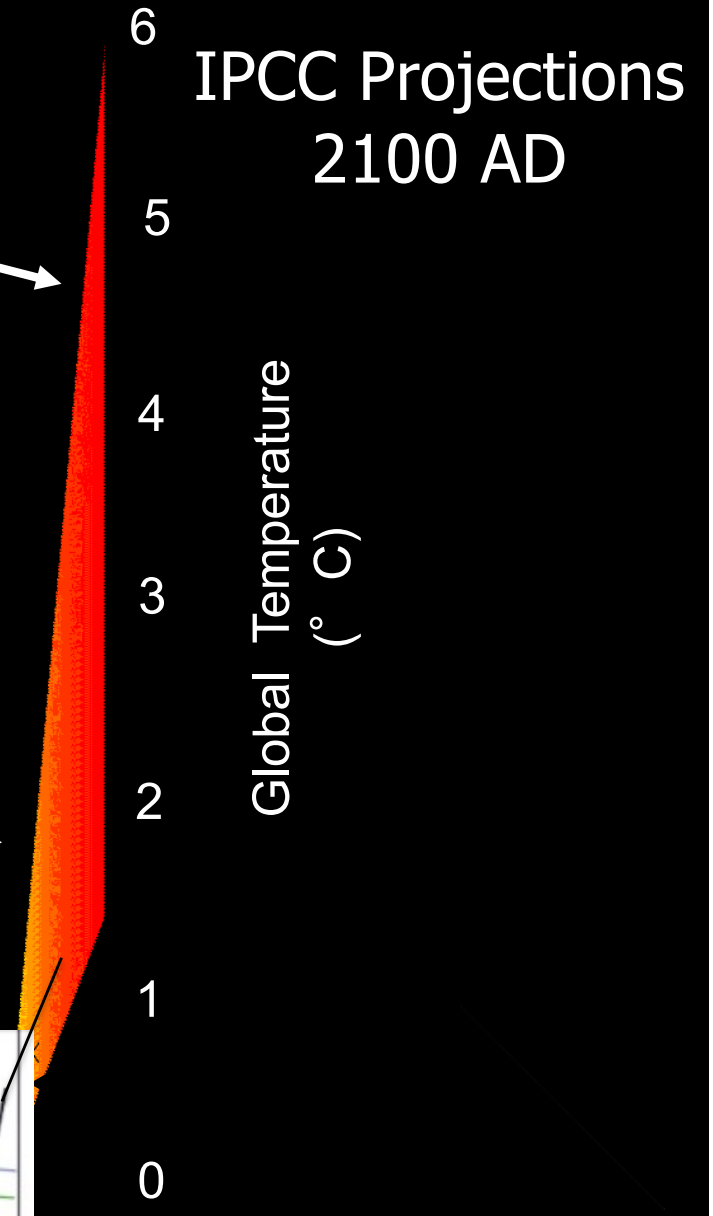


Collins et al. 2013 (IPCC AR5)

Earth System moves to a new state? Severe challenge to contemporary civilisation. Possible collapse?

Committed





Summerhayes 2015

Earth System moves to a new state? Severe challenge to contemporary civilisation. Possible collapse?

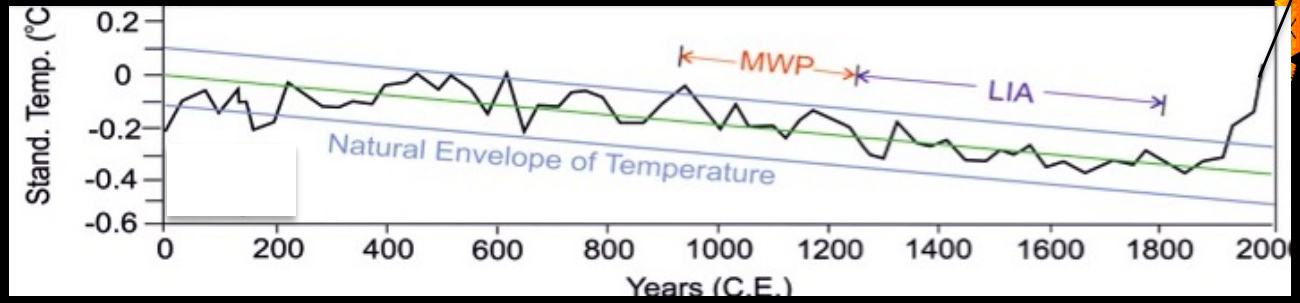
IPCC Projections 2100 AD

Tipping points?

Committed

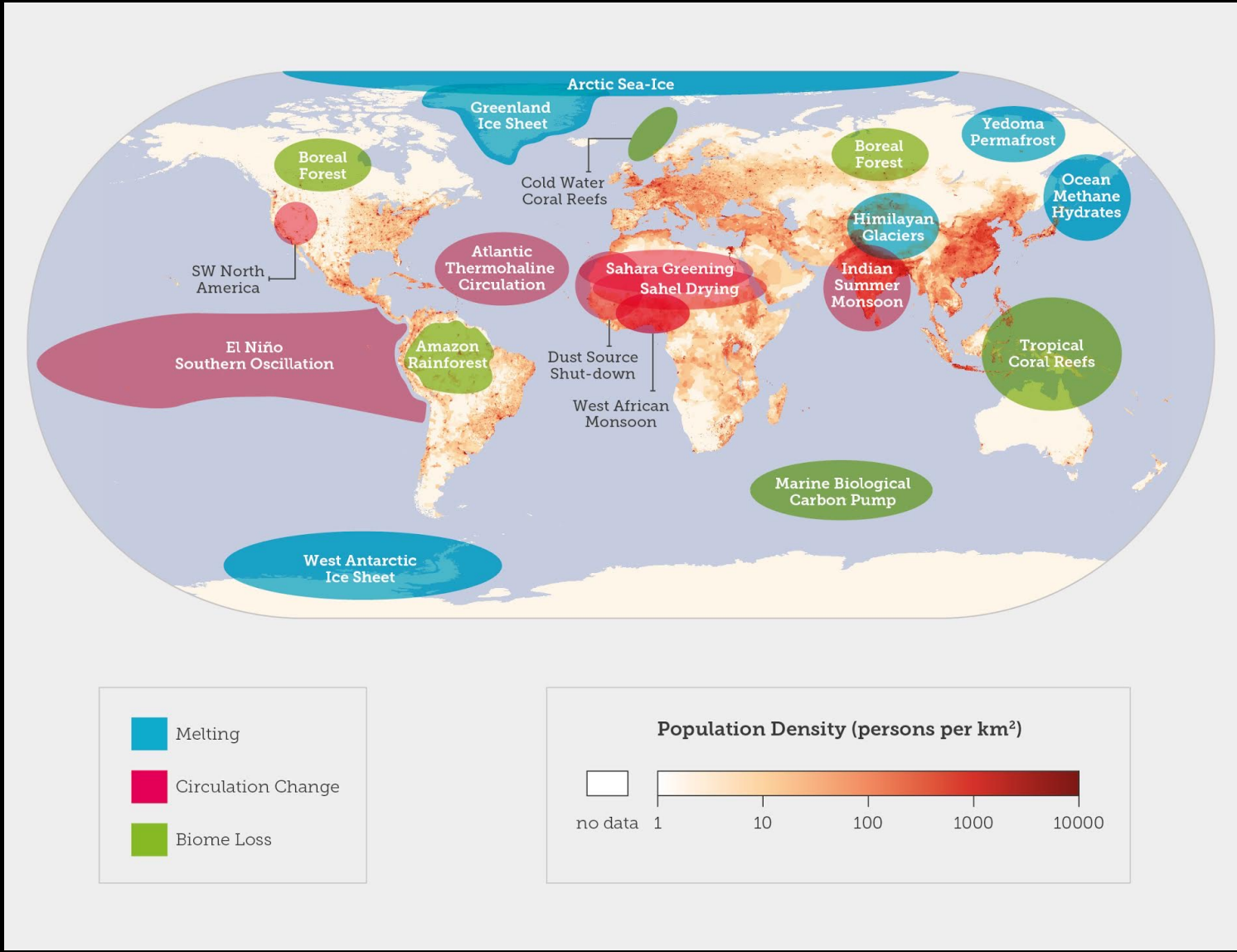
Global Temperature (° C)

6
5
4
3
2
1
0



Summerhayes 2015

Tipping Elements in the Earth System



Huber, Lenton, and Schellnhuber, in Richardson et al. 2011

An inconvenient truth:

With every IPCC report the temperature at which there is believed to be a risk of crossing tipping points has been lowered!

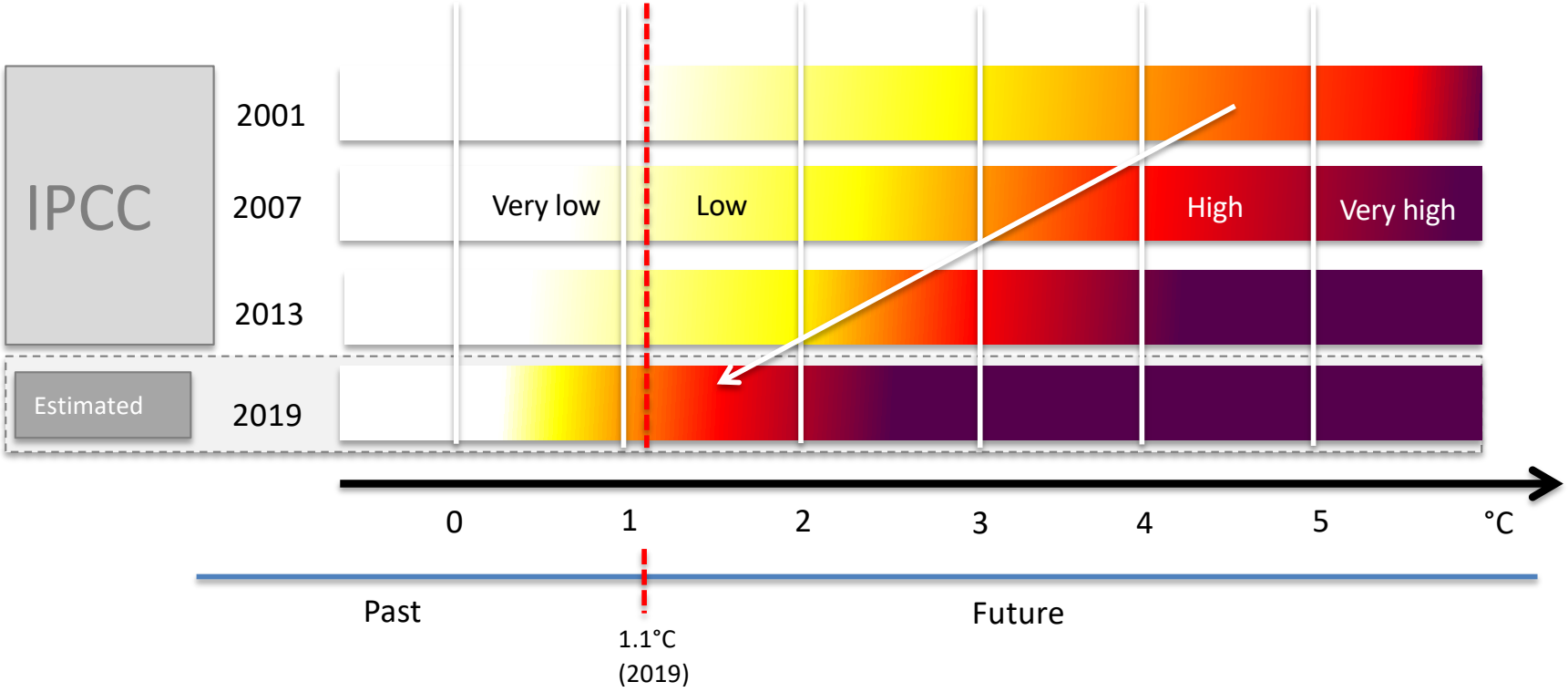
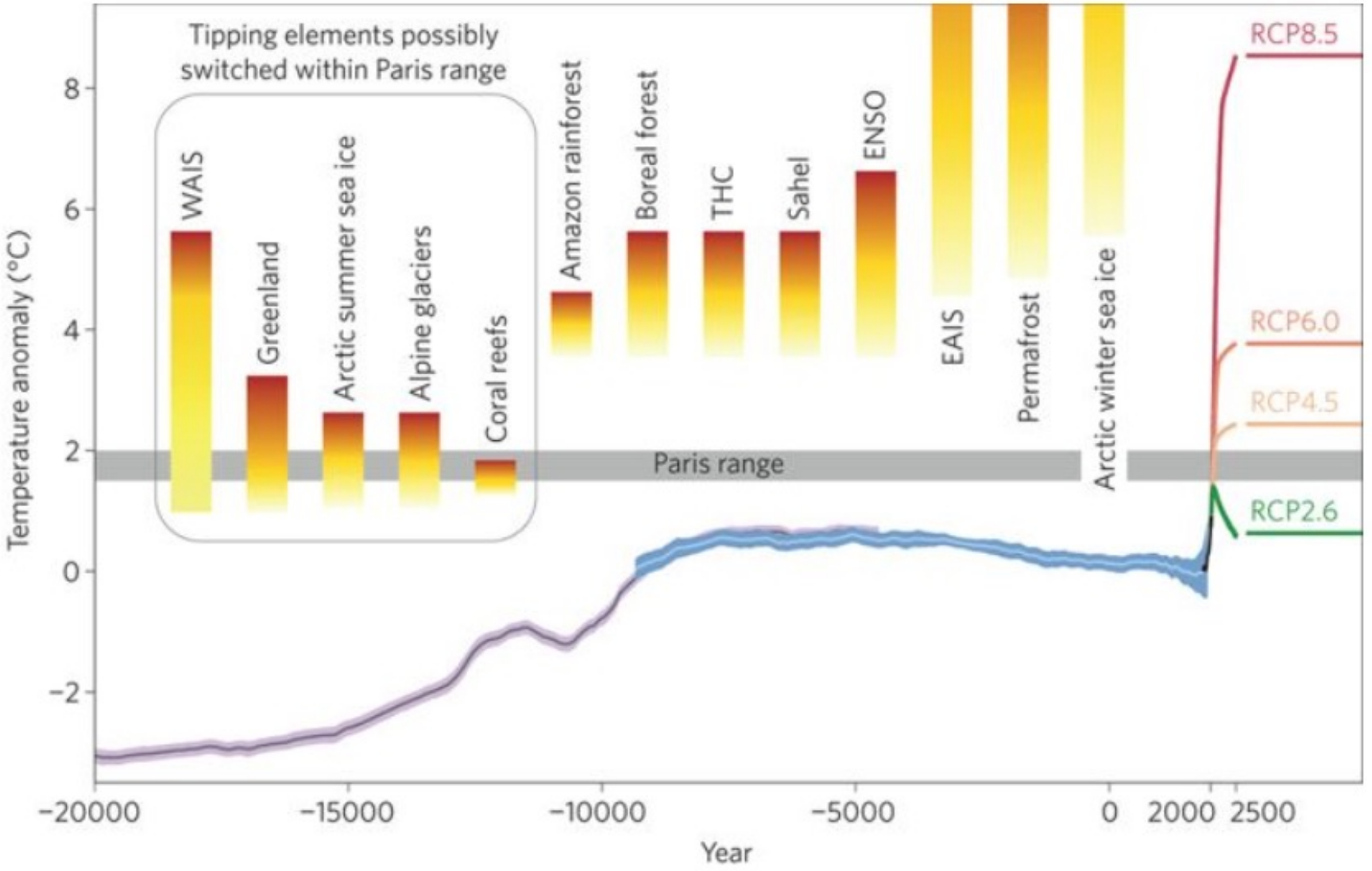


Figure 1: Tipping elements in context of the global mean temperature evolution.



Schellnhuber et al. 2016

Managing human-caused climate change:

- It is not politicians in Paris that alone can decide what the Earth's future temperature will be!
- 2^{o} isn't necessarily "safe"
- The risk of crossing tipping points increases with all incremental warming.
- **TIME** is of the essence!

First in 2015 we got an international agreement acknowledging that resources are limited!

SDGs are a vision for how we want to share the Earth's resources!

Relevant for all global citizens – not just for those in developing countries

Few goals are on track to be met and for several goals, the trend is in the wrong direction!

KØBENHAVNS UNIVERSITET

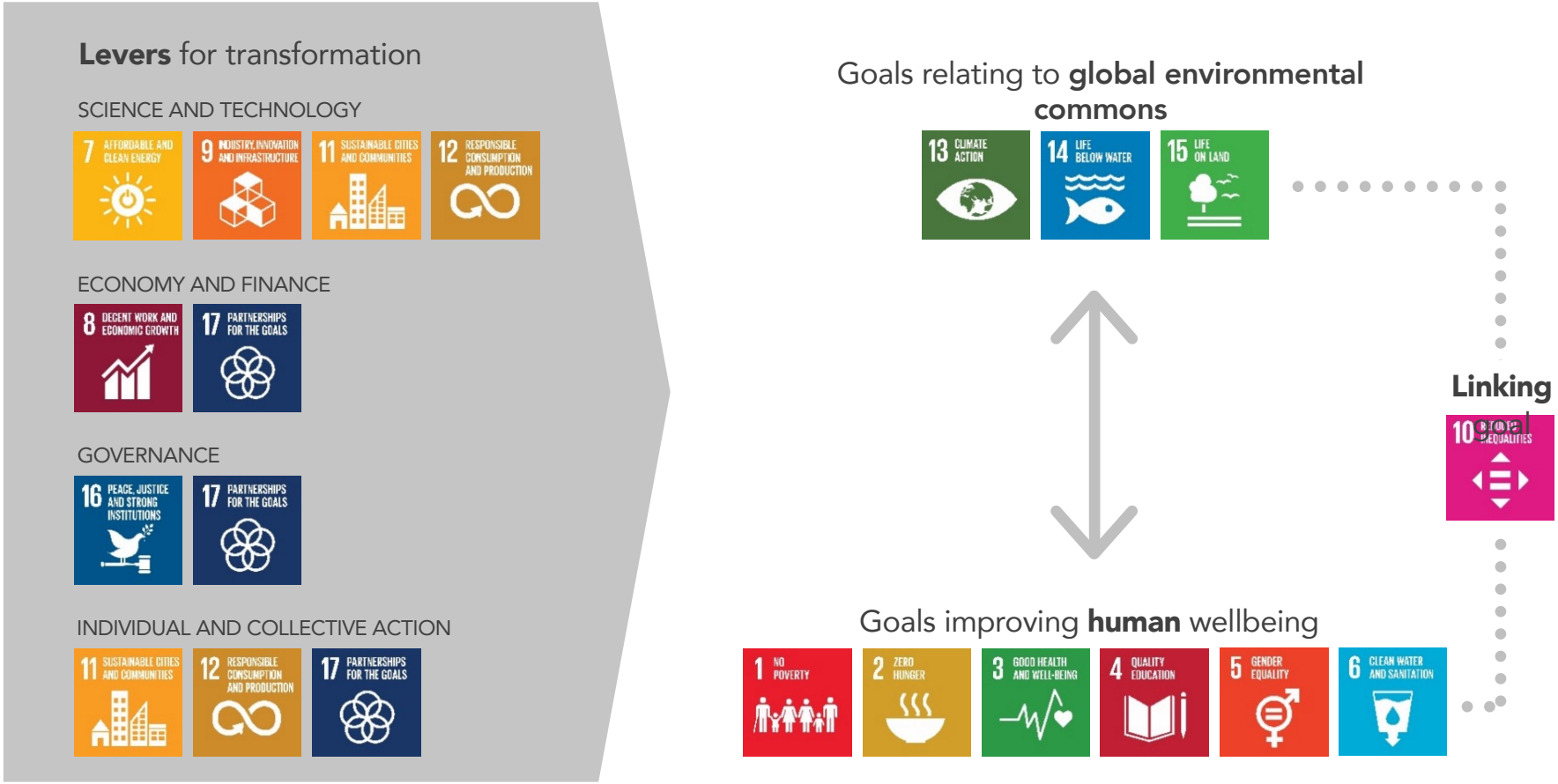
Business-as-usual approaches

GOAL	WITHIN 5%	5–10%	>10%	NEGATIVE LONG-TERM TREND
Goal 1		1.1. Eradicating extreme poverty	1.3. Social protection for all	
Goal 2		2.1. Ending hunger (undernourishment)	2.2. Ending malnutrition (stunting) 2.5. Maintaining genetic diversity 2.a. Investment in agriculture*	2.2. Ending malnutrition (overweight)
Goal 3	3.2. Under 5 mortality 3.2. Neonatal mortality		3.1. Maternal mortality 3.4. Premature deaths from non-communicable dis[illegible]ses	
Goal 4	4.1 Enrolment in primary education	4.6 Literacy among youth and adults	4.2. Early childhood deve[illegible]ment 4.1 Enrolment in secondary [illegible]ducation 4.3 Enrolment in tertiary [illegible]ducation	
Goal 5			5.5. Women political pa[illegible]icipation	
Goal 6		6.2. Access to safe sanitation (open defecation practices)	6.1. Access to safely m[illegible]aged drinking water 6.2. Access to safely m[illegible]naged sanitation service	
Goal 7		7.1. Access to electricity	7.2. Share of renewa[illegible]e energy* 7.3. Energy intensity	
Goal 8			8.7. Use of child labo[illegible]	
Goal 9		9.5. Enhancing scientific research (R&D expenditure)	9.5. Enhancing scien[illegible]ic research (number of rese[illegible]hers)	
Goal 10			10.c. Remittance cost[illegible]	Inequality in income**
Goal 11			11.1. Urban population [illegible]ving in slums*	
Goal 12				12.2. Absolute material footprint, and DMC*
Goal 13				Global GHG emissions relative to Paris targets**
Goal 14				14.1. Continued deterioration of coastal waters* 14.4. Overfishing*
Goal 15				15.5. Biodiversity loss* 15.7. Wildlife poaching and trafficki[illegible]
Goal 16			16.9 universal birth registration *	

* target not specified ** based on most recently available data

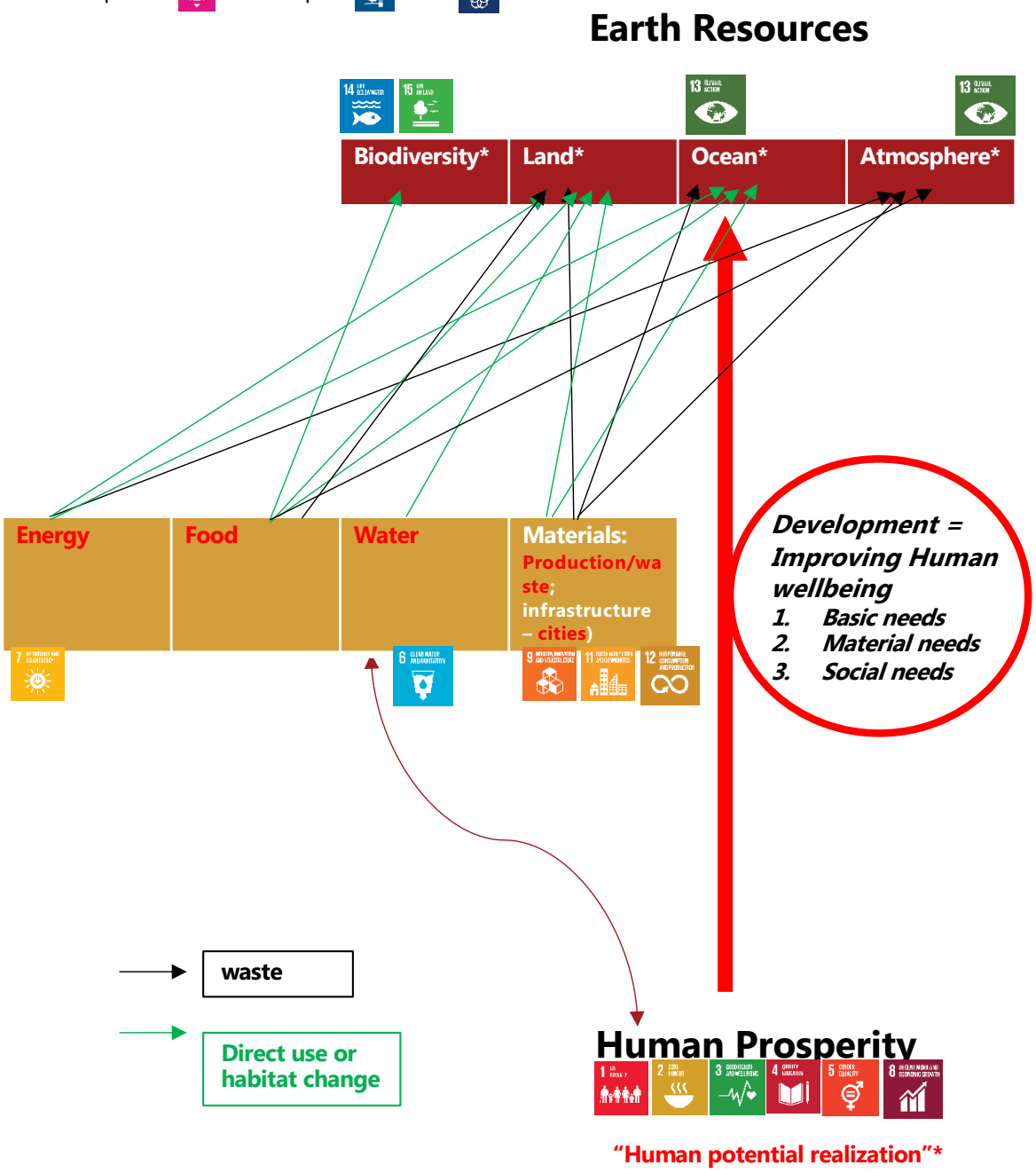
Global Sustainable Development Report, 2019

Interactions between the SDGs

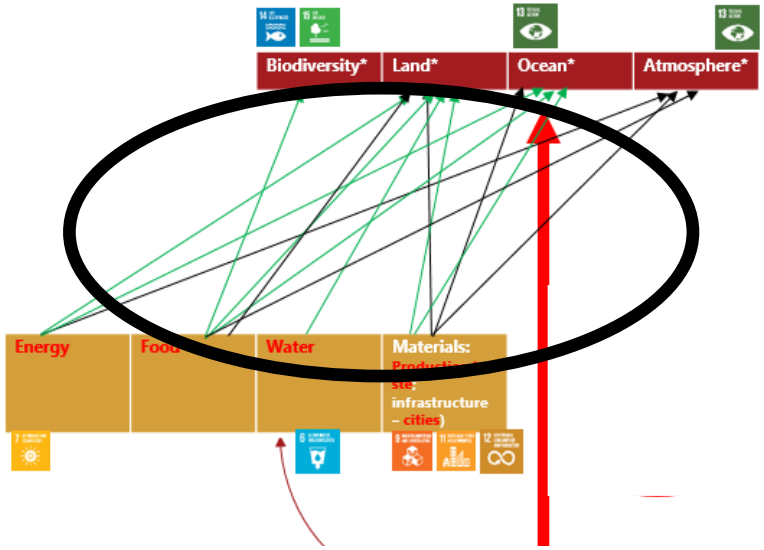


But we do not "think" in terms of SDGs!

The challenge of SD is giving all access to the finite resources necessary to allow continued development This requires and



Incorporate "cost-efficiency" into all sectors:



Goal for all sectors:

Maximise human welfare/environmental and social costs

Requires cultural change: ***The Earth's resources – NOT MONEY – is our real currency!***

Sustainable development in terms of environment: Resource demand must not exceed supply!

Climate…

Research helps us quantify the supply of other resources…

Planetary Boundaries: Exploring the safe operating space for humanity in the Anthropocene (*Nature*, 461 : 472 – 475, Sept 24 - 2009)

nature

FEATURE

Vol 461|24 September 2009

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.

Although Earth has undergone many periods of significant environmental change, the planet's environment has been unusually stable for the past 10,000 years[1,2]. This period of stability — known to geologists as the Holocene — has seen human civilizations arise, develop and thrive. Such stability may now be under threat. Since the Industrial Revolution, a new era has arisen, the Anthropocene[3], in which human actions have become the main driver of global environmental change[4]. There is a risk that human activities push the Earth system outside the stable environmental state of the Holocene, with consequences that are detrimental or even catastrophic for large parts of the world.

During the Holocene, environmental change occurred naturally and Earth's regulatory capacity maintained the conditions that enabled human development. Regular temperatures, freshwater availability and biogeochemical flows all stayed within a relatively narrow range. Now, largely because of a rapidly growing reliance on fossil fuels and industrialized forms of agriculture, human activities have reached a level that could damage the systems that keep Earth in the desirable Holocene state. The result could be irreversible and, in some cases, abrupt environmental change, leading to a state less conducive to human development[5]. Without pressure from human, the Holocene is expected to continue for at least several thousands of years[1].

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

ROAD TO COPENHAGEN

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 system and are associated with the planet's biophysical subsystems or processes. Although Earth's complex systems sometimes respond smoothly to changing pressures, it seems that this will prove to be the exception rather than the rule. Many subsystems of Earth react in a nonlinear, often abrupt, way, and are particularly sensitive around threshold levels of certain key variables. If these thresholds are crossed, then important subsystems, such as a monsoon system, could shift into a new state, often with deleterious or potentially even disastrous consequences for humans[6].

Most of these thresholds can be defined by a critical value for one or more control variables, such as carbon dioxide concentration. Not all processes or subsystems on Earth have well-defined thresholds, although human actions that undermine the resilience of such processes or subsystems — for example, land and water degradation — can increase the risk that thresholds will also be crossed in other processes, such as the climate system.

We have tried to identify the Earth-system processes and associated thresholds which, if crossed, could generate unacceptable environmental change. We have found nine such processes for which we believe it is necessary to define planetary boundaries: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading (see Fig. 1 and Table).

In general, planetary boundaries are values for control variables that are either at a 'safe' distance from thresholds — for processes with evidence of threshold behaviour — or at dangerous levels — for processes without

Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

E&S

Research

Planetary Boundaries: Exploring the Safe Operating Space for Humanity

Johan Rockström [1,2], *Will Steffen* [1,3], *Kevin Noone* [1,4], *Åsa Persson* [1,2], *F. Stuart III Chapin* [1,5], *Eric Lambin* [1,6], *Timothy M. Lenton* [1,7], *Marten Scheffer* [1,8], *Carl Folke* [1,9], *Hans Joachim Schellnhuber* [1,10,11], *Björn Nykvist* [1,2], *Cynthia A. de Wit* [1,4], *Terry Hughes* [1,12], *Sander van der Leeuw* [1,13], *Henning Rodhe* [1,14], *Sverker Sörlin* [1,15], *Peter K. Snyder* [1,16], *Robert Costanza* [1,17], *Uno Svedin* [1], *Malin Falkenmark* [1,18], *Louise Karlberg* [1,2], *Robert W. Corell* [1,19], *Victoria J. Fabry* [1,20], *James Hansen* [1,21], *Brian Walker* [1,22], *Diana Liverman* [1,23,24], *Katherine Richardson* [1,25], *Paul Crutzen* [1,26], and *Jonathan Foley* [1,27]

Ecology and Society **14**(2): 32
http://www.ecologyandsociety.org/vol14/iss2/art32/

ScienceExpress

Research Articles

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] R. 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] B. Reyers,[1,18] Sverker Sörlin[19]

[1]Stockholm Resilience Centre, Stockholm University, SE-10691 Stockholm, Sweden. [2]Fenner School of Environment and Society, The Australian National University, Canberra ACT 2601, Australia. [3]Center for Macroecology, Evolution and Climate, University of Copenhagen, Natural History Museum of Denmark, Universitetsparken 15, Building 3, DK-2100 Copenhagen, Denmark. [4]Department of Natural Resource Sciences and McGill School of Environment, McGill University, 21, 111 Lakeshore Rd., Ste-Anne-de-Bellevue, QC H9X 3V9, Canada. [5]Centre for Studies in Complexity, University of Stellenbosch, Private Bag X1, Stellenbosch 7602, South Africa. [6]Center for Limnology, University of Wisconsin, 680 North Park Street, Madison WI 53706 USA. [7]Alterra Wageningen University and Research Centre, PO Box 47, 6700AA Wageningen, The Netherlands. [8]Environmental Systems Analysis Group, Wageningen University, PO Box 47, 6700 AA Wageningen, The Netherlands. [9]Department of Environmental Science and Analytical Chemistry, Stockholm University, SE-10691 Stockholm, Sweden. [10]Beijer Institute of Ecological Economics, Royal Swedish Academy of Sciences, SE-10405 Stockholm, Sweden. [11]Research Domain Earth System Analysis, Potsdam Institute for Climate Impact Research (PIK), Telegraphenberg A62, 14473 Potsdam, Germany. [12]International Livestock Research Institute, P.O. Box 30709, Nairobi 00100 Kenya. [13]CSIRO (Commonwealth Scientific and Industrial Research Organization), St Lucia QLD 4067, Australia

(ii) updating the quantification of most of the PBs; (iii) identifying two core boundaries; and (iv) proposing a regional-level quantitative boundary for one of the two that were not quantified earlier (*1*).

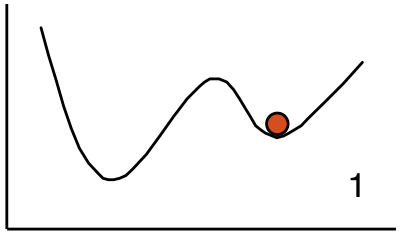
The basic framework: Defining a safe operating space

Throughout history, humanity has faced environmental constraints at local and regional levels, with some societies dealing with these challenges more effectively than others (*11*, *12*). More recently, early industrial societies often used local waterways and airsheds as dumping grounds for their waste and effluent from industrial processes. This eroded local and regional environmen-

on January 16, 2015

Planetary Boundaries: Guiding human development on a changing planet (*Science, 347, Jan. 15, 2015*)

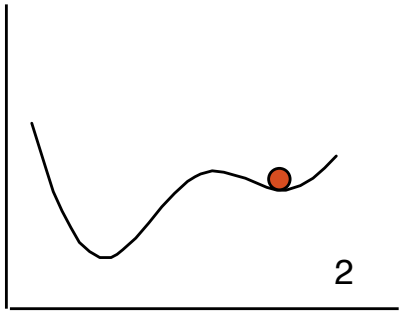
Valuable Ecosystem Services (Desirable) → **Loss of ecosystem services (Undesirable)**



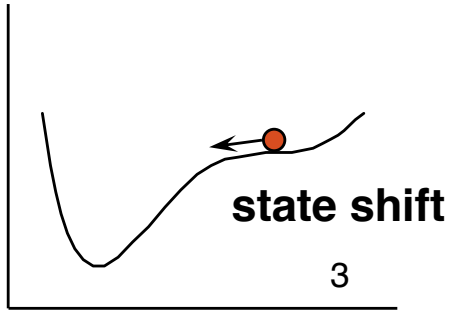
coral dominance

clear water

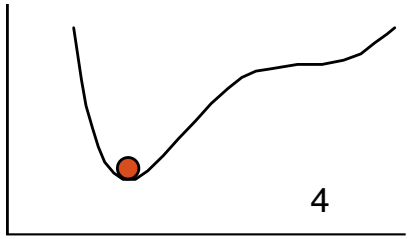
grassland



- overfishing, coastal eutrophication
- phosphorous accumulation in soil and mud
- fire prevention



- disease, hurricane
- flooding, warming, overexploitation of predators
- good rains, continuous heavy grazing

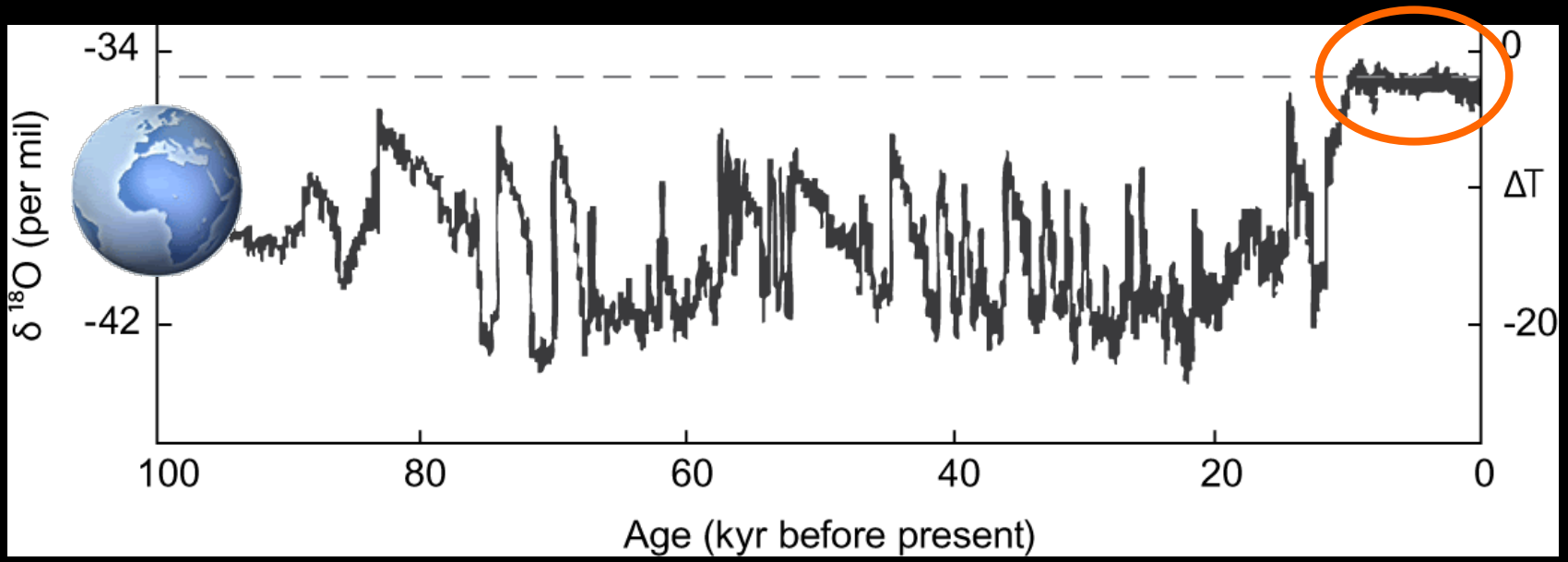


algal dominance

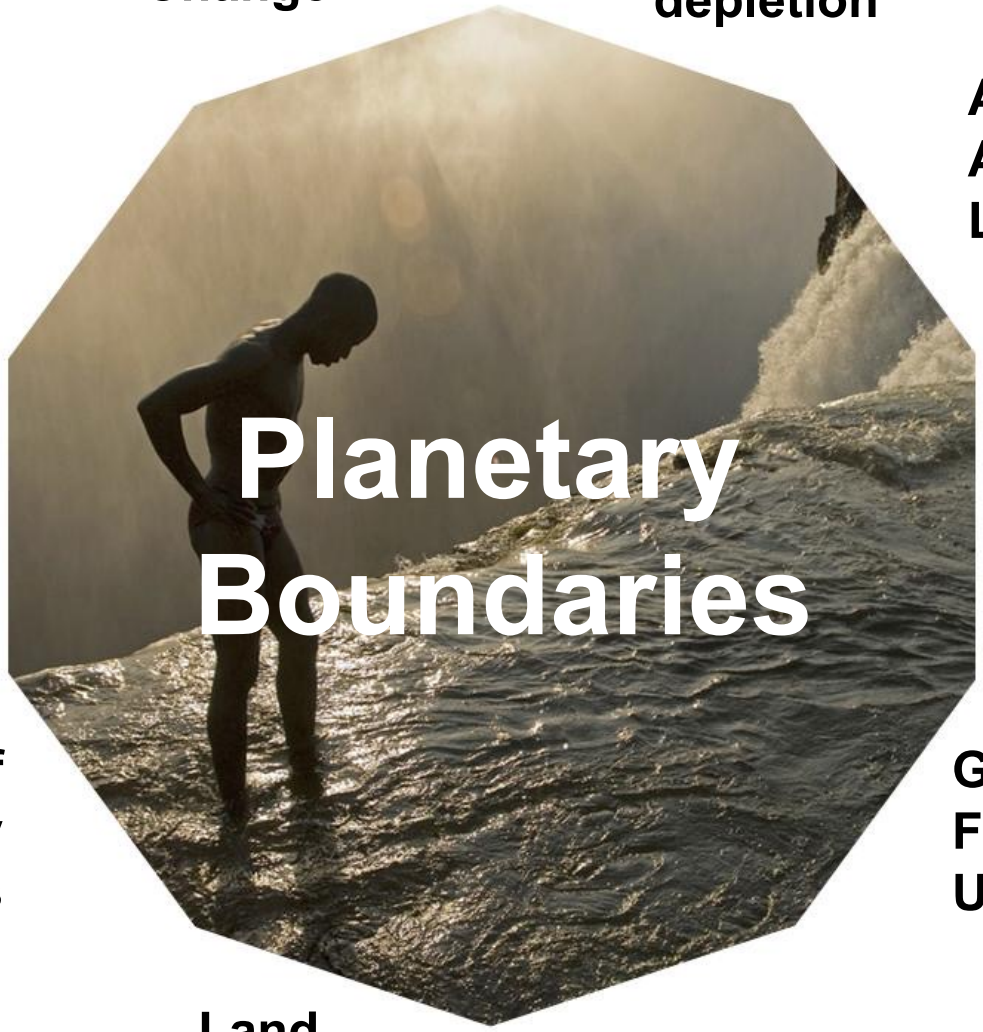
turbid water

shrub-bushland

Humanity's 12,000 years of grace



Planetary Boundaries



Climate Change

Ozone depletion

Atmospheric Aerosol Loading

Biogeochemical loading: Global N & P Cycles

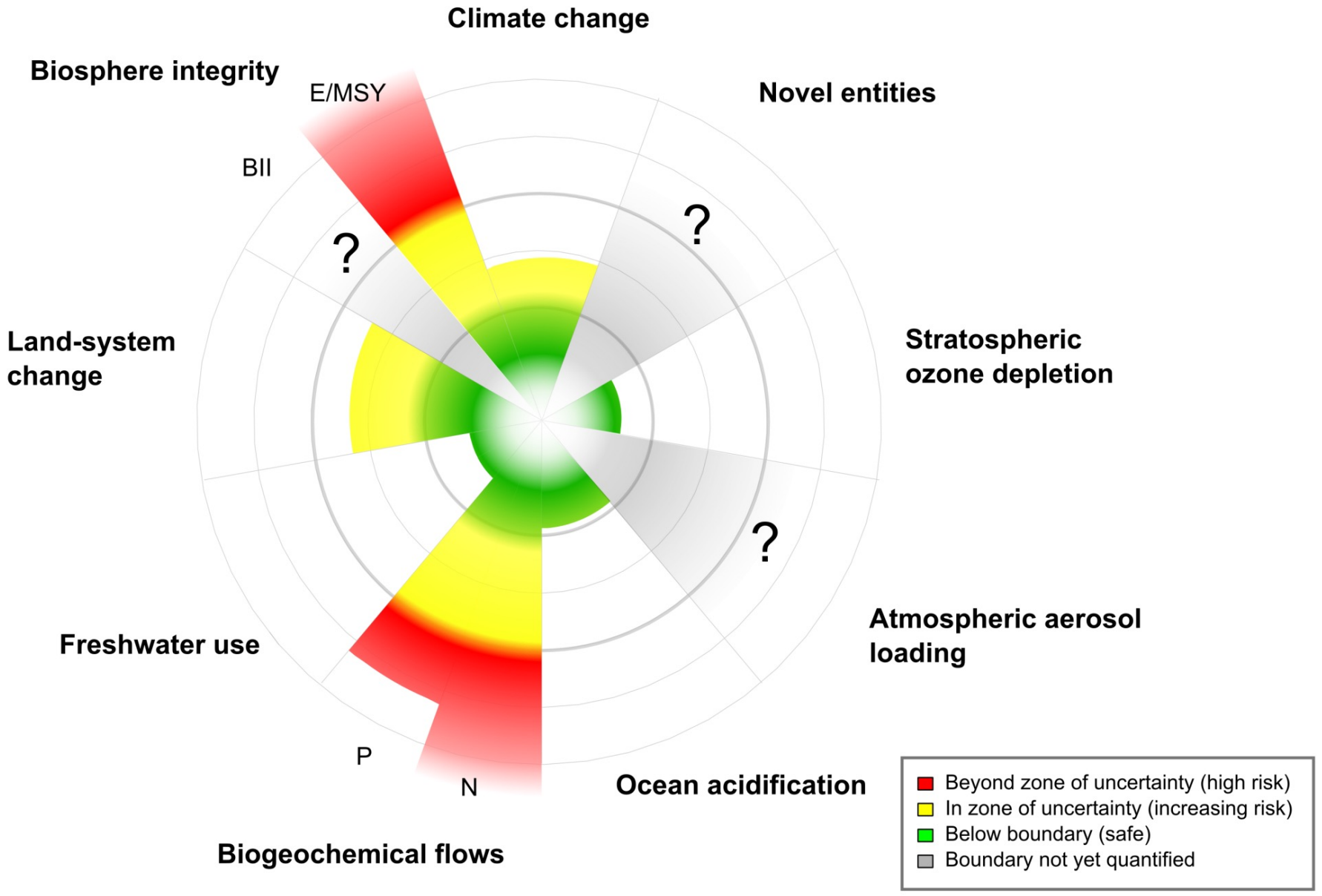
Ocean acidification

Rate of Biodiversity Loss

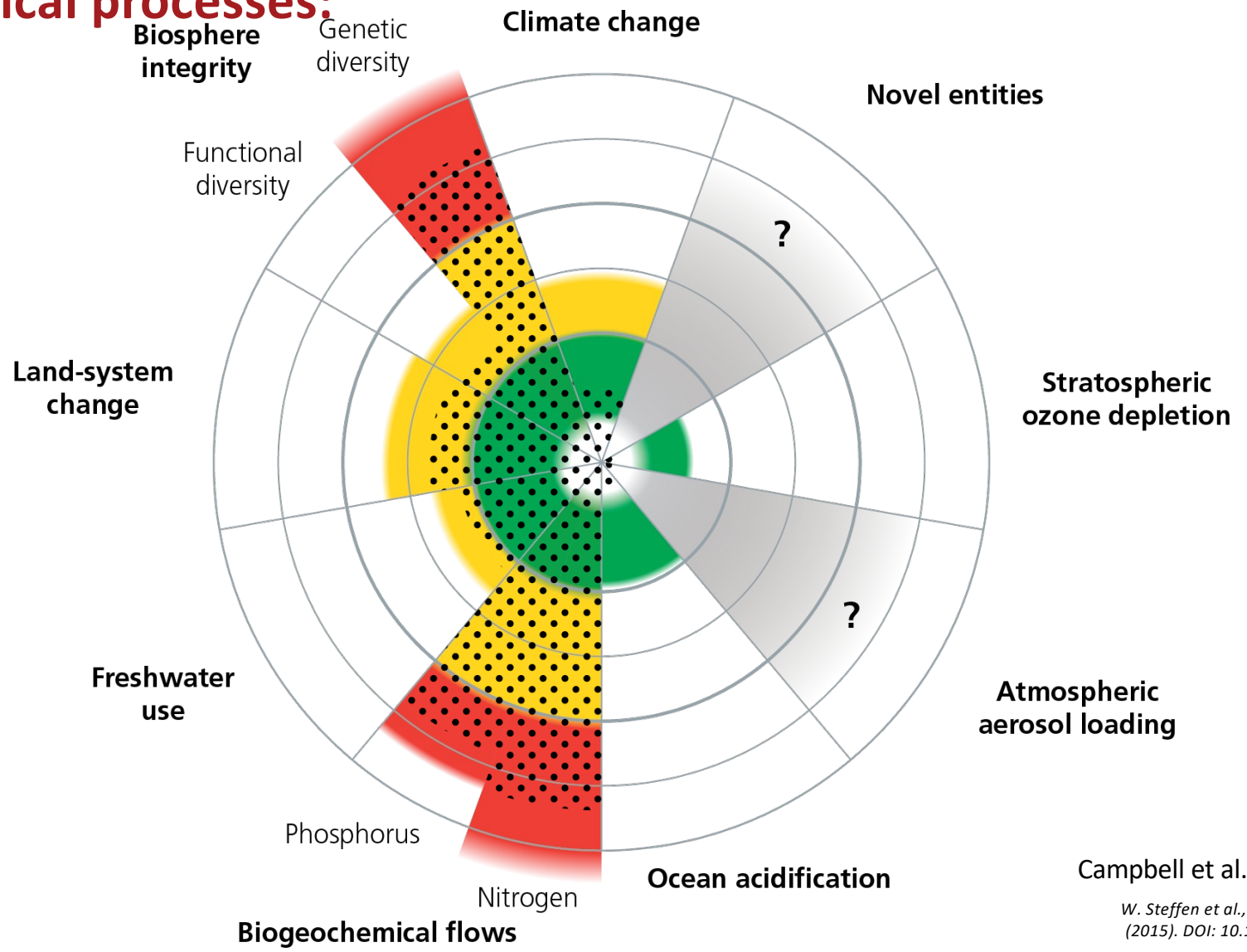
Global Freshwater Use

Land System Change

Chemical Pollution


Climate change
Biosphere integrity
E/MSY
BII
Novel entities
?
?
Land-system change
Stratospheric ozone depletion
?
Freshwater use
Atmospheric aerosol loading
P
N
Ocean acidification
Biogeochemical flows
Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified

Agriculture's contribution to human perturbation of critical biophysical processes:



Campbell et al. 2017

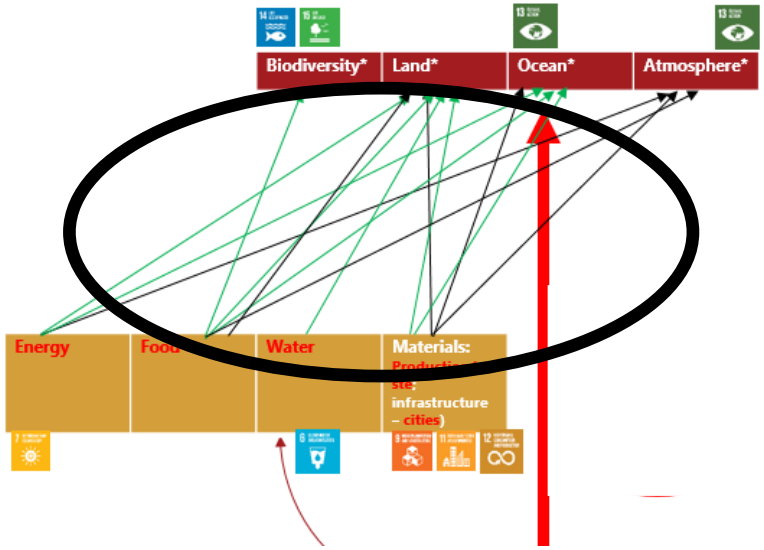
W. Steffen et al., Science 347, 1259855 (2015). DOI: 10.1126/science.1259855

PBs are scientifically-based levels of human perturbation of the ES beyond which ES functioning may be significantly altered.

The PB framework does not dictate how societies should develop.

*By identifying a safe operating **space for humanity** on Earth, the PB framework can make a valuable contribution to decision-makers in charting desirable courses for societal development and they (or something like them) are **essential for implementing the SDGs.***

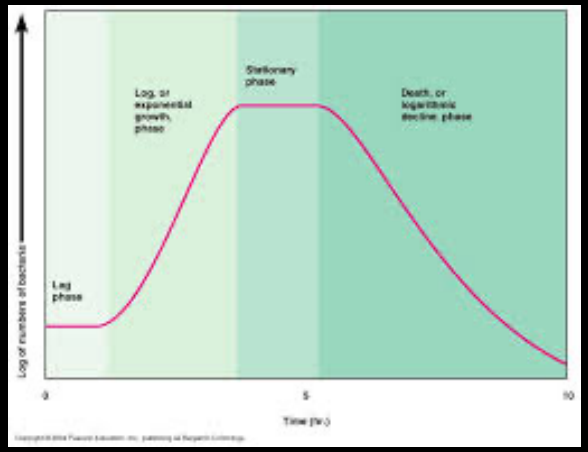
Reducing/eliminating the arrows essential to stay within Planetary Boundaries



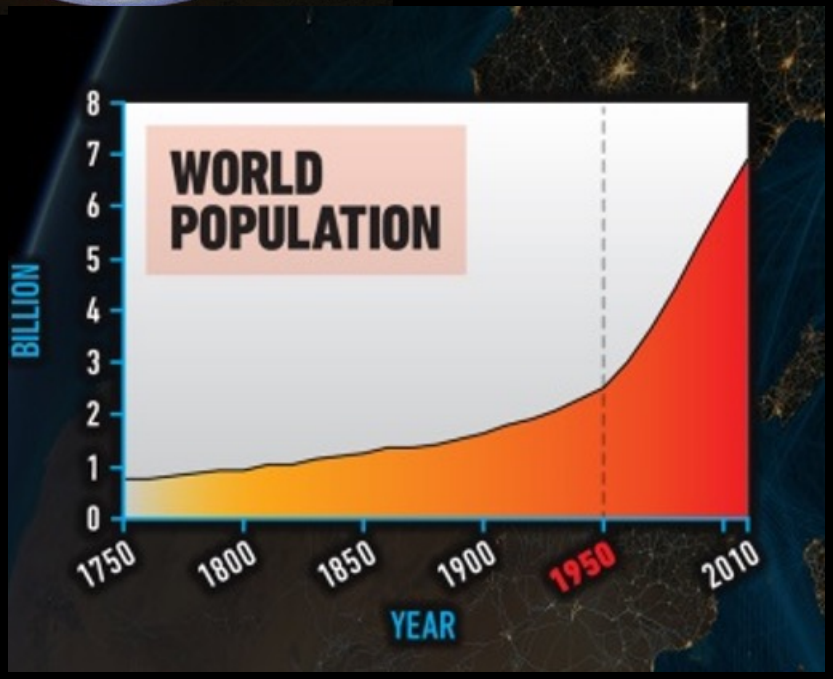
Goal for all sectors:

Maximise human welfare/environmental cost

Biology tells us what could happen if we don't..



Micro-organism in culture



Human population

Ecosystems are different!
Organisms persist

Ecosystems are ***Sustainable Circular Societies*** of different organisms!

The SDGs force us to respect the (eco)system of which we are a part!

"purchase order from the future"
John Elkington